CURRENT PERSPECTIVES IN SOCIAL AND BEHAVIORAL SCIENCES

Cultural-Historical Perspectives on Collective Intelligence

Patterns in Problem Solving and Innovation

Rolf K. Baltzersen

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CULTURAL-HISTORICAL PERSPECTIVES ON COLLECTIVE INTELLIGENCE

In the era of digital communication, collective problem solving is increasingly important. Large groups can now resolve issues together in completely different ways, which has transformed the arts, sciences, business, education, technology, and medicine. Collective intelligence is something we share with animals and is different from machine learning and artificial intelligence. To design and utilize human collective intelligence, we must understand how its problem-solving mechanisms work. From democracy in ancient Athens, through the invention of the printing press, to COVID-19, this book analyzes how humans developed the ability to find solutions together. This wide-ranging, thought-provoking book is a game-changer for those working strategically with collective problem solving within organizations and using a variety of innovative methods. It sheds light on how humans work effectively alongside machines to confront the most urgent challenges ever faced by humanity. This title is also available as Open Access on Cambridge Core.

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ROLF K. BALTZERSEN

Østfold University College

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For my children, Silvia and Johannes.

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CHAPTER 1

What Is Collective Intelligence?

1.1 The Need for New Types of Collective Problem Solving

In the new era of digital communication, collective problem solving is increasingly important. With the Internet and digitalization of information, large groups can now solve problems together in completely different ways than are possible in offline settings (Lévy, 1999). These novel online technologies and practices challenge our conceptions of individualized human problem solving in various domains, including art, science, industry, business, education, technology, software design, and medicine. It is urgent that we rethink our understanding of intelligence in a profound way. Among scholars, collective intelligence (CI) is increasingly used as a broad, multidisciplinary term to describe new types of collective problem solving. This notion of intelligence is not about individual ability or computer algorithms; rather, it describes how collectives of people, both small and very large groups, solve problems. This book intends to give an overview of some of the most important basic problem-solving mechanisms that comprise CI.

Throughout our evolution, our most extraordinary ability as humans is, without doubt, our ability to collaborate with each other. Our story is very much about how we gradually learned to solve problems together in increasingly larger groups. First, we started living in caves solving issues in small numbers, from there we formed villages, and, with time, the villages grew into kingdoms and nations. Today, many of us spend most of our time in a global online setting. In this new setting of billions of people, fresh ways of solving problems in large distributed groups are constantly being invented in a wide range of sectors. Open online innovation and citizen science are but a few examples of projects that center on open invitations, allowing anyone to join. In addition, various platforms and projects promote open online knowledge sharing, including the sharing of both knowledge products (e.g. online videos, Wikipedia) and knowledge construction processes (e.g. argument mapping). There is also a growing awareness that complex wicked problems, like climate change or COVID-19, require innovative problem-solving approaches that build on the combined scientific and political efforts of individuals and groups all over the globe.

The increasingly popular concept of CI attempts to encompass this development across various scientific fields. Concerning group size, studies of CI cover anything from small group cooperation in teams in the offline setting to large group cooperation in distributed online settings (Salminen, 2012). While some CI researchers still primarily examine the Internet and development of a broad macro level (Heylighen, 2017; Lévy, 2010), others focus on collaboration in small groups (Woolley, Aggarwal, & Malone, 2015; Woolley, Chabris, Pentland, Hashmi, & Malone, 2010).

However, the invention of the Internet undoubtedly renewed interest in CI. Pierre Lévy coined the modern version of CI in 1994 with the book *Collective intelligence: Mankind's emerging world in cyberspace.* Inspired by the recent invention of the Internet, Lévy (1999) defines collective intelligence as a new universally distributed intelligence that constantly improves and coordinates itself in real time. For the first time in human history, the Internet made it possible for members of a decentralized community to interact with each other within the same virtual universe of knowledge. This made possible a new knowledge-producing culture that built on rapid and open exchange of data and ideas. Lévy predicted that this would lead to a fundamental change in how we think about ourselves. Knowledge will no longer be about established facts, but rather the essential part of an ongoing knowledge construction project that includes all humans. The fundamental premise is that nobody knows everything, everyone knows something, and all knowledge resides in humanity. Inspired by Verdansky's notion of "noosphere," Lévy predicts the emergence of a new collective intelligence at a global level (Lévy, 1999).

Since the World Wide Web was created in 1990, it has grown enormously from under 40 million users in 1995 to about 1.5 billion in 2009 (Castells, 2010). In 2020, an estimated 4.5 billion people are active Internet users, encompassing 59% of the global population (source: statista.com). The Internet makes it possible for most people on the earth to interact, create, and exchange information in new ways that extend previous space and time limitations (Castells, 2010). It builds on the instant storage and transmission of information with no loss. The speed of message transmission removes the problem of time delay and transport time. In principle, the outreach is global to all people who have access to the Internet. This permits flexible and easy communication between persons who are located in very different places (Brabham, 2013: 12–13).

These capabilities make it possible to scale up activities and increase human collective capability in a range of different ways. As a result, people share information and communicate with each other in a huge range of online environments. During the last decade, participatory technologies, originally coined by Tim O'Reilly as Web 2.0 (Alexander, 2006), have connected a large amount of people and become increasingly important. As the first generation of web software in the 1990s provided easy access to a vast amount of information, it was still technically difficult to publish information and produce web pages. The major change came with the second generation of Internet technologies, which made it easy for anyone to publish information and communicate with others. The Internet opened up a range of horizontal communication networks within social media, multiplayer online games and fan discussion communities. While the traditional mass media (television, radio, newspapers) had unidirectional links, the architecture in the networked information environment has multidirectional connections among all nodes (Benkler, 2006).

These networks are built around peoples' initiatives, interests, and desires and are used to share all kinds of digital information such as texts, photos, and videos. In social media, individuals constantly produce short texts (e.g. Twitter), images (e.g. Facebook), or videos (e.g. YouTube). These short messages are part of an ongoing online social dialogue, and they are viewed by others immediately afterwards. Online cultural expressions and personal experiences have become a fundamental part of our daily life in the last decade (Castells, 2010). In addition, these new networks integrate local and global media and transcend traditional space limitations.

A fundamental premise behind this development is the radical reduction of the cost of becoming a speaker. Because the cost is so low and it takes very short time to reach others over the Internet, more people can find each other and create something together. Before the age of the Internet, there were only a few people who published their knowledge and opinions to a wider audience, and the publishing channels were usually under editorial control. Now anyone that can afford a digital device (like a cell phone or laptop) can access the Internet and produce and publish digital information. One consequence is that the traditional expert model of knowledge production, which has been taken for granted for centuries, is now being challenged. Increasingly, experts today not only compete for attention with each other, but with a large number of influencers and other amateurs who create, publish, and share their own content. In this networked information economy, knowledge production is much more broadly distributed in society.

Some of these large, loosely organized groups of people have also been surprisingly successful in building new knowledge products of societal value. The rise of effective, large-scale cooperative efforts like Wikipedia, which build on peer production of information, knowledge, and culture, was considered to be the most radical new innovation in the network society (Benkler, 2006). In the early 2000s, these new global online communities gave promise of a bright new future which would bring people from all over the world together. This development spurred a new era for CI research. A decade ago, the research report "Harnessing Crowds: Mapping the Genome of Collective Intelligence", Malone, Laubacher, and Dellarocas (2009) helped form a preliminary overview of what could be regarded as a new research field. Inspired by global online networks and communities like Wikipedia, the report proposes a relatively detailed typology, specific "building blocks," that can guide the design of CI communities. The researchers also claim that CI has existed throughout history. Therefore, the basic mechanisms are not new, but the main difference is that the Internet has created a new type of web-enabled CI that have resulted in new practices in fields like business and science. However, the link between our present and previous history is not clarified, and leaves the question open on how these new online practices are similar or different from previous ways of solving problems.

Today, CI has become a multidisciplinary notion within a range of different areas. The concept is used within disciplines such as psychology (Woolley & Aggarwal, 2017), political science (Landemore, 2013), business (Täuscher, 2017), complexity sciences (Heylighen, 2017; Stefanelli et al., 2019), biology (Bonabeau, 2009; Ioannou, 2017; Vercammen & Burgman, 2019), computer sciences and semantics (Alag, 2009; Lévy, 2010; Lollini, Farley, & Levy, 2019), and social media research (Schoder, Gloor, & Metaxas, 2013). The recommended list of topics at the annual conference on CI in 2020 illustrated the rich variety of topics: human computation, social computing, crowdsourcing, wisdom of crowds (e.g. prediction markets), group cognition, collective decision-making and problem solving, participatory and deliberative democracy, animal collective behavior, organizational design, public policy design, ethics of collective intelligence, computational models of group search and optimization, emergence and evolution of intelligence in biological systems, new technologies for making groups smarter, collective creativity and innovation, citizen engagement and participation, citizen science, artificial intelligence and collaboration, open source intelligence, collective computation, swarming, voting mechanism design, and collective forecasting (Intelligence, 2020). This overview shows that many different disciplines address separate aspects of collective intelligence. CI encompasses a wide range of practices that move beyond the individual level to include groups of peoples of various sizes who use different types of technology (Mulgan, 2014, 2018).

However, since CI is a relatively new academic concept, there are only a couple of books that aim to provide a broad overview of the concept, the field, and the different CI practices (Malone, 2018; Malone & Bernstein, 2015; Mulgan, 2018), including a few review articles (Peters & Heraud, 2015; Suran, Pattanaik, & Draheim, 2020). Although these publications represent important steps toward unifying the field, they also show how hard it is to summarize the field, primarily because of the lack of shared concepts. Separate disciplines use their own terminology within their own silo and there are few multidisciplinary studies. Although each discipline provides useful research, there is still no general framework that all disciplines can draw on which can provide a shared understanding of the basic mechanisms behind CI (Mulgan, 2018: 229–230).

According to Mulgan (2018: 229–230), the CI literature ranges from the limitlessly broad to the highly specific. The narrow variants describe collaboration in small groups, while the broader variants describe the whole of human civilization and culture (Mulgan, 2018: 1). For example, there is disagreement on whether collaboration in teams or smaller groups in an offline setting should be included in a definition of collective intelligence. Aulinger and Miller (2014) claim some definitions of CI imply that almost any collective action can be labeled as "collective intelligence." With this lack of precision, the concept may end up meaning nothing. They suggest the exclusion of small groups or team intelligence from a definition of CI. Instead, they propose that CI should focus on how individuals follow identical rules. This emphasis on a narrow variant of CI illustrates the conceptual struggle in this multidisciplinary field. Here, the basic question is whether CI studies of small group collaboration have anything in common with collective work in large global online communities. If this is the case, this connection needs to be further explained within a shared conceptual framework.

Because CI is a new research area, a range of other terms are obviously also used to describe the same or similar practices. One example is crowdsourcing (Brabham, 2013) or swarm intelligence (Corne, Reynolds, & Bonabeau, 2012). CI is also used to discuss

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nonhuman intelligence in some research areas, both animal intelligence and machine intelligence. In one review, Salminen (2012) found that only 25% of the papers on CI discuss human intelligence. A majority of the papers discuss collective behavior of cognitively simple agents such as insects, robots, and simulation algorithms. One area addresses new programming techniques used to analyze large amounts of quantitative data, which people leave behind when they use the Internet (e.g. Alag, 2009).

Although the focus of human CI research varies substantially, the shared assumption is that intelligence builds on some type of collective interaction or problem solving. It is something more than a psychological ability residing inside the head of an individual. For example, Jenkins (2009) challenges the view of intelligence as an attribute of individuals, and instead describes CI as being a new type of intelligence distributed across an extended technological and sociocultural online environment. In line with perspectives from distributed cognition, CI practices "offload" information into the environment.

1.2 Theoretical Perspectives on CI

As a scientific field, CI is still largely undeveloped and untheorized. There are relatively small research communities within areas such as computer science, psychology, economics, and biology. Some research studies also examine the interplay between human collective behavior and machine learning, but it is still not clear how CI differs from machine learning. There are few usable theories and a lack of analysis of CI at a large scale – in organizations, cities, nations, and networks (Mulgan, 2014, 2018). Typologies are practice-centered, often aiming to categorize and synthesize different online CI practices without any use of a dedicated theoretical framework (Malone et al., 2009; Suran et al., 2020).

Despite the lack of coherence, the scientific community has still identified some important mechanisms across different disciplines. First, at a micro level, empirical studies have identified a general group intelligence factor that explains problem solving in small groups. Second, many large-scale studies of collective work are explained through different self-organization mechanisms. Third, a vast number of CI studies, covering both a micro and macro level, address the role of informational diversity or cognitive diversity in different ways.

1. A general group intelligence factor
2. Self-organization
3. The role of diversity

1.2.1 A General Group Intelligence Factor

Historically, the invention of the intelligence test establishes the intelligence concept. In 1905, Alfred Binet designed the first version of this test. It identified French schoolchildren with learning disabilities who needed more support than other children (Binet, Simon, & Kite, 1916). At the same time, Charles Spearman (1904) developed the theory of general intelligence (or "g") that proposed that a large part of a person's intelligence was built on a general problem-solving ability. It would persist for many years before more complex definitions of intelligence were accepted (Piaget, 1952). In recent time, there have also been attempts to extend the notion of intelligence beyond its focus on human cognition. For example, Howard Gardner (1983) described the existence of seven different types of intelligence in his book *Frames of Mind: The Theory of Multiple Intelligences*. Three types covered cognitive abilities (linguistic intelligence, logical-mathematical intelligence, and spatial intelligence), and the four others, musical intelligence, bodily-kinesthetic intelligence, interpersonal intelligence, and intrapersonal intelligence, were new types of intelligence. Intrapersonal intelligence focuses on the capacity to have knowledge about oneself and control personal emotions, while socially orientated interpersonal intelligence describes the ability to understand and collaborate with other people. Still, human intelligence today is primarily connected to cognitive abilities and skills.

In contrast, CI research by Woolley et al. (2010) have found evidence of a general group intelligence factor, labeled the "c factor," in different types of group work. This has even led to the development of a group intelligence test, which is different from the cognitive tasks that are typical in standardized individual intelligence tests. The test tasks cover four different dimensions in authentic settings. The first task is about generating something new, like brainstorming various uses for a brick. The second category involves the selection of a pre-specified alternative, making groups solve visual puzzles from a standardized test called Raven's Matrices. The third dimension includes negotiating tasks, challenging the group to pretend they live together and have to plan a shopping trip. The fourth dimension is about executing tasks, and letting the group type a long text passage through synchronous online writing. In addition, other tasks involve word-completion problems, spatial puzzles, and estimation problems (Malone, 2018: 31).

In the original study, 152 groups of two to five members were set to solve a wide range of different tasks. Factor analysis of team scores identified one factor accounting for 44 percent of the variance, while the second factor only explained 20 percent of the scores. Here, collective intelligence is the inference one draws when the ability of a group to perform one task is correlated with that group's ability to perform a wide range of other tasks. The first factor with significant explanatory power is interpreted as a property of the group itself, not just the individuals in it. Nor was this factor correlated with the average or maximum individual intelligence of group members (Woolley et al., 2010). Other follow-up studies have shown similar results in other settings across different languages, cultures, and activities (Malone, 2018: 32–42; Woolley et al., 2015). For example, in high-performing teams playing online video games, collective intelligence scores were significant predictors of their performance in the game (Kim et al., 2017). The "c factor" has also predicted performance for other more complex tasks such as playing checkers against a computer or solving architectural design problems. In addition, the highly collectively intelligent teams exhibited steady improvement in performance across the series of tests, indicating that these groups also learn faster (Malone, 2018: 32–42; Woolley et al., 2015).

According to Malone (2018: 41), the combination of all these studies indicate that human groups have a kind of collective intelligence that is directly analogous to what is measured by individual intelligence tests. He highlights the distinction between (1) specialized intelligence and (2) general intelligence in individual intelligence tests (Malone, 2018: 24). First, specialized intelligence refers to the ability to achieve specific goals effectively in a given environment. The equivalent of this type at a group level will then be "group effectiveness." However, intelligence tests have been designed to predict your general intelligence or your ability to do a wide range of other tasks beyond those in the test. People who have much of this general intelligence are better at adapting to new environments and learn more quickly. Likewise, general collective intelligence refers to the group's ability to adapt to new environments and perform well on a wide range of different group tasks (Malone, 2018: 24–25, 41).

Although some researchers claim there is insufficient support for the existence of a collective intelligence construct (e.g. Bates & Gupta, 2017; Credé & Howardson, 2017; Woolley, Kim, & Malone, 2018), there is increased interest in the more general problem-solving abilities in groups in both offline and online settings. However, we still know little about which group processes or group qualities influence the "c factor." There are affiliated concepts such as group cognition and group mind. Within sociology, both Durkheim's concept of collective consciousness and

Gabriel Tarde's notion of group mind move beyond the individual self in their examination of societal beliefs in larger groups. In psychology, new theories of learning also highlight the qualities of group discourse and joint meaning making to a greater degree (Sawyer, 2006; Stahl, 2006). Knowledge does not reside inside the heads of individuals, but in the practice itself (Flick, 1998; Gergen, 1985). Likewise, this book analyzes CI as a group phenomenon.

1.2.2 *Self-Organization*

Another strand of CI research examines different types of self-organization. The first type of self-organization is at a macro level, describing the Internet as a self-organizing super-intelligence that unites all human intelligence into a worldwide network of information and communication. For example, Heylighen (2011) uses the metaphor of a global brain to describe the Internet as an intelligent, organism-like system, a brain of brains. CI emerges from the collective interactions between humans and machine in a global online communication network. This global brain is immensely complex and self-organizing without any centralized control, and emerges as an adaptive complex system. In an interview (Lollini et al., 2019), Levy claims this type of self-organization can best be described as stigmergic communication. Throughout our human history, improvements in CI has followed from inventions that augmented the power of human language. The invention of writing created a new collective memory that was further developed with the invention of the printing press. Moreover, the invention of the Internet completely removes the constraints of physical space and memory when knowledge becomes accessible from anywhere in the world. This is not only communication from many to many, but also a new way of connecting knowledge when it is stored in an online setting. The stigmergic element refers to the intermediary of a common shared environment that everyone uses. Almost the entirety of humanity can add knowledge to this shared memory, which anyone can access. In addition, every new trace of action on the Internet will continuously change the relationship between the stored digitized data. In this sense, everybody contributes to the transformation of the common memory at the same time. Although CI is facing huge challenges today, Levy proposes that the way forward is to design practices that can promote reflective communication between people in the online setting (Lollini et al., 2019).

The second type of self-organization describes the emergence of global online communities. One example is Wikipedia, which has more than six million articles in the English version alone (Rijshouwer, 2019). Another example is the development of open source software where many individuals contribute at different points of time (Raymond, 1999). Mulgan (2018: 76) also describes how stigmergy is important in self-organizing systems like Wikipedia, or among open source software development programmers who pass around tasks in the form of challenges until they find a volunteer. Human stigmergic problem solving is an important part of the analysis in this book (see Chapter 6).

Third, self-organization can build on market mechanisms, like the "invisible hand" that self-regulates the market economy by letting everyone pursue their own interests (Hayek, 2013). Widely dispersed markets use price signals efficiently to coordinate large-scale activities. Markets can adjust prices with little horizontal communication between the participants, but they are limited to the binary decision of whether or not to buy something (Mulgan, 2018: 111, 115). In CI research, this type of self-organization has been examined in studies of prediction markets (Buckley & O'Brien, 2017; Malone, 2018) which is also a topic addressed in this book (see Section 6.3).

A fourth type of self-organization studies swarm problem solving in animals. Peters and Heraud (2015) claim biological studies of "swarm intelligence" is one of six major areas within CI. It refers to the collective behavior of social insects and flocking behavior (Mulgan, 2018: 232). For example, Sumpter (2010) claims human collective behavior can be explained through self-organization and different behavioral algorithms. These principles, such as positive feedback, response thresholds, and independent decision-making, are also present in different animal groups and can inform our understanding of human societies. However, Willcox, Rosenberg, and Domnauer (2020), claim there is no good theory that explains how human swarms operate. Few studies examine large-scale human collective work in the offline setting. This area of investigation is labeled as human swarm problem solving in this book (see Chapter 4).

1.2.3 The Role of Diversity

In general, CI expects that new technologies will make groups better at solving problems than ever before (Malone, 2018). The predominant strategy is to scale up the size of the group and hope this can create more diversity benefits. A prominent example is the book *The Wisdom of Crowds* by Surowiecki (2005), which describes four qualities that make a crowd intelligent. First, the group should be diverse, so different individuals can

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supplement each other with different pieces of information. Second, the group needs to be decentralized, without anyone directing the answers from the center. Third, individual opinions need to be aggregated into a collective opinion. Aggregation typically depends on numerical contributions and statistical methods. Fourth, the individuals in the crowd should act independently of each other.

In a historical perspective, it was the British scientist Francis Galton who in 1906 first described the "Wisdom of the Crowd"-effect from a scientific perspective. He visited West of England Fat Stock and Poultry Exhibition, which had organized a contest where anyone could guess the weight of an ox. Eight hundred individuals made guesses, but none had the right answer. Galton decided to average all the guesses, and surprisingly discovered that the estimate of 1,198 pounds was only 0.8 percent different from the correct answer of 1,207 pounds (Galton, 1907). It was the first scientific paper suggesting that a large group could be much more accurate than individuals.

Today, the diversity prediction theorem, developed by Hong and Page (2004) represents perhaps the most important theoretical explanation of CI with its emphasis on diversity. The mathematical theorem explains the relationship between collective accuracy and the diversity of predictions based on expected errors. The theorem can be written as the following mathematical proof:

The Crowd's square Error = Mean square error of individuals – Predictive Diversity (Hong & Page, 2004).

The theorem states that the error of a crowd equals the average squared error minus the predictive diversity. First, the mean square error is the average of the individual squared errors. It includes the errors each individual has made as a distance from the correct or true value (Page, 2014).

Second, the prediction diversity equals the average squared distance from the individual predictions to the average prediction. From a statistical perspective, this is the same as the variance or how widely spread the predictions are, but Page prefers to use diversity as a term to underline the importance of variations in the predictions. This is the crowd diversity dimension (Page, 2014).

Third, the crowd error is the squared error of the collective prediction. It equals the average squared error (crowd's prediction) minus the predictive diversity. The crowd square error must always be smaller or equal to the mean square error. Consequently, the prediction of a crowd must always be better than or equal to the average prediction of its members. Much better prediction requires a larger degree of diversity, while a crowd that is only as good as its average member will have no predictive diversity. The main point is that when the diversity in a group is large, the crowd error will be small. Therefore, wise crowds will rely on not only individual accuracy (mean individual error) but also crowd diversity (Page, 2014: 1332).

Consider the following example. Two persons predict the annual snowfall in their hometown. Both deviate from the correct answer by 4 inches, making the squared error equal to 16. If both guess 4 inches too many or too few, there is no predictive diversity. The crowd error will then be 16, equal to the mean square error (Theorem score: 16 = 16 – 0). However, if one person predicts 4 inches too many and the other person 4 inches too few, the crowd will provide the correct answer because the diversity of predictions cancel each other out (Theorem score: 0 = 16 – 16) (Page, 2014).

In essence, this theorem points to cognitive or informational diversity being at the core of CI, and this book will further explore this topic in the discussion of different types of collective problem solving.

1.2.3.1 The Many Wrongs Principle

Furthermore, the "many wrongs principle" and "the many eyes" principle are two different principles that explain the benefits of diversity. In the "many wrongs principle," or "the generated framework" (Page, 2014), predictions are modeled as the truth plus a disturbance. For example, when a group of persons individually estimate (predict) the height of a tree, each person will observe the height from a slightly different position on the ground. Because of these variations in vantage point, each individual observes the true height plus some error term. When these errors are made independent of each other, they will be diverse, and the aggregated crowd error will be small because the individual random errors cancel each other out (Page, 2014).

Answers that aim to be accurate must avoid systematic bias. For example, in guessing the weight of the ox at the county fair, Galton (1907) noticed that the individual judgements were less biased by passion and joking because contestants had to pay a small fee to compete. This prompted each competitor to do his best. The competition for prizes probably also motivated contestants to make independent judgements and not discuss their estimates with other contestants, thus reducing the possibility of systematic bias.

According to the "many wrongs principle," the crowd wisdom builds on the aggregation of individually independent guesses that have random or symmetrically distributed errors. When many people with no particular bias make an estimate, they will be equally likely to make errors on the high and low side of the correct answer. By averaging the answers, these errors cancel each other out because of the law of the large numbers. Under these circumstances, the larger the crowd, the more accurate the estimate. The limitation is the requirement of numerical contributions, which leaves out many other types of collective problem solving (Krause, Ruxton, & Krause, 2010; Malone, 2018; Page, 2014).

1.2.3.2 The Many Eyes Principle

The "many eyes principle," or the "interpretive signal framework" (Page, 2014) provides an alternative explanatory framework by assuming that accurate collective predictions build on diverse mental models. Because people use different models, perspectives or heuristics when they solve a problem, they also make different mistakes. These techniques or strategies will vary depending on variations in life experiences, cultural background, and formal training (Page, 2014). For example, if you estimate the temperature outdoors, you will use your tacit "personal knowledge" that builds on previous experiences of estimating the temperature. When a group does this task, they will operate with uniquely different mental models, and the aggregated average of the temperature will therefore often be very accurate.

When guessing the height of a tree, the "many eyes principle" does not only include individual differences in vantage point, or the distance to the tree, but it also involves the differences in the cognitive strategies individuals use to estimate the actual size of the tree. For instance, do you try to compare the height of the tree with other objects close by or do you know how tall such trees usually are? When individuals build their estimation on different heuristics, this increases the cognitive diversity and helps provide a more precise estimate at an aggregated level. In the "many eyes principle," individuals filter the world in their own unique way, and therefore they will observe different approximations of the same phenomenon (Page, 2014).

According to this principle, the wisdom of the crowd in the ox contest is not about errors that cancel, but it is about the crowd providing a more complete explanation. At the county fair, a relatively large group of contestants was highly competent since they were butchers or farmers (Galton, 1907). According to the "many eyes principle," these individuals would still probably have used different heuristics when estimating the weight of the ox. One cognitive strategy could have been, "The ox is about ten times my size – I weigh 90 kilos – therefore the ox should be around

900 kilos." Another strategy could have been, "Oxen at my farm usually weigh 1,100 kilos, this ox seems to be a bit larger than average, so the weight should be around 1,200 kilos." The contestants who were not butchers may also have contributed with important "bonus diversity" by using relevant heuristics that are significantly different from how butchers or farmers estimate the weight. Here, the threat is that many in the crowd use the same mental models, which then leads to less cognitive diversity and a more imprecise aggregate estimation.

This implies that the collective problem solving was relatively accurate even with diverse individual perspectives. According to the "many eyes principle," errors still cancel out, not because of randomized draws, but because individuals use distinctly different mental models that together provide a better "collective mental model." Because the world becomes more complex and harder to predict, an individual model is likely to produce a large error, resulting in a large mean error on the aggregated level. Then, according to the diversity prediction theorem, the only way to keep the crowd error small is to ensure that the predictive diversity is large (Page, 2014).

Another implication of the "many eyes principle" is that it is risky to select team members based on their ability because they are then likely to be less diverse from each other. The well-known catchphrase that "diversity trumps ability" was originally inspired by a computational experiment by Hong and Page (2004), where the simulation results surprisingly showed that a diverse, randomly selected group of agents outperformed a group of the best agents. The reason this happened is because in large populations, the functional diversity of the group of individually best-performing agents becomes very small. If you choose the two best problem solvers from a large set, they are more likely to use similar perspectives and heuristics. Under certain conditions, the model predicts that diversity trumps ability, implying that it is better to select team members based on diversity of heuristics than their individual ability. The best problem solvers tend to be more similar, and IQ test scores will therefore not necessarily be a good predictor of the team performance. The exception is simple problem solving, such as some types of physical labor, where the individual with the highest ability will also be the best team member (Page, 2014).

The diversity prediction theorem covers collective problem solving at both at a micro group level (Page, 2017) and a macro group level (Page, 2008). It has inspired theoretical work within epistemic democracy (Anderson, 2006) and experimentation with new democratic models that can better tap the "wisdom of citizen diversity" (Landemore, 2013).

Although some question the relevance of using mathematical models to describe cognitive diversity, the diversity prediction theorem still constitutes an important theoretical premise for CI research. Cognitive diversity assumes that better solutions build on a broader set of perspectives that look at different parts of the problem (Page, 2018). Similarly, this book describes distinctly different types of collective problem solving that aim to provide a more comprehensive understanding of CI.

1.3 Top Solvers in Online Innovation Teams

In addition to reviewing relevant theory and CI practices, this book will also examine new data from online innovation contests. These contests are an important part of CI research. Page (2014) mentions these contests as an interesting example of a new type of cognitive diversity that enables thousands of problem solvers to participate in complex problem solving and thus increase the likelihood of producing an optimal solution. Today, specialized online innovation intermediaries often host these online innovation contests.

In recent years, it has become more common to enable teams to solve challenges instead of having a large number of individuals working separately from each other. Multidisciplinary teams can work on challenges that are more complex by moving beyond simple aggregation, towards combining and synthesizing ideas.

Several chapters in this book will include data on how top solvers experience participation in such online contests, including both small teams and larger groups. The data consist of selected excerpts from 80 interviews published on the IdeaConnection website, one of the most prominent online innovation intermediaries. All the solvers in the corpus have won a contest, so they are not representative of the large member database, which includes many who have not won any contests. These solver stories provide detailed, illustrative descriptions of the different types of collective problem solving, especially collaborative problem solving.

The contest format at IdeaConnection has several design features that aim to utilize cognitive diversity. The innovation teams will typically be both multidisciplinary and multicultural, and a successful solution will usually depend on this diversity. In this team contest format, individuals are invited to participate in teams comprising four to five persons and a facilitator. Only a few teams will compete for the prize, which increases the chance of each team winning, compared with the contests in which anyone can participate. At the same time, the diversity of proposed solutions increases because the competing teams develop solutions independently of each other. These teams are also interesting because they illustrate complex problem solving in an online setting. They point towards a future where online CI is likely to become more important in collaborative problem solving. While a significant amount of CI research today consists of experimental studies, these teams represents an interesting supplement in their descriptions of how collective problem solving unfolds itself in "natural" online settings.

1.4 A Cultural-Historical Perspective on CI

According to Mulgan (2018: 2), CI needs to address the big question today; how can societies and governing systems solve complex problems, or how do collective problems find collective solutions? Until now a lot of the CI research has addressed relatively simple one-dimensional problems, while some of the most pressing tasks today reveal conflicting interests and less clarity about what answers are right, which only time can resolve (Mulgan, 2018: 26).

Machine intelligence and artificial intelligence (AI) is also another important area within CI research (Peters & Heraud, 2015). However, this book will highlight this type of CI as something different, being primarily a human-to-human intelligence. CI mobilizes human intelligence at scale, often linked through the Internet, and includes new ways of organizing knowledge production and solving problems, as in crowdsourcing (Mulgan, 2018: 16). Although machine intelligence and CI are often closely connected with each other, CI is assumed to build on a different logic. According to Mulgan (2018: 237), CI is the capacity of groups to make good decisions through a combination of human and machine capabilities. Our lives will in the future obviously become even more interwoven with machine intelligence that both challenges and amplifies us, but human collectives and human intelligence must still be at the center (Mulgan, 2018: 6, 235).

As such, this will not be a book about machine learning or AI. Even without computer science, the CI field is very broad. It covers both small groups and large groups, and offline and online settings. One might even ask whether there exists any general mechanisms across the multitudes of settings and group sizes. Until now, most studies of CI describe new online practices. Although a range of multidisciplinary models and definitions have been introduced (e.g. Suran et al., 2020), none have, to my knowledge, examined CI within a historical perspective. One reason may be that the short format of a research article limits the possibility for detailed historical examination.

This book will address the lack of research in this area by analyzing how CI has evolved in a historical perspective. By including this perspective, one avoids perspectives that rely too heavily on technological innovation in itself, with the risk of ending up in technological determinism. Still, this book assumes that it is not enough to adopt a historical understanding, since major technological innovations are changing the way we solve problems. CI should align with both former and recent historical development.

From a Vygotskian perspective, the explanation of any human phenomenon, including CI, should consider both biological and cultural-historical perspectives. A scientific study should not only focus on CI as an improved product of what groups can achieve, but also investigate the processes by which a phenomenon emerges and how it originated. The emphasis is on human cognition in growth or transition, where different forces of development follow their own logic. Both natural and cultural lines of development interact with one another, but they are not necessarily united. It is only through analytical abstraction that we can separate one set of processes from others. A complete analysis of human psychological processes should still aim to integrate these perspectives and their corresponding explanatory principles (Wertsch, 1985: 17, 41–42).

Inspired by this methodology, CI is analyzed as a phenomenon comprising three types of collective problem solving: collaborative problem solving, swarm problem solving and stigmergic problem solving. These problem-solving types are not final or complete in any way. However, if analyzed in combination, they provide a set of explanatory principles that contributes to a more complex understanding of CI. The different types of collective problem solving include a range of different practices at different scales and levels, including both group work in a face-to-face offline setting at a micro level and large-scale collective work in an online setting at a macro level. In this sense, the book aims to contribute in establishing a full-fledged discipline of collective intelligence (Mulgan, 2018: 4).

This book also examines this issue by describing the origins of the three different types of collective problem-solving types. Although online practices are new, our societies accumulate knowledge and develop according to specific historical mechanisms. Different types of collective problem solving evolved gradually into more complexity in human history. This is perhaps most evident in the chapters about the origins of human swarm problem solving (see Chapter 5) and human stigmergic problem solving

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(see Chapter 7). The examination of the history of CI can also disclose core mechanisms in collective problem solving that are still relevant for online CI practices today.

Furthermore, a cultural-historical perspective avoids a reductionist approach that provides an overly simple description of CI. The goal with this book is to shed light on how CI practices today can contribute to the development of a better society and not just improved progress within a few narrow problem areas (Mulgan, 2018: 223). Hence, Chapter 13 analyzes the COVID-19 pandemic from a CI perspective. According to Mulgan (2018: 6), CI is in many ways humanity's grandest challenge, since we need to develop our ways of thinking and acting together if we are to solve the other grand challenges of climate, health, prosperity or war.

1.5 The Methodological Steps

The methodology in this book follows four steps, explained below in more detail.

1.5.1 Step 1: Review Current CI Practices

In the first phase of this research process, I undertook an extensive search of CI literature to obtain an overview of the most common practices and characterizations of the phenomenon. This phase dates back to the reading of a report in 2011 (Malone et al., 2009). Over the following years, several new scholars and stakeholders introduced new models covering a range of fields and sectors; however, these models typically concern a relatively small part of the multidisciplinary field. Chapters 1–3 comprise a summary of these readings on CI. They constitute the main review of CI literature, dividing the field into crowdsourcing and open online knowledge sharing as two major areas. Within these areas, a few important CI practices have been selected to provide a more detailed account. This approach coincides with Mulgan (2018: 236), who suggests that an emerging discipline should be descriptive and analytic, observing collective intelligence "in the wild" in finding the most successful CI practices.

Chapter 2 describes crowdsourcing, a process whereby problems are sent outside an organization to a large group of people – a crowd – who can help provide solutions (Surowiecki, 2005). Online citizen science and online innovation contests are of particular interest because of their societal value. Within innovation, the two selected examples are from IdeaConnection and Climate CoLab, two innovation intermediaries who

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host different types of online innovation contests. One of these contests, the IdeaRally, represents an interesting new crowdsourcing method that allows hundreds of experts to participate in a one-week long intensive idea building process. In online citizen science, Zooniverse (e.g. Galaxy Zoo) and Foldit are selected as two prominent, but contrasting examples. The online protein folding game Foldit stands out as a particularly successful project that show what amateur gamers can achieve. The game design combines human visual skills with computer power in solving protein-structure prediction problems by constructing three-dimensional structures. Most successful solutions are team performances or achievements made by the entire Foldit gaming community. All the examples in this chapter illustrate successful case stories, and the detailed analysis identifies basic problem-solving mechanisms in crowdsourcing.

Another important area in CI is open online knowledge sharing (see Chapter 3). Open sharing is becoming more important in all major sectors in society, including science, politics, education and innovation. This sharing includes both the domain of expert-produced scientific knowledge and massive amounts of citizen-produced practical knowledge. Because of lower publishing costs, Open Access has become the new dominant trend that makes research accessible to everyone. Increased production of open textbooks gives a more readable access to scientific knowledge and reaches a much wider audience. In addition, scientific knowledge construction processes are becoming transparent. This includes the establishment of many more open digital databases that allow anyone both to make their own contributions and get free access to all the data (e.g. citizen science project like eBird). There is also experimentation with making knowledge construction processes more open, both within scientific discourse (e.g. Polymath project) and the development of encyclopedic knowledge (e.g. Wikipedia). In addition, the recent decade has seen an enormous increase in amateur-produced practical knowledge, not only texts, but an abundance of images and videos. Enthusiasts share their skills and passions concerning any activity that might be of interest to other like-minded persons. It also includes the sharing of political opinions, for example with new digital technologies like argument mapping. Even some companies in the business sector have begun sharing more of its corporate knowledge.

These CI practices address aspects of what Peters and Heraud (2015) label as social innovation, new social practices that aim to strengthen civil society by improving working conditions, education, community development or health. This approach assumes that complex social problems require the involvement of engaged citizens. Citizens are capable of both co-evaluating and co-creating public goods and services that can reform the public sector (Peters & Heraud, 2015).

My perusal of the literature suggests that both crowdsourcing and open online knowledge sharing are central to CI, areas often highlighted at conferences, in research papers or in books on the subject. However, this does not imply that the CI examples are mainstream today. One example is argument mapping, an interesting practice that is not widely used. Online innovation contests and online citizen science (Chapter 2) are new, but still relatively peripheral practices.

1.5.2 Step 2: Identifying CI as Three Types of Collective Problem Solving

Collective problem solving is the core term in this book about CI. The term covers a range of different practices across different group sizes and periods, while retaining a common emphasis on aspects of problem solving. The term differs slightly from what is typical among other CI researchers, who often underline communication, coordination or other system characteristics (e.g. Suran et al., 2020). The main advantage with using problem solving as a term is that it intends to cover the "complete" intelligent process. My readings of biologically orientated CI research inspired me to distinguish between three types of collective problem solving: *1. collaborative, 2. human swarm and 3. human stigmergic.* Research on both swarm behavior and stigmergy is relevant for a large range of collective practices today. Subsequently, I searched for additional research studies to enrich the descriptions of the particularities of these subtypes (Chapters 4, 6, and 8), even when these studies did not explicitly mention CI. The goal in the first part of the book is to give a detailed description of the basic mechanisms that characterize these three types of collective problem solving.

Chapter 4 discusses human swarm problem solving as a distinct subtype of CI with biological antecedents in nest siting among honeybees and flocking behavior. Building on recent biological research, this chapter discusses five mechanisms that are also relevant for human swarm problem solving. These mechanisms are decision threshold methods, averaging, large gatherings, heterogeneous social interaction and environmental sensing. Studies of collective animal behavior show that they often make decisions that build on statistical rules (e.g. averaging, threshold responses). Even when in a group, individuals will often seek and assess information independently of others with the intention of optimizing decisions through the "many wrongs principle" or the "many eyes principle." Similarly, human "wisdom of the crowd" studies examine similar statistical rules and principles like the importance of making independent contributions. However, while early research on the wisdom of crowds addressed the importance of independent contributions, newer studies also examine the possible positive influence of dependent contributions. The increasing variety of crowdsourcing studies are in this chapter explained within the framework of different swarm mechanisms. In the summary, four basic characteristics of human swarm problem solving are highlighted: predefined problems, pre-specified problem-solving procedures, rapid time-limited problem solving, and individual learning.

Chapter 6 presents human stigmergic problem solving as a distinct "solution-centered" subtype of CI with biological antecedents in the trail-laying and nest-building of ants. Stigmergy describe how many individual agents are able to coordinate collective action only by leaving information in a shared environment. In this type of collective problem solving, a version of a solution will already exist, either partially or completely. The problem-solving process will, therefore, be a response that changes the existing version of a solution by rating it, in the case of, for example, an online video; re-estimating it through a prediction market; adapting it like an open textbook or completing it like a Wikipedia article. In human qualitative stigmergy, a preliminary part of a solution will be stored in the system or medium, and individuals will then respond to the unfinishedness of the solution in different ways. If many versions of a solutions already exist, human quantitative stigmergy can also be used to rate the most optimal solutions. In the online setting, solutions will be continuously compared with each other. These stored solutions can solve many different problems at various points of time.

Chapter 8 proposes collaborative problem solving as one of three distinct types of CI. Collaborative problem solving covers a wide range of disciplines and contexts, but this chapter primarily draws on studies that have explicitly used CI as a scholarly concept. The most important finding is the identification of a general group performance ability on a wide variety of tasks. This group performance is analyzed in relation to four dimensions that promote successful collaborative problem solving. First, "working well with others" is not only analyzed as an individual ability, but as a quality that emerges through the qualities of a symmetrical collaborative relationship. Second, "cognitive diversity" describes diverse repertoires in groups, also including multidisciplinary and multicultural diversity. Third, "equal participation" emphasizes that everyone in the group should

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be allowed to bring in their perspective, and group discussions need to be open-minded. Fourth, "joint coordination" is important in setting goals together, dividing tasks and choosing relevant problem-solving strategies. Solver experiences from online innovation teams exemplify how this type of CI can move forward in a highly relevant authentic online setting.

1.5.3 Step 3: A Historical Analysis of the Problem-Solving Types

The third step is a cultural-historical analysis of each of the three types of collective problem solving (Chapters 5, 7, and 9). It is assumed that all problem-solving types build on mechanisms that humans already use. Hence, both the historical and phylogenetical origins of these three types of collective problem solving and their inner contradictions are examined. In addition, this brief analysis explains how the different problem-solving types evolved in complexity until our present day. CI is analyzed as a practice that has evolved over time as humans have learned how to use increasingly advanced tools. Sources include various previous books and articles that describe the relevant historical practices.

Chapter 5 argues that the origins of human swarm problem solving can be traced back to group hunting, which required rapid problem solving during the hunt, but also planning activities. Collective actions build on synchronization in the sense that every contribution from individual hunters mattered. Another milestone was the emergence of premodern trade, which enabled human groups to utilize informational diversity from nonkin and even strangers. Knowledge was shared in new ways through large gatherings and trade networks. The third major achievement was the establishment of the first democracy in ancient Athens with institutions such as the Assembly of the People, the Council of 500 and the People's Court. These institutions enabled a large number of individuals to engage in rapid problem solving in a formalized manner. Individuals from all over the Athenian territory met in the city to solve societal problems. These historical examples show that human swarm problem solving is also a story about our ability to solve problems in increasingly larger groups.

Chapter 7 trace the origin of human stigmergic problem solving back to the invention of writing. Knowledge could now be stored, reused and made accessible to others. A human collective memory was established which made it possible to develop more complex societies. However, it is the "copy-revolution" of the printing press that enables human stigmergy to be used at full scale throughout society. The reduced cost of making a book allowed for a much more flexible reuse and sharing of existing knowledge across wider geographical distances. All types of written knowledge could easily be copied and made accessible to many more readers. Human stigmergy evolved into new forms. Frozen stigmergic problem solving describes how existing solutions in book format were copied and reused at an unprecedented scale. The mass production of identical copies made it possible to spread the same message to everyone across large geographical areas. This led to a radical increase in available knowledge; people began to learn faster from each other because knowledge sharing was amplified. In addition, fluid stigmergic problem solving describes how knowledge products were not only copied, but they were improved through new book editions and translated, which further spurred collective knowledge advancement.

Chapter 9 argues that the origins of collaborative problem solving can be traced back to mutual collaboration, which built on the evolution of more advanced forms of gestural communication. Elaborative collaborative problem solving builds on this type of collaboration and requires proximate mutual interaction and sympathy between the collaborators. In contrast, rule-governed collaborative problem solving centers on an idea of fairness and requires that collaborators adhere to specific rules or norms in their collaboration. At least two collaborative cultures were key in the evolvement of this type of collaboration. First, stone tool learning required deliberate practice and the presence of a community of learners with norms. Explicit teaching and individual training built on purposeful activities that were considered valuable, a collaborative culture which over time made it possible to refine stone tools across generations. Second, it is likely that hunter-gatherer groups were important in the development of ideas on equal participation, building on reciprocity and norms that emphasized equal sharing of food. Calculated reciprocity represents a significant move away from the dominance of a few individuals in groups. Equal sharing of food required increased control of emotions and the establishment of norms that kept free riders out. A fair sharing of spoils also permitted role differentiation in groups because not everyone had to participate in the hunt in order to get food.

1.5.4 Step 4: Design of CI

The second part of the book examines in more detail how CI can be successful in the scientific and political domain. The analysis covers three interrelated dimensions: intelligent engagement (Chapter 10), intelligent contributions (Chapter 11), and intelligent evaluations (Chapter 12).

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On one hand, CI points to the emergence of Open Science, an umbrella term that describes a movement that aims to make scientific research accessible to everyone in society. This involves both citizen participation in scientific processes and the increased open sharing of scientific publications. On the other hand, CI orientates itself towards Open Democracy, which is a term used to describe how the Internet and digital technology can strengthen democratic participation and put ordinary citizens at the center of political systems in new ways.

Chapter 10 analyzes the relationship between citizen participation and citizen expertise, particularly in the political domain. New types of intelligent citizen engagement are emerging, such as mass deliberation, mass voting and social media activism. Mass deliberation describes the evolvement of new democratic institutions that aim to recruit citizens in direct participation. Two examples, the Citizens' Council in Ostbelgien and the online ideation platform Better Reykjavík, are part of this new trend. Mass voting is another type of citizen participation that has received increasing popularity because of the Internet. Technological platforms make it easy to enable everyone to vote, such as the Five Star Movement does with its party members in Italy. Social media activism has also become increasingly important. This involves both informal political debate and political activism, which the social movement My Stealthy Freedom exemplifies. All these CI projects build on different conceptions of participatory diversity. In addition, transparent collective work is important in promoting intelligent engagement between large groups, both in scientific work like crowd peer review or political processes like the Icelandic constitutional experiment. However, there is a concern about the threats to democracy that dysfunctional engagement presents, such as fake news and echo chambers in social media.

Chapter 11 address how contributions are combined in different ways when designing CI. One approach utilizes many different perspectives in the same work, like in collective work on the same Wikipedia article. Multidisciplinary innovation teams also include a diversity of perspectives in creative problem solving. Second, contributions can be combined under the assumption that the golden middle way is the best solution. One example is the identification of a quantitative middle point, such as an average, that provides the most accurate solution if contributions are diverse. Another strategy is to find the middle way by developing a balanced representation of all sides, as in collective argument mapping. In addition, the middle way can identify commonalities, like the online environment vTaiwan that lets the crowd find consensual statements in political conflicts. A third approach scales up the number of contributions in the search for an unexpected solution. Many breakthrough ideas happen at the outskirts of a field. Online innovation contests aim to bring in creative outsiders or unknown others by inviting anyone to join. Furthermore, most of the contributions in CI projects build on a modularization strategy that splits a complex challenge into many smaller subtasks.

Chapter 12 describes different types of intelligent evaluation. At all group levels, most CI practices are reliant on some degree of explicit evaluation of the collective work. Digital technology also makes it possible to design metacommunicative feedback loops in most group work and organizational work. While some systems build on shared coordination, others let coordinators regulate the collective work. In the political system, intelligent evaluations are at the core of any well-functioning democratic system, from the nomothetai in ancient Athens to the Citizen Assembly in Ireland today. These new institutions strengthen citizen metadiscourses about important societal issues. A strong knowledge commons is also an important basic condition for this type of critical discourse. In general, digitized evaluations are becoming more common in society, exemplified by online reputation systems that rate a person's trustworthiness, not only on business sites, but also in social media. However, there is increasing concern about the negative consequences of evaluating persons in the emerging reputation society.

Chapter 13 describes COVID-19 as a wicked problem and shows how different CI mechanisms have been used to cope with the pandemic. The first CI mechanism is the transparent flow of information during the pandemic. Knowledge is being shared at a rapid pace in the global online setting. Most of the big news sites provide citizens with updated statistics on the spread of the virus. Another example is the governmental "test and trace" strategy that aims to maximize information about the spread of the virus at all times. A second CI mechanism is citizen responsibility. Citizens in all countries have faced the challenge of complying with behavioral rules enforced by the government. Rules on social distancing and voluntary quarantines depend on citizen cooperation. Here, New Zealand stands out as one of the most successful countries. Third, collective learning at a system level has been important in dealing with the pandemic. One example is South Korea, which learned a lot from the Middle East Virus (MERS) in 2015 a couple of years before the COVID-19 outbreak. Their learning from the past failures in coping with that outbreak made them much better prepared than other countries.

Chapter 14 explores what motivates individuals to contribute to CI projects. If we think CI can benefit society, we need to understand what motivates individuals to engage in collective problem solving. However, both the complexity of the tasks and the required skill levels varies a lot. It ranges from innovation contests that often look for individuals with specific formal qualifications to citizen science project that require simple image detection skills. In a historical perspective, we have more spare time than ever before and many CI projects depend on this extra "time resource", but the competition with social media and other entertainment services is fierce. The chapter examines a wide range of motivational factors, such as being immersed, being recognized, being part of a community, learning as motivation, economic motivation and making societal contributions. Statements from top solvers in online innovation contests comprise an important part of the content in this chapter.

Chapter 15 concludes by describing two radically different future visions of the intelligent society. On the one hand, instrumentarian intelligence assumes that algorithms tracking human behavior can predict human behavior more accurately than ever before. In Western countries, this intelligence manifests itself in a new surveillance capitalism, with companies like Google and Facebook constantly searching for behavioral surplus in both online and offline settings. In the political domain, instrumentarian intelligence seeks a reputation state built on a neobehavioristic governing model. The most prominent example is the nationwide social credit system in China that makes it possible to grade citizens on different behavioral indicators.

On the other hand, civic intelligence highlights a use of technology still controlled by the community and citizens, in contrast to the dehumanizing aspects of instrumentarian intelligence. While machine intelligence also craves for informational diversity in its hunt for behavioral surplus, civic intelligence seeks a broader diversity that includes not only information, but also multicultural, cognitive, biological and participatory diversity. The "fuel" of CI is people who are different from each other, with different interests and unique perspectives. Civic intelligence also builds on a strong knowledge commons and an open, shared collective memory. It does not hide information to produce the best predictions but promotes complete transparency and individual empowerment. In contrast to instrumentarian intelligence, CI still enables human-to-human intelligence, and not the algorithms, to be at the core of human collective problem solving.

CHAPTER 2

Crowdsourcing

2.1 What Is Crowdsourcing?

In 2006, Jeff Howe coined the term crowdsourcing as a way to capture how large groups of people in the online setting were coming together to solve different types of problem. By combining "crowd" and "outsourcing," the new term emphasized how organizations made open calls in an online setting to outsiders who could help them solve tasks that they had previously completed within the organization. Instead of "outsourcing" the task to one specific external expert or company, the new call invited anyone to contribute. Today, crowdsourcing tasks vary significantly, and can be anything from the design of a new product to a scientific problem, but the problem is usually formulated in advance. The most important advantage with inviting a large group of people to contribute is that the outreach and the number of contributions offer more diversity and can therefore potentially offer a better solution. The contributors are typically unknown to each other and will have many different types of backgrounds (Innocent, Gabriel, & Divard, 2017). Another aspect of crowdsourcing is the emphasis on volunteering and self-selection of tasks. Although many people receive an invitation, only the individuals who think they have the skills and the time to contribute will participate (Brabham, 2013).

Today, crowdsourcing is receiving increased attention from a wide range of stakeholders, like businesses, scientists, policymakers and funding agencies. Crowdsourcing is part of open innovation, a new paradigm that expects organizations to use external ideas to advance their innovations. In open innovation, outsiders are valued because they can contribute to new and unexpected ways of solving a problem. Before the invention of the Internet, this type of innovation would typically happen at fairs, conferences, exhibitions or through joint projects (Von Krogh, Netland, & Wörter, 2018). The basic assumption is that knowledge will always be widely distributed in the economy, or in more popular terms, "most smart people work for someone else" (Bogers, Chesbrough, & Moedas, 2018). More specifically, crowdsourcing resembles "outside-in" open innovation; a strategy that involves direct use of ideas and knowledge from external stakeholders outside the organization. By reaching out to new potential problem solvers, the aim is to utilize a larger degree of cognitive diversity (Chesbrough, 2017). Today, numerous businesses and other organizations recruit outsiders to help them solve different type of organizational challenges (e.g. Innocentive, IdeaConnection), design challenges (e.g. Threadless), scientific problems (e.g. Foldit), IT challenges (e.g. Topcoder), financial challenges (e.g. Kickstarter) or broader societal challenges (e.g. Climate CoLab). The goal will often be to find outsiders who can think "outside the box" and utilize unconventional sources of knowledge. In addition, crowdsourcing covers a range of simpler tasks or routine activities, like classifying images in science (e.g. Galaxzy Zoo). Although the methods vary, all crowdsourcing strategies assume that they can harness unique human knowledge in a way that machine intelligence is not capable of (Franzoni & Sauermann, 2014; Innocent et al., 2017).

In an attempt to better understand the basic collective problem-solving mechanisms in crowdsourcing, this chapter will cover a broad range of examples from both open innovation and citizen science, two of the perhaps most interesting new areas in relation to the potential societal benefits of crowdsourcing. In open innovation, the two examples are from innovation intermediaries who host online innovation contests (IdeaConnection and Climate CoLab). In citizen science, Zooniverse (e.g. Galaxy Zoo) and Foldit are selected as two prominent examples that will be introduced and analyzed in detail. Note that the examples chosen are relatively successful case stories, and not failed examples. This is with the intention of identifying in this chapter the basic problem-solving mechanisms in crowdsourcing. In addition, the selection of topics and case stories reflects those areas where it was possible to find relevant in-depth information and relevant research studies.

2.2 Online Innovation Contests

2.2.1 Background

Organizations have always tried to use external expertise when they have been unable to solve their own internal problems. However, because of the easy access to a large number of competent individuals in a global online setting, online innovation contests have increased in popularity in recent years. In these contests, a solution-seeking organization will host an open challenge to solve a specific problem. The host can be a company, a public organization or a nonprofit organization. Solvers will usually win prize money, ranging from a few hundred dollars to several million dollars depending on the complexity of the challenge. Some large organizations host their own innovation contests (e.g. Cisco and Starbucks). One of the most well-known examples is the Google Lunar prize contest that received wide media attention in 2007. Contestants could win US$20 million in prizes if they managed to land a robot on the Moon, travel more than 500 meters on the surface and send back high-definition images and video (Innocent et al., 2017). However, in recent years it has become more common to use intermediaries that help the solution-seeker in organizing and hosting the innovation contest (e.g. marketing, answering questions, selecting winners). Some intermediaries have been around for more than a decade, with InnoCentive (founded in 2001), IdeaConnection (2007) and Topcoder (2001) being among the first. While most platforms are orientated toward research and developmental work, others, like eÿeka, focus on marketing. The innovation intermediaries usually offer a “package” of support, like guidance in formulating an appropriate challenge, connecting seeking companies with problem solvers, finding relevant technology, or help strengthening innovation networks. Several intermediaries host hundreds of innovation contests every year for their clients (Agogué et al., 2017; Terwiesch & Xu, 2008).

Both Innocentive and IdeaConnection host contests in similar areas such as chemistry, life sciences, medical science, engineering, IT and business. The Topcoder Community specializes in IT and covers areas within visual design, code development and data science projects. They offer both innovation contests and paid crowd work to its over one million members. Today, some of the intermediaries also address issues on social innovation. For example, in November 2019, one public challenge on polio eradication sought proposals on how to tackle anti-vaccination propaganda on social media in Pakistan. There were three prizes of $10,000 USD each and 316 active solvers working on a proposal (Innocentive, 2019b).

Only solvers who provide successful solutions will receive the money, transferring the risk of failure from the organization to the solver. Many contests also have a winner-takes-all competition, where the likelihood of being paid is relatively small. However, the size of the reward varies a lot. In IdeaConnection, the public challenges will usually have prizes that range from a few thousand to several hundred thousand dollars. More prize money will usually attract the most competent experts, while in the low-prize contests; there will be fewer contestants, but a greater chance of winning. In Topcoder, some of the prizes are very small (as low as $20), because the tasks are relatively simple and have been split into many small tasks through modularization. Here, many contests also have more than one winner (e.g. first and second prizes) (Topcoder, 2019a). The financial awards are typically larger because this challenge requires more work (Innocentive, 2019c). Most intermediaries also use a fixed-price reward structure, which is known in advance. The solution-seekers will therefore know the innovation cost, and will only pay the prize money if the solution is acceptable. Therefore, more companies today consider this innovation strategy to be interesting because it can reduce innovation costs.

Another reason why innovation intermediaries are popular is that the seeker can choose to remain anonymous throughout the solving process. However, the degree of anonymity depends on the specific challenges and the intermediary. For example, in Topcoder, the winning submission is shared with the other finalists (Shafiei Gol, Stein, & Avital, 2018). After the seeker has paid for the solution, the intellectual property is transferred from the problem solvers to the solution-seeker. The solvers agree to this before they begin working on the challenge (IdeaConnection, 2019b, 2019e). The intermediaries are important because they have expertise in dealing with legal issues concerning the transfer of the intellectual property of winner solutions (Hossain, 2018; Innocent et al., 2017).

All the intermediaries are reliant on some basic requirements. They need a large and diverse pool of talent which can connect with the solution-seekers. Topcoder, which both arranges contests and offers paid crowd work, has more than a million members. Another example is Innocentive, which has 400,000 solvers with nearly 60 percent educated to Masters Level or above (Innocentive, 2019a). Most of the solvers are highly skilled, with both a relevant educational background and working experience in the field (Hossain, 2018; Innocent et al., 2017). However, in the public challenges, anyone can submit a solution and, in principle, participation is independent of age, gender, location, skill level, education or experience. Solvers are not only professionals in work, but "amateur scientists" or "garage scientists," motivated by financial reward. For instance, in the case of IdeaConnection, the solvers will also include students, retired scientists and scientists not in full-time work (Hossain, 2018).

The innovation intermediaries depend on their members bringing into play the untapped expertise from around the world. The large number of potential solvers is necessary because solutions must be produced within a short period, both detailed proposals and working prototypes. If there are more experts in the member database, this increases the probability of reaching a potential solver with the optimal solution at that exact point in time. Because many of the challenges require advanced creative skills, it will be an advantage to recruit experts from many different fields, which increases the probability of arriving at an unusual but relevant solution (Innocent et al., 2017).

The solving rate appears to have improved significantly over the last decade. For example, Innocentive claims to have run over 2,000 Premium Challenges, with a total payout of over $20 million. And in 2016, 80 percent of the prizes that year were awarded (Innocentive, 2019a). This is a radical increase from the 30 percent solving rate that Jeppesen and Lakhani identified ten years earlier (Lakhani, Jeppesen, Lohse, & Panetta, 2007).

There may be many reasons. As time has passed, the pool of expert members has increased and the intermediaries have also improved their ability to formulate challenges in a more precise way, thus increasing the likelihood of finding the correct problem-solver. In the first phase of the problem-solving process, it is important to give precise information about the challenge. Members need to assess whether they are capable of solving the problem quickly. This increases the likelihood of solving the problem. Therefore, the innovation intermediary will often guide the solution-seeking organization in describing the problem in a format that is motivating and easy to understand. If the solutions to a problem already exists, it is essential to describe the problem in such a way that it is possible to identify the already-available solutions and customize it to fit with a seeker's problem (Hossain, 2018; IdeaConnection, 2019b; Innocent et al., 2017).

Another probable reason why the solver rate has increased is that some of the challenges have become easier to solve. For example, a technology scouting challenge invites professional searchers to locate critical technology that the seeker lacks. This challenge only requires that solvers identify existing technology that can be reused in a new context. One solver also states that some challenges primarily require laborious work, "I think this particular challenge was rather straightforward but laborious. And this is the trend I am seeing on IdeaConnection – rather than seeking 'innovation' per se, companies find this an easy place to crowdsource a lot of very cumbersome literature plowing."[1] Some of the work is more time consuming than creative, although some element of expertise is still required.

Still, although the innovation contests are organized in different ways, they will typically require that solvers come up with proposals within a relatively short period. Challenges range from a week (IdeaRally in IdeaConnection) to a few months (Confidential challenges in IdeaConnection). Because of the time constraints, the seeker will want a very specific solution. Either solvers can work individually or in a group, but in recent years, teamwork has become more common. Even Innocentive, which originally organized only individual challenges, now also offer team challenges where individuals can form their own teams.

2.2.2 The IdeaRally: Rapid Problem Solving in Large Groups

Recently, IdeaConnection have also introduced the IdeaRally, an interesting new crowdsourcing method that allows dozens and even hundreds of experts to participate in a one-week-long intensive idea-building process. By increasing the group size, it is assumed that a quality solution can be developed even within a very short problem-solving period. The large group produces and refines a much larger number of ideas compared with what a small team manages (IdeaConnection, 2019c). One solver describes it as a brainstorming process, "I think people are much more creative together absolutely because you can't just think of everything. With other people, their comments and ideas can lead you off into other areas. So brainstorming with multiple people is definitely advantageous." The brainpower of the large group is underlined, as well as how the group manages to coordinate their action so they can pursue particular ideas. In one specific IdeaRally, more than five hundred researchers participated during a period of only a week. A solver describes it as a "great learning experience":

> My first reaction to the IdeaRally® was the big surprise of having to encounter so many people with so many ideas which were mostly interesting. Now, my task became more complicated since I needed to put up some ideas which were different from others. However, I soon discovered that I do not really need new ideas all the time but could develop ideas from others or build on others' ideas . . . Building on the ideas of others is useful to both individuals and also the sponsor. Philosophically, it is by such collaboration, we all can move forward in life rather than an unhealthy competition.

When so many ideas are produced, the solver discovers that he does not have to invent new ideas but can instead build on others' ideas. It illustrates that it is possible to create online innovation contests that synthesize and refine ideas and not only rely on individual competition between the contributors. According to the intermediary, often hundreds of ideas are being discussed, and participants are challenged to criticize, defend and expand upon ideas. A peer review process let participants vote and rank ideas, and also move them to particular strings so they can be discussed separately (IdeaConnection, 2019c). One solver describes the voting as an important part of the discussions because it makes it easy to ignore bad ideas: "If it was a bad idea it would get down voted and ignored. What was nice was that there was a lot of active discussion on some really good ideas in terms of what's doable and we know about, what hasn't been explored yet, and how do we build on things that have been explored." The participants vote on ideas, and this helps them move the discussion towards the most realistic solutions. Ideas can both be virgin ideas or a novel take on some already known ideas.

The design of the IdeaRally is interesting in that it makes it possible for participants in a large-scale innovation contests to move beyond the production of superficial ideas, a typical critique of different crowdsourcing methods that build on aggregation of ideas. A solver illustrates this by expressing excitement about this idea development process, "I was most impressed with how an idea could evolve from something very simple to one with several add-on features, simply by including suggestions and ideas from the scientific community." The solver underlines how an idea moves forward rapidly from a simple to a more complex format through the large-scale collective work. One explanation is that most of the contributors are like-minded people who work in scientific communities. The same solver also underlines how the discussion included a broader multidisciplinary group that usually do not communicate with each other:

> With global online discussions such as the Crop Yield IdeaRally®, it is so important that we can collaborate with people in such diverse fields, people we don't typically have the opportunity to work with, or even talk to. It is rare that we can work together globally and reach consensus on a single issue, but an IdeaRally® creates a platform for scientists to interact in a timely manner; it allows us to have an exchange of ideas that crosses boundaries of normal modes of scientific interaction.

There are significant diversity benefits in multidisciplinarity, but the solver also experiences a global platform that offers a type of scientific communication that is unusual in its boundary-crossing mode. In this specific IdeaRally on crop yield, the solver reports that bioinformaticians, molecular biologists, and agricultural and social scientists were all working together. In addition, the strict deadline forces the group to rapidly reach

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consensus on a single issue. A solver is stunned by the amount of valuable information that was produced, "The breadth of expertise was extraordinary and the seeker received a huge amount of valuable information from people who were knowledgeable in many areas." Large-scale collective work can produce a richer solution because of the "breadth of expertise." Another solver thinks this crowdsourcing method is ideal in providing a better overview of a complex area, "I think that when you're applying so many minds to something you have a better chance of teasing out important trends or important themes in the data that can be extended into the future or that can have possibility for innovation." By including more people, the probability of identifying the most important trends increase. This may be particularly important in large research areas where it is difficult to be updated on all the published research, "especially in biological sciences now, we have this massive database of published literature. But any one single person can really only mine so much of that data or literature on their own to get a background on their research topic or what they're trying to solve."

In most innovation contests, there are several different types of challenge. For example, at Innocentive, the Ideation challenges aim to produce a breakthrough idea, whether it is a technical problem or a new commercial application for a current product. Theoretical challenges involve the production of detailed description that can bring a good idea closer to becoming an actual product, technical solution or service. Practical challenges require physical evidence that proves the solution will work according to the predefined requirements (Innocentive, 2019c).

In a typical contest, the challenges will be announced to a large pool of members with potentially relevant expertise, and they will then be given a relatively short period to solve the problem (e.g. weeks or months). Note that the IdeaRally as a type of large-scale collective problem solving involves hundreds of motivated solvers who have the opportunity to join the project within a short time period. The solvers will also join and contribute with quite different approaches, adding up to the necessary cognitive diversity. For example, one solver contributed to the IdeaRally by focusing "on the things I knew about." He did not read any extra sources, but only engaged in "the things that I wanted to talk about." By using the knowledge he already possesses, this makes participation time efficient because he does not need to do extra research. Another solver is more of a "knowledge synthesizer," explaining that he contributes with a breadth of his understanding, and "being able to put together information from many different areas." In addition, the solution-seeker organization can invite individuals who they think should be part of the process.

In this way, the IdeaRally is different from other crowdsourcing methods in how it mixes both internal company members and external expertise. Members from the internal organization can engage in the discussion or just highlight ideas that solvers should explore in greater depth. At the end of the Rally, the seeker receives a document with all the ideas and discussion. Although this type of contest involves many persons, it can still be confidential. Typically, there are thousands of dollars in prizes and awards offered each day to sustain motivation. In the end, those who have provided the most valuable ideas also receive a significant award (IdeaConnection, 2019c).

Another interesting characteristic of the IdeaRally is that solvers enjoy being part of this type of online community. One solver states that being in one project with scientists from all over the world made "a deep impression on him." This setting enables all expertise in one field to meet and discuss ideas. Another solver enjoyed the comradery of the group and the feeling of being connected with people from all over the world that one might not otherwise have met.

Several solvers also highlight the learning experience. One solver emphasizes the value of being in a transparent online environment where one can access other ideas. He likes to "read everyone else's ideas." and describes it as a learning experience:

> I learned a lot. What I really liked was learning how other people would put things together. How they would come up with their solution and the different ways that people have of looking at the same problem. . . . There were all sorts of neat ideas that people had about parts of the plant, like improving parts of the plant to improve yield that I had not thought of. So I liked that a lot.

The solver enjoys the richness of perspectives raised when many look at the same problem together. Likewise, another solver values the access to others' ideas: "I think it was interesting from an intellectual perspective to see some information from other people's areas. It gave me some extra depth in an area, and I actually came up with a potential invention, which was in a related field. So that was an unexpected benefit." This solver claims that the access to "other people's areas" triggered his own creativity and was the reason why he came up with a "potential invention." Likewise, another solver emphasizes the excitement of building ideas in this way, providing insights into other possibilities, "Working and building ideas with one's peers is very exciting and pushes one's curiosity to a good level. Beside this, ideas from other contributors can give you a great insight into other possibilities in the science world. Reading and arguing about others' ideas is very exciting and thought provoking. It also builds on your knowledge." This solver also describes how the collaboration gave "insight into other possibilities" and had a major impact because it was "thought provoking."

Furthermore, all the ongoing activities in the IdeaRally require that facilitators keep an overview of the collective work. One solver explains how several facilitators helped the large group to move forward with some ideas:

> Having facilitators was a benefit as they helped the participants to move forward in the right direction by asking right questions or directing them to what they need to do and what not to do. Personally, I benefited from a few instances where they brought to my attention that a similar idea was posted by another elsewhere. This could help me collaborate with that person.

In this specific case, the facilitator "matched" the solver with another solver who was interested in the same idea, but had been working in another area in the online environment. Another solver also mentions that the number of ideas that are produced, risk fragmenting the debate, "I appreciated having a facilitator onsite during the Rally. Having different perspectives on one side opens up the discussion to out-of-the-box ideas, but at the same time, diffuses the focus of the debate. The Facilitator helped in keeping the focus on the matter that is discussed in the Rally and avoided tangential discussions that would derail from the scope." Here, the facilitator helps keep the focus on the matter at hand. The facilitator encouraged solvers to seek more in-depth information and not emain at a superficial level.

2.2.3 *The Climate CoLab: Transparent Innovation Contests*

Furthermore, transparent online innovation contest is another crowdsourcing method that let contestants build on others' work in previous contests. For example, in Topcoder, software development contests will usually be modularized and split into smaller transparent pieces. Solvers often develop a specifications document with a detailed system requirement. Afterwards, the winning specifications might become the basis for a new contest during the problem solving, solvers also ask the seeker questions in an open web forum, which makes this information visible to all competitors. (Malone, 2018: 190–191). While most innovation contests have a limited degree of transparency, the MIT Climate CoLab platform is also different in how it allows all contributions and reviews to be open and visible to others. The Climate CoLab, a nonprofit organization affiliated with Massachusetts Institute of Technology (MIT), was established in 2009. The contests invite people from all over the world to develop proposals on what to do about climate change, including both technical, economic and political issues (Malone et al., 2017). Anyone can join, and by early 2018, the Climate CoLab community had over 100,000 participants. In total, more than 2,000 proposals have been submitted and evaluated (Malone, 2018: 171–172). The goal of Climate CoLab is to harness the collective intelligence of people from all around the world to address global climate change as a complex societal problem. By engaging a broad range of scientists, policymakers, businesspeople, practitioners, investors and concerned citizens, the aim is to develop plans that can achieve global climate change goals that are better than any that would have otherwise been developed (CoLab, 2020; Malone, 2018: 179–180).

In the first three years (2009–11), the CoLab-activities organized a set of annual online contests that addressed general topics like “What international climate agreements should the world community make?” Some proposals were interesting, but most of them tended to focus on some narrow part of the overall global problem. They were limited in supporting the development of complex solutions. Therefore, the contest format was revised in 2013. The problem of climate change was divided into a family of a dozen contests that all were related to each other, but they focused on a different aspect of the same problem. For instance, there were separate contests on how to reduce emissions in transportation, buildings and electricity generation, how to change public attitudes about climate and how to put a price on carbon emissions. With this new way of organizing the contests, the proposals were more detailed and interesting. For instance, in 2013, the winning proposal came from a nonprofit organization in India, describing how small Indian farms could replace their expensive, emission-intensive diesel irrigation pumps with cheaper and more environmentally friendly foot-powered treadle pumps (Malone, 2018: 179–180).

However, the proposals were still limited because the contestants did not look to each other’s work and try to combine ideas. To address this issue, integrated contests were introduced in 2015 with a new prize (currently $10,000) awarded to contributions that integrate and combine existing proposals. This contest type aims to motivate the creation of solutions that can address larger parts of the whole problem, because entries from previous contests have to be reused. Some of these integrated contests cover climate plans for the whole world, while others are orientated plans for the largest emitting regions (like US, Europe, China, India) (Malone et al., 2017). Compared with the other innovation contests, the openness and transparency is much larger in the Climate CoLab. Contestants are given access to others' work, and have to assess and review this work in order to submit a proposal. The contest aims to utilize a better mix of competition and cooperation in the same online environment. For instance, the Popular Choice global winner in 2015 began originally with work done by the user "biocentric stayathome mom." After posting her original proposal, several authors contacted her, and agreed to make a global proposal that eventually included over 25 authors. Many of these members did not know each other, and are now actively working together to raise money for the ideas in their proposals (Malone et al., 2017). Here, the contestants had to contact each other and collaborate in the production of a new solution that combined pieces of previous work done by others. A complex problem like climate change requires a multitude of different types of knowledge about what to do in different places around the world. By enabling more people with diverse backgrounds to combine their knowledge, this increases the likelihood of producing better solutions.

2.3 Online Citizen Science

2.3.1 *Zooniverse: Online Citizen Science Platforms*

Citizen science is research conducted by amateurs or individuals who do not necessarily have a formal science background. They voluntarily contribute time, effort and resources toward scientific research in collaboration with professional scientists or alone. Many citizen science projects build on a long tradition of environmental research, but today they involve most other scientific fields (Hecker et al., 2018). The last decade, the interest in online citizen science has also increased significantly, and there are now thousands of projects worldwide. On one hand, the digitization of information (e.g. low-cost sensors) provides an opportunity to collect massive amounts of data that need to be analyzed. On the other hand, the Internet and smart phones has made it much easier for volunteers to engage in citizen science in new ways. Individuals cannot only collect data themselves, but they are also involved in analyzing data that researchers have collected.

As a result, citizen science is both becoming more institutionalized with the establishment of practitioner organizations in Europe (European Citizen Science Association – ECSA), and the US (Citizen Science

Association – CSA), and increasingly recognized as a distinct field of research. In 2016, the first scientific journal dedicated specifically to citizen science was established (Hecker et al., 2018). Compared with traditional research, citizen science differs in the openness both of project participation and intermediate inputs such as data or problem-solving approaches, which are widely shared (Franzoni & Sauermann, 2014). From this perspective, online citizen science is an example of a new CI practice that is of significant societal value.

If we look at online citizen science more specifically, it is worth mentioning that there are several different online platforms that have strengthened its visibility and accessibility. Many countries have their own citizen science portal, such as Scotland (Scottish Citizen Science Portal), the US (e.g. SciStarter, Zooniverse, CitSci.org) and Australia (Atlas of Living Australia). These platforms have made it easy to create new projects and also establish networks among participants and prospective stakeholders (Hecker et al., 2018). Today, Zooniverse is the largest citizen science platform in the world, with more than 550 million classifications done by 2.2 million registered volunteers, as of December 2020. The online platform hosts a range of different science projects that invite volunteers to analyze and interpret large datasets. Anyone can start a Zooniverse project by uploading data to the platform. The projects cover anything from counting penguins and drawing diseases in nuclear cells to the digitization of historical records. Initially, most of the projects were in astronomy. Before 2010, seven out of eight were astronomy projects, while this only includes three out of ten projects in the period afterwards (2010–14). Projects now involve a broader suite of ecology and humanities subjects, and the amount of new users and projects have increased steadily by around 30 percent a year (Graham et al., 2015). In December 2020, volunteers could choose from 75 ongoing projects on the site. In total, researchers have published more than two hundred articles using data produced by these projects.

Originally, Zooniverse grew out of the Galaxy Zoo project. In 2006, a spacecraft collected samples of interstellar dust particles from the comet Wild 2. The particles in the sample were extremely small and NASA had to take 1.6 million microscope images. However, because computers are not particularly good at image detection, volunteers were instead given the task of visually inspecting the material and reporting candidate dust particles. The project, known as Stardust@Home, received a lot of interest from astronomers all over the world (Michelucci & Dickinson, 2016). Because of this success, the researchers created the online platform Galaxy Zoo the year after. Volunteers were invited to investigate millions of astronomical images collected by the Hubble Space Telescope, the Sloan Digital Sky Survey and others. Building on basic human pattern recognition, the image detection tasks were quite simple, and anyone could therefore join the project. Individuals were asked a number of questions about the shape of a galaxy captured in an image (e.g. the number of spiral arms or how round or elliptical they are). The project received 70,000 classifications per hour within 24 hours of its initial launch and more than 50 million classifications within its first year. Because of the positive media attention, this also strengthened the public engagement (Crowston, Mitchell, & Østerlund, 2018; Graham et al., 2015). Concerning accuracy and reliability, the quality of the work was ensured by letting multiple volunteers repeat the same classification task. Because there are a small number of possible results, a simple consensus rule is usually sufficient to merge the classifications. This reduces the need for coordination, nor is it necessary to have any information about the image or volunteer (Crowston et al., 2018). Because of this success, it was decided to establish a cooperation with other institutions in the UK and USA (the Citizen Science Alliance) to run a number of projects on an online platform "The Zooniverse" that involved other fields such as marine biology, climatology and medicine (Franzoni & Sauermann, 2014).

If we look at the overall mission of citizen science, the production of *scientific knowledge* and publications is still vital, with peer-reviewed scholarly publications being the most important indicator of scientific success. Likewise, the first main objective in the online Zooniverse platform is to make scientific contributions. Usually, volunteers are involved in scientific problem solving by transforming a huge amount of labor-intensive data into a manageable "data product." The data are usually not possible to analyze with computer algorithms, and the tasks are still simple enough for volunteers to do without any need for specialist knowledge or a formal background in science. In a few cases, citizen science contributors have also been included as coauthors in a scientific publication. In Zooniverse projects, such instances have only been observed in astronomy-related projects; specifically, variants of Galaxy Zoo, Planet Hunters and Solar Stormwatch. The most common reason is that a citizen scientist has made particularly significant and unusual discoveries when visually inspecting datasets (Graham et al., 2015). For example, a citizen scientists found Hanny's Voorwerp, a novel astronomical object (Crowston et al., 2018). However, while volunteers do classification tasks within the present knowledge domain, it is more uncertain how effective they are in noticing unknown objects outside the predefined classification schemes.

Although volunteers seldom participate in the complete research process, most researchers agree that they can make substantial contributions to data collection and data coding. While there have been concerns about the data quality, one of the most successful examples is eBird, which lets volunteers use an online checklist program to report bird observations. The eBird project was initiated by the Cornell Lab of Ornithology in 2002 and has resulted in more than one hundred peer-reviewed papers. The success builds on a substantial collection of data across both time and geographical areas. When most volunteers also use the same observation scheme, it is much easier to do rigorous data analysis afterwards and publish findings in scientific journals. Since the data are Open Access, more researchers have also become interested in the project and this has strengthened the scientific impact (Hecker et al., 2018) (see more information in Section 3.2. Open Sharing of Scientific Knowledge, Open Database Projects). However, not all projects end up with scientific publications. Graham et al. (2015) find that almost half the projects in the sample (7/17) from the Zooniverse platforms have not produced any publications to date. The projects with most scientific publications are primarily "early" projects within astronomy (e.g. Galaxy Zoo). Another interesting new trend is that some projects now offer video analysis of animal behavior (e.g. ape behavior in their natural habitat).

The second overall mission with citizen science is to strengthen the *public understanding and trust in science*. The scientific engagement emerges both through the informal learning of the volunteer work, and through activities arranged by the educational system and museums. Most citizen projects aim to recruit participants with various backgrounds in an attempt to empower citizens to make scientific contributions. Citizen science is also part of a policy that aims to create a more transparent government system. For example, most projects incorporate open source software, open hardware, open data and Open Access publications (Hecker et al., 2018). If we look at the online Zooniverse platform, many projects use blogs, Twitter and Talk pages as a way of communicating with the outside world. The projects also aim to educate and change public attitudes towards science by offering opportunities of learning. One example is that volunteers receive information about the scientific publications that are a result of their project participation (Graham et al., 2015).

While large public engagement has primarily happened in astronomy projects, one exception is Snapshot Serengeti. This project studies migration and behavior patterns for a range of species in the Serengeti. Snapshot Serengeti has a median number of 4.3 hours of sustained engagement per volunteer versus an average of just over 30 minutes for all other projects. It has a median of 61 classifications provided by each volunteer, compared to 21 classifications in other projects (three times as many classifications). A potential reason for this variation may be due to the different lengths of time it takes to complete a single classification. Other better performing projects tend to be in the area of astronomy, like Galaxy Zoo projects and Planet Hunters. Overall, these measures show a significant contrast between projects that have strong project appeal and those that do not. A typical challenge in most projects is a high incidence of users leaving the project after supplying a low number of classifications. (Graham et al., 2015).

2.3.2 FoldIt: Citizen Science Games

Online games are also becoming more popular in citizen science projects (e.g. EteRNA, Eyewire, Cancer Research). One important reason is that gamification designs motivate participants to contribute over longer periods and attract individuals with more time available (Hecker et al., 2018). Today, the protein-folding game Foldit, a collaboration between the Center for Game Science and the Department of Biochemistry at the University of Washington, arguably stands out as the most successful project. The online puzzle game is designed to enhance our knowledge of protein structure and shapes, an area that scientists have struggled to understand. This is important because a lot of biological research is reliant on figuring out the three-dimensional shapes into which the molecules in a protein chain will fold. These specific shapes explain how proteins function and interact with other proteins and cells.

However, since the configuration possibilities are endless, the most common strategy has been to make computers identify the three-dimensional movements of the protein chains. The disadvantage is that the computation is extremely intensive. Therefore, back in 2005, volunteers were allowed to help by sharing computational power from their personal computers. By chance, the screensaver was designed with a visual interface that showed proteins as they folded. To the surprise of the researchers, some volunteers began posting comments that suggested better ways to fold the proteins. This spurred the idea that human visual ability could supplement computers in doing protein modeling in a more efficient way (Franzoni & Sauermann, 2014).

In 2008, Foldit launched an online multiplayer game that aimed to combine human visual skills with computer power. Any person could join the game and attempt to solve protein-structure prediction problems by constructing three-dimensional structures. Players compete against each other in the lowest free energy of a protein model (Koepnick et al., 2019). Because players did not need any background knowledge in biochemistry, the game became an instant success, with several thousand users signing up.

The basic gaming principle in these protein-folding puzzles is that proteins fold to their lowest free-energy state. Computer power can automatically calculate this energy level (Koepnick et al., 2019). The players use the mouse to move and rotate the chain branches of proteins in an attempt to find the most stable, low-energy configuration. A high score indicates that the protein shape has a low energy state according to the computerized energy function. The gamers use their spatial reasoning ability to manipulate three-dimensional shapes in space (Cooper, 2016: 120). This special cognitive skill does not require any background knowledge from biochemistry. Nor can computers do it effectively (Franzoni & Sauermann, 2014). The game let the players create their own scripts or short programs that automate game tasks. These scripts can improve a fold or identify the part that needs to be improved. Hundreds of such scripts have been publicly shared. All the collective work is also informed by the computerized game score, which provide precise feedback on the most useful strategies. If one high-scoring player shares a strategy, other players pay attention (Nielsen, 2011: 147).

From the very the beginning, the players showed that they were good at solving several difficult problems, and some players even outperformed the best structures designed by the computer (Cooper, 2016: 120). Some Foldit players even competed in the 2008 and 2010 worldwide competition of biochemists, using computers to predict protein structures, and they performed as well as protein-folding experts (Nielsen, 2011: 147). Because of this initial success, Foldit players were in 2011 given a challenge that had puzzled scientists for over a decade. They were to figure out the folded shape of a special type of protein associated with AIDS in monkeys (Mason-Pfizer monkey virus). Astonishingly, two teams managed to develop the most likely fold of the protein in only three weeks. The refined structure provided new insights for the design of antiretroviral drugs. These teams were also credited as coauthors in a paper published in the journal *Natural Structural and Molecular Biology* (Cooper, 2016: 120; Malone, 2018: 183). It is regarded as the first instance in which online gamers solved a longstanding scientific problem (Khatib et al., 2011). Another success came in 2012 with the remodeling of a computationally designed enzyme (the Diels-Alderase enzyme) so it could increase its ability to catalyze chemical reactions. A typical problem with such designed enzymes is that they have significantly lower catalytic efficiencies than naturally occurring enzymes. The enzyme became 18 times more efficient after the players had improved the shape (Cooper, 2016: 124–125; Eiben et al., 2012).

The most recent trend in Foldit is de novo design of an entire protein. In the first years, this challenge was considered too difficult for amateur gamers. This is because the creation of a plausible protein backbone that could be the lowest energy state of some amino acid sequences is an extremely open-ended problem. In principle, there will be a practically unlimited number of solutions, so computers cannot do this work. In a recent experiment, Foldit players were repeatedly only given a week to design stably folded proteins from scratch. Based on the results, the game design was improved several times. Initially, most top-scoring designs were not good enough, but after many iterations of model improvement, both the top-scoring solutions and the game design improved (Koepnick et al., 2019).

Most of the protein designs were exceptionally stable, including 56 of the 146 Foldit player designs. The protein designs are comparable in quality with those of expert protein designers, and the diversity of these structures is unprecedented in de novo protein design, representing 20 different folds – including a new fold not previously observed in natural proteins. These results are impressive especially because de novo protein design is a completely new research area. The 56 successful designs were also created by as many as 36 different Foldit players (the most prolific player created ten successful designs); and 19 designs were created collaboratively by at least two cooperating players. It shows this is an achievement made by the entire Foldit gaming community and not just one or two exceptional Foldit players (Koepnick et al., 2019). Because of the diversity of contributions in the community, the players used more varied and complex exploration strategies than computer-automated design protocols. Although the players lack formal expertise in protein modeling, they have acquired a high level of knowledge and intuition just from playing the game. It illustrates that human game players can be exceptionally capable at finding and exploiting unanticipated solutions that are otherwise unexplored by experienced scientists. One possible reason is that gamers approach the problem in a different way than the researchers, because they aim to get the best high score, not only solve a scientific problem (Koepnick et al., 2019).

During the years, players have also regularly made suggestions on new automatic tools that could improve the game. The game has been modified several times based on player feedback and observations of player activity. Initially, most of the tools in the game did not exist, and the game design has adapted to players' best practices (Cooper et al., 2010). For example, one player strategy, called "Bluefuse" involved wiggling a small part of a protein, rather than the entire structure. It outperformed "Fast Relax," a piece of code that the researchers had worked on for quite a long time (Khatib et al., 2011; Nielsen, 2011: 147).

Most of the active players are part of a team. While some players work independently, most successful solutions come from larger teams which have developed solutions collaboratively by building on each other's ideas (Franzoni & Sauermann, 2014). The successful teams consist of a mix of players with different expertise who specialize in different parts of the puzzle. For instance, some players will concentrate their efforts on the start phase, while others are best at the end stages. The finishers or the "evolvers" are usually highly skilled and at the top of the rankings. They will complete puzzles that others haven't been able to finish. The players in a team also switch between being in a competitive and collaborative mode. In one team, three or four evolvers would first compete against each other in finishing a puzzle. Afterwards, they share their results with each other and collaborate in the design of the final structure. The players become better by studying each other's solutions (Cooper, 2016: 124).

The game includes several scoreboards that lists players' performance, both individually and in teams. Many players form teams to improve the rankings. In addition, there is an online community between the gamers. Gamers communicate with each other in a forum, and they share information about strategies in a wiki (Nielsen, 2011: 147). To attract a large audience and prolonged engagement, the game designers have attempted to develop a diverse reward structure, including short-term rewards like game score and long-term rewards like player status and rank. Gamers also motivate each other in chats and forums. Although players are motivated by the competition, a survey of player motivation shows that the ability to contribute to science is the most motivating factor. Social interaction is also important, as well as the feeling of being immersed in the game (Cooper et al., 2010).

Like in many other global online communities, a small group of enthusiasts is vital in the Foldit community. There are many more registered participants than active participants. About two to three hundred players actively attempt to solve most of the puzzles. Many drop out early because of the mandatory training period; new players need to complete a series of 32 tasks (already solved) as part of a tutorial (Cooper, 2016: 121). Furthermore, only 20–30 persons comprise the core who discuss the game on forums, dominate in-game player statistics, write content for the game wiki and mentor new players. In this group, participation is a very important part of their leisure time activities. One survey shows that most of these gamers have been playing for more than two years, spending about 15 hours per week. They enjoy being part of scientific activities. One player illustrates this point, "the real point is that Foldit simply allows us folks without the proper CVs, and [who] would crawl over broken glass to participate given half the chance, an opportunity to do this stuff. It's that simple" (Cooper, 2016: 121). Most players emphasize that the game requires skills such as patience, dedication and scientific inquisitiveness (Cooper, 2016: 121).

The active players also have a similar background profile. Nearly 80 percent are male, and 70 percent in this group are over 40 years old. Interestingly, the large majority of these players have no interest in other computer games (Cooper, 2016: 121). Although training matters, one should be aware that some young people might have better visualization skills than adults. For example, one of the best players is a 13-year-old American boy. When thousands of people tried the games, the people who were good at playing returned to the game. The broad outreach is important in an attempt to recruit the few persons who possess great intuitive visualization skills. They are often difficult to find, because the persons may not even be aware that they have these special skills (Malone, 2018: 182–183).

2.4 Summary

In relation to CI, both innovation contests and citizen science projects represent promising new ways in which large groups can help solve problems of societal value. All the examples in this chapter illustrate how outsiders or unknown others can make significant and valuable contributions within the framework of a predefined challenge. The formulation of a specific problem makes it possible to bring a group of problem solvers together, whether this is an innovation intermediary, a game challenge in Foldit or a micro task in Galaxy Zoo. As mentioned in the introductory chapter, the power of the group size is about crowd production of cognitive and informational diversity, which leads to better or more accurate decisions. However, if we compare the online innovation contests and citizen projects with each other, there are also significant variations in the collective problem-solving process, concerning both the type of skills that are used and the more specific crowdsourcing methods (crowd contests vs crowd community).

2.4.1 Crowdsourcing Skills

In most crowdsourcing projects, the outreach is broad and anyone can join. Most of the online communities have many more registered members than active participants in a specific project, making self-selection of tasks an important part of the process. The different examples show various use of different human skills.

First, in some of the citizen science projects, the tasks are simple and the contributions require only a very small amount of work. These projects typically utilize visual perception skills that most people have by analyzing images. Although the pattern recognition tasks are simple for humans to do, computers have until now not been able to do such work effectively. Project like Galaxy Zoo and Snapshot Serengeti shows that amateurs can participate successfully in providing metadata to images that researchers have already collected (Michelucci & Dickinson, 2016).

Second, some crowdsourcing projects aim to utilize special skills or special interests that only a few persons have. For example, in the citizen science game Foldit, the best gamers have exceptional spatial reasoning skills that they may not even be aware. Such three-dimensional pattern-matching skills are required to solve challenging scientific problems in the game. Computers have not been good at performing such tasks because the task also requires some degree of human intuition. Good gamers are more likely to have these skills than good researchers are. In their struggle to achieve the highest score, the gamers follow a logic that motivates them to find "unanticipated solutions that are otherwise unexplored by experienced scientists" (Koepnick et al., 2019). Not so differently, the Climate CoLab aims to identify local solutions that would perhaps not otherwise have been made public. In the open database eBird, volunteers can also contribute with local information about birds. Here, passion and interest in the topic will be more important than expert skills.

Third, online innovation contests will typically recruit highly skilled expertise. Participation in such contests may take weeks or months of work and will often require advanced expert skills. Innovation contests within science and IT will require a significant amount of specialized background knowledge or skills. Participants also know that the competition is fierce, with no guarantee of winning any prize money. This makes intrinsic motivational factors more important, like passion for the work or learning something new (Baltzersen, 2020).

2.4.2 *Design of Crowdsourcing*

In designing crowdsourcing, the examples show that crowds can either be organized to aggregate a collection of contributions, compete against each other, or collaborate and share ideas. First, several of the crowdsourcing projects build on *crowd competition*, including both individual and team competitions. In both Foldit and in several types of innovation contests (e.g. InnoCentive) members create their own teams. While Foldit is built around a game design with leaderboards that include a ranking of everyone, the online innovation contests are centered on winning the first prize by coming up with the best solution. In Foldit, there are no economic rewards because gamers to a larger degree are intrinsically motivated. Depending on the tasks foldit also displays many types of different leaderboards. In innovation contests, economic rewards will be more important. However, since the basic principle in innovation contests is that "the winner takes it all," solvers must also be intrinsically motivated to sustain participation (Baltzersen, 2020). The size of the economic reward depends on the size of the tasks. If the online contest and the tasks are highly modularized like some challenges in the Topcoder community, the prizes will be small. If the contest requires advanced skills, the prizes are typically higher.

Second, several of the crowdsourcing projects aim to build a *creative crowd community.* These crowds share knowledge openly, even when the main activity is organized as a competition. In the IdeaRally, a large group shared ideas as part of the competition. This environment produces many ideas because of the large number of participants. The participants play a more important role in evaluating the ideas, when they comment and vote on them, as a part of the ongoing work. With the support of facilitators, the community selects a few of the most promising ideas that they continue to work with.

The integrated contests in Climate CoLab represent another example of how a challenge invites contestants to combine and build on previous winner solutions. The basic assumption is that Climate Change is a wicked systemic problem that does not have any quick fix, but requires complex solutions. Proposed solutions are part of a contest web that provide an overview of a large number of contests and proposals that are interlinked with each other. This transparent contest environment aims to amplify the sharing and development of new ideas.

Many Foldit players also share problem-solving strategies with each other, and this might be easier when there is no prize money to top performers. The recent experiment in de novo protein folding illustrates that the achievement should be regarded more as a community effort than a specific individual or team performance. The community of players use more varied and complex exploration strategies than both computer automated design protocols and the small group of top-performing enthusiasts. Some players even give advice in the further development of the game design (Koepnick et al., 2019).

When problems are complex, ill-defined and unknown, it is likely that such community approaches will be more effective. All these examples illustrate that transparent crowdsourcing methods can be successful by letting everyone produce, reuse and combine solutions that others have already made. In these ideagoras, proposed solutions are commented on, evaluated and enriched in a continuously iterative process. The process of sharing appears to utilize the "many eyes" principle in a different way that permits a much larger degree of synthesizing efforts than the competitive mode.

Crowdsourcing has only been around for two decades and is still a new and immature way of solving problems. Because of the online setting, it is evident that this type of collective problem solving can be both a time-efficient and cost-effective way of including a large number of contributions. The examples in this chapter illustrate that crowdsourcing can both encompass simple and complex creative tasks. New crowdsourcing methods are likely to be invented in the near future. This topic will be further examined in the forthcoming chapters (see especially Chapter 5).

Note

1 This and the following quotations in this chapter are selected excerpts from 80 interviews of top solvers published on the IdeaConnection website. See more information in Section 1.3 Top Solvers in Online Innovation Teams.

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CHAPTER 3

Open Online Knowledge Sharing

3.1 Background

This chapter addresses open online knowledge sharing, which some label as the "memory component" in CI. Several different examples will be presented to illustrate how this new culture of sharing is emerging. Before the time of the Internet, only a very small part of the population made their opinions and knowledge publicly available to others. The communication model was built around enabling experts to disseminate their knowledge to the rest of the population. Today, the situation has changed entirely, with a majority of the population publishing and sharing all kinds of information with each other through social media. The costs of producing and publishing both unimodal and multimodal content have almost disappeared, permitting anyone to publish almost anything. Individuals do not need to be passive recipients of the "wisdom" of certified experts, but they can now publish their own opinion, information or product. Consequently, there has been an enormous increase in people participating in the cultural production and public conversation through the online setting.

A decade ago, this development was regarded as an amazing new step towards a better society through a democratization of knowledge production processes (O'Reilly, 2005). Benkler (2006) claimed these new online networks strengthened individual autonomy and human freedom and represented a fundamental improvement in human life. Everyone with Internet access can now take a more active role than what was previously possible in the industrial information economy. In the online setting, individuals can produce their own cultural environment. They can do more by themselves and create their own expressions. If a person wants to publish something, one does not need help from others or a permit from a licensing body. Individuals are also free to continue to develop and build upon much of others' creative work. The invention of new license systems such as Creative Commons has also made it much easier for anyone to share their work in a flexible way. In a range of different sectors like science, education and business, both amateurs and experts are now sharing more knowledge than ever before.

In this chapter, examples of open online knowledge sharing will cover both the domain of expert-produced scientific knowledge and the massive amounts of citizen-produced practical knowledge. Not surprisingly, the sharing of scientific knowledge has become much more effective with the Internet. When the costs of publishing are reduced, open access has become the new dominant trend that makes research accessible to everyone. Increased production of open textbooks gives a more readable access to scientific knowledge and reaches a much wider audience. In addition, scientific knowledge construction processes are becoming transparent. This includes the establishment of many more open digital databases that allow anyone both to make their own contributions and get free access to all the data (e.g. citizen science project like eBird). More of the knowledge construction processes are becoming open, including both advanced scientific discussions (e.g. Polymath Project) and the development of encyclopedic knowledge (e.g. Wikipedia). Furthermore, the recent decade has resulted in an enormous increase in amateur-produced practical knowledge, involving both the sharing of texts and videos. Enthusiasts share their skills and passions concerning any activity that might be of interest to other like-minded persons. It includes a wide range of content, including more sharing of political opinion through video publishing and argument mapping. Inspired by open innovation, even business has begun to share more of their knowledge openly instead of concealing it.

3.2 Open Sharing of Scientific Knowledge

3.2.1 OpenAccess Publishing

In the history of science, the sharing of scientific knowledge has been an essential part of how humans have advanced their collective knowledge about the world. However, in the world of pen and paper, it was expensive to produce and publish research papers. A published paper required extensive typesetting, layout design, printing, and hardcopies of journals had to be sent all over the world if scientists were to have access to each other's research. With the Internet, there is no need for printed versions, and it is easy and cheap to distribute scientific papers. As a result, there has been a gradual shift in the last 15 years from a pay-for-access model in scientific publishing towards more open access (OA) publishing. There is no consensus on the definition of OA, but the most influential definition, the

2002 Budapest Open Access Initiative (BOAI), highlights that content must be free to read and free to reuse. The long-term goal is to make all research results openly available because this is how science can work optimally. Access is important because new research should build on all previously established results that are relevant. This knowledge will also be freely available to others who can potentially benefit, such as companies, journalists and student (Piwowar et al., 2018; Schiltz, 2018).

However, this transition is not happening without resistance. Publication paywalls are still withholding a substantial amount of research results from a significant part of the scientific community and from the rest of society. Because the cost of subscriptions from the large publishing houses has increased, more universities and libraries cancel their subscriptions (Piwowar et al., 2018; Schiltz, 2018). Consequently, policy guidelines have been and still are pivotal in supporting this transformation towards more open sharing of knowledge products within science. A recent political milestone happened in 2016 when the EU Ministers of science and innovation decided that all European scientific publications should be immediately accessible by 2020.

Moreover, Plan S is a new policy that aims for full and immediate access of all scholarly publications from 2021, which are to be published with a Creative Commons Attribution license (CC BY). Major stakeholders (researchers, universities, libraries) and public funders of research in Europe are supporting the plan. Several American research-funding institutions have now also made OA publishing mandatory, including US National Institutes of Health, US National Science Foundation, and the Bill and Melinda Gates Foundation (Schiltz, 2018).

Interestingly, some studies also find an "open access citation advantage" (OACA), indicating that OA scientific papers maximize visibility and receive more citations than other papers (Piwowar et al., 2018). In addition, the Plan S guidelines strongly encourage the early sharing of research results and data through preprints. A "preprint" is the final draft of a scientific paper, which is ready to be reviewed by a scientific journal for publication. The publication of these preprints have increased the speed of knowledge sharing, and it is now common that scientists publish a preprint at a local institutional website, or through academic social networks like ResearchGate and Academia (Nielsen, 2011: 161).

3.2.2 Open Database Projects

Furthermore, digital databases are becoming increasingly important. One example is the National Cancer Registration and Analysis Service, which links hundreds of thousands of cases of each year. It collects diagnoses, scans, images and past treatments. These data are then combined into tools that can help patients choose different treatment options and doctors in their daily work (Mulgan, 2018: 28). It has also become easier to let volunteers provide data to such online databases. There are examples from many different areas and contexts, like in environmental research (e.g. Luftdaten.info) and disaster management (Bhuvana & Aram, 2019).

One prominent example is the eBird project, a citizen science project initiated in 2002 by Cornell University's Laboratory of Ornithology. On this website, amateur birdwatchers share their observations: what species of bird they saw, when they saw it and where they saw it. Most contributors submit checklists that give a complete account of both the birds that were present and absent in the area. Still, doing this work primarily requires available time as a resource, rather than a very high level of expertise about birds. In addition, some organizations and federal agencies upload and share their data on eBird. In 2016, over 270,000 volunteers had provided over 280 million bird observations. At an aggregated level, all the submitted observations provide a unique overview of the world's bird populations.

The website offers intuitive graphics and maps that show the density of particular birds in different locations. These maps are useful in tracking how climate change influences bird populations. They can also be used to inform the public. In total, 120 scientific publications have used data from the site, showing that the database has produced a significant amount of scientific knowledge (Cooper, 2016: 44–49).

The volunteer birders will typically be motivated by a desire to help bird conservation. In one incident, the Nature Conservancy in the United States used eBird data to decide which "pop-up" wetlands to fund during bird migration through Central Valley in California. The Pacific Flyway is a migration route for shorebirds traveling the Artic to South America, and the Central Valley is the natural stopover site for migrating water birds. It supports 30 percent of shorebirds and 60 percent of waterfowl, thereby hosting the highest density of migrating waterfowl in the world. The problem is that more than 95 percent of the original wetlands have been lost, and because of extreme drought in the region, the migrating birds have even fewer stopover sites. In this situation, the Nature Conservancy decided to help these birds by renting land from farmers and creating artificial "pop-up" wetlands. The key to the project's success was about identifying the right acres to be flooded at exactly the right time. Here, the citizen science data in California are invaluable, with over 30,000 checklists of the area. With the help of these data and high-performance computing, the eBird team was able to forecast where birds were likely to be present. Farmers in specific locations temporarily filled their fields with a few inches of water during spring and fall migration, in periods of six and eight weeks. All 57 species of shorebirds and a total of 220,000 birds were recorded in these pop-up wetlands during migrations (Cooper, 2016: 44–49).

Members in eBird also become part of a global network of birdwatchers, with both amateurs and researchers sharing checklists. Many use the site to locate where birds are in a specific area when they are planning birding trips. While millions visit the site, only a very small percentage of these users submit the vast majority of bird sightings (Cooper, 2016: 44–49).

3.2.3 Open Textbooks

Open textbooks is a third emerging area, which shares scientific knowledge in a format more accessible to a wider audience. The digital version is made freely available with a license that usually also allows modification of the content. The print version will typically resemble a traditional textbook, but at a significantly lower price. In tertiary education, one challenge today is that the cost of textbooks prevents many students from buying them. In one recent study from a large private university in the US, more than half of the students said that they had not purchased a textbook because of cost (Martin et al., 2017). Likewise, in another study, Feldstein et al. (2012) found that only 47 percent of the students purchased the paper textbooks, but when they switched to an open textbook, 93 percent of students reported reading the free online textbook. The cost of textbooks is a barrier especially for students from lower socioeconomic backgrounds (Feldstein et al., 2012). Other studies also show that the use of open textbooks is as good as other alternatives concerning content quality and student performance (Delgado, Delgado, & Hilton III, 2019; Hilton III et al., 2019; Jhangiani et al., 2018; Pitt et al., 2019).

Some of the most successful projects have received both financial and political support. For example, in 2012, the Ministry of Advanced Education announced its economic support for the creation of open textbooks for the 40 highest enrolled subject areas in the post-secondary system. The University of British Columbia (BC) in Canada was responsible for running the project, and it resulted in 180 open textbooks during the five first years. In June 2019, the site estimates that over 100,000 students have saved a total of approximately ten million dollars, involving more than 500 Faculty at over 40 institutions (open.bccampus.ca). Another example is OpenStax, an open textbook publisher based at Rice University in Houston, which since 2012 have published 29 free, peer-reviewed, openly licensed textbooks for the highest enrolled high school and college courses. More than six million students have used these books. In 2018, 2.2 million students in 5160 institutions saved a total of $177 million by using free textbooks from OpenStax. This includes approximately half of all US colleges. In addition, many schools outside the US, as in the UK or Poland, use the textbooks (Ruth, 2018). In contrast to the BC textbooks, OpenStax is reliant on philanthropic funding. Authors are usually paid to produce curriculum-aligned textbooks, which are both peer reviewed and regularly updated (Pitt et al., 2019).

Until now, the usage of open textbooks has largely been confined to North America (Allen, 2018). Although the cost of textbooks is a more significant barrier among US students, there is, for example, a rising concern around student costs in UK higher education (Pitt et al., 2019). Therefore, an increasing number of institutions have now begun to fund the production of open textbooks. These books are used much more often than other forms of Open Educational Resources (OER). One likely reason is that it is easier to use these books in the same way as traditional textbooks, not having to change any part of the pedagogical practice. If the quality of the book is sufficiently good, the cost savings will motivate a change (Pitt et al., 2019). Another advantage with open textbooks is their availability in different formats, making the book readable on digital devices.

However, there are still significant barriers. First, it is a challenge to find the relevant high-quality open textbooks that meet users' needs. Although a large amount of content has been produced, it is archived in local repositories that are not necessarily connected with each other. Neither are all repositories well organized, making it difficult and time consuming to find the best open textbook (Al Abri & Dabbagh, 2018).

Second, quality assurance of open textbooks is important because people are still skeptical about the quality of free and open resources. Consumers often use price as a measure of quality if they do not have access to other measures of quality. A free textbook is assumed to be of inferior quality compared with a costly textbook (Abramovich & McBride, 2018). Therefore, textbooks and other OER materials will have to be peer reviewed because this is the most legitimate quality control processes in academia (Al Abri & Dabbagh, 2018). For instance, when The Open Textbook Network runs workshops at member universities, it encourages participants to review open textbooks. Open reviews also make the quality of the textbook transparent, adding an extra advantage to traditional textbooks (Pitt et al., 2019).

Third, the open license makes it possible to adapt or change the educational content, but people still lack an understanding of how this can be done. Nevertheless, this is important to ensure that the quality is maintained over time (Al Abri & Dabbagh, 2018).

3.2.4 *Wikipedia*

The online encyclopedia Wikipedia represents one of the largest knowledge-producing communities in the world. It has greatly extended our ability to provide "vast and complete" encyclopedic knowledge. It was established in 2001, and by 2020, the English edition of Wikipedia had more than six million articles ("Wikipedia:Size comparisons," 2020). Every article will usually also have a large number of internal links to other articles and external links to more relevant information on the web, and the complexity of the encyclopedia is also displayed through the enormous number of articles that are linked together. The sheer size, the open invitation to participate and the quality of the content have made many researchers claim that Wikipedia is the ultimate example of what CI can achieve in its attempt to support a more informed global society (Benkler, Shaw, & Hill, 2015; Bonabeau, 2009; Castells, 2010; Malone et al., 2009)

Common sense suggests that if amateurs without payment or ownership make millions of contributions, the quality of the work will be poor. However, studies have shown that the quality is comparable to traditional encyclopedias (Giles, 2005), and that vandalism and inaccuracies are often quickly reverted (Kittur & Kraut, 2008). Today, Wikipedia is one of the most important sources when looking for reliable and valid information on the Internet. It is the world's most frequently used source of medical information, not only used by patients, but also health professionals. For example, in 2017, the English language medical pages registered more than 2.4 billion visits, far more than websites like those of the World Health Organization (WHO). An article on pneumonia has 8,000 views a day. The popularity makes it even more important keep the articles updated with reliable information sources, so all stakeholders can access the same background information (Murray, 2019).

The production of articles introduces new types of collective writing. Articles are constantly modified and updated, and are in this sense never completely finished. With this as a premise, contributors only need to publish a draft version on an article and expect unknown others to continue the work on the article at a later point in time. Work on the articles also includes a range of different microtasks, such as keeping an article updated with new information, removing "nonworking" links, and adjusting the article to an encyclopedic format. Often, it will not be too difficult to find relevant secondary sources to use in a Wikipedia article, and a lot of the writing translates content between encyclopedias in different languages.

The writing process is special in that most articles can be changed by anyone at any time. Revisions continue until there is an informal consensus that the article has reached a sufficient level of quality. There is no hierarchical editorial process. If two people disagree on the content in an article, they are strongly encouraged to find a solution on the specific article's talk page. Here, anyone can discuss issues regarding a specific article, like shortcomings, improvements and even a proposed deletion of the article. Because everything written on Wikipedia needs to have a source, this is an essential component to all articles, and often a popular topic of discussion. Most of the editors have never met each other in real life (Carleton et al., 2017; Malone, 2018: 117).

For example, Wikipedia's medical pages require that all content refers to a high-quality secondary source which is regarded as being more reliable, with less content bias. One avoids primary sources because this information can be refuted. The articles aim to represent the current state of knowledge, presented in an impartial manner. Organizations with a mission of disseminating information, like Cochrane and Cancer Research UK, are therefore now collaborating with Wikipedia. Since the encyclopedia is widely used, increased engagement from health professions can provide better information to everyone about health issues (Murray, 2019).

Although the Wikipedia user community is without a centralized structure, it still depends on a range of different norms and policies that guide actions. Guidelines help contributors to write appropriate articles within the genre of an encyclopedia and resolve conflicts between contributors. Although anyone can participate and contribute to Wikipedia, many norms regulate online behavior. Instead of letting a central body monitor all behavior, the Wikipedians monitor each other (Carleton et al., 2017). The norms build on a general hacker ethos, and include sentiments such as "Be bold" and "Leave things better than you found them." The Wikipedia community resembles a participatory culture in its emphasis on behavioral guidelines like "civility," which refers to a social policy that encourages respectful and civil participation. Contributors should both try to understand others' positions and "strive to become the editor who can't be baited" ("Wikipedia:Civility," 2020). The guideline "Assume Good Faith" refers to the treatment of others as if they have good intentions and one should avoid accusing others of harmful motives without clear evidence ("Wikipedia:Assume good faith," 2020). If a disagreement is not solved, the debate can involve a third party (Algan et al., 2013; Carleton et al., 2017). These social norms are an important reason why the community manages to produce articles of high quality.

A major concern in open editing is that, when anyone can change an article, how can we trust that the information is correct? Wikipedia tackles this through the participation of a dedicated community of Wikipedians, volunteers who continuously monitor articles and receive automatic alerts when articles are changed. This makes it possible to quickly remove vandalism and restore the original article. Other controversial edits are discussed on the articles talk page until consensus is reached. The norms emphasize a civil, open debate in an attempt to produce unbiased objective content (Murray, 2019). An important technical feature in the wiki software is that it stores all edits permanently, making it possible to trace and restore previous versions of both articles and discussions. This makes the production environment very transparent because the complete decision-making process can be scrutinized by anyone at any later point of time. The success of the online community is reliant both on this transparent quality control mechanism and on specific social norms.

3.2.5 The Polymath Project

The Polymath Project, initiated by Fields Medalist Timothy Gowers in 2009, is another interesting example of open scientific knowledge construction processes. Inspired by web 2.0, Gowers wanted to explore if massively collaborative mathematics could be possible. In his personal blog, he invited anyone to join him in solving a mathematical problem through a virtual math team effort. The goal was to find a new proof for a theorem, which had previously only been proven in a very indirect and obscure way. The invitation was accepted by Terence Tao, another fields medalist working at UCLA, in addition to a number of other less famous colleagues, including both schoolteachers and graduate students. Although the project required a high level of mathematical skill, the participants were a mix of both researchers and hobby mathematicians (Michelucci & Dickinson, 2016; Tao, 2014).

The first Polymath project was solved successfully after approximately one month (37 days), involving contributions from 27 persons. The number of contributors in the projects are usually relatively small, typically not more than a few dozen persons. Although the outreach is large, and anyone can join, participation still requires a high level of background knowledge.

Newcomers also have to build on previous work in a sequential fashion by leaving comments on blog posts. In the early phase of the project, it was quite easy to keep an overview of the ongoing discussion. However, because of the popularity of the project, the number of comments grew quickly, eventually reaching 800 comments and 170,000 words. Although a wiki site was set up to extract the most important insights from the discussions, it was difficult for newcomers to join the project in a late phase because they had to read an increasingly large portion of previous contributions that had been made (Franzoni & Sauermann, 2014; Gowers & Nielsen, 2009; Nielsen, 2011: 51). Until 2016, there have been nine Polymath projects taking place over the course of several months to a year; three of them also resulting in published papers (Kloumann et al., 2016).

In the Polymath projects, the problems are usually at first presented as a unified whole, and any decomposition needs to arise from the collaboration itself (Kloumann et al., 2016). The disadvantage with this lack of initial modularization is that it becomes more difficult to let a very large group of mathematicians contribute (Nielsen, 2011: 51). For instance, the successful Polymath8 project had a much stronger modular structure with a problem that could be decomposed into separate pieces. This made it easier for people to contribute on one subtopic without necessarily being expert in all other areas. It was easier to measure progress in the project and there was a guaranteed end to the project (Tao, 2014). Another issue is if the modules or subtasks are relatively large, and require a significant amount of time and effort, the number of potential contributors will usually decrease (Franzoni & Sauermann, 2014).

Although most Polymath projects require some level of mathematical background knowledge, they do not require a lot of very specialized and technical mathematical expertise. This is important if one wants to recruit a large group of people to join the project. However, a consequence is that these projects have only made progress on problems where there has already been a number of promising ways to make progress. For the truly difficult mathematical problems, where some genuinely new insight is needed, it has not been proved that these projects have achieved more than what an individual mathematician could (Michelucci & Dickinson, 2016). The Polymath projects have been very good at solving minor technical or mathematical issues, like tracking down a little-known piece of mathematical folklore, or performing a tricky computation (Tao, 2014). In addition, the online setting has recruited people with relevant expertise who would never have heard about the project if it had been done in a traditional way.

Furthermore, Gowers not only describes the problem and the background materials, but he has also made a list of collaborative rules. These rules are important in creating a polite and respectful atmosphere during the informal discussions. One of these guidelines encourages participants to publish ideas even if they are not fully developed. It underlines the importance of sharing unfinished ideas, rather than thinking offline and waiting to contribute with a larger idea in a single comment.

At all stages of the research process, the comments are fully open to anybody who are interested. All the participants can follow the rapidly evolving conversation and jump in whenever they had a special insight. In the online setting, this is much easier to do. The project illustrates how a relatively large group can effectively harness each participant's special competence, "just-in-time," as the need for that expertise arises. In conventional offline organizations, such flexible responses are usually only possible in small groups. In larger groups, this will normally not be possible and participants will instead be focus on a preassigned area of responsibility (Nielsen, 2011: 34–35).

The blog is also interesting because it gives an insight into the minds of some of the world's leading scientists. When all posts are archived, they are left open for others to read afterwards, and leave traces of the knowledge construction process. The discussions follow a timeline, and provide a glimpse into the minute-by-minute communication between scientific partners. It is possible to observe how the best in the world struggle to extend our understanding of some of the deepest ideas of mathematics. It also shows how individual ideas are refined and further developed through open collaboration. A wide range of ideas is displayed, but not all are followed up. It is possible to read a record of the entire collective process that leads to the proof, giving a complete account of how a serious mathematical result is discovered. In this way, the Polymath Project makes both the scientific culture and the exploration of scientific problems more transparent (Kloumann et al., 2016; Nielsen, 2011: 167–168). The archived comments show how proposed ideas grow, change, improve and are discarded. It reveals that even the best mathematicians make mistakes and pursue failed ideas. False starts are an integral part of the process, but through the mistakes and wrong choices, the insight gradually emerges. The transparency surrounding the ongoing problem-solving process stands in contrast to how research results are usually proved in private and presented in a finished form. The Polymath Project illustrates how knowledge construction processes that have traditionally remained tacit in scientific research can be openly shared with others (Tao, 2014).

The discussions of mathematics in the blog are different from a face-to-face conversation in other ways, too. In the online setting, most comments in the Polymath Project focuses on only one point in a relatively sharp way. This is usually not possible in offline academic conversations because someone will become confused, it will be necessary to backtrack, while others will leave the discussion. However, asynchronous communication let everyone read the comments at a suitable time, and they can even do so several times before they write their own comment. In complicated mathematical problem solving, this can be a significant advantage. It is not necessary to take an immediate stance to a problem, which will usually be the case in a conversation in an offline setting (Nielsen, 2011).

Furthermore, in the online environment, it is easy to have a quick look and ignore irrelevant comments. In the project, there were a small number of contributions of low quality, but it was relatively easy for well-informed participants to ignore them. This is often a major concern in other open online environments because of trolls, spammers or even people who are just plain unpleasant. In the Polymath Project, the strategy was simply not to give these participants the same amount of attention. In comparison, when this situation occurs in an offline setting, you may have to stay and listen to a person speaking about something irrelevant for a longer period before you can move on. In the blog, you can more freely choose between what ideas you want to continue to work with. In addition, one can easily return to previous comments at a later point in time because they are archived and can be retrieved through search engines (Nielsen, 2011). The Polymath Project illustrates the potential of scaling up the number of participants in academic discussions, but it is more uncertain if such projects are sustainable without coordinators who have the main responsibility.

3.2.6 Galaxy Zoo Quench

The Galaxy Zoo Quench project is interesting because it aimed to be more ambitious than most other citizen science projects. Citizen scientists were invited to be involved in the complete research process, not only classify images, but also analyze data, discuss the findings and write a research paper (Franzoni & Sauermann, 2014). In the first phase, the participants classified galaxies independently from each other, following a common coding system in the Zooniverse platform. This task was quite simple and was completed successfully. However, the difficulties began already in the next phase, when the volunteers were assigned to create a dataset suitable for analysis. This was the first collaborative task. A suitable sample of galaxies needed to be included in an unbiased way, but because the volunteers refined the data differently, they did not manage to reach a decision together. The lack of academic background knowledge made it difficult to know what selection criteria were appropriate in making the dataset ready for analysis (Crowston et al., 2018).

In the data analysis phase, the volunteers struggled even more in coordinating the collective work. They were uncertain of the most relevant set of results to include in a research paper. The lead scientist encouraged the volunteers to "play" with the data and try to find some interesting trends, but they did not receive any specific advice. They found it difficult to do these explorations on their own because they had not written scientific papers before. As a result, the volunteers did different analyses independently of each other. Because they had limited scientific domain knowledge, they did not know what data would be interesting for publication. Therefore, the project never reached the writing phase. In the evaluation, the volunteers suggested that the lead scientist should have coordinated more of the work and provided more feedback. At the same time, collaborative writing of a paper requires much more complex interdependent work and it is not certain whether volunteers can be trained in developing these skills over a short period (Crowston et al., 2018). This project shows the importance of also examining limitations in volunteer contributions to scientific knowledge.

3.3 Open Sharing of Practical Knowledge

3.3.1 Open Sharing of Videos

If we look at the scale of online knowledge sharing in recent decades, videos arguably represent the most important contribution to human collective memory in its production of amateur content. YouTube is the dominant media platform in the world, and in 2017 it had over 800 million unique visitors each month (Lee et al., 2017). The company website claims that their billion users are watching a billion hours of content each day (Burgess & Green, 2018). Unlike social media platforms like Facebook, the user engagement on YouTube is centered around the sharing of content, and the video in itself is regarded as the primary vehicle of social communication (Klobas et al., 2019). Established back in 2005, more than a decade ago, YouTube became an instant success, making it easy for anyone to share and stream videos with standard web browsers and modest Internet speeds. Videos could be rated or commented, and the website also became popular because of new social features like the automatic receiving of other video recommendations, the possibility of embedding video and the sharing of comments through email links (Burgess & Green, 2018). Already from the beginning, the content contributors were a diverse group with multiple interests, including large media producers, major advertisers, small-to-medium enterprises, cultural institutions, artists, activists and amateur media producers. All had their own separate aims, looking for a cheap distribution alternative. With the exception of violent and sexually explicit content, users could upload whatever content they wanted. This turned YouTube into a dynamic cultural system (Burgess & Green, 2018: vi–vii, 3).

YouTube's popular culture is still characterized by its own two "native" genres, the clip or quote, and the vlog. Early YouTube contained a wealth of short video quotes, snippets of material that captured the most significant part of a program, shared by ordinary users. The quotes are edited selections of TV shows, news, sketch comedy, music videos or movies uploaded informally by ordinary users, highlighting a particular moment from a favorite television show or sporting match. This quoting is very different from sharing a complete TV program. It is similar to how GIFs on Facebook and Twitter are used as visual annotations or reactions. The quotes give information about what engages the audience, but some also express particular identities, like footage from soccer matches, edited to include pictures of fans and a certain theme highlighted throughout the season. Although these clips may attract many viewers, they do not necessarily trigger a lot of discussions (Burgess & Green, 2018: 50, 75, 81, 129).

Furthermore, the "vlog" (short for videoblog) genre is one of YouTube's most central cultural forms, dominating the "amateur" videos and vernacular creativity from the early years of the platform. The vlog only requires a webcam and is technically easy to make. The emphasis is on good storytelling and a direct, personal address, typically presented as a monologue delivered directly to a webcam, including home movies and personal photography. The topic can be anything from comedy, celebrity gossip, political debate to the mundane details of everyday life. It is a mode of individual self-expression and everyday aesthetic experimentation that not only wants a large audience, but invites feedback in a direct face-to-face address to the viewer. It is a genre of communication that invites critique, debate and discussion, with direct response, through comments or video response, being at the core of this type of engagement. Early vlogs were frequently responses to other vlogs, directly addressing comments left on previous vlog entries (Burgess & Green, 2018: 39–40, 81, 127). The vlog builds on live performance traditions and resembles the vaudeville tradition of the late nineteenth and early twentieth centuries, with a wide range of short memorable acts, usually under 20 minutes. Without directors, actors in this tradition chose their own emotional material and adjusted their performance based on direct audience feedback. Like in the vlog, the emphasis is both on immediacy and conversation (Burgess & Green, 2018: 80–82, 87).

From the perspective of knowledge sharing of societal value, the vlog is relevant in how it transforms everyday life into more "public" debates around social identities, ethics and cultural politics. Existing assumptions are questioned through the presentation of intimate and vulnerable moments, making it possible to promote a public discourse about uncomfortable, or difficult topics that other media avoid. For instance, the sharing of "coming out" videos have become important "social media rituals" for LGBTQ YouTubers, displaying stories about difficulties and how one overcomes them (including homophobic bullying). It illustrates how popular culture becomes a part of political participation and citizenship, especially for woman, LGTBQ people, and religious or ethnic minorities (Burgess & Green, 2018: 124, 127–128).

A major difference today is that the scale and complexity of its commercial practices has increased, providing content watching for a large number of users. However, the informational content still includes user-created newscasts, interviews, documentaries that resemble the vlog genre, in that they frequently critique popular media through commentary or visual juxtaposition and commentary. Many music artists also preface their work through a discussion of their motivation, attempting to establish a more intimate relationship with the audience by responding directly to suggestions and feedback (Burgess & Green, 2018: vi–vii, 3, 22, 81, 87, 94, 126; Klobas et al., 2019). The highly invested content creator is not only a media company, but also professional "amateurs." On the one hand, online video businesses are working to professionalize previously amateur YouTubers. But on the other hand, the vlog and the vernacular aesthetics is often held up as the gold standard of the YouTube brand. There still remains a cultural logic of community, openness and authenticity that highlights ordinary people's active participation (Burgess & Green, 2018: vi–vii, 22, 87, 94, 126; Klobas et al., 2019).

Furthermore, educational videos are the third most commonly viewed type of content, after music and entertainment videos, including videos made by both professionals and amateurs (Klobas et al., 2019). Auto-captioning and translation of YouTube videos have also increased the potential audience that can watch a video (Lee et al., 2017). All this video content can support students' learning. For example, in one study in medical education, the vast majority of students report using internet sources, with 78 percent using YouTube as their primary source of anatomy-related video clips (Barry et al., 2016). Many universities publish video lectures, also in combination with Massive Open Online Courses (MOOCs) that offer more affordable education to a global community that would otherwise not have access to this kind of content (Lee et al., 2017).

Furthermore, a rich mix of knowledge providers outside of the traditional higher education institutions also produce and publish short clips that attempt to explain complex in a simple way (e.g. health issues). For example, science channels are made by media companies (e.g. National Geographic), science journalists (e.g. Periodic Videos) and science educators (e.g. SciShow), while other videos are made by hobby amateurs who have a passion for science. Many videos aim to be both educational and entertaining at the same time, targeting both children and adults. A typical video will explain a particular issue in just a few minutes, with music and sound animations; some will also include funny scenes from everyday life (Rosenthal, 2018; Schneider et al., 2016). One example is a video demonstrating the Magnus effect with a back-spinning basketball dropped from a very high point, which has been viewed more than 40 million times (Rosenthal, 2018; Veritasium, 2015).

In this genre, there are millions of amateur-produced clips that intend to help users with everyday tasks just about any subject, craft or skill – guitar-playing, cooking, dancing, maths, repair work or computer games. These instructional videos are especially effective in supporting procedural learning, and in principle, anyone can teach others a skill by creating a video. For examples, gamers will often show in-game achievements by showing and talking about what they are doing in the game. This is both a way of sharing knowledge as well as "showing off" one's own competencies. These clips are often made by private persons in their leisure time and illustrate how people want to share their passion and knowledge for hobbies with others who have the same interest. This peer learning is both about making your own knowledge explicit, and letting others learn from what you know (Burgess & Green, 2018: 125–126; Lee et al., 2017). Studies show that videos on YouTube are used to support both formal learning and self-directed learning, offering individuals a large degree of autonomy and control regarding what and how to learn (Lee et al., 2017).

Note that YouTube is not only a massive repository of video content but also a constantly growing record of the popular culture of the Internet. Users from all over the world have created a diverse and disordered public archive of contemporary cultures. Major music labels have contributed videos from their catalogues and TV channels such as HBO and BBC. Today, a majority of viewers go to YouTube to listen to music they are already familiar with. Adults can listen to old music videos or watch old clips from TV series, as a way of recapturing memories from their childhood or young adulthood (Burgess & Green, 2018: 135–136).

3.3.2 Open Sharing of Geographical Resources

Another interesting open database project is OpenStreetMap (OSM), founded in 2004 by Steve Coast. He wanted to make a local map but became frustrated with all the restrictions on traditional maps because of copyright and excessive royalty payments. Therefore, he bought a GPS and started collecting tracks around his local area of central London. The data were then displayed openly, and when he presented his work at a conference, many people wanted to join the project. Within 16 months, there were 1,000 registered users, and after five years, the number had grown to 100,000. Although the coverage varies, OSM has continued to grow. The data sources are free of charge and allow anyone to reuse the data as they like (Chilton, 2009). Local maps have been created to serve different purposes, such as skiing, hiking or public transportation. The Wheelmap project is one example of how maps can be tailored to wheelchair users or visually impaired pedestrians, utilizing haptic feedback. Another example is how the maps have been successfully used to produce and distribute free mapping resources in disaster management ("Humanitarian OSM Team," 2020; Neis & Zielstra, 2014).

In 2020, the OSM project had more than six million registered members. Most of the information about the project information is shared in the official OSM wiki. This includes information about usable software and tutorials for beginners on how to map an area. In the past, volunteers could only report an error in the map data in the form of a note, but now they can make direct modifications or corrections in the map. This "wiki-solution" has strengthened the collective effort of the project. Like in the eBird project, only a small percentage (1.6 percent in 2013) of volunteers contribute on a regular basis. A few individuals will usually collect most of the data from one specific area. Although contributors can communicate with each other on internet relay chats (IRCs) or mailing lists, most of the collaboration is purely incidental, as most work is done by individuals separately (Neis & Zielstra, 2014).

3.3.3 Open Sharing of Corporate Knowledge

Moreover, open sharing of knowledge has increased in sectors that traditionally have kept their knowledge secret to others. In the business sector, some companies are changing their strategy and emphasizing open sharing of knowledge to a larger degree. According to Bogers et al. (2018), there are two important kinds of open innovation: outside-in and inside-out. As mentioned in Chapter 2, crowdsourcing, or the outside-in part of open innovation, is about integrating external inputs. In addition, the inside-out innovation requires organizations to allow underutilized ideas to go outside the organization for others to use. The basic assumption is that openness can be useful for process innovation (Bogers et al., 2018). According to Chesbrough (2017), this type of innovation is inspired by open source methods from software communities. Usually, innovation activities are concealed because they are a source of competitive advantage that should not be shared with anyone.

As counterintuitive as it may seem, Von Krogh et al. (2018) find that most companies can build greater advantage by following a policy of open process innovation. One strategy is to open up the organization internally as much as possible. By sharing innovative practices and success stories, this increases the likelihood that the best ideas become part of the overall corporate program, thus improving the operational performance. It is often easier to implement new ideas within the same organization because the different factories will usually be comparable. In one example, a Volvo Group remanufacturing factory were forced to think harder about their current practices when they learned about the best practices from other units. Companies can also improve if they use ICT to share practices more systematically (Von Krogh et al., 2018). In another example from Xerox, the technicians were usually alone while they repaired a copier, but the time they spent together at breaks was a critical resource for open sharing of their work. There, they discussed how to fix important work-related problems not written in the official manuals. Partly because of this work, Xerox later created an online tool called Eureka that technicians could use to share tips with one another across the company (Malone, 2018: 118–119). Likewise, the Volvo group collects best practices from factories and shares them in a global online database. In addition, global online knowledge-sharing conferences are held ten times a year, with a couple of hundred persons attending. The conference slogan illustrates the core idea behind this intracompany open process innovation strategy: "Everyone has something to teach; everyone has something to learn." The best-in-class factories also develop their own expertise by teaching others about what they do. The better you are, the more you can gain by opening up. For instance, in a Volvo Group truck assembly, the customer fairs moved to the factory site. In this way, customers could question blue-collar operators working directly on the line, and received passionate answers. In addition, the operators learned firsthand what customers really wanted from Volvo trucks (Von Krogh et al., 2018).

The key issue here is to put more emphasis on the pace of the process innovation. Protecting innovation processes will give a competitive advantage for a limited time only. In the end, it will be a losing strategy because competitors usually catch up. Instead, it is important to compare your own practices with someone else's practices. This exposure motivates both managers and employees to speed up problem solving and idea generation. The key is not to be better, but faster than competitors at process innovation (Von Krogh et al., 2018).

3.3.4 Open Sharing of Political Arguments

Regarding CI in the political domain, there is today an increasing disappointment with lack of informed political debate in the online setting. Currently, popular social media produce little deliberation, large volumes of highly disorganized and low-quality content, toxic interactions, and in some cases, clique formation amplifies extreme political points of view (Fujita, Ito, & Klein, 2017). From a technological perspective, part of the problem can be due to limitations in the communication technology. For example, in time-centric tools like blogs or discussion forums, the contributions are organized according to when a post is submitted. When the number of contributions increase, posts about the same topic will often be widely scattered, and it will be increasingly time consuming to identify all relevant issues, ideas, and arguments in a debate. As this becomes more difficult, so the likelihood of redundancy increases. There will be a lot of repetitions, digressions and people talking past each other (Klein, 2012, 2017).

Collective argument mapping represents an interesting technological alternative that attempts to avoid these problems by letting a large group co-construct the bigger picture of an issue from multiple perspectives. This is done through the collective production of a coherent argument map (e.g. Deliberatorium, Kialo). User contributions are organized through the construction of a tree structure consisting of specific issues, potential solutions, and pro and con arguments. This structure provides a better overview through easy navigation, rating and collaborative editing of the map. The goal is to produce a well-organized map with nonredundant, high-quality content for complex controversial problems. The map intends to support deliberation, long and careful discussions where groups of people identify possible solutions for a problem, evaluate these alternatives, and select the solution or solutions that best meet their needs (Fujita et al., 2017; Klein, 2017).

In the map, the arguments are captured as topically organized tree structures where arguments comprise questions, possible answers, arguments or statements in favor of an answer or argument. All relevant arguments and subarguments within the same topic are organized hierarchically in the same branch of the tree. The map can grow collaboratively from a simple seed question into a large range of ideas that represent a single, coherent, meaningful structure. With the visual support of a multidimensional map structure, all participants in a community can bring forward any question or issue on a topic, and the community can evaluate the content together (Bullen & Price, 2015; Klein, 2017).

In political discussions in large groups in an offline setting, many perspectives will easily be ignored. Typically, small groups of people will outline a policy, and then attempt to engage wider support for their preferred options. The large majority will not be involved in formulating alternative solutions. If the problem is complex, many important ideas may be ignored. Therefore, the map aims to offer a group a comprehensive overview of a problem that supports more informed deliberations that can lead to better collective decisions (Bullen & Price, 2015; Klein, 2017).

Today, several different collective argument-mapping tools support large-scale discussions. One example is the Deliberatorium, a software developed by Mark Klein and associates, which mediates complex collective discussions with a large number of persons involved. The objective is to facilitate deliberation that is more effective (Fujita et al., 2017). In one experiment, 220 masters students discussed biofuels in Italy over a period of three weeks. During that period, the students posted over three thousand ideas and arguments and 1,900 comments into one single argument map (Klein, 2012). About 1,800 posts were eventually certified, 70 percent without any changes. It demonstrated that most authors were able to create properly structured posts. This community of nonexperts were able to create a comprehensive map of the current debate on biofuels, with references to technology and policy issues to environmental, economic and sociopolitical impacts. Klein (2012) compares the collective work with gathering 200 persons to write a book together on a complex subject over a period of a couple weeks where no one is in charge.

Another argument map is DebateGraph. This tool also supports complex policy topics in different fields like education, health, conflict resolution and policy dialogue (Bullen & Price, 2015). Participants explore problems together by first breaking down the subject under discussion into discrete ideas. These ideas are displayed as thought boxes, and can be enriched with videos, images, charts, tables, documents, as well as being cross-connected to other relevant maps. Arrows and colors signal different types of relationships between the ideas in the map. In addition, both the ideas and the relationships between them are visualized in the map structure. This makes it easier to explore and get an overview of clusters of interrelated ideas. When the understanding of a topic evolves, the participants revise both the map and the interrelationship between the ideas. All members can add new ideas and information, or edit and rate existing ideas (Bullen & Price, 2015).

In a deliberative process, there are at least five advantages with using argument maps. First, the map can provide a very good overview of all the arguments in a discussion. If it is well organized, the argument will appear at only one place in a coherent map system (Klein, 2017). If we assume that ideas have a Gaussian distribution, widely known points will be submitted frequently from multiple sources, and the valuable "out-of-the-box" arguments will be far less common. Consequently, the number of ideas will grow much more slowly when the number of participants increase. The goal is to avoid some of the redundancy problems that large groups face in online discussion fora (Klein, 2012).

Second, when all the content is co-located in a hierarchical tree structure, it will be easier to identify what has and has not already been said. It becomes easier to work towards a more complete coverage when everyone has a better overview of the discussion. Argument mapping increases users' chances of "finding their tribe" or other person who have the same interests. In comparison with an online discussion forum, the benefits of contributing to an argument map will increase as the community scales up in size. It is much easier to place your own contribution and identify other relevant contributions in a tree structure. You only have to pick the correct top-level branch, and the right subbranch, until you reach the place where your argument belongs. This does not require a lot of extra work, and the overall costs of participation are therefore relatively low even when the size of the community scales up. In comparison, in unstructured online discussions, the high volume and redundancy decreases the likelihood of actually finding other relevant posts (Klein, 2012, 2017).

Third, every argument becomes more valuable when being part of a wider argumentative context. Participants can freely choose to engage with one particular aspect of the map or the totality of it. Before making a new contribution, it is also necessary to read existing views and opinions in the map. The process of placing an argument in the map will automatically enhance the participant's understanding of the topic. Instead of just adding to free-flowing online discussions, individuals will ideally be exposed to all parts of the logical structure of the argument: What decisions must be made? What are the arguments for and against each option? Critical thinking is stimulated in the process of making the map (Bullen & Price, 2015; Klein, 2017).

Fourth, idea sharing and equal participation is important in order to avoid extreme opinions. The map offers a greater diversity of ideas by letting every voice be heard. Compared with discussion in an offline setting, a much larger number of participants can be involved. The tree structure might also reduce balkanization by visualizing all competing arguments right next to each other. It offers a more intuitive access to the complexity of an issue, and aims to challenge both readers and contributors to overcome the constraints of groupthink and homophily (the tendency for people to associate with others who share the same beliefs) (Bullen & Price, 2015; Klein, 2017). In many other online discussions, it is also a problem that some people intentionally ignore others and try to "win" a discussion by repeating the same arguments many times. Consequently, potentially promising ideas from smaller groups or less vocal individuals will easily get lost. These individuals may feel overlooked and reject the final decision. In contrast, the argument map can more easily integrating all positions in a debate (Klein, 2017).

Fifth, the quality of the arguments may improve. If many persons can provide multiple independent verifications, this will, according to the many wrongs principle, reduce the number of errors or cancel out the bias (Klein, 2012). The large group size will also increase the diversity of perspectives. Some participants may be better at proposing ideas; others will be good at finding practical solutions. Some may be more critical and better at finding counterarguments. The sharing of all these ideas in the same map environment can also potentially stimulate synergistic solutions that build on combinations of existing ideas (Klein, 2012, 2017).

Traditional online discussions seldom elicit such win–win solutions that maximize the collective outcome for all participants. They often only elicit solo ideas or "dream choices" of individual participants, and seldom provide support or incentive for members to work together to collaboratively develop new ideas. Participants tend to push their own ideas rather than collaboratively try to find new ideas that might give both parties most of what they want. Collective decision-making typically follows a zero-sum frame where competing cliques will stick to their original solutions. A collective solution will be decided either by voting or through a bargaining process where both parties make concessions. While negotiations where parties meet in the middle can produce optimal agreements for simple decisions (i.e. with a few independent issues), this is not the case for complex decisions which often involve many interdependent issues (Fujita et al., 2017; Klein, 2017). Although argument maps are not mainstream, they represent a promising new way of enhancing political deliberation in large groups.

3.4 Summary

The examples in this chapter illustrate the growth in open online knowledge sharing. A major trend is the enormous increase in *complete knowledge products* of various size and formats. Both open access research and open textbooks show how scientific knowledge products are more available today. In addition, practical knowledge products are shared at an unprecedented scale, particularly "know-how" videos on open platforms (e.g. YouTube). These amateur-produced instructional videos obviously vary a lot in quality, but represent a new type of knowledge product that centers on passionate contributions from enthusiasts. Videos represent an important knowledge format that can inform and educate viewers in new ways because of the level of detail in the content. On the one hand, some of these products like online videos and open access research papers will typically be reused but remain unchanged. On the other hand, content modification has become much easier with Creative Commons licenses. One example is open textbooks that make it possible to produce new versions adapted to local context.

Another major trend is that *knowledge construction processes* have become more available and transparent in the online setting. Within the scientific knowledge domain, this includes open scientific discussion (e.g. Polymath – scientific knowledge production) and encyclopedic knowledge production processes (Wikipedia). Both in Wikipedia and the Polymath Project, people do not need to be formal experts, demonstrating that scientific knowledge production today is not only restricted to professional researchers. In addition, a range of new, open digital databases allow anyone to both make their own contributions and get free access to all the data. Volunteers or informal experts are invited to make important contributions in different citizen science projects. Argument maps also make it easier for a large group to participate in political discussions.

Although the knowledge construction processes are different, they show how individual contributions are part of a larger collective work, whether it is a database, a Wikipedia article or a comment in an argument map. For example, in the eBird project, volunteers collect and upload data from many different areas, which provides a much larger value on an aggregated level. In a collective argument map, new contributions will add to existing contributions, and the complete argument map will provide an overview of the collective knowledge. However, with the exception of Wikipedia, most advanced collective writing projects have failed. One example is the Galaxy Zoo Quench project, which challenged a large group of amateurs to write a scientific paper. These failures are important in understanding the limitations of amateur contributions.

Both knowledge products and knowledge construction process can be regarded as important parts of the memory dimension in collective intelligence. Most knowledge products provide long-term sharing in an online setting (e.g. research databases or YouTube). Therefore, the target group of the knowledge sharing can both be universal and directed towards a specific local context at the same time. For example, a published video can target one specific local community or area, but the information may also be relevant for others in another context at a later point in time. When knowledge is shared more rapidly, whether as corporate or scientific knowledge, this amplifies collective knowledge advancement in the society as a whole.

Furthermore, this new openness illustrates the value of transparency. In large-scale deliberation, this transparency gives the group the opportunity to make choices that are more informed. Knowledge is not only reused but can easily be improved by new contributors. For example, in Wikipedia, it is common to translate and adjust articles to many different language versions on the same topic.

Many of these new knowledge products, including both unimodal and multimodal formats, build on what some label as a peer production model (Benkler, 2006; Benkler et al., 2015). This production model, building on CI, involves open creation and knowledge sharing in an online setting. Groups will work in a decentralized manner, set goals together and typically have nonmonetary motivations. Knowledge products are typically common property and build around participatory, meritocratic and charismatic organizational models of governance. It is arguably the most significant organizational innovation that has emerged from the Internet, being an alternative to competition models in more traditional, market- and firm-based approaches. The peer production model is also different from crowdsourcing, which to a larger degree is built around centralized control and external predefined formulation of problems (Benkler et al., 2015). These issues will be further analyzed in the forthcoming chapters (see particularly Chapter 4).

CHAPTER 4

Human Swarm Problem Solving

4.1 Background

In CI research, biological research and studies of animals' collective behavior is considered to be one of the most important research areas. Although biologists sometimes use CI as a term, the more biologically orientated term "swarm intelligence" is more common. Usually, the notion of a swarm describes the collective behavior of a decentralized, self-organized system like fish schooling, bird flocking, ant colonies, animal herding and honeybee swarming. When operating in large groups, these swarms are together able to solve far more complex problems than a single of these individuals can do alone (Bonabeau, Dorigo, & Theraulaz, 1999; Corne et al., 2012; Krause et al., 2010). One of the most remarkable features of this type of collective behavior is that it often can be described and predicted with mathematical models. Although individual behavior varies, the predictive value of statistical models suggest the presence of unique mechanisms at a group level (Sumpter, 2010). Inspired by the behavioral rules these animal groups or swarms use to coordinate actions, humans have even invented similar artificial systems that can function effectively by following the same principles. As an academic term, swarm intelligence was introduced by Gerardo Beni and Jing Wang (1993) who created robotic systems where agents were programmed to follow very simple interactional rules without any centralized control structure that dictated local individual behavior. Despite the simplicity of these rules, the collective behavior of the agent would be surprisingly intelligent at a level that was unknown to the individual agents (Bonabeau et al., 1999; Corne et al., 2012; Krause et al., 2010). Such artificial systems will not be the topic of this chapter. Instead, the chapter will address how human swarm problem solving also builds on some of the same behavioral rules and basic mechanisms that other animals use. The term "swarm problem solving" highlights that the sections are organized according to a few selected biological mechanisms that also resemble how large human groups sometimes solve some types of problems together.

As such, the chapter will primarily link current biological research on animals' collective behavior to the wisdom-of-the-crowd approach within CI research. In 2005, Surowiecki coined the term the "wisdom of the crowd" in describing how a crowd, a large groups of amateurs, can outperform individual experts in many different areas if four conditions are fulfilled. First, a heterogeneous group with diverse opinions produces better quality solutions than a homogeneous group. Second, individual must make independent contributions without being influenced by others. Third, individuals should work in a decentralized and autonomous manner. Fourth, the contributions need to be aggregated in an effective way. Under these conditions, an increase in the group size will also increase the chances of producing the best solution (Surowiecki, 2005).

These principles became the most important guidelines for a new research area within CI that examined new crowdsourcing methods and "wisdom of crowd" effects. However, Surowiecki and few others have compared human crowd behavior with animal crowds. This chapter will address the issue by examining five different swarm mechanisms that, to some degree, humans and animals have in common when they solve problems. Several crowdsourcing methods will be analyzed and framed with terminology from biology. By choosing this approach, the goal is to illustrate how biological research can provide valuable insights into mechanisms that are often studied in the "wisdom of crowd" literature as being uniquely human.

The biological studies in the chapter primarily describe how animals make consensus decisions. In many situations, animals have to decide between two or more options. Most of these examples concern how groups choose a new shelter or migrate to a new home. In this setting, information transfer is required and collective decisions build on alternatives that remain stable. Cohesion, speed and accuracy are considered important factors that will influence how all or nearly all group members come to agree on the same option. The overall key question is how individuals reach a rapid consensus for the best of a number of available options (Sumpter, 2010).

Building on recent biological research, this chapter discusses five mechanism related to animals' collective problem solving that are also considered to be relevant in explaining human swarm problem solving. These mechanisms are:

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- Decision threshold methods
- Averaging
- Large gatherings
- Heterogeneous social interaction
- Environmental sensing

Animals also use both averaging methods and decision threshold methods that build on statistical rules and resemble how humans aggregate information from a large group. In addition, biological studies show that animals coordinate qualitatively different actions in effective ways when they solve different types of problems. Here, three animal mechanisms – large gatherings, heterogeneous social interaction and environmental sensing – will be presented and compared with how large human groups operate in similar ways.

A key issue in human decision-making is whether it should build on aggregation with no information exchange versus letting a group inform each other in different ways (Tindale & Winget, 2019). While the original wisdom of crowd literature stressed the need for individual independent opinions in crowds, there is today a stronger emphasis on the possible positive influence of dependent contributions (Davis-Stober et al., 2014; Tindale & Winget, 2019), such as in prediction polls or decentralized communication networks (Becker, Brackbill, & Centola, 2017). New technological platforms that build on dependent swarm contributions are also being invented (e.g., Willcox et al., 2020). By connecting these studies to biological research, I found human swarm problem solving to be the most appropriate term to cover a large variety of crowdsourcing methods. Here, the notion of a swarm covers the aggregation of both independent and dependent crowd contributions.

4.2 Decision Threshold Methods

Decision threshold methods attempt to reach consensus by following a response threshold rule. This can primarily be done in two different ways. On one hand, quorum decisions ensure that a minimum number of individuals (the actual quorum number) are ready to shift from one behavior to the next. On the other hand, a majority decision let all contributions or votes count, but only a certain percentage of consensus is required to reach a decision, typically a simple majority.

4.2.1 Quorum Decisions as Swarm Problem Solving among Animals

In animals' collective decision-making, quorum decisions will rely on independent assessments in the first phase of the process. When a specific threshold is met, there will be a distinct behavioral shift in mode towards dependent behavior. Everyone will copy the preferred behavior. Most importantly, both the speed and accuracy of decision-making can be improved by copying the choice of a better-informed neighbor (Sumpter, 2010). Quorum decisions ensure that a minimum number of individuals (the actual quorum number) are ready to shift from one behavior to the next. Because decisions taken by several individuals are generally more accurate than individual decisions made alone, quorum thresholds reduce the risk of errors (Bousquet, Sumpter, & Manser, 2011).

This behavior has primarily been studied in honeybees, ants, and fish (Bousquet et al., 2011). However, there are differences, as ants use tandem runs as recruitment signals, while bees use dances (Figure 4.1). Still, there are also strong similarities between the decision processes of Temnothorax ants, honeybees, and even cockroaches since all three species exhibit positive feedback and quorum responses. Because decision-making in animal groups often will be decentralized, positive feedback plays an important role. A plausible explanation is the evolutionary consequence of a need by individuals to reach consensus (Sumpter, 2010).

In one experiment, small groups of fish had to swim through a Y-shaped maze where replica conspecifics were set up down both sides of the maze. Interestingly, smaller groups of one or two fish were more likely to be influenced by the replicas than larger groups of four or eight fish. If the difference between the number of replicas moving to each side was only one (e.g., if left:right was 1:0 or 2:1), the larger groups were not influenced by the majority at all. However, if the difference in replicas was two (e.g., if left:right was 2:0 or 3:1), the larger groups were much more likely to follow the majority. The results show that fish only follow a certain majority size (response threshold), and they are able to compare their own group size with the numbers of fish in their surroundings (Sumpter, 2010).

In another experiment on a potentially dangerous situation, groups of four or eight fish only swam past a predator replica when guided by two or more "leader" replicas, while they usually ignored the behavior of one single "leader" replica. However, a single fish who would never swim past a predator alone would still do it sometimes if led by a single "leader" replica. The results show that uncommitted individuals in larger groups only follow above a threshold number of leaders. This threshold dramatically reduces the probability of errors being amplified because if the probability of one individual making an error is small, the probability that two fish independently make the same error simultaneously is very small.

Interestingly, experiments show that humans also ask for the opinions of two other individuals if they want to be more certain about a particular choice. The quorum rule of following more than one leader allow both fish and humans to make more accurate decisions as group size increases (Sumpter, 2010).

Another example is Temnothorax ants who live in colonies of between 50 and 500 individuals in small rock or wood cavities. If their nest is damaged, they are able to move to a new site within a few hours, and will nearly always choose the best site from as many as five alternatives. They are able to assess new sites from several environmental cues such as cavity area and height, entrance size, and light level. Around 30 percent of the colony participate in the nest siting, and these ant scouts go through different phases of commitment. Each ant first searches for nest sites, and when finding a spot, the length of the evaluation will be inversely proportional to the quality of the site. Once the site has been accepted, the ant moves into a canvassing phase, whereby she leads tandem runs, in which a single scout ant follower is led from the old nest to the new site. However, the newly recruited ants make their own independent evaluation of the nest and then return to recruit new ants. Since ants use more time to accept lower quality nests, the better quality nests will have a more rapid recruitment. Here, the ant decision-makers face a *trade-off between speed and accuracy*. Greater speed in making a final decision increases the risk of not choosing the best available nest site option. Recruitment via tandem runs is rather inefficient because ants only move at one third of their usual walking speed. When the size of support for one site exceeds a certain quorum threshold, a recruiting ant will move into a committed phase, and instead begin to carry passive adults and other items to the new nest site. These transports are done at a normal walking speed, marking a shift from slow to rapid movement into the new nest (Sumpter, 2010).

Until recently, researchers have thought that dominant individuals lead decision-making in vertebrate groups (animals with backbones: mammals, birds, fish, reptiles, amphibians). However, recent studies show that consensus decisions are more common than previously thought, for example when animal groups decide in what direction they want to move. Only a small proportion of individuals in the group may possess the relevant information about the route. Some may also differ in their preferred direction. A consensus decision is then necessary to prevent the group from splitting. Typically, a group begins to move in a particular direction when a certain threshold of individuals make the same signal with their head movements (whooper swans), gaze in a particular direction (African buffalo), or use calling (gorillas) (Dyer et al., 2008).

Figure 4.1 Two worker ants of the species *Temnothorax albipennis* performing a tandem run, image courtesy of Thomas O'Shea-Wheller, 2016

Another example is meerkat groups which stay together during daily foraging (Figure 4.2). Some of their specific moving calls build on quorum decisions, which is used as an efficient temporal coordination tool of group movement. A quorum of at least two and usually three meerkats are necessary to enable the whole group to move to a new foraging patch. The quorum shows that an accumulation of evidence is needed, increasing the likelihood of the foraging patch actually being food-depleted. This decision-making system avoids that one individual makes the wrong conclusion. Neither dominance status, sex, nor age affects the calls and suggests they are made as independent individual assessment of the food patch quality. If none or only one extra individual join in on the moving call, the group will continue to forage in the same area. However, the moving calls are not used as a directional coordination tool. Because meerkats' prey are widely distributed underground, it is more important for them to know when it is best for them to leave instead of where to go next. The system provides a simple mechanism to coordinate group cohesion while at the same time maximizing foraging success for the majority of the group (Bousquet et al., 2011).[1]

It is also interesting that the quorum number is an absolute value, either two to three individuals. Other studies show similar results: it takes more

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Figure 4.2 Meerkat (*suricata suricatta*) digging in the Kalahari Desert, photo © Tim Jackson/Getty Images

than two fish to make a decision in groups of up to ten individuals. It appears that two to three individuals acting as signalers is a common requirement in several species, at least for group sizes ranging from six to 22 individuals. It shows that a quorum number does not need to be large to be effective since errors decrease exponentially with quorum size. If the probability that one meerkat wrongly concludes that it is time to leave a foraging patch is 5 percent, then the probability that two and three individuals will independently reach the same conclusion is 0.25 percent or 0.0125 percent, respectively (Bousquet et al., 2011).

However, recent studies suggest that the response threshold in several different animal groups does not depend on the absolute number of other individuals exhibiting a certain behavior, but rather on a fraction of the perceived individuals who exhibits a certain behavior (Couzin, 2018). For example, a study of whirligig beetles, tested at what threshold the beetles initiated a flash expansion when observing a predator. The ratio of sighted beetles was manipulated so one could test whether the threshold was an absolute number or a proportion of the group size. The results supported the proportional hypothesis since the response occurred when more than 10 percent of the beetles saw the predator (Romey & Kemak, 2018).[2]

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Sumpter (2010) emphasizes that quorum responses can substantially reduce errors compared with independent decision-making. Positive feedback combined with quorum responses can aid accuracy in collective decision-making without requiring full consultation of all group members. While the quorum mechanism leads to improvement in accuracy over individual decisions, it does not achieve the same accuracy level as in majority decisions. For example, if 40 individuals each have a 2/3 probability of making the correct choice, the probability of a majority error is just 3.33 percent. In a similar group, a quorum response that is elicited when 5–15 persons make the same choice will produce an approximate error rate of 10 percent. In a quorum response, there is a risk that small initial errors can be amplified and lead nearly all individuals to make the same incorrect choice, which they would not have made by themselves. However, compared with making individual decisions the simple copying rule based on threshold responses substantially reduces the number of errors. The mathematical model suggests that response thresholds not only provide cohesion, but also facilitate accuracy. This is because quorum responses allow effective averaging of information without the need for complex comparison between the options. Evidence shows that in most cases, quorum responses allow for greater accuracy than complete independent behavior or just having weak responses to the behavior of others (Sumpter, 2010).

4.2.2 Human Quorum Response as Swarm Problem Solving

The noun "quorum" is plural of *qui* in Latin, meaning "of whom." The first quorum refers to commission papers that authorizes a group to be the justices of the peace. Today, the meaning of the term typically refers to the minimum number of members who must be present at a meeting in order to make official decisions. A human quorum often refers to the majority or supermajority of quorum (in most cases, the bylaws will state the rules for a quorum), but as in animal groups, a quorum can require a group minority significantly lower than 50 percent. It varies whether a specific percentage (quorum quotient) or a fixed absolute number is required to make decisions.

The main purpose of a quorum is to avoid a few members becoming too powerful when important decisions are made. Many democratic institutions also use quorum rules to ensure the "legitimacy" of decisions if it is likely that not all eligible voters will participate. For example, it may not only be enough with a majority, but the total number of votes will also need to exceed a particular threshold. Quorum rules are common in referendums like for example in Switzerland, which let citizens challenge a law approved by the parliament or propose a modification of the federal constitution. They organize several different types of referendums, including mandatory referendums that propose a modification of the national constitution, optional referendums which require that citizens collected 50,000 signatures against a law accepted by the national Assembly and demand a referendum, and there are also federal popular initiatives with voting on a change of the constitution, which require a minimum of 100,000 ("How to launch a federal popular initiative," 2020). With 1,000 signatures in Kraków, Poland, a proposal can be presented to organize a citizens' assembly, and with 5,000 signatures, the mayor is required to organize an assembly (Gerwin, 2018). Town meetings is another example of a quorum response where those who show up make the decision. However, there are major challenges in this method since studies show that very few eligible voters show up and very few speak up in these settings. In Switzerland, direct democracy continues to play an important role at a local (cantonal) level, but it is increasingly as a referenda and not as the large gatherings where everyone meet together face-to-face. The Landsgemeinde or cantonal assembly only persists in two cantons (Fishkin, 2018: 26, 47) (see Figure 4.3).

With the emergence of new digital technology and an online setting, quorum response mechanisms are now also used in new ways. In certain types of synchronous decisions-making systems, individual votes can be graded and collective decisions are made when a certain threshold level of support is reached (Patel et al., 2019; Willcox et al., 2020) (see example in Section 4.4.2 Large Gatherings as Human Swarm Problem Solving). One interesting example is Kickstarter, which is a crowdfunding platform that gathers money from the public as a new way of financing new ventures and bringing creative projects to life. Here, the quantitative response threshold is not votes, but money. Project creators in need of economic support will describe the project on the website and choose a deadline and a minimum funding goal. The model builds on microfinancing and make it possible for anyone to contribute from anywhere in the world within a short fixed period (Kuppuswamy & Bayus, 2017).

In 2017, Kickstarter reportedly received more than $1.5 billion in pledges from 7.8 million persons to fund approximately 200,000 projects. The projects range from the invention of equipment, art projects, design, technology, film, music, games, comics, and food-related projects. People who support Kickstarter projects are usually offered tangible rewards and

Figure 4.3 People raise their hands to vote during the annual Landsgemeinde meeting at a square in the town of Appenzell, April 29, 2012. Appenzell is one of Switzerland's two remaining Landsgemeinden, a 700-year tradition of an open-air assembly in which citizens can take key political decisions directly by raising their hands, photo Christian Hartmann/ Reuters/NTB ©

the opportunity to buy some of the products for a reduced price (Kuppuswamy & Bayus, 2017). The collective decision of whether to fund the project or not is left open to unknown others or outsiders in a global online setting. In some projects that aim to sell a product, it may be relevant to check whether the product is interesting for potential customers in the future. These online platforms enable people to create products that it would have been very difficult to fund in other ways. In this way, crowdfunding resembles arts patronage, where artists go to the audiences to fund their work. The difference is that the outreach is to potential backers from all over the world.

This fundraising resembles a quorum response because it builds on an "all-or-nothing" model. If the project is not fully funded within the deadline, the project owner gets no money at all. If the funding goal is overambitious, there is a risk that one may raise no funds at all. However, the project can continue to receive contributions until its deadline even after the funding goal has been reached. The crowdfunding process is also transparent in providing information about the total amount of money received at any point of time. Anyone can see how much money is needed to reach the pledge or the decision threshold point. There is also information on the number of backers and days of the crowdfunding period (Kuppuswamy & Bayus, 2017). Micro funders have an updated overview of the aggregated collective contribution at any time. Because contributions are given as money, the size of the contribution is also much more flexible compared with votes.

4.2.3 Majority Decisions

Majority decisions is another decision threshold method that is particularly important in human decision-making and democratic political systems. When problems involve discrete alternatives, large groups will often use majority or plurality rule to make a decision. The most important theorem that explains the epistemic advantages is the Condorcet Jury Theorem from 1785. According to the theorem, majorities are virtually certain to be right when some assumptions are fulfilled. The theorem states that if voters (1) face two options, (2) vote independently of one another, (3) vote honestly and not strategically, and (4) have, on average, a greater than 50 percent probability of being right, then, as the number of voters approaches infinity, the probability that the majority vote will yield the right answer approaches certainty (Anderson, 2006). These principles were first applied in the design of a jury system that aimed to determine the optimal number of jurors. Today, it is used in a much broader sense to prove how majority rule decisions can be better than individual decisions. It explains the relative probability of a given group of individuals arriving at a correct decision. The theorem also covers plurality voting with multiple-choice options (Anderson, 2006; Landemore, 2013: 70–72, 75).

Voter Competence

However, in reality, it is often very difficult to meet the Condorcet conditions of voter competence and voter independence. First, voters need to be better than random at choosing the correct solution. Then the probability of being correct increases rapidly even in a relatively small group. For instance, if the probability that each individual is correct is 60 percent ($p = 0.6$), a group of one hundred individuals will hardly ever make a majority error if each individual also makes independent decisions (Sumpter, 2010). Among large electorates voting on yes and no questions, majoritarian outcomes will almost certainly make the best decision if the Condorcet conditions are fulfilled. If ten voters have a 51 percent of being correct, a majority of six individuals will have 52 percent chance of being right. However, when the group size increases to 1,000, a majority of 501 persons will have 73 percent change of being correct. Because of the properties in the law of large numbers, the majority opinion moves closer to complete certainty as the group size moves toward infinity (Landemore, 2013: 71–72, 148–153).

While Condorcet originally believed that each voter had to better than 0.5 correctness probability, it is today considered to be enough that the median voter is above 50 percent change of being correct. This permits a larger diversity in voter competence, and one can still end up with a correct result (Landemore, 2013: 72). Unfortunately, the theorem also implies that if the group is sufficiently big and the individuals are slightly worse than 50 percent average, the group as a whole will almost always be wrong. The same mechanism that pulls the results up also pulls the results down (J. F. Mueller, 2018).

In direct democracies, the voter competence may be quite low on issues related to new laws or constitutional amendments. The voters may not have considered the issue before or they may lack knowledge. This opens up special interest groups who can try to confuse or manipulate voter preferences, or simply discourage them from voting. There is a risk that the voting does not end up with the best result (Fishkin, 2018: 49–50). Most of the problems in democracies are also complex, with different effects on individuals depending on geographic location, social class, occupation, education, gender, age, race, and so forth. In addition, knowledge about these effects will be distributed unevenly in the population (Anderson, 2006).

Enhancing citizens' competence can also strengthen the majoritarian outcome. If the percentage size of the majority is higher, it increases the probability of being right (Landemore, 2013: 71). Therefore, one option can be to use supermajority rules (see information about the Delphi method in Section 4.5 Heterogeneous Social Interaction). In democracies, this rule is often used in important political decisions. The long tradition of requiring supermajorities rather than simple majorities implies that opinions should approach unanimity. The disadvantage is that supermajority privileges the status quo over change (Fishkin, 2018: 20).

Voter Independence

The second condition in Condorcet's theorem is that individuals must vote independently of each other and be unbiased. Votes cannot have causal effects on each other. The probability of one person being right on the problem must have nothing to do with whether other persons are right on the same question (Landemore, 2013: 72). In practice, it will often be difficult to determine variation due to error or systematic bias. The assumption that individuals are independent leads to a paradox in the theory of many wrongs. On the one hand, the theory says that the group is collectively wise, but if individuals behave completely independent from each other, there is no sharing of information or benefits from the input of others. On the other hand, if there is too much information transfer between individuals, the decisions will not be independent anymore. Positive feedback can spread particular information quickly through the group, and also encourage all individuals to make the same, possibly incorrect choice (Sumpter, 2010).

Another paradox is that deliberation before voting is likely to increase voter competence, but it may also have a negative influence on voter independence. However, in a free and plural society that values a diversity of perspectives, it is essential to let voters influence each other through political discussions. From this perspective, Condorcet becomes less relevant for modern democracies that rely on critical discourse, a free press, and public discussions prior to voting. If it is not possible to share information and opinions, this can easily create incompetent voters, which according to Condorcet is also a threat against the best solution (Landemore, 2013).

Majority Decisions among Animals

Even animals sometimes follow a majority rule when making decisions between binary discrete options. This typically happens when there is a conflict of interest and large discrepancies in the group, for example, when the angle between two directional options is more than 90 degrees (Strandburg-Peshkin, Farine, Couzin, & Crofoot, 2005). Condorcet's theorem is also relevant in explaining how animal groups are able to make accurate decisions when there are discrete options, like when fish swim through a river network (Berdahl et al., 2018). One experimental study shows that when the size of groups of fish increased, more of the fish managed to follow the more attractive leader fish. Decision accuracy improved with group size (Sumpter, Krause, James, Couzin, & Ward, 2008 & Sumpter, 2010).

When navigating, animal groups operate according to the "many wrongs principle." Each individual makes a noisy estimate of the "correct" navigation direction, but by pooling these individual estimates, the accuracy is improved. The basic mechanism builds on the law of large numbers. If errors in individual estimates are unbiased and not perfectly correlated with each other, then a simple averaging across estimates reduces noise and comes close to the optimal decision. This mechanism covers both group movements and selection of alternative pathways. In this case, majority rule serves the same purpose as simple averaging (Berdahl et al., 2018).

4.3 Averaging

4.3.1 Averaging as Swarm Problem Solving in Animals

The section on decision threshold methods describes situations where one individual has a piece of information, like the location of food, which is then transferred to others through positive feedback. It can then be effective to copy the behavior of the individual that possesses the relevant information. However, animals also make decisions when there are two or more options when none in the group knows more than the others. For example, when a group looks for food in an unfamiliar environment, each individual has some probability of making the "correct" decision, but no individual is more likely to be correct than any other (Sumpter, 2010). Under such circumstances, animal groups will sometimes use an averaging strategy.

As already mentioned, the "many wrongs principle" refers to the general idea that social interactions reduce individual errors, improves navigational accuracy when groups move together. For instance, individuals which move together in herds, flocks or swarms, will continually adjust their route based on real-time perceptions of the movements of other agents. Simulations have demonstrated that averaging can describe local social interactions if individuals balance their own preference with how their neighbors move. These simple mathematical models assume that all individuals in the group are identical, follow the same interaction rules and have the same level of navigational information or error (Berdahl et al., 2018).

At first, one might think that averaging is a distinctly human decision method since it follows a relative complex statistical rule, but surprisingly, animal groups are also able to use this mechanism when navigating. Already in the 1960s, some researchers proposed that birds and fish moved in the average preferred direction of all individuals (Berdahl et al., 2018). Recent empirical studies have also proven the existence of such a mechanism. One example are wild baboons, which prefer a process of shared decision-making instead of following dominant individuals when they

Figure 4.4 Olive Baboons crossing Uaso Nyiro River in Kenya, photo Don Farrall/Getty Images ©

navigate (Figure 4.4). If the disagreement on the angle of the direction of movement is above 90 degrees, the baboons will choose to travel in one of two preferred directions. In this case, majority rule counts, and every one will eventually move in the same direction. However, below a critical angle, if the differences in preferences are lower than approximately 90 degrees, the baboons' compromise. The group will then move towards the average of the preferred directions (Strandburg-Peshkin, Farine, Couzin, & Crofoot, 2015). Honeybee swarms use the same mechanism. Prior to lift-off to a new nest site, the bee dances encode the direction to the chosen nest site with some individual differences. The actual flight direction will then be close to the average direction advertised by the different bees in their dances (Oldroyd, Gloag, Even, Wattanachaiyingcharoen, & Beekman, 2008).

When averaging, both baboons and honeybees improve their navigational accuracy because of the "many wrongs principle" (Simons, 2004). When all individuals want to reach the same target destination, they will navigate according to their unique directional information such as visual landmarks, internal compass, and smell and so on. Each individual will therefore navigate with some error, but when this error is unbiased, the

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average direction of the group is more likely to be correct than a random individual in the group. Assuming there is no cost to aggregating information, navigational error in the average direction decreases in proportion to the group size. This is analogous to the central limit theorem that shows how the standard error shrinks when the sample size increases. Averaging effects reduce "noise" at the individual level of information, and produce more accurate collective actions (Berdahl et al., 2018; Krause et al., 2010; Strandburg-Peshkin et al., 2015; Sumpter, 2010).

However, animal groups do not explicitly average individual estimates in a group because they can only observe their near-neighbors. Instead, the collective behavior relies on individuals having access to different information. According to "the many eyes principle," animal groups can integrate more information about the environment because it is distributed among all the individuals. Therefore, the dominant male in the baboon group does not have a higher chance of getting followers, in decision-making on group movements. These daily decisions are shared equally between the members of the group (Strandburg-Peshkin et al., 2015).

4.3.2 Human Averaging as Swarm Problem Solving

By now, there exists a lot of research that demonstrates averaging effects within the "Wisdom of Crowds" literature (Surowiecki, 2005). A classical example is the jelly-beans-in-the-jar experiment, in which the group's estimate is superior to the vast majority of the individual guesses. In one study with 850 beans in a jar, only one of the fifty-six individuals beat the crowd guess of 871. If ten different jelly-bean-counting experiments are done successively, it is likely that one or two students will beat the group each time. However, it is very unlikely that the same student outperforms the group. Over ten experiments, the group's performance or the crowd will almost always be the winner compared with single individuals (Surowiecki, 2005; Treynor, 1987).

The basic requirement in human averaging is that estimations, predictions, or judgements can be quantified. The crowd will often be studied as the aggregation of separate individual judgements. Typically, the crowd will solve simple tasks that assume the existence of a correct solution, such as predicting changes in the stock market or betting on a sports event. Each member of a crowd will submit some relevant information (signal) and some random errors (noise). When these errors are truly random and not systematically biased, the average will perform very well because the errors cancel. A good example of the crowd estimate is the temperature in a room, since individuals use uniquely different strategies when they guess the temperature (Davis-Stober et al., 2014; Surowiecki, 2005).

If certain conditions are fulfilled, a group can be remarkably smart when their averaged judgements are compared with the judgements of individuals. The individual heterogeneity in the group makes the aggregate more accurate (Lorenz, Rauhut, Schweitzer, & Helbing, 2011). From one perspective, this effect is primarily a statistical phenomenon that requires some type of averaging technique. A typical definition of "crowd wisdom" refers to the performance of a group average compared with an individual selected randomly. If guesses exhibit a random deviation from the correct answer, these deviations tend to cancel each other out when a large number of them are aggregated. When inaccurate perceptions are diverse, the shortcomings of the ones tend to compensate for the shortcomings of the others. This gives a more accurate, global estimate. Other definitions of crowd wisdom are more mathematically orientated, comparing the mean of the individuals with the mean individual or defining accuracy as the average squared error of prediction (Davis-Stober et al., 2014).

Several of the citizen science projects from Chapter 2 use averaging techniques to aggregate independent volunteer contributions. The same micro task is done by several persons independent of each other a certain number of times. This increases the likelihood of getting correct and valid information. For example, in the Galaxy Zoo project, hundreds of thousands of online volunteers helped astronomers by classifying the shapes of astronomical objects. Even though some single volunteer made mistakes, this became less of a problem when many volunteers looked at that same object. The group results were very accurate and showed that the crowd can perform well on relatively simple tasks.

A comparison of several wisdom of crowd studies found that simple crowd average is robust across different aggregation and sampling rules. In most cases, the simple average of individual judges is wiser than a single individual estimate. If the true score is well bracketed by multiple estimations (near the median or average), the aggregate accuracy will perform much better than the typical judge in the group. This crowd wisdom effect is present even when judges are individually biased and the crowd aggregate is not particularly accurate. Unless it is easy to identify the best individual across tasks that are done repeated times, the best option is instead to choose the unweighted aggregate of the crowd if the size is large. Over time, even the best performers will lose against the crowd average (Davis-Stober et al., 2014). Although the simple average or mean is the most popular aggregation technique, others have argued that median is a viable option. When group size is small, medians are less sensitive to extreme member estimates and may provide a more accurate result (Tindale & Winget, 2019).

There are also other treats against averaging. If individual have very little background knowledge, the crowd aggregate may be very bad. In one study, the crowd made a very poor estimate when asked how many times a coin must be tossed for the probability that the coin shows heads (and not tails) on all occasions to be roughly as small as that of winning the German lotto. Here, the estimate of a single "expert" is better, as a person with competence in mathematics can quickly estimate the correct answer to be 24 coin tosses. Compared with the jelly bean experiment of the temperature task, the coin example shows not only that those individuals are imprecise, but there is also a huge systematic bias. Most real-life problems include both imprecision and bias, and it is not always easy to distinguish these from each other (Krause et al., 2010).

One way of improving the averaging methods is to weight individuals differently, for example by giving more weight to expert members (Tindale & Winget, 2019). However, there is still a risk that the decrease in variance of predictions can offset bias in future aggregations. Another key concern is the role of social influence. It is almost impossible to collect independent opinions in society because people are part of social groups and will be influenced by each other (Davis-Stober et al., 2014). An important condition in the original "wisdom of crowds" approach is that the estimations need to be made independent of each other (Surowiecki, 2005). While animal groups are very effective in producing individually independent information, humans are much more vulnerable to social influence. There is a risk that negative social influence can reduce the diversity of perspectives. For example, one study found that when the crowd received information about the group estimate, the individuals changed their estimates and performed worse as a group.

In the first round of the study, all subjects answered independently. Afterwards, the subjects were allowed to reconsider their response after having received full information of the group response. The new estimates narrowed the diversity of opinions in a negative way even when the individuals were not allowed to discuss the task with each other. One explanation is that when individuals become aware of the crowd estimate, they may move closer to the average because they assume that the crowd is wiser. If all predictions are more narrowly distributed around a value, this "range reduction effect" makes the crowd less reliable. The negative effects of social influence will also be smaller if the individuals are more confident in their own estimates (Lorenz et al., 2011). The Delphi method builds on this assumption (see Section 4.5.2).

4.4 Large Gatherings

4.4.1 Large Gatherings as Swarm Problem Solving among Animals

Are humans the only ones who let a large number of people come together to solve a problem? Not entirely. Arguably the most famous example in the animal world is the "waggle dance meeting" which is an event honeybees arrange to find out where to move their nest. The house hunting will usually begin when colonies become overcrowded in their nesting activities. About a third of the worker bees stay at home and rear a new queen, while the rest, a group of ten thousand bees, leave together with the old queen to create a daughter colony. The migrants travel about 30 meters before they stop and form a beardlike cluster, where they stay for a few days. From this place, several hundred house hunter bees will travel out and explore 70 square kilometers (30 square miles) of the surrounding landscape for potential home sites. They will usually identify around a dozen potential home sites, which are evaluated by several bees to check if they are sufficiently spacious or provide good protection. What is remarkable is that the bees almost always select the single best site from the options they have first identified (Seeley, 2010: 6). In this process, they utilize a range of strategies that are also relevant for human swarm problem solving.

The scout bees follow three steps in their collective decision-making process. First, they search widely for prospective nesting sites and identify all the available options in the surrounding area. They look for small, dark openings that can provide a roomy and protective nest cavity. None of the bees checks the same area; they are able to maximize the diversity of their searching behavior, and thus optimize the chances of finding an excellent home. The differences in flight routes may be due to where they have previously worked as foragers or differences in their "personalities." Since the search group is so large, with several hundreds of bees participating, they are usually able to identify the best sites very quickly, usually within hours or a few days (Seeley, 2010: 224, 234–235).

The second step is that the bees meet at the cluster and freely share information about all the available options. The scout bee that has located a good potential nesting site announce the discovery through a waggle dance which aims to recruit other scouts to the fly-out and evaluate the sites. These recruited bees will then fly out, assess the site independently, and then return to dance for that site. Dances are more frequent for better sites, leading to a faster recruitment of scouts. This is how the positive feedback loop of recruitment to the different sites begins (Sumpter, 2010).

What is extraordinary with the honeybee waggle dance is that it gives specific information about the distance, direction, and desirability of the site (Figure 4.5). The duration of each waggle run is the distance coding and gives information about the length of the outbound flight. Second, the waggle run is positioned as a direction coding by running at the same angle as the proposed outbound flight relative to the sun's direction. The dance is a specific flight instruction: "Should we consider this site which is located X degrees to the right (or left) of the sun and Y meters away." In addition, the number of dance circuits inform the relative desirability of the site. The better the site is, the stronger the advertising dances will be, resulting in a stronger positive feedback for this site. The dance attracts the other uncommitted scout bees to a specific site, and the scouts who made the original discovery tend to be especially persistent in sharing their information (Seeley, 2010: 11, 224, 226–227 235–236).[3]

One can look at the waggle dances as a large gathering with competing "dance" advertisements for different candidate nest sites. At any given point of time, some scout bees will be committed to a candidate, while others are still uncommitted. A committed scout will advertise "her" site to uncommitted scouts and recruit them to visit the advertised site. When the recruited bees return, they advertise the same site and begin to recruit even more scouts to the particular site. Supporters of one site can also become apathetic and rejoin the neutral voters. Since the bees that have found the best site will dance most intensively, they will gain supporters more rapidly and these supporters will move back to a neutral status more slowly. The interest in some sites will shoot up, while others fade away.

All bees are free to advocate any site, and all views are voiced and respected. What is important is that the scout bees do a personal, independent evaluation of the different sites. Each individual decides whether she want to fly out to the site and whether she want to advertise it when returning. No scout bee will follow another dancer without inspecting the site. This is important because if scout bees blindly copy other bees, they would make biased decisions by overemphasizing the reports from the first scouts. The aggregated information builds on an open debate with contributions from dozens, if not hundreds of scout bees with independent opinions (Seeley, 2010: 224, 226–228, 235–236).

Figure 4.5 The honeybee waggle dance. The direction the bee moves informs others about where the site is. The duration of each dance informs about the distance to the site, photo Paul Starosta/Getty Images ©

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The positive feedback mechanisms aim to recruit a sufficient number of scouts to one site to pick a winner. Even when the best site is discovered several hours after the other candidates, it will still quickly dominate the competition. The decision-making process is essentially a competition between alternatives to accumulate support, and the winning alternative is the one that first surpasses a critical threshold of support from the bees. When the scouts visiting one of the potential home sites exceed a specific threshold number, a quorum response is initiated which suddenly makes them return to the swarm. There is enough evidence to make the best decision. Back in the swarm, the scout bees who are convinced begin using piping signals to inform thousands of nonscout bees to begin warming their flight muscles. These preparations even start before all scouts have reached consensus since it is vital to speed up the process. Quorum responses ensure that the consensus decisions are both very accurate and time efficient since not all have to agree before a decision is made (Seeley, 2010: 8, 230). At the same time, the honeybees show that their solutions are surprisingly accurate (Seeley, 2010: 8, 226–230).

The bees' survival depends on the decision about their new home. This is why they expend a lot of effort in searching for possible home sites and debate it for several days. The large gatherings of honeybees are interesting also in relation to human swarm problem solving, both in how all relevant options are identified, how this information is effectively shared, and how accurate decisions can be made more quickly through a quorum response (Seeley, 2010: 226–230). If we look at the basic idea of deliberative democracy, there are several similarities. People should listen to each other, include all relevant arguments, and criticize them in a fair way. Without these qualities, democracy can easily end in manipulation and misled opinions (Fishkin, 2018).

4.4.2 Large Gatherings as Human Swarm Problem Solving

Deliberative Polling

If we look at large gatherings as a specific mechanism in human swarm problem solving, Deliberative Polling is one example that resemble how honeybees quickly solve problem together. It is a participatory governance method developed by James Fishkin (2018). It includes the "whole territory" by inviting a representative sample from the whole population. Random sampling is a strategy that ensures inclusion by gathering the whole population in a smaller group to make it easier to deliberate. The problem with self-selected participation is that the samples are unrepresentative, and participants who show up will often have special interests and not really be engaged in finding out what is best for the whole community. In Deliberative Polling, criteria for demographic and attitudinal representativeness are therefore included to optimize representation. Demographics representativeness cover standard categories such as class, gender, education, income, and ethnicity. Attitudinal representativeness is equally important and seeks a representative microcosm of the political viewpoints in the population. It is also important that the group is large enough, so the sample size is representative and includes all relevant diversity in the whole population. A large group makes it possible to produce meaningful statistically representative results. Usually, several hundred persons will participate in a poll. One of the advantages with this sampling, is that it is an effective way to get access to the opinions of an entire nation. If all members have an equal chance to participate, this is another variant of equal opportunity. Demographic and attitudinal representativeness ensure that all relevant viewpoints and interests are included in an appropriate proportion in relation to the population (Fishkin, 2018).

The poll participants are the "scout humans" that do the work for the entire population. Similar to bee nest siting, the poll participants will typically meet to deliberate a couple of days. While the bees are genetically designed to share and listen to all information in an open way, humans will often need somebody to help them organize a similar process. Small group discussions can easily become polarized. Cass Sunstein has found that if an issue has a midpoint, the group will often move further away from the midpoint and become more extreme. One reason is an imbalance of arguments. If most people are positioned on one side of the midpoint, they are more aware of arguments supporting only one of the positions. Another reason is the "social comparison effect" which occurs when people compare their views and feel a social pressure to fit in (Fishkin, 2018: 76, 142).

Deliberative Polling addresses this challenge by using balanced info materials and moderators that ensure that everyone is allowed to speak. Discussions can easily become too dominated by men or those who are educated. It is important that the ground rules for the discussions protect individual opinions from the social pressures of consensus. Therefore, the facilitators are trained to bring out minority opinion and to set a tone for respecting all opinions equally. The briefing materials are typically made beforehand by an advisory group which seek to include competing accounts. The participants also pose answers to experts with different opinions in the plenary sessions. In order to ensure independent opinions, and avoid conformity pressure, the participants' final considered judgements are collected in confidential questionnaires at the end of the process (Fishkin, 2018).

An interesting example of Deliberative Polling is the participatory budgeting project in the capitol of Ulaan Baator, Mongolia. Over two days, 317 persons participated in the Government Palace. These respondents were drawn from a larger stratified random sample of 1,502 residents. The randomly selected individuals comprised a balanced representation of households, from both apartment areas and the traditional tent communities. When the participating residents arrived, they were randomly assigned to small groups of about 15 persons who would be together during the weekend. The participants received briefing materials and the moderators supported the group processes. The groups also identified key questions that panels of competing experts addressed in the plenary sessions (Fishkin, 2018: 94–95).

It was expected that the final results would give the proposed Metro system top priority, but instead the best-ranked proposal was "improved heating for schools and kindergartens," mainly because Ulaanbaatar is one of the coldest major cities in the world. The groups also opted for a cleaner environment, even if it would make energy prices higher. In addition, the participants reported greater respect for others' opinions by being part of the process. The results from the Poll were afterwards included in the Action Plan for the City Master Plan in the exact order determined by the citizens. Other elected representatives in the city experienced the process as a legitimate democratic process (Fishkin, 2018).

Furthermore, in 2017, the parliament of Mongolia passed a law that requires Deliberative Polling as a form of public consultation before the parliament can consider amendments to the constitution. In the first poll that built on this law, a national random sample of 785 was invited over the weekend to deliberate in the Government Palace. It was an extraordinarily high rate of participation for those invited. Also on this occasion, the results gave important advice to the national parliament. Two of the most ambitious proposals for change, the indirect election of the president and introduction of a second chamber, were rejected. The main reason was the negative results from the Deliberative Polling (Fishkin, 2018).

Deliberative Polling appears to be a successful example of human swarm problem solving. According to Seeley (2010: 224), the honeybee researcher, swarm problem solving depends on four things. First, the group needs to be large enough for the challenge. Likewise, it is important that

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the sample size in the Poll is large enough to be representative for the whole population. Second, the swarm must consist of people with diverse backgrounds and perspectives. The Poll ensures this through not only demographic representativeness but also attitudinal representativeness. Third, individuals should, like the bees, be encouraged to do independent exploratory work. In the Poll, this happens by letting many smaller groups deliberate independent of each other. In the end of the process, the participants also make an individual, independent assessment through anonymous voting. While the bees end up selecting only one winner site, the Poll ends up with a ranked list of prioritized solutions. However, a major difference is that the bees identify all available options and collect information by themselves during the process. In the Poll, most of the background information is collected in advance by experts and summarized in briefing material. It is essential that this information is balanced and unbiased.

Fourth, it is important to create a social environment where everyone feels comfortable about proposing solutions and sharing information with full honesty. The waggle dance of the bees shares information regarding the options in a precise way, and the goal with the deliberation is also to let everyone be free to put forward arguments and criticize them in an open way. In the Poll, a moderator supports the group to ensure that the group dynamics are as good as possible. The bee competition for the best site is friendly because the bee swarm has a common interest. Likewise, the Deliberative Poll often addresses issues that are relevant for all citizens, like constitutional change.

Hackathons

Obviously, there is a huge variation in how humans use large gatherings to solve problems together, also in nonpolitical areas. In the offline setting, the hackathon is one such example of a gathering with up to 1,000 participants (Figure 4.6). It is an event where people who not usually meet, gather for a few days to solve a problem together. Most hackathons center on software development. For instance, Google, Facebook, and open-source software projects like Linux host hackathons to rapidly advance work on specific development issues. In addition, universities and national and local government agencies increasingly arrange hackathons to build technology that addresses different societal issues, such as helping the elderly cope with dementia. Some events may have as many as 1,000 participants (Trainer, Kalyanasundaram, Chaihirunkarn, & Herbsleb, 2016). A hackathon is also called a "hackfest," which is an

Figure 4.6 Hackathon in Berkeley, California in 2018. Students work at Cal Hacks 5.0, the largest collegiate hackathon, in Berkeley, CA, November 3, 2018, photo Max Whittaker/The New York Times/NTB

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abbreviation of hacking festival. Codesprints or codefest is another term that avoids some of the negative connotations associated with the term "hack." These sprints are usually organized as an intensive computer-programming event with specific goals and a short timeframe. However, most hackathons are quite open-ended and exploratory, with various activities going on at the same time. At the end of hackathons, individuals or groups will usually present or demonstrate their results (Briscoe & Mulligan, 2014).

Like with the honeybees, the participations will work hard within the short time period of the event. Typically, a hackathon will last between a day and a week in length. Eating and sleeping is often informal, and sometimes people will even sleep on the site. Participants will usually need computer programming skills; the exception is some hackathons organized for educational or social purposes. Participants must also be able to work comfortably with new people in small informal teams. This includes intense work conditions with time pressure. At the end of the hackathon, they must be able to present the work to others in a compelling way in a short time (i.e., pitching to potential investors) (Briscoe & Mulligan, 2014).

Hackathons will usually begin with a plenary presentation about the event and the contest format, including the challenge prizes if available. Sometimes, the prizes will be a substantial amount of money. A panel of judges will then select the winning teams, and prizes are given. The judges can be organizers, sponsors, or peers. It varies to what degree information is shared online before the conference starts. The number of participants and the organization of teams will depend on the concrete tasks. Usually, the participants suggest ideas and form teams, based on individual interests and skills. Sometimes they will pitch their ideas to recruit more team members (Briscoe & Mulligan, 2014). This is somewhat similar to how the honeybees also attempt to recruit other scouts to join them in investigating one specific site.

Although the hackathons are brief, one of the expected benefits is to build a community (e.g., often only a few days). When the participants observe and interact with another, they share the feeling of being at the same place. This proximity can contribute to the development of durable social ties. During the hackathon, it is important that the interpersonal relationship is of such a quality that people feel free to ask and offer help, and work openly so others can observe their work. By getting in contact with others, participants have the opportunity to identify common interests. If they share the same interests, it is more likely that they will trust each other and want to work together (Trainer et al., 2016). Like with the honeybees, the hackathon let all participants move freely around, interacting with whomever they want.

Because of time pressure in completing work within the deadline, participants learn a lot about each other. However, one study still found that some participants were not comfortable asking for help, showing the importance of participants becoming acquainted. Some participants also maintain contact after the hackathon (Trainer et al., 2016). Hackathons illustrate that an offline setting can be used to let a large gathering of people solve problems in effective ways within a short period.

Swarm Platforms

In the online setting, new swarm platforms are being invented that attempt to involve large gatherings of people in collective problem solving. One interesting example is the UNU platform, which attempts to enable large groups to solve a challenge within an extremely short period. This is done in an online environment that enables a group to synchronize all their contributions in real time. Modeled after biological swarms and how many species reach group decisions by deliberating in real-time systems, the platform lets online groups work together as a dynamic moving group or "swarm" that can quickly answer questions and make decisions by exploring a decision-space and converging on a preferred solution. By giving people a very short decision-making time, the intention is to reduce social biasing effects like snowballing, which is considered to be a problem in majority voting systems, which arise from sequential voting where persons can observe how other votes have been given (Rosenberg, 2015).

The design of the UNU platform is inspired by honeybee nest siting – how they integrate diverse information, competing alternatives, and converge on a unified decision when a sufficient quorum is reached. The primary goal is to design a system that allows networked users to make intelligent decisions by reaching decisions in real-time systems, modeled after natural swarm behavior (Patel et al., 2019; Rosenberg, 2015; Willcox et al., 2020). This process is labeled as Artificial Swarm Intelligence (ASI) because the system architecture runs algorithms modeled on the decision-making process of honeybee swarms. All participants receive instant feedback on the movements of the human swarm group. This allows each user to adjust their own preferences in relation to the changing swarm behavior. Inspired by the complex body vibrations in the "waggle dance," the technology intends to model something similar in human groups (Patel et al., 2019; Willcox et al., 2020).

Individuals in the swarm respond to a question by pulling a “graphical magnet” with their mouse cursor towards one of the proposed answers. The group will in real-time collectively pull on the puck toward one of the preferred answer options. Every individual can also at any moment change behavior, making it possible to negotiate among alternatives. The answer period varies, but is usually within 60 seconds, often much quicker. The group output is the result of a “tug of war” between all participants. Individuals who do not adjust their magnet will lose influence over the swarm’s outcome, just like bees vibrating their bodies to express favor for a new home site in a biological swarm. The pull from each user’s magnet is visible to other users, and the aggregated force from all of the magnets controls the movement of the puck (Patel et al., 2019; Willcox et al., 2020).

Like with the bees, the collective decisions build on reaching a threshold level of support, weighing the input from the group of swarm members, and their mutual excitation and inhibition. When a certain number of individuals prefers one specific option, and exceeds a certain threshold, the answer is eventually selected (Patel et al., 2019; Willcox et al., 2020). A study of the system found that the group’s final answers when swarming were significantly different from the swarm initial mean and the survey answers. The results show that individuals respond to the swarming experience and do not only change their answer to conform to most of the individuals in the group. The changes in responses are both influenced by the dynamic expression of individual answers and the confidence in those answers. Individuals must intuitively negotiate many factors in a short period, including their own conviction in their answer and the real-time, changing distribution of answers in the group at large. When individuals choose to pull for other alternatives, they choose a nearby option that is also still close to their original preference (Willcox et al., 2020).

Human online swarming can be regarded as a new wisdom of crowd approach. However, the collective performance of such systems is still uncertain. A few scientific studies have shown positive results compared with other wisdom of crowd approaches. It illustrates that it is possible to utilize real-time dependent contributions and not only aggregate separate independent contributions (Patel et al., 2019; Rosenberg & Willcox, 2018; Willcox et al., 2019, 2020). For example, when assessing whether patients were positive for pneumonia based on their chest X-rays, a group of radiologists reduced the percentage of errors by 33 percent compared to the averaging the individual estimates (Rosenberg et al., 2018). In another study, the human swarm also performed better than one of two machine-learning models (Patel et al., 2019). In general, these online swarm platforms are interesting because they allow for a very large group of individuals to gather for a very short time and make effective, relatively accurate, decisions.

4.5 Heterogeneous Social Interaction

4.5.1 Heterogeneous Social Interaction in Animal Swarm Problem Solving

Do individuals in animal groups usually behave the same way when they solve problems together? While averaging methods and decision threshold methods assume that individuals are identical units, there is today increased interest in how individual differences influence group behavior. For instance, genetically diverse honeybee colonies maintain a more stable nest temperature than genetically uniform bees. The reason is that diverse bees respond at different temperatures, thereby avoiding "all or nothing responses" that could easily overshoot the target temperature (Sumpter, 2010).

In other animal groups, group heterogeneity includes the presence of both leadership and other specific social structures (Jolles, King, & Killen, 2020). Individuals will fulfill different roles in a group when they solve a problem together. When chimpanzees hunt monkeys in groups, they take complementary roles. The driver chases the prey in a certain direction, while the blockers prevent the prey from changing directions. Although this type of group hunting looks like genuine collaboration, the most likely explanation is that they follow simple interactional rules. Each animal fills whatever spatial position is still available at any given time. Encircling is, in this way, accomplished in a stepwise fashion. The group hunting does not require a prior plan or agreement; each individual chases the prey from its own position (Moll & Tomasello, 2007).

Complementary roles in a group hunt can be explained as simple associative learning. One simple rule is that each individual follows their preferred stalking pattern and goes straight towards or circle around the prey. The timing of actions between the animals needs to be synchronized to make the hunt effective. For example, when wolves fan out and encircle prey, they follow two simple rules; get to the closest safe distance from the prey, and get the best possible view of the prey (Figure 4.7). By following these two rules, each individual will at the same time move both towards the prey and away from other individuals, so those in front do not obstruct their view (Bailey, Myatt, & Wilson, 2013).

Body posture may be important as communication, particularly in instances where the prey is only visible to the first animal. It provides

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Figure 4.7 Cow moose defends her newly born calf from the Grant Creek wolf pack while surrounded in a tundra pond in Denali National Park, Alaska, photo Patrick J. Endres/Getty Images ©

information about prey position and direction of travel to the other pack members. For example, when lions see prey, they adopt a ridged, alert posture which give the other lions information about the prey's presence and location. In addition, individuals often choose to adopt a similar posture or speed of travel to that of conspecifics during hunts resulting in greater synchronization. This copying of behavior between individuals is effective because individuals base their decision both on information from the environment and from each other. In most circumstances, these strategies, which require a low level of cooperation with simple interactional rules, may be very effective (Bailey et al., 2013). Studies of schooling fish have also shown that they organize themselves in an attempt to obtain independent individual information. Their network of social influence is structured to reduce the probability that individuals obtain correlated (redundant) information from others (Couzin, 2018).

Furthermore, in most cooperative hunting species, there is some degree of information transfer amongst individuals in group hunting, achieved via visual, tactile, vocal or olfactory cues/signals or a combination of these. Depending on the hunting strategy, this can take the form of both

Figure 4.8 African Elephant herd walking on marshy area of Amboseli National park, Kenya. The oldest female is the leader of the herd, photo Manoj Shah/Getty Images ©

inadvertent behavioral cues or intentional signals. For example, vocal communication is ineffective for predators that typically rely on ambush, because the sound would alert prey. Dogs, however, rely less on surprise and thus can use vocal communication. In high levels of vegetation with poor visibility, calls may help coordinate pack movements, but they do not communicate specific hunting behaviors (Bailey et al., 2013).

These studies are interesting because they illustrate that higher-level cognition is not necessary to perform highly organized cooperative hunts. Effective coordination is achieved by following simple interactional rules in combination with some degree of associative learning (Bailey et al., 2013). Although chimpanzees are "mutually responsive" and adjust their individual actions according to the actions of other individuals in the group, there is no indication of joint planning. Nor is there any indication of a chimpanzee leader which directs the group activity (Moll & Tomasello, 2007). The collective behavior of these animal groups illustrates how simple interactions at the local level create complex patterns of coordinated activity at the system level.

Although these examples illustrate collective problem solving without leadership, many animal groups will still rely on a small minority acting as leaders. Leadership emerges when informed individuals successfully guide naive individuals towards favorable environments. Like elephants, smaller groups may recognize some individuals to be leaders, but this leadership is usually anonymous in large groups (Figure 4.8). For instance, if information sharing about who has the relevant knowledge cannot be directly signaled, leadership can instead be achieved when the informed subclass moves more quickly than the naive majority. When speed variations are used to transfer information, surprisingly few informed individuals are required to effectively lead a group (Berdahl et al., 2018). When moving together, individuals with faster speeds or slower turning behavior will tend to end up at positions towards the front and edge of groups. The leader in the front of groups will have a larger influence over group movements and decision-making because of how the information flows in the group. For example, fish leaders will elicit following from naive conspecifics by showing more directed movement paths or greater likelihood of initiating motion. In many cases, those individuals with relevant information or experience are more likely to get followers. For example, in groups of elephants and killer whales, knowledgeable and older individuals lead foraging decisions, especially when the environment is changing. Individuals which are central in social networks are also more likely to get followers (Jolles et al., 2020).

However, there will be a conflict of interest between maintaining group cohesion and moving towards the individually preferred target. If the group becomes too large or too diverse, it may become fragmented. One mechanism that helps avoid this is that members of the group rotate at being leaders. Because it is costly to devote a lot of attention to gathering information, it may also be more effective to have some leaders who primarily focus on environmental cues and followers who predominantly rely on social cues. This group heterogeneity may be an outcome of evolution, rather than simply a consequence of age structure or mixing (Berdahl et al., 2018; Jolles et al., 2020).

Studies show that only a very small group of goal-oriented individuals is required to lead a large numbers of uninformed individuals to novel resources. Naive individuals can even improve collective navigation, because they, in line with the many wrongs principle, contribute with errors that can actually stabilize consensus decision-making and increase the speed and sensitivity of consensus (Berdahl et al., 2018; Jolles et al., 2020). Likewise, studies of human groups show that a small, informed minority (5 percent) could guide a group of naive individuals to a target without verbal communication or obvious signaling. When conflicting directional information was given to the informed individuals in the group, the time taken to reach the target did not increase significantly. It suggests that this mechanism can also be effective even when the informed subgroup disagrees on the preferred options. When there was a disagreement, the majority dictated the group direction (Dyer et al., 2008).

Another aspect of group heterogeneity is the possibility of *social learning*. Social learning allows knowledge possessed by informed individuals to spread through the group and across generations through unidirectional copying behavior. If naive individuals follow more knowledgeable group individuals along a path or a migration route when they travel, they may learn the route by being exposed to the cues associated with that route. This learning is unidirectional in the way that individuals gain personal information by following others who already have that information. Over time, they will become an informed subset. For example, cranes have no genetically encoded preferred direction in navigational tasks but will instead rely on social learning over generations. Because there are different levels of knowledge in the group, naive individuals can learn migratory routes that may be helpful in future journeys. In such groups, there will both be informed and naive individuals. Intergenerational leadership will be one way that social learning can emerge. For example, neither genetic, nor environmental factors, explain Atlantic herring annually returning to specific sites to feed and breed. The most likely explanation is that young individuals school with and learn from older and more experienced individuals. Light-bellied brent geese also choose staging and wintering sites in adulthood that are identical or very near to those of their parents, indicating social learning of migratory routes. In such cases, successful navigation will be more effective with leadership by the informed subgroup. The other alternative, navigating by the "many wrongs" principle and averaging estimates across the entire group, would be worse when a large group of naive individuals lack experience of the route (Berdahl et al., 2018).

4.5.2 Human Heterogeneous Social Interaction as Human Swarm Problem Solving

There is also CI research that examines heterogeneous interaction through collective problem solving in different social network structures. These social structures will follow specific interactional rules. For instance, an important part of the original wisdom of crowd approach is decentralization (Surowiecki, 2005). Centralized networks are organized around a core or a leader, while decentralized networks open up for more direct social interaction. Here, the emphasis is on utilizing local and specialized individualized knowledge and avoiding a too strong centralization of the collective work.

In contrast, centralized networks have a structure where communication flows disproportionately through one or more members instead of being equally distributed among all members. In highly centralized structures, the core, or a coordinator, will broker all interactions amongst the peripheral group members. This guarantees that the core has access to all critical information and sole responsibility for coordinating activities for the whole group. The potential disadvantage is that the periphery will then become completely dependent on what the cores decides to share of information. Individuals in the periphery cannot share knowledge or learn from each other directly, and this is assumed to inhibit the problem-solving process. The core may end up being a bottleneck if a large quantity of information must flow through it or it can lead the whole network astray with bad ideas (Shore, Bernstein, & Jang, 2020).

Decentralized Networks

Because of limitations in centralized networks, decentralized structures have become more popular in recent years. It is assumed that a peripheral individual, who is closer to the problem, is more likely to provide a good solution. In addition, knowledge sharing can be done more effectively throughout the system. One study finds that in decentralized communication networks where everyone is equally connected, group estimates become more accurate because of information exchange instead of just aggregating the independent individual contributions. The social learning results in both individual and collective judgements becoming more similar and more accurate. In decentralized networks, social learning aims to utilize the heterogeneity of contributions in a more effective way (Becker et al., 2017). The results point to the importance of learning between near-neighbors and having a transparent access to information in these closer surroundings. Less confident or informed individuals can adopt better solutions from their peers. This communication may also lead to learning and important sharing of knowledge that increase the collective performance. It can be particularly valuable to rely on peers' knowledge when newcomers lack sufficient relevant experience (Lave & Wenger, 1991). Both IdeaRallys and hackathons, mentioned in the previous section as an example of a large gathering, also build on a decentralized network structure. This structure allows for flexible social interaction that enables participants to easily engage with each other without needing to communicate through a central core. The Foldit gaming community also resembles a decentralized network with different teams competing against each other, but at the same time, they share information and learn from each from other. Individuals take on different roles in teams, being both "solvers" and "evolvers" (see Section 2.3).

However, some wisdom of crowd studies also point to negative effects of social influence and knowledge sharing because individuals align their judgements and produce more bias. If a few individuals dominate, group estimates will more likely increase the error (Lorenz et al., 2011). Social influence does not automatically lead to learning but can result in "herding," with individuals just following the group instead of making their own individual independent judgement. Subgroups within a decentralized network may become too attached to an existing set of ideas. In uncertain environments, individuals will also have a tendency to copy their peers, which can lead to collective bubbles and clustering that increase conformity pressure (Shore et al., 2020).

Centralized Networks

There is lack of research in the field and it is far from obvious that decentralized networks are always superior to centralized networks. Human groups use many different network structures depending on the problem they want to solve. For example, wisdom of the crowd problems typically focus on a limited range of problem types, which involve static information. In rapidly changing environments, one recent study finds that centralized networks are more effective. This experimental study tested the effect of seven network structures on problem solving in a shifting environment. A murder mystery task was given, and early information encouraged individuals to first draw the wrong conclusion. When they later received new information, they would have to change the proposed solution (Shore et al., 2020).

The results show that the best performers were the centralized networks with peripheral nodes not being connected with each other. The core nodes in the centralized network identified more unique solutions than other networks structures such as a complete clique or local cluster. The two-way communication between the core and the periphery ensured the flow of communication and spread of good ideas. The positive effects arose because herding and conformity pressure were minimized and learning maximized. The inability of peripheral nodes to interact with each other did not limit problem solving, but preserved a degree of independence of judgement. This resulted in more openness and adaptation to new information. The periphery was more adaptable to new information and less likely to retain a wrong answer that had been established in the group too early. The centralized network also generated solutions that were more diverse. Although these were not recombined, good ideas still spread effectively even when they contradicted the majority opinion (Shore et al., 2020).

Furthermore, the core node appears to be essential in this network structure. The core gets access to many different opinions and uses its special position to learn from the peripheral independent nodes. It also acts as a filter, selecting promising ideas and sharing them with the periphery. Nor will the central node feel the same group pressure as a smaller cluster that is internally cohesive. This reduces the likelihood of being stuck with a premature consensus solution. The core can also make everyone voice their opinion to maximize the production of diverse ideas. The success lies in limiting conformity pressure, but still retaining efficient connectivity, promoting social influence as learning without herding.

However, there is a risk that the core becomes a bottleneck by giving too much weight to a few ideas or their own idea. If a central node has a bad idea, it can have a negative influence throughout the network. This is in line with the original assumption by Surowiecki (2005) that crowd wisdom occurs only if no single individual is too influential. Another issue is that in the experiment, random individuals were in the key central positions, which is not usually the case in authentic problem solving (Shore et al., 2020). Still, the findings suggests that both centralized and decentralized networks can utilize heterogeneous social interaction in effective swarm problem solving.

The Delphi Method

Moreover, there are specific crowdsourcing methods that seek to solve complex problems by using a centralized network structure. One of the most well-known methods is the Delphi technique or the Delphi method, a method often used in idea-generation and forecasting, but has since been widely applied in other areas (Tindale & Winget, 2019). It has been applied in various fields such as program planning, needs assessment, policy determination, and resource utilization (Hsu & Sandford, 2007). The method can be used to determine expert consensus when it is difficult to use other research methods or there is a lack of research on the topic. Panel members will typically be invited to solve the problem by using their professional or personal experience, i.e., practice-based evidence (Jorm, 2015). It is a widely used and accepted method for gathering data from respondents within a specific domain of expertise. The communication is organized to stimulate a convergence of individual opinions around a specific problem. The consensus evolves gradually through a collection of data from the panel members in multiple iterations (Hsu & Sandford, 2007).

The method is used to explore possible strategic alternatives within an area, explore underlying assumptions around a problem, and seek out a broad range of information, like connecting informed judgements on a multidisciplinary topic. Evidence may be available, but it can be incomplete or cannot be adapted to practice in a simple way. For example, in mental health research, the method has been used to define foundational concepts or determine collective values within an area (Hsu & Sandford, 2007; Jorm, 2015). The panel members who often are experts will use a range of different evidence to make their judgements, such as systematic reviews, individual experiments, qualitative studies, and personal experience. The panel may also include a wide range of stakeholders such as clinicians, researchers, consumers, and caregivers (Jorm, 2015).

The process has many variants, but the first step is usually to formulate a clear question that is answerable by the methodology. The group is challenged to make an estimation or a prediction, such as for example what mental health research topics should be prioritized by funders (Jorm, 2015). A facilitator will organize the Delphi study and recruit a group of individuals (panel members) with some expertise on the topic. Ideally, there should be a specific sampling strategy to recruit these experts. Although the group size can vary a lot, it will typically be from ten to 50 participants. Since the process depends on a statistical analysis, it is normal to recruit a relatively large number of participants to produce stable results (Jorm, 2015).

Typically, questionnaires will be used to collect data. The facilitator will compile a questionnaire with a list of relevant statements that the experts are to rate for agreement. The items can build on literature search or through qualitative feedback from the expert panel or other stakeholders. These items will usually attempt to give a complete coverage of an area (Jorm, 2015).

The facilitator will then send out and collect independent individual responses from the questionnaire. The invited group members make a series of independent estimates, rankings, or idea lists on a specific topic. The facilitator then compiles or aggregates the member responses and sends it back again to each participant as a meaningful summary (mean rank or probability estimate, list of ideas with generation frequencies, etc.) (Tindale & Winget, 2019). The feedback is sent anonymously to each individual in the group, but they can still compare the individual responses with the rest of the group. The results will typically be given as percentage endorsement or mean score for each item on a Likert rating scale. The emphasis is on describing the participant's own position in relation to the whole group. Qualitative feedback is used less often. It will be distributed as a summary of the group comments and make each participant aware of the range of opinions and the reasons that are given (Hsu & Sandford, 2007; Jorm, 2015).

In the second round, the participants can choose to revise or re-rate their initial estimations or judgements based on reading the group results. The results are presented in a well-organized summary of the prior iteration, which allows each participant to learn, gain new insights, and clarify or adjust their own choices. Individuals who deviate from the majority opinion can be asked to explain why, and this new information may also be sent to everyone and can potentially change the majority opinion in the group (Hsu & Sandford, 2007; Jorm, 2015).

Responses will usually converge after some rounds, and a statistical criterion is used to define when consensus has been reached. There is no single answer to what the percentage should be, but the cutoff may be lower for a multidisciplinary group than a single disciplinary group. Since the aim is to reach consensus, a supermajority rule will typically estimate when the group agrees, with items needing up to 90 percent endorsement to be included in the final iteration. Items in the initial questionnaire that deviate a lot from the consensus criterion might be eliminated immediately (Hsu & Sandford, 2007; Jorm, 2015; Tindale & Winget, 2019).

The Delphi method can go over several rounds, but two rounds is most common. The presentation of group opinions as statistical results allows for a more impartial summarization of the collected data. It also ensures that opinions generated by each individual is well represented in the final iteration. The final outcome can range from a frequency distribution of ideas to a choice for the preferred outcome or the central tendency (mean or median) estimate (Hsu & Sandford, 2007; Jorm, 2015; Tindale & Winget, 2019).

The Delphi method deviates from the wisdom of crowds approach proposed by Surowiecki (2005) in some ways. The original claim of making independent individual contributions is only important in the first round of the data collection. This strategy intends to avoid groupthink. In groups where members have similar backgrounds and interests, there is a risk of creating conformity pressure. However, the process is entirely different in the second round. Then, the participants are challenged to modify and seek consensus with the rest of the group based on aggregated group results. The anonymity of the responses intends to reduce conformity pressure and bias by ensuring that individuals do not have to agree with the rest of the group. Since the outcome will be an aggregated quantified result, it is reliant on equal participation and avoids influence from dominant individuals. In addition, the facilitator can remove irrelevant content that focuses on individual interests or statements rather than focusing on the collective problem solving process (Hsu & Sandford, 2007).

The social structure is very similar to a centralized network and dependent on the competence of the facilitator. The process emphasizes knowledge sharing between members, but without any direct contact between group members. The iterations show that individuals are allowed to be influenced by other decisions, but the primary emphasis is on learning and on providing more relevant information to every individual, and at the same time minimizing herding or group pressure. This procedure allows for knowledge sharing between the group members but avoids conformity pressure or undue influence by high-status members (Hsu & Sandford, 2007; Jorm, 2015; Tindale & Winget, 2019). Overall, the purpose of these procedures is to allow for some information exchange while holding control over potential distortions due to social influence. Research on the Delphi method has tended to show positive outcomes and do at least as well as, if not better than, face-to-face groups. (Tindale & Winget, 2019).

Although diversity of expertise is not a requirement, it is often recommended when selecting panel members. Because panel members do not have to meet offline, it is possible invite experts from all over the globe and make it easier to invite a diversity of expertise. Since the process is anonymous and builds on aggregated contributions, there are fewer disadvantages with using the online setting. Part of this diversity is also about ensuring that a diverse range of relevant topics are included in the questionnaire (Hsu & Sandford, 2007; Jorm, 2015).

As these examples show, both centralized and decentralized networks can be regarded as important examples of heterogeneous social interaction.

4.6 Environmental Sensing

4.6.1 Environmental Sensing in Animal Swarm Problem Solving

As mentioned in the previous section on large gatherings, the honeybees display a fascinating ability to maximize environmental information when they search for the best nest site in their surroundings. It is a matter of life or death for the bees, and they are usually able to identify all relevant

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Figure 4.9 Starlings move as one giant organism to synchronize their defence against predators, Kent, United Kingdom, photo Sandra Standbridge/Getty Images ©

options in the surrounding area. This is possible because the individual searching areas do not overlap with each other. Most other mobile animal groups will also aim to utilize individual sensing capabilities by collecting information about the surrounding environment in an effective way (Berdahl, Torney, Ioannou, Faria, & Couzin, 2013). Previous sections showed how groups are able to pool imperfect individual estimates according to the many wrongs principle and use this information to navigate noisy and complex environments.

Often, animals will combine environmental information and social information between members in the group. For example, birds will utilize the "many eyes principle" when they synchronize their decisions on when, and where, to move to find food or avoid threats. A bird spotting a danger will start to fly, and by this example set off the whole flock to fly away. Starlings synchronize their individual actions very rapidly (Figure 4.9). When a predator attacks, a few peripheral group members will make the first encounter. This elicits a sudden change in direction, which then spreads through the rest of the group. Because the birds have different spatial positions in the group, they acquire different information about the surroundings and utilize the "many eyes principle" when spotting danger (Couzin, 2018; Dyer et al., 2008).

Likewise, giant honeybees synchronize their activity to avoid threats. Because they nest on a single, open comb, they are a target for predatory wasps. When attacked, the bees respond by create "shimmering" waves collectively. Initially, a subset of individuals starts a wave by rapidly raising and lowering their abdomens, making the other neighboring bees do the same. As with neurons and other "excitable" cells, individual bees will need

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to "recover" for a short period after one round of activity. This creates very visible waves of rapidly expanding rings or spirals across the colony surface (Couzin, 2018).

Individuals respond to the body orientation of near-neighbors by alignment. It requires that each agent both independently gathers information about the environment, but also imitates the behavior of others. These simple rules or behavioral algorithms provide the basis for the "many eyes effect" by letting individuals benefit from others, such as when detecting a predator or finding food. This collective navigation is possible even when individuals do not know which cue other group members respond to at any moment in time. It is enough to copy or imitate the response of others in the vicinity (Krause et al., 2010). The group's capacity for surveillance also increases with the number of alert animals. Fragmented individual information will be integrated at a group level and provide a better overall "picture" (Feinerman & Korman, 2017).

Emergent sensing is a label used to describe how animal groups in different ways combine environmental information and social interactional rules, which can be different types of repulsion, alignment, and attraction (Berdahl et al., 2018; Puckett, Pokhrel, & Giannini, 2018). According to Berdahl et al. (2018), emergent sensing occurs when a group is able to navigate even when no individual is aware of the correct direction. In a school of fish, each individual fish directs its behavior based on the perception of the position and speed of its immediate neighbors. For example, if an individual fish has no memory and is only able to make a scalar, one-dimensional, measurement of the environment, it will not be able to assess the gradient of an environmental cue. However, when information from multiple individuals is compared with each other, the group can collectively measure and follow a gradient in the environment. This is possible because a part of the group behavior is orientated towards the environment, like when a school of fish navigate through a changing "noisy" light field. Although these fish are not able to detect environmental gradients individually, the school still manages to swim toward darker waters because of a simple context-dependent rule: when observing the light field, golden shiners swim faster in bright regions and slower in dark regions (Berdahl et al., 2013; Puckett et al., 2018). The movement is not directed by the behavior of one or a few "leader fish," but a self-organizing intelligent swarm system (Figure 4.10).

A study shows that when the fish make movement decisions, they respond more strongly to social influences like the location of near-neighbors compared with the environmental influence of light gradients.

Figure 4.10 Bronze whaler shark swimming through a giant ball of sardines, waiting to feed on them. Off the East coast of South Africa, photo wildestanimal/Getty Images ©

Fish located in bright regions will travel more quickly, but because the fish also attract each other, this creates a rotation in the school, turning the whole group toward the darker region. The swim speed differences within the group causes a turning toward those who move more slowly. The collective sensing of the group level is both a result of individuals adjusting their speed in response to local, scalar, measurements of light (environmental gradient) and the social attraction to others in the group. The group operates as a distributed sensor network (Berdahl et al., 2013, 2018). Another type of fish, the tetras, outperform many other types of fish because they can sense the environmental gradient individually. They rely more on environmental information and less on social information, and can therefore have more distance between the individuals in the group. Most groups will not only navigate on the basis of sharing of information within the group, but they will respond to local environmental cues like light, odor, temperature, or finding the winds or currents that provide a better migration route (Berdahl et al., 2018; Puckett et al., 2018).

Another interesting finding is that simulations of schooling fish show that the group-level responsiveness to the environment improves spontaneously as group size increases. Although increased group numbers reduce measurement error, the key determinant of improved performance is the spatial extent of the group in relation to the length scale of the environment. Groups that are able to span a larger area are more likely to capture variations in environmental cues that are necessary to elicit speed differences between individuals in the group. Each individual exhibits a rudimentary, nondirectional response to the environment. This emergent sensing creates a collective response to the environment not present at the individual level. The results suggest that the ability to respond to environmental information may decline if the group fragments or is reduced in size (Berdahl et al., 2013). Studies of salmon in the wild have shown that in years with more fish, navigation to natal streams is more accurate. The journey home may benefit from the many wrongs principle when crossing the ocean, consensus decision-making when choosing between two freshwater streams and emergent sensing when locating the odor of a river or entrance of a fish ladder (Berdahl et al., 2018).

Social learning within groups is also important. If the size and composition of the groups varies and animals move throughout the environment, there will be present a large local heterogeneity of knowledge about the environment. In such cases, animal groups can make the best decisions by harnessing information from every one and follow the most informed group members. Naive individuals can even contribute with random noise and errors that may lead to the discovery of improved routes over time. This interaction between multiple individuals can sometimes lead to the production of new knowledge. For example, a group can jointly discover an improved route, through "the many wrongs principle," and individuals in the group will then learn this new route (Berdahl et al., 2018). By collecting both social and environmental information, a group of individuals can improve their collective decisions if they are able to balance this information in an efficient way (Puckett et al., 2018).

4.6.2 Human Environmental Sensing

In environmental sensing, the basic assumption is that large groups can perform better because they can access more environmental information. One way of maximizing relevant information from the environment is by having a broad outreach. Many CI projects build on open calls for participation where anyone can join and all who join have equal status. The communication is not targeted towards one specific person or group. Like with a warning cry, the call for participation is just "released" into the surrounding environment, which in this case is the Internet as a global environment. The aim is often to recruit the right problem solvers with relevant competence. The goal is to either find the unknown intelligent outsider or recruit a large enough group of people that can provide a collective estimation or solution to a problem.

Crowdsourcing in Disaster Management

One example of environmental sensing is crowdsourcing in disaster management. In these scenarios, it is important that everyone who is affected contribute with data. Crowdsourcing was first used in the management of the Haiti Earthquake in 2010. Nearly 40,000 independent reports were analyzed in a volunteer-driven effort to produce a crisis map after the earthquake. Volunteers, recruited through social media, did the translation and geocoding of these messages. The countries had limited infrastructure and few roadmaps that could be used to distribute disaster aid. In only two weeks, 640 volunteers helped create road maps of Haiti and mapped displaced persons camps of Haiti. People in the worst disaster areas could send requests for shelter, food, and medicines to the government through an online system. This crowd effort made it easier for the government to organize help (Kankanamge, Yigitcanlar, Goonetilleke, & Kamruzzaman, 2019).

Today, mobile technologies provide new opportunities when citizens can act as moving sensors, reporters, and micro-taskers. An enormous amount of real-time georeferenced information can be collected with speed and diversity (Kankanamge et al., 2019). For instance, citizens produced massive amounts of digital, real time, local information on critical events such as Hurricane Sandy in 2012, or the Nepal earthquake in 2015 (Poblet, García-Cuesta, & Casanovas, 2018), wildland fire incidents (Manavi, Gould, Smith, Thorp, & Guerin, 2020), or floods (Bhuvana & Aram, 2019).

In disasters, traditional communication modes such as wired telephones, television, mobile applications, and radios frequently crash, but social media will often remain intact. Especially, the propagation speed and the reaction time of social media has challenged the use of traditional communication modes during disasters. The communication flow between people through social media has enabled more personalized warnings in disaster areas and is today challenging the conventional disaster warning methods. Today, emergencies are often first reported through the "eyes" of personal mobile cameras and then shared on social media, rather than reported to officials. The first warning alerts happen through communication in personal and informal social networks in the local language. These provide assurance that family and friends are safe. At an aggregated level, this information will typically provide the best updated information about the status of a situation. Ordinary citizens are becoming increasingly important in solving these type of emergent problems (Kankanamge et al., 2019).

If we look more specifically at geomobile technologies, they can maximize environmental information in at least three different ways (Poblet et al., 2018). First, the "crowd as sensors" is a type of crowdsourcing that enables the collection of data from multiple devices, including mobile handsets, and each of these devices provides some local information that can be either automatically generated by sensors running in the background or it can be generated by humans. A large number of users can generate raw data by merely carrying their mobile devices. Sensor-enabled mobile devices (processes run in the backend by GIS receivers, accelerometers, gyroscopes, magnetometers, etc.) automatically collect data in the background. These types of data are especially important in the mitigation and preparedness phases of disaster management. They can inform about stampedes or traffic jams, seismic sensing, and how the population is distributed. Participants do not actively have to contribute with information. However, GPS location services require users' explicit permission of access, while other location sensors such as accelerometers and gyroscopes do not (Poblet et al., 2018).

A second type of crowdsourcing is the crowd as reporters. Social media users (Twitter, Facebook, Instagram, etc.) will also produce first-hand, real-time information on events as they are unfolding (e.g., tweeting about a hurricane and the damages in a specific location). This user-generated content is important in information sharing and also contains valuable metadata added by the users themselves (e.g., hashtags) (Poblet et al., 2018). These data can be used to extract semantically structured information that can give important situational knowledge during an emergency.

One example is data mining of all messages people have posted about the disaster in social media channels like Twitter or Facebook. However, it is not easy to analyze data effectively within a very short period. For example, in the case of 2012 Hurricane Sandy, 26 million tweets were produced over a two-week post period. This is a huge amount of data, which poses challenges for filtering and synthesizing the relevant information (Kankanamge et al., 2019; Poblet et al., 2018). The quality of the data will depend on the credibility of the reporters and a lack of control in this step can mislead decisions. There needs to be some quality control mechanisms based on experience, reputation of sources, and verification with other sources of information (Poblet et al., 2018).

Therefore, the response time of this type of tasks will increase compared with other types of geodata that can be used immediately. Some of the critical issues concerning trustworthiness and privacy are easier to handle as the crowd actively take the role of a "reporter." When people are already identified, assessing the trustworthiness of the source and verifying the incoming information may be less problematic (Poblet et al., 2018).

Finally, "crowds as micro-taskers" includes people executing specific processing tasks, which typically involve a modularization of a complex task into many smaller and independent tasks. One example is the categorization of raw data (labeling images, adding coordinates, tagging reports with categories, etc.). Volunteers can be part of a global response that allow them to participate in a number of tasks such as social media monitoring, data collection, data filtering, tagging, geolocation of events, etc. Because essential information needs to be analyzed rapidly, it requires active contributions from many volunteers. Sometimes, these processing tasks may require a training phase. Automatics tools and machine learning algorithms can also do some of this work and reduce response time further in a disaster management scenario. Still, rescue forces are the key volunteers during disasters, but online volunteerism can potentially support this ground work through information sharing on missing people or damaged property (Kankanamge et al., 2019; Poblet et al., 2018).

New forms of participation for individuals and communities often blurs the skill-based distinctions between amateurs and professionals. This can make it difficult to establish a shared understanding of how different sources of data should be used. Shared standards have also become crucial to facilitate interoperability and reduce misunderstandings (Poblet et al., 2018). The crowdsourcing methods in disaster management are still immature, but the potential in this type of human environmental sensing is significant.

Collecting Environmental Information in Smart Cities

A new trend in human environmental sensing is the development of smart cities that aim to employ information and communication technologies to improve the quality of life for its citizens. Many researchers claim citizens' use of technological infrastructure based on the Internet of Things and mobile technologies could potentially help societies in solving a range of different problems, such as environmental pollution, local economy health problems, or traffic management (Ismagilova, Hughes, Dwivedi, &

Raman, 2019; Staletić, Labus, Bogdanović, Despotović-Zrakić, & Radenković, 2020). These technologies are used to collect digitized information about the city environment.

One area is "smart mobility" that often addresses traffic management. This involves how to avoid road congestion by gathering data from sensors networks, which also involves tracking of moving vehicles. "Smart living" comprises areas such as public safety, healthcare, education, tourism, and smart buildings. For example, in developing countries, public safety is a big area of concern because of growing urbanization. One example is a crowdsourcing project in South Africa that tested the usability of an Interactive Voice Response (IVR) system to let people voluntarily report on any safety issues (Breetzke & Flowerday, 2016; Ismagilova et al., 2019). "Smart environment" is another area that emphasizes quality of air, water, green spaces, emission monitoring, waste collection management, energy efficiency, and monitoring of city trees. In some projects, citizens collect environmental data with their mobile phones. In one study, a crowdsourced weather app combined automated sensor readings from mobile phones and manual input by citizens to estimate current and future weather conditions. The results showed a high level of accuracy in estimating actual weather conditions, indicating that hybrid participation that combine machine intelligence and human intelligence can improve weather condition estimation and prediction (Ismagilova et al., 2019; Niforatos, Vourvopoulos, & Langheinrich, 2017).

Sensor-rich mobile phones allow for the collection of a range of new types of data about the environment. Mobile crowdsensing let ordinary citizens contribute data from their mobile devices, which are aggregated at a collective level. Users are typically supposed to act together, in order to generate knowledge beyond an individual level. The different modalities of sensing include numeric values (such as air quality and GPS coordinates), audios, and pictures or videos. Visual crowdsensing that uses built-in cameras of smart devices has become increasingly popular. In specific projects, people can be asked to capture objects, for example in the form of pictures or videos. Many crowdsensing projects have been developed in the context of smart cities. One example is how phones perform passive tasks and monitor noise and sound in the smartphone's microphones as sound sensing devices for creating large-scale noise maps and for suggesting city managers suitable noise reduction interventions (Staletić et al., 2020).

The notion of smart cities also includes citizen engagement and new types of interaction with the government. In some cases, this is primarily to ensure full adoption of new changes and services, but other models utilize user-generated content and underline the codesign and coproduction of government functions. This includes the collection of user generated content and use of analytics that can be used to generate predictive models, enabling local government to be more strategic and proactive in its responses to citizen requirements (Ismagilova et al., 2019). Decisions are made by aggregating active user contributions (students' favorite jogging and cycling routes, places with major social activities, etc. (Bellavista, Corradi, Foschini, Noor, & Zanni, 2018). One simple example is crowdsourcing of cycling routes in the city, where city planners have gathered data from cyclists to analyses traffic and improve urban infrastructure by adding racks or widening lanes (Ismagilova et al., 2019). Other active tasks may involve taking pictures, using tags, committing actions, answering a survey, etc. Collection of data from passive tasks can be performed automatically by users' smartphones, e.g., triggered by geo-localization of the user position. This can be self-monitoring activities like how much time has been spent walking (Bellavista et al., 2018).

Data are assumed to provide a better understanding of the community conditions and facilitate better evidence-based decision-making (Alizadeh, 2018). Many of these projects are reliant on people being willing to collaborate toward continuous data harvesting processes. It allows people to participate in any aspect of urban planning, by collecting and sharing data, reporting issues to public administrations, proposing solutions to urban planners, and delivering information of potential social interest to their community. Although these projects can be helpful for citizens, mobile users are reluctant to use their devices for these purposes, mainly due to privacy issues (Bellavista et al., 2020).

Furthermore, there is a growing number of planning departments at different levels (e.g., local and state) that use crowdsourcing to seek public opinions, ideas, and feedback on their, mostly strategic, planning. In some cases, especially designed digital platforms have been used to facilitate active crowdsourcing of ideas. However, they are often expensive to maintain and compete with other social media platforms (e.g., Facebook). For instance, the City of Vancouver used an online platform to seek feedback as part of the participatory process involved in the development of its first urban digital strategy document (Alizadeh, 2018). Another example is Citizen Design Science, which challenges citizen to become urban designers by drawing their own habitat. They will build their design on residential rather than economic interests. Neighborhood interests may also diverge from how the municipality thinks (J. Mueller, Lu, Chirkin, Klein, & Schmitt, 2018).

Moreover, in participatory planning, *passive crowdsourcing* has been introduced as an alternative channel to gather people's voices in urban decision-making processes. This type of crowdsourcing passively collects information, knowledge, opinions, and ideas concerning hot topics of the day created by citizens without any initiation, stimulation, or moderation from government postings. It can exploit the extensive political content continuously created in numerous social media platforms by citizens and inform public policy. It differs from the original "task-oriented" crowdsourcing approach in its emphasis on "crowdsourcing of opinions" (Alizadeh, 2018; Alizadeh, Sarkar, & Burgoyne, 2019).

One study illustrates how this type of crowdsourcing can be performed as a sentiment analysis in relation to traffic issues. On Twitter, the query "Parramatta road" is particularly active during traffic congestion or accidents. Tweets can be analyzed automatically according to their sentiment, including both positive and negative opinions. In this particular study, words like "happy," "good," and "sun" were given a positive score and words such as "angry," "traffic," or "lost" were given negative scores. The aggregated results would then inform on when there was a potential breakdown in the road system. Timing is an important factor since certain events create a burstiness of tweets, followed by spans of silence (Alizadeh et al., 2019).

Here, crowdsourcing is no longer about getting a certain task done with intentional help from the crowd. Instead, opinions, ideas, or perceptions from the public are aggregated through polling, sentiment analysis, and opinion mining. Sentiment analysis uses language processing and machine learning to identify which topics different groups talk and care about the most. Social media like Twitter are rich sources of opinions; and can be used for this type of analysis. Social media monitoring is used to continuously crawl and analyze data already available and mostly untapped, sometimes in real time, such as Twitter. These methods are already used by private companies today when they map potential markets, but have rarely been used for public purposes to strengthen the citizen voice (Alizadeh, 2018; Alizadeh et al., 2019). Still, passive crowdsourcing can be regarded as a type of environmental sensing that utilizes a more open government structure that can perhaps complement traditional urban planning approaches in the future.

4.7 What Is Human Swarm Problem Solving?

If we summarize the chapter, we have shown that sections show that animal groups and humans share some of the same mechanisms when they solve problem together. What is both amazing and perhaps quite surprising to the reader, is that animals are able to benefit of wisdom of crowd effects. There are commonalities concerning both decisions threshold methods and averaging methods. These two sections show how information from many individuals can be aggregated in effective ways when solving problems. The three other sections describe social practices that support collective problem solving. The section on large gatherings shows how large groups can solve problems effectively together in various ways; the section on heterogeneous social interaction describes the importance of individual diversity and learning in groups. The final section provides examples of how one can collect environmental information in different ways to maximize informational diversity. Together, these mechanisms provide a picture of a distinct type of collective problem solving, which here is labeled as human swarm problem solving. Compared with the wisdom of crowds literature, this account of human swarm problem solving provides a broader framework that includes both independent and dependent contributions and both quantitative and qualitative contributions. What, then, are the commonalities of the swarm problems described in this chapter? In comparing the analysis in the different sections, a tentative typology of human swarm problem solving will here be described, covering the following four areas:

1. Predefined problems
2. Prespecified problem-solving procedures
3. Rapid time-limited problem solving
4. Individual learning

4.7.1 Predefined Problems

If we look closer at all the examples in this chapter, we see that the problems are predefined in different ways. A project will describe an initial problem or challenge and formulate an "open call for help." In the online setting, the outreach can be to a very large group of potential problem solvers. Some projects look for individuals with special expertise (e.g., IdeaConnection), but in several projects, such as within citizen science (e.g., Galaxy Zoo), anyone can participate. This also includes most of the crowdsourcing projects in Chapter 2. Because the outreach is broad, it is important to formulate the problem in a precise way, so it is easy for potential participants to assess whether the task is relevant to do. Some problems are well-defined because the tasks are relatively simple tasks and do not require much background skills (e.g., Galaxy Zoo project). Regarding complex problems in innovation contests, intermediaries will often support the solution-seeker in formulating the problem in an accessible way. Deliberative Polling and the Delphi method are other examples of complex problem solving that involve a high degree of uncertainty about the best options. Still, both these approaches are reliant on a precise formulation of the problem. In Deliberative Polling, participants receive briefing material that aim to give a balanced and comprehensive introduction to the problem in a short time. In the Delphi method, the problem is described in the questionnaire sent out to the participants. In both these processes, the solutions will also be presented as a statistical result. Disaster management is another example of a predefined problem that centers on an emergency. Although part of the challenge may be to get an overview of the situation and what actually is happening on the ground, there is still no doubt about the general problem whether it is an earthquake or wildland fire.

4.7.2 Prespecified Problem-Solving Procedures

In human swarm problem solving, there is usually no need to metacommunicate about the collective work because the problem, the interactional rules, and the aggregation rules are defined in advance. By minimizing the need for explicit coordination, problems can be solved more rapidly. Nor is direct coordination possible when the group size is large. Two examples are Deliberative Polling and the Delphi method, where both the interactional rules and aggregation rules have been formulated in advance in a quite detailed way. In a hackathon, there are fewer interactional rules and more participant autonomy. Still, the core of the collective work, like the sessions and the contest format, will have been planned.

As animal groups follow a few simple rules in swarm problem solving, so will human swarms do the same in this approach. However, the human swarm contributions are obviously much more heterogeneous, being anything from a vote, an argument, or an informational report. Problem-solving procedures, like interactional rules and aggregation rules, will also vary a lot. Still, both honeybees and humans will in this type of problem solving be similar in the sharing of a common interest and agreement on the objective (Seeley, 2010: 233–234).

Participant Selection

Concerning participant selection, some projects allow for self-selection (e.g., citizen science and innovation contests), while other projects invite specific persons to participate, for example by random sampling (e.g., Deliberative poll) or expert sampling (e.g., Delphi method). Participant selection is important in both the Delphi method and Deliberative Polling when the goal is to maximize comprehensive information about an issue. In the political domain, random sampling of any citizen can give information about the entire population. In contrast, the Delphi method typically invites formal experts to provide a broad coverage of one specific area. In different ways, both approaches seek informational diversity through the careful selection of participants.

Near-Neighbor Alignment

Human swarm problem solving is also characterized by interactional rules, like near-neighbor alignment. The human swarm in the UNU platform has real-time access to the group opinion and will typically align to each other in the rapid "tug of war" problem-solving process. In the Delphi method, near-neighbor alignment is possible through the sharing of statistical results. Participants are asked if they want to adjust or align their individual opinion based on the results from the group opinion. A certain aggregated percentage threshold needs to be reached for each item to be included in the final report, which represents the group opinion. In addition, small group discussions in Deliberative Polling can be regarded as a type alignment to near-neighbors that emerges through discussions. A large group of hundreds of persons is split into many small groups with 15 persons. These groups deliberate in a decentralized network and each group will be "near-neighbors" to each other, being mostly separated from the other small groups.

Coordinators Enforce the Interactional Rules

In animal swarm problem solving, individuals follow interaction rules as a part of their innate behavior. There is no need for someone to control their behavior (Seeley, 2010: 233–234). This is very different in human swarm problem solving because individuals will not automatically follow rules or guidelines. In many of the examples in this chapter, coordinators also need to support the collective problem solving by ensuring procedures are followed. Facilitators in Deliberative Polling ensure equal participation. In the Delphi method, a moderator helps summarizing the work. In a hackathon, coordinators are important as event organizers.

Competition between Different Proposed Solutions

Human swarm problem solving often centers on some type of competition. In Foldit, this requires competition rules and active use of leaderboards. In a hackathon, the individuals compete for prizes within a short time period. Even the Deliberative Polling can be regarded as a contest between different proposed solutions, which in the end will be ranked against each other. The UNU platform can be looked on as a "tug of war" contest between different predefined alternatives. Likewise, the waggle dance meeting among the honeybees also functions as an open competition among the proposed alternatives. Groups compete to gain additional members from a pool of scout bees who are not yet committed to a site. Whichever group first attracts a quorum of supporters win the competition. The winning group then goes on to build consensus among the scouts (Seeley, 2010: 73–75, 226). The difference between bees and humans is that humans use a variety of competition rules, like different voting procedures.

According to Malone et al. (2009), competition is especially useful when only a few good solutions are needed. For example, solution-seekers in innovation contests do not want a large number of alternative solutions to their problems, but only one or a few solutions of optimal quality.

Prespecified Aggregation Rule

Many of the CI projects in this chapter build on the aggregation of all group contributions. Together these contributions can produce one single or a set of optimal solutions, but it can be achieved in various ways. Four aggregation rules are mentioned in this chapter. First, both humans and other animals use averaging strategies. In line with the original wisdom of crowd approach, this statistical rule assumes that the crowd is intelligent when individuals contribute with diverse perspectives in combination with, independent and unbiased opinions.

Second, all contributions can be ranked. In the Delphi method, all items in a questionnaire that receive a certain level of support are included in the final report. Another example is Deliberative Polling, which ranks all results by letting participants vote on proposed solutions.

Third, quorum response ensures that a minimum number of individuals agree before the group shifts to a new behavior. The most well-known quorum response is the majority rule, which selects the most preferred of one of two alternatives. Everyone will then follow this decision. This is an essential decision-making method in all types of democratic decision-making, and even animal groups sometimes use this aggregation method. Today, digital technologies and the online setting make it easier for large groups to use voting methods. Simple majority is most common, but supermajority rule is also sometimes used in political systems and in other types of swarm problem solving such as the Delphi method.

Animal groups even show that the decision threshold can be much lower than a majority. However, there are few such examples of human quorum responses. One example is the presence of a certain number of people to be present to make the vote valid. When not everyone has to be present, this makes the decision-making system more efficient. The UNU platform also uses a decision threshold, but it is uncertain how much support is required. Crowdfunding is another example that illustrates how the total amount of money can function as an alternative quorum response, offering a more flexible individual contribution than equally weighted votes.

A fourth aggregation rule concerns the qualitative contributions. In disaster management, this can be the collective production of a digital map of the disaster area. In these situations, it is essential to get precise information because difficult decisions need to be made within a short time frame. Passive crowdsourcing is another example that illustrates how one can automatically collect social media data. These data can be used to quickly aggregate crisis information. Fluctuations in the use of key words, for instance hashtags, can provide information about what is happening on the ground. This type of aggregation resembles environmental sensing; in letting the "many eyes" of different individuals provide an updated continuous overview of a complex problem. All the individuals operate as one unit, like a synchronized sensor network that maximizes the collection of environmental information through a broad outreach. Smart cities build on the same approach, but here the privacy concerns are much more apparent (Zuboff, 2019).

If we compare the different aggregation rules, we see that optimal swarm problem solving involve both quantitative and qualitative contributions that can be both independent and dependent on each other. However, the aggregation seldom recombines or synthesizes contributions. The aggregation rules are typically prespecified, whether it is an averaging strategy or majority rule.

4.7.3 Rapid Time-Limited Problem Solving

This chapter shows the importance of rapid problem solving. Animal groups operate according to a speed vs. accuracy tradeoff. Among ants, the evaluation time of different nests regulate decision-making because they use longer time to accept lower quality nests. To speed up decision-making, a relatively low quorum number is required. When a certain number of ants move in the same direction, all ants will suddenly switch

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from slow to rapid movements and begin moving to one of the new nests. Honeybees also act under time pressure when looking for a new nest site. A decision must be made within a few days. The bees elicit a quorum response long before a majority of bees has checked the site and the accuracy of the decision is still very high.

If we look at the examples of human swarm problem solving, they also highlight "decision speed." Both hackathons and Deliberative Polling require a weekend. Decisions in the UNU platform happens within seconds, and in disaster management, even lives depend on rapid decision-making.

The challenge is to enable a large number of individuals to produce new levels of insight under significant time compression. Swarm problem solving is in a hurry or it has a tight schedule to follow. This includes both tasks that allow direct interaction and other projects where contributions must be made separately from each other. The rapid problem solving is typically made possible because everyone adheres to prespecified problem-solving procedures. Here, two types of rapidity are highlighted, solving a problem as fast as possible or within a prespecified deadline.

Making a Decision as Fast as Possible

In some cases, a human swarm will want to make decisions as "fast as possible." When there is an emergency, there will be an immediate need for crowd data that can provide information about the problem. There is no final deadline, just a general sense of urgency. The crowd can be involved as both sensors, reporters, and micro-taskers. Social media is also a channel that continuously produces relevant information that can be utilized. In smart cities, mobile crowdsensing aim to solve problems by collecting sensor data from mobile phones and other geo-technological tools. Citizens can also actively report information through different types of online communication. Today, companies already use these data commercially, and there has been few legal regulations, but this will likely change in the future.

Short Deadlines

In other cases, the human swarm will operate within a prescheduled deadline, typically a short period. There is still a wide range of timescales, covering anything from seconds to months. In swarm platforms, the period can be as shorter than a minute. Hackathons or Deliberative Polling demands intense done during a weekend. However, it varies how tightly organized the work is. A hackathon is more loosely organized, while the Deliberative Polling follows a tightly organized procedure. The Delphi method may last much longer, like several months, since the problem solving covers several iterations. The limitations of a short problem-solving period is compensated by increasing the number of participants joining the project.

Moreover, innovation contests often cover only a few weeks or months. The deadlines can have a positive influence on the creative problem-solving process, as this statement from a top solver illustrates:

> *For me the solutions tend to come quicker nearer the deadline, like a lot of students writing a thesis who tend to get most of it done at the end. I have to confess some of that's true with me. When the deadline comes, it tends to spur creativity a lot. You now, you might think about it for a while and do a little research, but it seems like the biggest breakthroughs tend to come closest to the deadline.*

The solver shows how being in a hurry can boost creativity when closing in on the deadline. This urgency is at the center of what characterizes swarm problem solving.

4.7.4 *Individual Learning*

It is not apparent that human swarm problem solving always promotes individual learning. In the original wisdom of crowd approach (2005), the ideal is to reduce negative social influence such as herding effects. The risk of individual learning is that it can reduce diversity of opinion and promote herding instead of informed opinions. According to "the many wrongs principle" incorrect guesses at an individual level can make the crowd wiser. This suggests a possible conflict between collective performance and individual learning.

This dilemma is present in several citizen science projects (e.g., the Galaxy Zoo project). When using averaging, it is usually important to gather independent contributions, which ensure the quality of the work. The single individual will then have no information about other contributions. Social interaction is avoided because it can introduce herding effects, groupthink, or systematic bias.

Another example is decision-making process in the UNU platform. It is performed so rapidly to reduce potential negative effects of long-term social influence. As biologists have noted, even naive individuals can improve collective navigation, just by contributing error. Although some individuals are not particularly accurate, they introduce valuable "noise" that makes the crowd wise relative to the individual. Another advantage with minimizing individual learning is that the task can be done faster and make the problem-solving process more time efficient.

Nevertheless, there is much more attention today around the possible positive effects of individual learning in human swarm problem solving. While wisdom of crowd literature originally highlighted the importance of making independent separate contributions, dependent contributions are today considered to be equally important. Even animal groups appear to be able to both share information and simultaneously make individually independent assessments.

In human swarm problem solving, individual learning within a group can also improve crowd performance if one avoids herding or conformity pressure (Shore et al., 2020). However, there is a tension between the need for independent opinions and the need for some degree of information transfer. Learning and herding are two different types of social influence that can be present at the same time (Shore et al., 2020). Collusion, alignment, and peer group pressure are constant threats when social interaction is possible. Groupthink ("Social proof") is our tendency to assume that if lots of people believe something, there must be a good reason why. One important factor is to get people to pay much less attention to what everyone else is saying.

Still, there is a need for learning and deliberation between individuals. The challenge is to find the balance between independent thinkers who create their own opinions and do not simply follow the views of others and those who are able to build on other ideas. This can be described as an *independence vs. learning tradeoff*, which open for different participatory designs. Both Deliberative Polling and the Delphi method expect individual learning to happen during the collective problem-solving process. However, the processes differ because Deliberative Polling promotes direct interaction, while the Delphi method builds on indirect interaction. Participants only get access to aggregated group information. The emphasis is on knowledge sharing and ensuring informational diversity, but without the opportunity of having any discussions. This is very different in Deliberative Polling because participants are encouraged to discuss ideas, but still primarily in separate subgroups.

Individual learning can happen in several different ways in the human swarm, both through observational learning and conversational learning. In *observational learning*, individuals learn by observing what others are doing and what they are discussing. One relevant example is hackathons in an offline setting and the traces of discussions in an IdeaRally in the online setting (Chapter 2). Here, the transparency of the environment is key, as is how it supports knowledge sharing. In centralized networks, the core node will spread information to everyone in the crowd without creating the same conformity pressure (Shore et al., 2020). The Delphi method is one example of how aggregated group results are shared with everyone. This is done anonymously through a facilitator. By not allowing direct interaction between participants, the degree of independent assessment is larger and the role of social influence is minimized. The goal is to maximize learning and minimize herding, like conformity pressure or uncritical copying of others' behavior.

Another example of observational learning is how disaster management platforms give everyone an updated overview of what is happening on the ground. By effectively aggregate all information on one site, individuals will more quickly learn about the situation and act more appropriately. In areas where such incidents occur often, like frequent occurrences of wildfires or flooding, it is essential that individuals learn how to take such systems in use in effective ways.

Furthermore, *conversational learning* is another important part of many human swarms. Both a hackathon and Deliberative Polling center on conversational learning between participants. The discussions can last for two days, and because participants are together most of the time, this allows for intense discussions. There is also experimentation, with discussion in similar large groups in an online setting, such as the previously mentioned IdeaRally (see Chapter 2).

Deliberative Polling can be regarded as a decentralized network, which divides several hundred participants into separate discussion groups comprising 15 persons. Individuals will engage in conversational learning with "near-neighbors" in these subgroups, most of the time separated from others. This may reduce potential negative herding effects.

Compared with the Delphi method, the learning potential is likely to be larger in Deliberative Polling because it is easier for participants to elaborate on each other's arguments. However, this also increases the risk of negative conformity effects. A facilitator is included to avoid such effects and ensure equal participation. Another aspect of this learning process is the briefing materials participants receive. They offer individual learning, but they may also unintentionally create negative herding effects. However, both Deliberative Polling and the Delphi method collect the final results anonymously to strengthen the independent voices in the process.

4.7.5 Summary of the Basic Characteristics in Human Swarm Problem Solving

In conclusion, the quality of human swarm problem solving depends on whether one is able to utilize sufficient diversity of perspectives. Most of

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the swarm designs aim to produce informational diversity by bringing in people with different backgrounds from different environments. As mentioned in the sections on averaging and decision thresholds methods, individuals may benefit from pooling information to overcome inaccurate estimates according to "the many wrongs principle." These contributions will be aggregated and not recombined or synthesized. The sections on heterogeneous social interaction and large gatherings show how cognitive diversity can be utilized in accordance with the diversity prediction theorem (Hong & Page, 2004). Likewise, the section on human environmental sensing shows how environmental information can be maximized according to "the many eyes principle." Large gatherings also stand out as one of the most interesting swarm mechanisms in an online setting (e.g., IdeaRally).

Honeybee nest siting is in many ways a prominent example that can provide inspiration for human swarm problem solving. When searching the surroundings for the ideal home, they utilize "the many eyes principle" by identifying all relevant options with an extraordinary precision. They then compare all contributions through the waggle dance and are almost always able to identify the best solution through a quorum response mechanism. They have perfected both the informational search process and knowledge sharing process afterwards so the whole process is completed within just a few days. (Seeley, 2010: 73–75, 224). We are still far from designing human swarm problem solving to be as successful as the honeybees, but by better understanding its basic mechanisms, one can hope that new technological inventions can make us better able to utilize this type of problem solving in both an offline and online setting.

Notes

1 Meerkats forage for insects. https://www.youtube.com/watch?v=cFC8irxuvcQ
2 Flash Expansion of Whirligig Beetles. https://www.youtube.com/watch?v=Civ1zL3nIzU
3 The Waggle Dance of the Honeybee. https://www.youtube.com/watch?v=bFDGPgXtK-U

CHAPTER 5

The Origins of Human Swarm Problem Solving

5.1 Background

In human evolution, it is likely that important transitions in group organization, both increases in group size and new types of cooperation between human groups, were motivated by attempts to solve problems more effectively. It is here suggested that it was the gradual evolution from small group cooperation to interaction in large groups that eventually made human swarm problem solving possible. But how did this process unfold in evolution? This is a hard question to answer, and this chapter will only briefly address the issue by highlighting a few of the historical milestones that are considered important antecedents.

If we look back in time, most researchers agree that group hunting of large animals is an important achievement in human history. This new practice made it possible to gain access to more food. Group hunting also resembles the basic characteristics of human swarm problem solving with its emphasis on rapid problem solving, specific interactional rules, and the involvement of all group members. Although group hunting required some degree of planning and higher-order cognition, it is plausible that the first type of group hunting resembles how other animal groups hunt together.

A second major milestone was the establishment of peaceful interaction between different human groups or communities. In evolution, this is a major achievement, as we know that our close relatives, the chimpanzees, do not trust strangers. It is likely that this first interaction with strangers across groups began through trade. Collective problem solving between groups made it possible to utilize informational diversity from nonkin and even strangers, and must have amplified human learning, knowledge sharing, and our opportunities to develop better solutions to problems.

The third major achievement was the establishment of the first democracy in ancient Athens. Several democratic institutions were invented, such as the Assembly of the People, the Council of 500, and the People's Court. These institutions recruited a large numbers of citizens to engage in rapid and effective swarm problem solving. New decision-making methods were taken in use, such as majority rule and ostracism. The institutions also brought strangers together from all over the Athenian territory, and transformed them into their new role as citizens. This chapter argues that this direct democracy was built around a multitude of swarm mechanisms that became formalized for the first time. It led to the creation of a unique society, which was extraordinary successful, both culturally and economically.

5.2 The Emergence of Group Hunting

Obviously, humans have gradually become more able to solve problems together in larger groups. On this evolutionary path, group hunting is an important achievement that not only resulted in effective hunting, but also made it possible to live together in larger groups. For hundreds of thousands of years, humans only hunted smaller creatures and gathered food. They ate the carrion left behind by other carnivores and used stone tools to crack open bones in order to get to the marrow. As human groups increased in size to dozens, so did the demand for food. Small game would not be enough, making it vital to learn to hunt large animals, like bison, horses, and mammoths. A large food supply would save the group a lot of time and energy, but hunting large animals alone is both more difficult and more dangerous. In contrast, group hunting is easier and more effective. The human bands who mastered this skill would have had an advantage in evolution, also because they improved their general abilities to collaborate with each other. Hunting of large game would have required a plan and a hunting strategy, indicating collective problem solving that requires some degree of higher order cognition. At some point in time, humans managed to develop more advanced hunting tools and moved to the top of the food chain and began to hunt its predators instead of being hunted (Harari, 2014; (Holler, 2017)).

Recent research suggest that planned group hunting may have occurred much earlier than previously thought. The findings from a site on the shore of the lake at Schöningen show evidence of planned group hunting of wild horses among hominins about 300,000 BP. Horses regularly return to known predictable water resources and lakeshores are often used to ambush prey drinking at the waterline (Conard et al., 2015; Voormolen, 2008). However, it is both difficult and dangerous to hunt horses on foot

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because they are strong and fast moving. Nor is it easy to kill a horse with spears. If the horse is wounded, it is still mobile and even more dangerous. The hominins probably used an ambushing and stalking approach. If the horses were surprised, it would have been possible to drive the animals into the wet soft lakeshore zone to reduce their mobility and minimize the risk of horse defense injuries. This would have made it much easier to kill the horses by throwing multiple spears or stabbing at close distance. Some researchers even claim that a dozen or more animals were killed at the same time, requiring highly coordinated attacks (Conard et al., 2015; Voormolen, 2008).

The hunting behavior clearly demonstrates a high degree of planning depth, in combination with the use of deadly weaponry. The spears and the throwing stick had to be made well in advance of the execution of the hunts. The preferred raw material for making hard and strong spears was slow-growing spruce that grew under dry or otherwise unfavorable conditions. To make these wooden hunting tools requires planning, since it takes several hours to make a spear and the spruce trees are not found in the near-lakeshore environment. These tools were not made on the spot because of an immediate need. It suggests that the hominins were able to communicate about contexts beyond the here and now. It is likely that their hunting behavior required some type of language skills, since they were able to communicate about context beyond the here and now, talking about the past and the future, and about the spatial relationships in the environment. The spears are curated gear that were perfected through experimentation, optimization, and possibly exchange of information within and between generations. The use of these wooden artifacts demonstrates a high degree of planning, shared goals, and coordinated collective action. It shows that both *Homo heidelbergensis* and Neanderthals showed much more than purportedly primitive behavior (Conard et al., 2015).

These hominins used a range of sophisticated artifacts, were at the top of the food chain, exhibited a high level of planning depth, and coordinated behavior in their successful hunting. There is evidence that they repeatedly executed well-coordinated and successful group activities that likely resulted in new types of division of labor. For example, after the animals were dispatched, hominins systematically butchered the horses. Since a single horse can weigh as much as 550 kg, the amount of food would far exceed the needs of an individual hominin. The butchering process also indicates that the food was shared between the members in a group (Conard et al., 2015).

The findings from Schöningen indicate that human language developed gradually over the course of human evolution. Unambiguous evidence for fully modern language with fully developed symbolic and syntactical communication appears not before around 50,000 years ago. Nor is there any reason to assume that this evolution was uniformly gradual (Conard et al., 2015). Obviously, the cognitive level of hominins around 300,000 BC was obviously limited. However, if we look at how animal groups hunt together, it is plausible that human group hunting emerged as a mix of environmental sensing and primitive levels of higher order cognition. Like other carnivores, the human hunters may have followed simple behavioral rules in combination with some level of gestural communication, perhaps also verbal communication. As mentioned in the previous chapter, chimpanzees can perform advanced group hunting behavior just by following a few simple interactional rules. It is likely that human group hunters also utilized similar behavioral rules when surrounding the prey. Gestural communication could have been used to support coordinated collective movements and the production of hunting tools in more effective ways (e.g., using spears). These hominins were able to adapt and refine their hunting techniques in the specific local environment along the lakeshore and utilize the power of working together in increasingly large groups.

Certain evidence of advanced planned group hunting of large game can first be identified much later in human history. At one site in North America, a Columbian Mammoth was killed 10,000 years ago with eight different spear tips, found lying near the skull, ribcage, and shoulder. It shows humans hunted together, probably by throwing many spears at the same time while keeping a safe distance to the animal. It is likely that a human group could exhaust the injured mammoth by following it across long distances (Haury, Antevs, & Lance, 1953). Two Russian sites, dated to around 21,000 BP and 13,500 BP, also show direct evidence for mammoth hunting. At one of the sites, the projectile was thrown from within five meters of the animal, so the mammoth was killed at close range. Because the size of African elephants and mammoths are similar, it is plausible that prehistoric hunters used the same hunting techniques as recent hunters who also kill elephants through group hunting (Germonpré, Sablin, Khlopachev, & Grigorieva, 2008). In addition, the butchering process would probably have required teamwork. Experimental studies in which individuals have butchered an elephant with prehistoric tools show that the processing of skinning, meat removal, and dismemberment took 8–35 persons 2–10 hours (Germonpré et al., 2008).

Most researchers agree that mass hunting among humans was not purely instinctive, as with the group hunting of carnivores, but it required higher order cognition (Nitecki & Nitecki, 1987: 3–6). When hunting large animals, it is more effective to be in larger groups and coordinate the attacks. In addition, it is an advantage to be able to communicate about different locations, map territories, and be able to use time and energy effectively when hunting. Here, linguistic skills are of help, but it appears to have evolved slowly over time (Holler, 2017). With time, human groups developed more advanced hunting weapons and hunting techniques that made it possible to throw projectiles with more precision and accuracy (Holler, 2017). About 40,000 BP there was a major advancement in human hunting with the invention of new weapons and hunting techniques. These techniques were adapted to big game hunting like a battue, a driveline, and a surround. We know this from artwork that illustrate hunting in European caves, and it is also likely that the development of group hunting contributed to the prehistoric overkill, in the extinction of large mammals, the mammoth, mastodon, saber-toothed cat, and glyptodonts (Nitecki & Nitecki, 1987: 3–6). It illustrates that a new and more advanced type of collective problem solving does not necessarily result in a uniformly positive development.

5.3 The Emergence of Premodern Trade

Another important question in collective problem solving is when and how humans began to cooperate with each other across groups. In human evolution, most Paleolithic hunter-gatherers lived in small camping communities where their movements were shaped by the seasons and the migratory patterns of the wild animals, birds, and fish. However, these communities or human bands were not isolated from each other, but appear to have been directly connected with each other through both trade networks and periodic large gatherings (Gosch & Stearns, 2007: 7–8).

From time to time, small groups of hunter-gathers would meet in large gatherings to renew friendships, to feast and dance, and to exchange information about animals and plants (e.g., like the powwows of Native Americans). Rituals and initiations were important, like the selection of marriage partners. Individuals or groups would also exchange various small objects (seashells, polished amber, carved wood or stone, etc.), which were both gift giving and trade. These exchanges are an important reason why one artistic style could spread across widely dispersed hunter-gatherer communities although the meetings only were occasional. The purpose of the large gatherings was not trade, but primarily to sustain social networks and symbolize the promise of mutual assistance (Gosch & Stearns, 2007: 8; Smith, 2009: 13–14).

Second, it is also likely that premodern trade was an important antecedent to collective problem solving "between groups." It was organized as trade networks or down-the-line exchange, with a relay network that indirectly linked communities. For example, modern humans living in a cave in Tanzania 100,000 years ago had tools made of obsidian which can only be found 200 miles away, far beyond the normal foraging area of about 50 miles. It indicates that exchange network may have existed very early in human history. Another possibility is that the earliest trade occurred when hunting bands accidentally bumped into each other. However, dealing with strangers would be dangerous, so most exchange would take place between groups who lived close by and were connected to each other (Smith, 2009: 13).

Extensive premodern trade also coincides with expansion of Sapiens between 30,000 and 70,000 years ago. Within a remarkably short period, Sapiens reached Europe and East Asia. A range of important artifacts was invented like boats, oil lamps, bows, arrows, and needles. The first art artifacts appear, and there is evidence of religion, which suggest that humans are developing a new self-awareness (Harari, 2014). The most valuable artifacts were typically symbolic artifacts. Small sculptures of mature females, called Venus figurines, have been found over a huge area stretching from Western Europe to Siberia (Figure 5.1). Although, the tiny sculptures differ in many ways, they have enough similar features to suggest the spread of a common artistic style. It is highly unlikely that a group of travelers brought these figurines around; the wide distribution was probably made possible because of trade in a down-the-line system (Gosch & Stearns, 2007: 7–8).

At sites in the middle of Europe, archaeologists have also found seashells from the Mediterranean and Atlantic coast at Sapiens sites that are 30,000 years old. These shells were probably part of long-distance trade between different Sapiens bands (Harari, 2014). The Greek historian Herodotus tells an interesting story about something that was probably an amber artifact. A people called the Hyperboreans, who lived on the edge of the world, originally made this product. In honor of a long-established tradition, this group periodically, sent "sacred objects tied up inside a bundle of wheat straw" to their neighbors with orders to pass them on from tribe to tribe until they reached the Adriatic Sea. From there on, they were sent to Greece and ended up at the island sanctuary of Delos. It is interesting how

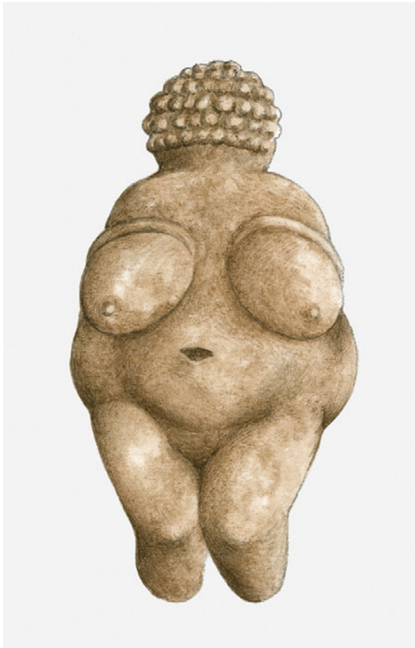

Figure 5.1 *The Venus of Willendorf.* This is an 11-centimetre Venus figurine estimated to have been made around 25,000 years ago. It was found in Austria and is carved from a limestone that is not local to the area, photo Dorling Kindersley/Getty Images ©

it was possible to transport such objects across such a long distance, with it being trustfully passed on through an unknown number of different people and places. The advantage with the down-the-line system was also that it did not require that anyone moved beyond their territory, which could be dangerous (Smith, 2009: 15, 22).

In general, premodern trade did not involve goods that were necessary for everyday living, nor did it mean that one band was dependent on receiving goods from other bands. Items could have some practical uses, like the exchange of weapons. It was mainly about prestige items, artifacts of ritual or social value, like figurines or ocher for skin application. It could also include ornaments for personal decoration, like beads, necklaces, bracelets, and pendants made of bone, antler, animal teeth, shell, and stones (Smith, 2009: 14). The distance an object traveled was usually related to its value. Even a mundane object like certain kinds of flint or seashells could become valuable if they were transported hundreds of miles into territories where the objects were unknown. There, it would be perceived as exotic, and make the owner special (Smith, 2009: 14). Although the trade was not directly useful, it is likely that these groups at the same time also trade information, thus creating a denser and wider knowledge network.

Although these human groups did not necessarily move a lot outside their territory, premodern trade was still dependent on trusting people from other bands. Harari claims it is our ability to cooperate with strangers that has made us so successful in evolution, "Sapiens can cooperate in extremely flexible ways with countless numbers of strangers. That's why Sapiens rule the world, whereas ants eat our leftovers and chimps are locked up in zoos and research laboratories" (Harari, 2014: 28). Perhaps the most important difference between humans and our nearest relatives, the chimpanzees, is that chimpanzees do not trust strangers or others outside their group.

It might not appear to be a big issue to collaborate with strangers, but early in human history this would have been very dangerous (Harari, 2014: 29).

It is likely that trade was important in this human transition. It is a uniquely human activity that requires cooperation with strangers outside your own band, and it cannot exist without trust. Trust between strangers also became stronger when we began sharing some kind of common identity or shared belief in being similar to each other (Harari, 2014: 38–40, 52).

The human thrill of working with strangers is even evident in CI projects today. A solver in a virtual innovation team explain why he enjoys working with people from all over the world: "One of the things I really like about IdeaConnection is that you can meet people that you would have never met otherwise. So I've been on teams with people from Sweden, Switzerland, Mexico, USA, Canada, South Africa, Egypt and the UK and have made some enduring friendships, and some of these have led to other potential projects." The excitement is about meeting people that one would not have met otherwise. Here, the unknown other is someone who potentially can become a friend. What is interesting is also how fast people get to know each other through the intense work, as another top solver states: "I'm a people person so I like working with strangers. Out of the 16 people I have worked with, I'm still friendly with 15 of them. They don't remain as strangers after one week or so. That's a good part of working on the challenges." It is not unlikely that premodern trade had the same effect of establishing social networks between human bands who were neighbors to each other. With time, these systems enabled humans to share ideas and solve collective problems together in a much more effective way than previously.

5.4 Human Swarm Problem Solving in Ancient Athens

From 800 to 300 BC, Greece experienced a long and prosperous period, and the population became richer and more urbanized. In the period 508–322 BC, Athens is regarded as the most successful polis in Greece in terms of wealth, power, stability, and cultural influence. The outstanding achievements in this society were primarily driven by the establishment of the first large-scale democratic government in recorded human history. Reformed by Cleisthenes, this direct democracy let the citizens themselves govern society. Ancient Athens was a stable, prosperous democracy for roughly 200 years (Carugati, Hadfield, & Weingast, 2015). This section argues that the new democratic institutions built on human swarm problem solving in their adoption of rapid decision-making in large groups. Four specific swarm mechanisms will be analyzed in more detail:

1. Maximizing information about the Athenian territory
2. Heterogeneous social interaction through rotation and lot
3. Decision threshold methods in the Assembly and the People's Court
4. Large gatherings in Athens

5.4.1 Maximizing Information about the Athenian Territory

An interesting characteristic with the Athenian democracy in the late sixth century BC is how it maximized information about the whole territory. Cleisthenes developed a new political system where adult males were given extensive rights to participate in the central institutions of polis government in Athens. He also reorganized the residents of the Athenian territory by intermixing the four traditional Ionian tribes and instead creating ten new artificial tribes. Each tribe was named after an Athenian mythical hero and would become a key marker of new Athenian identity (Ober, 2008).

The most important innovation in the new tribe system was to ensure that people from different geographic and economic zones would be a part of every tribe. Each tribe was divided into ten parts, with approximately one third being from the coastal, inland, and urbanized regions of Athenian territory. The new part of the tribe from the three different geographical sections were allocated by lot and each tribe was further divided into geographically based communities called demes, numbering a total of 139 in the fourth century (Tridimas, 2011). For example, the village of Prasiai became one of the 11 demes in the tribe of Pandionis, together with other towns, villages, or urban neighborhoods. Prasiai and three other nearby villages were the coastal demes of the tribe. In addition, there were four inland demes to the west, and three city demes – neighborhoods close to the city of Athens. As a result, all the villages from the same tribe would not be located in the same area and share a common border. The newly created tribes mixed a wide range of people in the Athenian population (Ober, 2008).

The new tribes would loosen up the existing strong-tie networks in villages and the traditional four tribes, and form a bridge between a stable local village identity ("resident of Prasiai") and the desired citizen identity ("participatory citizen of Athens"). The notion of citizenship was an important conceptual development, which implied that all locally born free men within a city-state had equal political rights and enjoyed legal protections, combined with obligations to serve the community (Carugati et al., 2015; Tridimas, 2011). Athenians from all over the territory would rule together, and participate together in psychologically powerful activities like fighting, sacrificing, eating, and dancing. Together, this new system strengthened the collective identity of the polis. This also made it easier to recruit soldiers to a national army that could effectively stand up against Sparta. In this time period, the Athenians were worried that the Spartans could destroy them (Ober, 2008). The members of a tribe would consist of all citizens from all over Attica and this new system helped forge a united army which had the immediate effect of defeating Sparta in 506 (Tridimas, 2011).

If we look closer at the organizational design of the political system, the new tribe structure stands out as a key success factor. Good systems rely on many local bridges as the new tribal system aimed to create. Before Cleisthenes, the residents of Prasiai would have had relatively few bridging ties outside their local community, few connections with other towns or neighborhoods in Attica. This would limit the overall Athenian capacity for effective joint action like military operations. The tribe system established ties between groups that did not know each other from before, while retaining a sense of community at both a small and large level. In order to promote knowledge sharing, the basic requirement is to stimulate communication between people who in the beginning are strangers to one another and do not necessarily trust each other. The incentives were not necessarily only material, but equally important in establishing new relationships was the perception of being part of a new common culture and collective identity. In the tribe, groups came to know each other who would never otherwise have had contact. People with different backgrounds and knowledge would more frequently work together with people. The geographical representation in each tribe aimed to maximize diverse information about the Athenian territory, by including groups from coastal, inland, and urbanized parts (Ober, 2008).

In addition, it was necessary to create a meeting place for the new tribes if they were to get to know each other and share their knowledge with each other. To solve this challenge, Cleisthenes established the Council of 500 ("boule") in 507 BC, a new and remarkable institution of Athenian democracy. The Council prepared the agenda for the Assembly and had responsibility for the day-to-day administration of state affairs, supervising the state's finances, the fleet, cavalry, sacred matters like collecting tribute, construction work and care for invalids and orphans. They also monitored various projects that had been approved by the Assembly. The Council also met foreign delegations and reviewed the performance of the magistrates who worked in the government. This was done to avoid corruption and misuse of power (Ober, 2008; Wallace, 2013).

While all important matters of state policy, including finance and matters of diplomacy, war, and peace were decided in the Assembly of Athenian citizens, the Council had the important agenda-setting function by deciding what matters should be discussed in the Assembly. It was private citizens who brought issues for discussion to the Council. The Council would then consider if they wanted to bring the issue to the Assembly, for ratification of a specific decree. The Assembly, which any citizen could attend, was often chaotic because thousands of citizens were present. In addition, they had only 40 meetings per year, while the Council met daily and could therefore act more expeditiously than the Assembly (Ober, 2008; Tridimas, 2011).

Furthermore, the 500 persons in the Council comprised ten 50-man delegations from each of the newly created tribes. The members of each tribal delegation were selected by the demes and served in Athens for a one-year period. The number of councilors from each deme varied, depending on population in the deme. For example, the deme Prasiai annually sent three councilors as part of the tribe Pandionis' 50-man delegation to Athens. In contrast, one large inland deme sent 11 councilors, while a small deme only sent one person (Ober, 2008). It illustrates that the system built on demographic representation.

The Council met every day except certain holidays, eventually in a purpose-built architectural complex in Athens. In a normal year of 354 days, the Council met on about 275 of them (Hansen, 1991: 251). Because of the intensity of the work, the tribal teams would get to know each other well during the one-year period they served. All the duties and collective work that were required would have stimulated rapid social tie formation, and made it easier to form new friendships with strangers. Every tribe would also work together with the other 450 councilors from the nine other tribes. Over the course of the year, members in the different tribes would become acquainted and likely establish weak ties in a new and extended social network. By establishing contact with men from other demes, one could hope to advance the family's position by seeking good marriages for his sons and daughters (Ober, 2008).

Nearly all members of the Council were ordinary citizens with limited administrative experience. A new group of 500 would join into service every year. Although councilors could serve twice in their lifetime, though not in successive years, it is likely that this did not happen often. It is likely that approximately 400 members were new to the Council (Hansen, 1991: 249). Consequently, no subgroup of old councilors could control the agenda in the Council, and all new councilors began on equal terms. They would quickly have to learn and acquire appropriate skills. Since all councilors were new in the job, this facilitated rapid knowledge sharing because it was important to get the government "running" as fast as possible. There was also a formal archival system, and many of the work routines for accomplishing the Council's work were codified. This must have been an important part of the knowledge sharing (see also Section 7.2). However, the regular turnover of councilors ensured constant innovation in the system as new people would bring in new perspectives every year (Ober, 2008).

Because the tribal teams served together in Athens for a whole year, it is likely that a lot of knowledge sharing between individuals would happen by itself. A councilor from a coastal deme might learn new pottery skills from someone in the city or how to improve olive farming from a councilor from the inland. The cost of communication is very low because all the councilors lived and worked together every day. The egalitarian structure of the Council would also have made it easy to bring forward relevant information to the right place, at the right time as a part of the collective problem-solving process (Ober, 2008).

The weak social ties connected individuals across regions, kinship groups, occupational groups, and social classes across the Athenian territory. Knowledge sharing was also promoted through state sponsored "knowledge aggregation contests" with public honors to the winners.

The winners had to be capable of persuading others to do likewise. By creating an "economy of esteem," knowledge sharing was considered valuable throughout the community (Ober, 2008). For example, the work of the councilors was evaluated according to how well they had served the public purposes of the polis, and it could be rewarded at the end of the one-year period. The evaluation also reduced corruption or the risk of the Council developing into a self-serving identity (Ober, 2008).

Through its day-to-day operations, the Council sought to identify and make effective use of experts in many different knowledge domains. The councilors would also work in a range of different collegial boards that oversaw many of the administrative duties, typically composed of ten citizens. These teams were dedicated towards specific public tasks in the government like leading armies or keeping oversight of public festivals. In this way, the councilors would develop a certain expertise while still staying together with all the other councilors and sharing this knowledge (see more information about collegial boards in Section 9.3.2) (Ober, 2008).

The Council also played an important role because of its deliberative functions in the system. They would know who had a certain expertise and whom to contact to get relevant information. Each councilor would also have a network of contacts in the local home area. The Council would therefore easily have access to a significant amount of the total knowledge available in the entire Athenian population. In this new system, the Athenian population developed an increased capacity to discriminate among sources of expertise and information, and to cross-appropriate relevant knowledge from different domains (Ober, 2008).

5.4.2 Heterogeneous Social Interaction through Rotation and Randomization

In the last chapter, we looked at how heterogeneous social interaction is an important mechanism in human swarm problem solving. This section will investigate how heterogeneous social interaction first became part of an intentional institutional design in an attempt to solve different societal problems.

Several of the most important democratic institutions in ancient Athens used both random sampling and rotation to ensure that many citizens were allowed to participate. Every year this included 6,000 members to the Court, 500 members to the Council, and another 700 magistrates who served as public officers. Even though only the citizens who volunteered were part of the lottery, this lottocracy was an essential part of the democracy. When selecting candidates to the Council, there were assembly meeting in all 139 demes in the Athenian territory. For example, a deme entitled to four seats had to present at least eight persons. Some demes used lot in the selection of candidates, while others would struggle to get enough candidates. These candidates would then be part of a lottery in Athens that decided who would be the councilor and who would be the stand-in (Hansen, 1991: 248; López-Rabatel, 2019).

Another interesting characteristic is the different rotation methods that were used to ensure shared responsibility in the Council. Each 50-man tribal team would take a leading role in directing the Council's business for a tenth of the year (36–37 days). In the Council, there was a monthly lottery regarding which tribe was to exercise the presidency of the Council. Every day, a new member from the tribe was also chosen by lot to serve as the chief executive officer or president of Athens. Every day at sunset, a new person would be appointed chairman who had not yet held the post. The chairman counted as the head of the state of Athens, holding the seal of Athens and the keys of the treasuries. He received foreign messengers and envoys and presided over meetings of the Council and the Assembly. As with most other positions, it was only possible to hold it once in a lifetime. A majority of the members in the Council would therefore have held the most important formal position in Athens during the year. The rotation principles aimed to reduce the domination of factions. Another positive effect was that a very large number of Athenians served in the government, and became more politically competent (Hansen, 1991: 250; López-Rabatel, 2019; Ober, 2008; Wallace, 2013).

Furthermore, any citizen could also become member of the "People's Court," including the poorer members of society. The main purpose was to optimize a good rotation among the jurors and to stop any attempts to bribe jurors. The jurors were selected by lot at the beginning of the year and become members of the panel of 6,000 citizens. Those selected then swore the Heliastic Oath, and could choose when they wanted to turn up for the daily court meetings. However, they had to be picked by lot on a given day to serve for that day. On a normal court day, the Athenians had to use 2,000–3,000 men from the jury list to pick up by lot 1,500–2,000 jurors (Hansen, 1991: 181–189). The law courts selected thousands of citizens every court day through complex randomized procedures that guaranteed that jury panels were broadly representative of the Athenian population as a whole (Carugati et al., 2015).

In the fifth century, the potential jurors formed a queue in the morning in front of the courtrooms and were let in according to the order of their arrival until the required number of jurors was reached. From the end of the fourth century, the jurors were selected by lot and also allocated to the different courts by lot. The courts were all placed in the corner of the Agora behind an enclosure, with one entrance per tribe. Court proceeding began at dawn with the selection by lot of the day's jurors from those of the eligible 6,000 who had met. In front of each of the ten entrances, there were ten chests. People met at their tribe entrance and put their jury plaques in the specific chest that displayed the same letter that corresponded to the one they had on the plaque (Hansen, 1991: 183, 197–198).

When all potential jurors from one tribe had delivered their plaques, one person would be selected randomly from the ten chests to help organize the lottery with the help of a kleroterion (Figure 5.2). The Athenians invented this lottery machine to execute the lotteries in an effective and fair way. The machines were designed to guarantee equality between all participants in the lottery, avoid fraud and allow a faster and more complex way of drawing of lots. The kleroterion marks a decisive turning point in the evolution of political tools intended to serve the democratic ideal. It made the drawing of lots much more effective in the fifth and fourth centuries BC. Lotteries became more frequent, and included a larger group of citizens. For instance, in the People's Court, it was necessary to draw lots for thousands of jurors approximately 200 days a year (Hansen, 1991: 198; López-Rabatel, 2019).[1]

These lottery machines were made of marble, were almost two meters, and would normally have five columns of slots corresponding to the size of a jury plaque. The lottery organizers picked identification plaques from the chest and inserted them into the kleroterion. One had to fill the columns with the section letter that appeared on the citizens' identification plaques (pinaikon) and identified the tribe. The kleroterion also had a narrow vertical tube, where they put a specific number of black and white balls that corresponded to how many jurors they needed. The balls were then removed from the bottom of the tube, one at a time. When the ball was white, the row of the five plaques were accepted as jurors; if they were black, they were rejected. Regardless of the size of the group that was to be selected, the number of columns of the machine would match the number of tribes. Two lottery machines were used to include representation from all the ten different tribes. The machine established a uniform procedure that ensured a fair lottery (Hansen, 1991: 198; López-Rabatel, 2019).

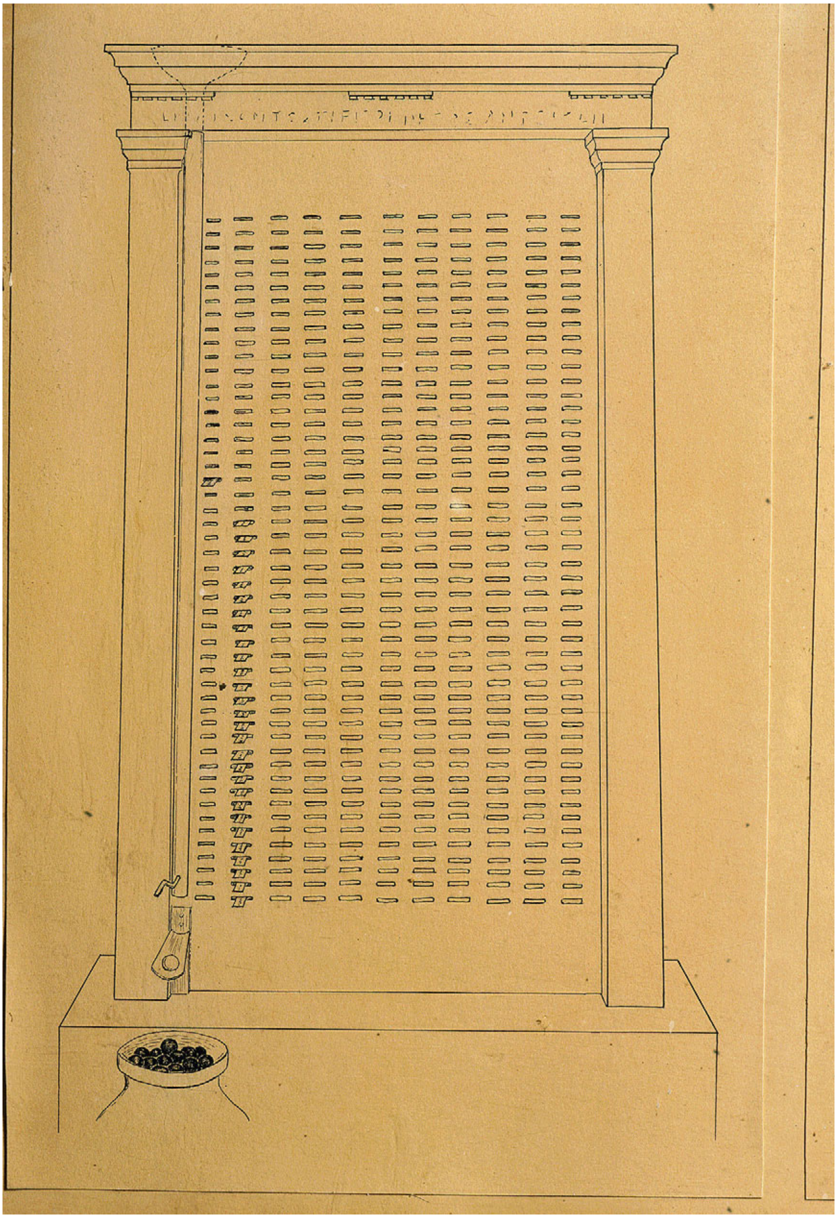

Figure 5.2 The kleroterion, the Greek lottery machine. These machines were primarily used to select jurors in Athens. Each court had machines placed in front of the entrance. The model of this kleroterion has 11 columns and was probably not used in the courts, but in the Council. There were 12 tribes in the third century BC and the kleroterion could then be used to select committee members representing all tribes except the one holding the presidency, photo Gianni Dagli Orti/REX/Shutterstock editorial/NTB ©

After the selection of jurors, another selection by lot began that distributed them between courts. It varied whether the day was devoted to smaller private suits with 201 jurors or larger ones with 401, or to public prosecutions with 501 or more. The most important political cases could include panels of 1,001, 1,501, 2,001, and 2,501. Because the size of the jury was designed to increase with the seriousness of the case, this suggests that the Athenians had some awareness of a wisdom of the crowd effect. By increasing the size of the jury, it was assumed that this also increased the likelihood of reaching an accurate and fair decision (Hansen, 1991: 187–188, 199).

Since the distribution of jurors between the courts was done by lot, it is likely that all courts were of the same size on a specific day, for example 201 or 501 individuals. On an ordinary day, there would be activities in at least three courts, and probably four or more. During the day, it would be possible to arrange at least three public prosecutions or at least 12 private suits. The whole lottery process might have lasted an hour involving more than 2,000 citizens, approximately 200 days a year (Hansen, 1991: 187–188, 199).

The drawing of lots was an important part of the institutionalized practices in Athens. The machine could involve the entire citizen population through rigorously defined procedures. It seems to have taken a century after Cleisthenes reforms to invent a "democratic machine." Exposed to the sight of all, the kleroterion also guaranteed transparency and a fair procedure, with the lottery becoming part of the rituals of public life. It became a powerful symbol of the new political logic. It gave every citizen the same chance of being selected, and it made bribery very difficult. No one knew in advance who would be in the juries, nor what case they would judge. The voting equipment also underwent a gradual transformation towards standardized voting tokens with less emphasis on religious symbols. In the classical period, it appears that religious symbolism was not as dominant in the procedure of lottery (López-Rabatel, 2019) (Hansen, 1991: 199).

Furthermore, most of the magistrates or public officials were selected by lot. They were appointed annually to different posts in public office, working on religious, judicial, or financial matters, as army and naval commanders or inspectors (of markets, building, roads, water, and country districts or in steering committees for the Assembly). Their power was limited because they could only serve one period in a specific area, except for the generals, who could be reelected. Still, a citizen was allowed to hold a different position at a later point of time. This system created frequent rotation and a large proportion of the citizens would therefore hold office eventually. The various magistrates were amateurs and there were very few professional administrators (Hansen, 1991: 236, 243; Tridimas, 2011).

If we look closer at the lottocratic selection of magistrates, several advantages are apparent. First, the citizens have equal chance to serve in public office independent of the wealth, or ability to finance an election campaign. Because a large pool of candidates is randomly selected for a limited period, this resulted in a significant rotation in office, which increases the likelihood of getting the position. This creates a system that is perceived as fair. The frequent rotations ensures that every citizen will alternate between being governed and governing, which further reduces factionalism. Second, because the number of appointees is "large," the process of randomized selection will ensure the magistrates reflect proportionately the preferences of all citizens in the population. When the number of officials appointed in a board of magistrates is sufficiently large, the law of large numbers applies. Third, compared with elections, the lottocratic system is relatively easy to administer and produces outcomes more quickly. It reduces the economic costs of making collective decisions. Fourth, the lottocratic model prevents the development of a professional political class or an elite group that can gain too much power. There will be fewer interest groups which influence the system and less corruption. The benefits of holding office is spread widely across the citizenry and promotes equal opportunities for all citizens to occupy office. It also decreases the power of the office holder and the attractiveness of office; reducing conflicts among individuals over power and possibly discouraging corruption in seeking office. The system is perceived as fair since it provides citizens with equal opportunities to assume public office.

Fifth, the frequent rotation of citizens in various public posts as magistrates, councilors, or jurors must have significantly increased citizens' knowledge about the Athenian society. Knowledge was shared through participation between most of the citizens in various weak-tie networks. Although jurors could not discuss issues during the case, there must have been many discussions afterwards (Tridimas, 2011). Likewise, the councilors who worked together for a year would most certainly learn a lot about the polis and gain a deeper understanding of the democratic system and the larger governmental system. Gradually, a very large number of citizens in the entire Athenian territory would have acquired political expertise. Athenian performance also improved because more citizens gained political expertise and became part of the self-government system. This type of participatory democracy also creates a transparent governmental structure and was designed to strengthen support for the Athenian polis. The democratic institutions were refined and modified over time, but some of its original parts from the late sixth and early fifth centuries proved remarkably durable (Ober, 2008).

However, several of the democratic institutions had age restrictions. The Assembly was open for all Athenian males above 20 years, but all other institutions such as the People's Court, the public office (magistrates), and the Council required participants to be at least 30 years old. The system favored certain age groups. Since a juror in the People's Court had to be at least 30 years old, it limited the eligible candidates from thirty to twenty thousand citizens. In the Council of 500, the average age of first-time members was about 40, so citizens did not become councilors when they had just turned 30. The group over 40 years of age represented only 2 percent of all citizens. Consequently, about two thirds of all Athenian citizens over 40 would have been a councilor. Since 6,000 jurors were drawn every year, the numbers suggest that the average citizen above 30 would be juror every third year. The eldest and most experienced were considered better qualified in doing this work, indicating the presence of organized group differentiation. In addition, adults in their 20s were needed for many other types of work in the society (Hansen, 1991: 181, 249).

Moreover, one should be aware that there are potential disadvantages with rotation and random sampling. It is not possible to select the persons who are considered to be the most qualified to do work. If individuals know that they will be doing the work only for a limited time, such as a year, this might reduce their motivation. Since the model is based on volunteering, the recruitment may still not be good enough. The lotto-cratic appointment of public officials also requires that all citizens can learn the skills to do a sufficiently good job in a short time. The success of the system provides evidence that amateur officials were able to perform both simple and complicated duties. However, officers responsible for defense were appointed by election in Athens, which shows that some posts required expertise (Tridimas, 2011).

5.4.3 Decision Threshold Methods in the Assembly and the People's Court

In the previous chapter, both quorum responses and majority decisions were identified as essential decision threshold methods in human swarm problem solving. In this section, I examine how these methods were first taken in use in societal institutions. If we look back to ancient Athens, both the Assembly and the People's Court were organized around majority rule and also a few quorum rules. Simple majority rule became formalized as the preferred decision-making method in two of the core institutions in society. For the first time in human history, it became possible to aggregate opinions in mass audiences in a very effective way – 6,000 citizens in the Assembly and 200–500 jurors in the courts. Both institutions made essential societal decisions under significant time constraints (Ober, 2008). The new voting methods symbolized the beginning of democracy, a radically different society, built upon a new type of individualism that ensured individual rights and equality of the votes (Pitsoulis, 2011).

If we want to trace the first voting practices, we have to move even further back in time to the Spartan popular assembly around 750 BC. In making decisions, the supporters of conflicting proposals organized a "shouting contest." A couple of persons were locked up in a room nearby so they could not see nor be seen by the "shouters," but only hear the sound level of the shouting in the assembly. This impartial group then decided which candidate had received the loudest acclamations and could become a senator. We know less about the origins of majority rule in Athens, but it probably began with formal voting at the end of the seventh century. However, it was the democratic reforms by Cleisthenes in the fourth century that formalized majority rule as an essential decision-making method in the democratic Athenian constitution (Pitsoulis, 2011).

It is likely that military practices led the Greeks to begin using majority rule. Because new weapons were invented, like the double-handled shield, battles were increasingly won through group formations. The hoplites emerged as a new group of free landowning citizen-soldiers in the sixth or seventh century. They became powerful because they could now defeat the aristocratic horsemen with their superior military strategy. The group of soldiers would move together in a phalanx, a rectangular mass military formation, and they would battle by pushing against each other until one broke (Figure 5.3).

Numerical superiority was decisive in these battles. There were numerous civil wars between hoplites in Greece, and it is from one of these that Xenophon reports that the battling parties found out that it was better idea to just count the number of soldiers instead of fighting, and then give the victory to the group with the most soldiers who would anyway win. Frequent warfare became very costly, and majority rule in the battlefield was a conflict resolution mechanism that would be beneficiary for both parties. The hoplites were also "middling men" who wanted more influence in the city states, and one way of achieving this was through majority rule. In the

Figure 5.3 The Chigi vase from seventh century BC showing hoplites going to battle, photo Francesco Bino, image courtesy of The National Etruscan Museum ©

Solonian Athens in the sixth century BC, only the hoplites had the right to vote and the privilege of being eligible for public office (Pitsoulis, 2011).

Voting in the Assembly

If we move a century forward to the Assembly in Athens during Chleistenes, we know more about the voting system. Citizens normally voted by show of hands in contrast to the People's Court who voted by ballot. The "ayes" were first called to raise their hands and then the "no's," with abstention also being an option. It is most likely that there was no exact counting of hands, a voting practice that is still used today in the Landsgemeinden in Switzerland. Because every vote counted equally, it is easy to get a visual estimate of the majority by just observing how many hands are raised. Since exact counting was unnecessary, this was an extremely time-efficient voting method. It was the nine chairmen of the assembly (proedroi) who estimated the majority, with the vote being repeated if they were in doubt. Therefore, the Assembly could make many decisions in just half a day. Six thousand citizens would normally be present at an Assembly meeting, which was the maximum number the meeting space, the Pnyx, could contain when it was full. This made voting easier when a quroum rule of 6,000 was required to vote, because one did not have to count the individuals who were present. Pay was also introduced to motivate attendance, being much more lucrative than in the courts. It was more difficult to get one fifth of the citizen population to turn up regularly compared with the courts, which required less attendance (Hansen, 1991).

Figure 5.4 Ostraka, shards of pottery used as a voting ballot. The name of Themistocles, son of Neocles, are written on the shards of pottery. He was banned from Athens through ostracism in 470 BC, Agora Museum, Athens, Greece, photo Akg-images/NTB ©

Furthermore, Cleisthenes invented ostracism, a unique voting method that aimed to pinpoint the person who posed the largest threat towards the society. The individual who "won" this vote, usually a political figure, was banned from Athens for ten years. However, this was not an ordinary penalty, because the person did not lose status or property, and could access his fortune from abroad. Once a year, the Assembly voted by a show of hands whether they wished to hold an ostracism. If the majority answered yes, a special sort of "election" was to be held in the Agora two months later. Each citizen was expected to make up his mind, and there was no publicly available information. In the final vote, any citizen wrote the name of a person who they thought should be banished on a pottery sherd (ostrakon) (Figure 5.4). A quorum rule was used in the voting. If there were more than 6,000 votes, the person with the highest number, who received a plurality of votes, was exiled (Hansen, 1991; Ober, 2008; Tridimas, 2011).

The characteristics in ostracism are exceptional. Although a person was exiled, there was no legal trial because no charges were filed. There were no public speeches of prosecution or defense from the expelled person in the Assembly. The logic in the procedure was the opposite of a trial; citizens were first asked whether they wanted someone to be guilty and they would then have to select this person afterwards. The invitation to ostracism was performed every year and did not require any initiative. This voting method can be interpreted as a type of prediction vote on which person is most likely to cause the greatest harm to the city in the near future. By aggregating the opinions from all citizens, one can prevent this from happening. However, one could only expel one person, but others who had been close to being expelled might also have felt a pressure to improve their behavior. In the two months before the vote, ordinary citizens must have felt some degree of power over the most privileged groups in society. While we don't know if ostracism had an overall positive effect, it was used 15 times during the fifth century and quite frequently in Athens' most successful period (480s–440s BC) (Hansen, 1991; Ober, 2008; Tridimas, 2011).

Voting in the People's Court

If we look to the voting method in the People's Court in Athens, it was built on simple majority rule, but still it was quite different from the assembly. The group of voters was much smaller than in the Assembly, although it was still very large compared with modern standards.

Jurors would never be below 201 jurors, and groups of 401 or 501 jurors were most common. However, in a few very important public cases, several thousand jurors were invited. The procedure was organized in such a way that the jurors first listened to speeches from both parties, the prosecutor and the defender. Then there was a vote by secret ballot, not by hand like in the Assembly. Jurors were not allowed to deliberate on the case before the casting of the votes. The jurors were given two different bronze voting-disks, one that supported the defendant and the plaintiff or prosecutor. The valid votes were then cast into a bronze urn, while the others were put in an urn of wood. To avoid cheating and ensure secrecy, the urns were covered in such a way that they only allowed one vote at a time. The verdict was made in favor of one of the two litigants by simple majority rule, and the decision was final. There was usually no risk for a private prosecutor if he lost his case, but in certain cases, he would have to pay a fine of one sixth of the sum at issue. If the prosecutor in a public case received less than a fifth of the jury's votes, he received a fine of 1,000 drachmas and lost some of his citizen rights. These rules were designed to reduce the frequency of political prosecutions, which potentially could "overheat" the court system (Carugati et al., 2015; Hansen, 1991: 192, 199, 202, 218).

This second round of deciding the penalty followed the same anonymous voting procedures. In most cases, the two involved parties proposed one penalty each. After the first vote was finished, both parties held a new short speech where they argued for the proposed penalty. The jurors were required to select one of these two options, and they could not propose their own penalty. This made the penalty decision very time efficient. If a party, also the defender, wanted to win a majority vote, he would have to propose a reasonable penalty that could stand a chance of winning the vote (Hansen, 1991: 202). In the legendary trial against Socrates, scholars have claimed that he invited his own death by first joking and arguing he should be rewarded and not punished. Eventually, he proposed a very small fine ("Socrates was guilty as charged," 2009). The jury found Socrates guilty by a vote of 280–220, which suggests that he probably would have avoided the death penalty if he had not joked and proposed a higher fine (Linder, 2002).

The most common explanation of why the jurors were not allowed to discuss the cases with each other, was to avoid corruption. Since the courts were set on the same day and decisions were made the same day, it was very difficult to bribe the jurors. If one examines the voting method in a swarm perspective, it is strikingly similar to a traditional wisdom of crowd approach (Surowiecki, 2005). Quality decisions were ensured through large group size, representative jury panels, majority voting with binary options, and independent judgments. Independent judgment was highlighted in several different ways. The jurors had sworn the Heliastic oath, they made secret votes, and were not allowed to discuss issues with each other. Because the jury would never be less than 201 independent decisions, it appears that the system unknowingly utilized advantages of the law of large numbers. Large groups increased the probability of reaching a correct verdict when individual opinions were unbiased. The jury system also adhered to this logic by increasing the jury size even further in the most important cases. In addition, the lottocratic selection of jurors ensured a randomized representation. The median juror had preferences close to the normative expectations of the median member of the Athenian community. Therefore, the litigants would need to take into account the existing "citizen spirit" when arguing for their views in the court (Carugati, 2015).

The People's Court system builds on a trade-off between accuracy vs. speed, a typical characteristic in human swarm problem solving. Athenians definitely emphasized decision speed, as court decisions were made within a day. This is much less time than what is common in courts today and suggests a significant risk of making bad decisions. However, one could argue that these rapid decisions were compensated by increasing the jury group size, which was much larger than a normal jury size today. Most citizens must have acknowledged the jury system as a legitimate decision-making method, as even Socrates accepted his verdict, claiming, "He owed it to the city under whose laws he had been raised to honor those laws to the letter" ("Socrates was guilty as charged," 2009).

5.4.4 Large Gatherings in Athens

In ancient Athens, all democratic institutions can be regarded as large gatherings of people coming together to solve problems. This swarm component includes the Council of 500, but also the Assembly and the Court, which involved a large number of citizens, but for a much shorter period.

The Assembly Meetings

In Ancient Greece, the Assembly in Athens was particularly important. In 594 BC, nearly all adult male Athenian citizens were allowed to participate in the Assembly at the age of 20 after they had completed their military service. Excluded were woman, metics, slaves, and citizens who had lost their rights. Still, this allowed the poor group of citizens to become the new majority. Meetings of the Assembly were normally held on the Pnyx, a low hill about 400 m southwest of the Agora (Figure 5.5). In the fifth century, the people sat in a semicircle directly on the rocky surface, and on the north side, there was a low wall that must have been the place of the speakers' platform. The area was about 2400 square meters and the elevation sloped from south to north. The Pnyx was almost a symbol for the Assembly, and even for the democracy itself. Very few other cities had an independent Assembly place, and most used the Agora or the theatre (Hansen, 1991: 127–129).

The Assembly was always summoned by the executive group (prytaneis) in the Council of 500. It originally met ten times a year, but it gradually increased to 40 meetings a year. The meeting could not be held on festival days, "taboo-days" or when the People's Court had juror meetings. The Council normally set the agenda on their own initiative, and it was typically published four days in advance. In this way, citizens had some time to discuss issues prior to the meeting. Normally, at least nine items

Figure 5.5 The Pnyx hill in Athens where the Assembly had its meetings, photo Miguel Sotomayor/Getty Images ©

would be on the day's agenda, but the meeting would last only half a day, so the pay was full compensation for ordinary hours of work. The Assembly was most important in relation to foreign policy. Diplomacy was important, illustrated by how both Phillip of Macedon and Alexander the Great were made Athenian citizens. The Assembly also rewarded deserving foreigners, metics, and citizens. A large number of decrees were ratified, such as citizenship grants and honorary decrees or those related to foreign and military policy. Often, the ratifications were simple and uncontroversial and they would pass without debate, as is often the case in the Swiss Landsgemeinde today (Hansen, 1991: 133–157).

In the Assembly of 6,000 people, deliberation or extensive discussions were not possible. The debate would therefore consist of a series of speeches of varied length. It varied whether the speeches were prepared or not prepared (also with or without a text). Communication was only one-way, from speaker to audience. According to the law, there was to be no communication from audience to speaker. Nor were there to be any communication between speakers, but one could obviously refer to previous speeches. However, at every meeting the audience interrupted with applause, protests, or laughter. Heckling from the auditorium was often

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unrehearsed, with questions requiring clarification and some dialogue between the speaker and members of the audience. Still, the vast majority of the audience of 6,000 would listen and vote on the motion without discussion. Although only a tiny minority were active in the Assembly, the democracy would still very much depend on the active contributions from this group. Honorary decrees and prizes like gold crowns were even awarded to the best rethor of the year in the Assembly or the best executive group of 50 from the Council (prytaneis). "Rhetoric, or the 'art of persuasion' was considered to be important when individuals presented an issue" (Hansen, 1991: 142–157).

The Court Meetings

Another important large gathering was the People's Court, which met approximately 200 days a year. The Court was a separate and independent institution from the Assembly. In the classical period, the Court tried both civil and penal cases, but the most important function was political control of the other institutions. It organized prosecutions against public officials and helped prevent misconduct or abuse by office holders. Although formal written law existed, and the court was regulated by written legal procedures, the system was dependent on the voluntary efforts of citizens at large. Prosecutions relied primarily on private initiative and citizens had to "present their case" without any lawyers. There was no public prosecutor who brought a charge. All the judges were also citizen-amateurs, and an amazingly large number of citizens took an active part in the law, not only as jurors but also as prosecutors or plaintiffs. Originally, only the injured party had the right to bring a case. A citizen would have to learn how the system worked because it was forbidden by law to pay another citizen to appear as your advocate in court. If the jury permitted, one could share speaking time with a friend or relative, and in political trials there were usually several speakers from the same group. One could also get help from a professional speechwriter although this profession was regarded with skepticism and suspicion (Carugati et al., 2015; Hansen, 1991: 189, 191, 194; Tridimas, 2011).

The judges volunteered by choosing which days they wanted to turn up for the daily court meetings (Hansen, 1991: 181). The court meeting followed specific procedures. A public prosecution took the whole day, lasting nine and a half hours. The accuser and the accused had about three hours for their speech. The remaining three hours were needed to select jurors, read the charge, vote, and arrange new speeches for meting out punishment, a further vote on the punishment, and so forth. In private suits, the time for speeches varied according to the value of the suit: suits for over 500 drachmas got the longest time and could perhaps last more than two hours, while suits for less than 100 drachmas could perhaps be heard in less than an hour (Hansen, 1991: 187). The hearing began with the reading aloud of the written charge and the reply of the defendant. The plaintiff or accuser would begin their speeches and then the defendant. In a public prosecution, each party made only one speech, but it could last up to three hours. In a private suit, the time could at most be about forty minutes. In these cases, the parties were both given a chance to meet each other's point in a short reply and reply-to-reply (Hansen, 1991: 187, 200).

Since the cases were allocated by lot in the morning, the jurors would have few opportunities to discuss the cases in advance. However, for the Athenians, the purpose with the large number of jurors was to counterpose those who are so rich that they could buy followers (Hansen, 1991: 188). Compared to court trials today, these procedures are much shorter, and one can reasonably ask if they are too short because there is no time for juror deliberation. Although the rapid problem-solving time and the independent anonymous voting may have originally been motivated by an attempt to avoid corruption, this organizational design resembles the wisdom of crowd approach in several ways (Surowiecki, 2005). First, there is an emphasis on independent individual opinions, which is present in the fact that jurors had to swear the Heliastic Oath:

> *I will cast my vote in consonance with the laws and with the decrees passed by the Assembly and by the Council, but, if there is not law, in consonance with my sense of what is most just, without favor or enmity. I will vote only on the matters raised in the charge, and I will listen impartially to accusers and defenders alike* (Hansen, 1991: 182).

Both the emphasis on individual assessment of what is "most just" and the ability to "listen impartially" resembles the original focus on independent opinions as a basic characteristic in a wisdom of crowd approach (see Section 4.1). Jurors were to make up their own opinion without discussing the issue with other jurors during the court meeting. Because jurors were selected every day, new people would sit together every day, which made it difficult to establish informal subgroups. The phrase "without favor or enmity" in the oath also shows how social influence is perceived as a potentially negative factor. Because voting was anonymous, the oath might seem like an empty formality, but jurors feared divine punishment. Therefore, a decision made by sworn jurors was considered more important than decisions in the Assembly where participants did not swear any oath (Hansen, 1991: 183).

Second, the involvement of a large group of jurors was assumed to improve the collective problem-solving process. Even the smallest group of 201 jurors is large enough to benefit from the law of large numbers and the many wrongs principle. By having a large number of jurors, the Athenians minimized the case time and still hoped to reach accurate decisions. Although the Athenians increased the meeting time in important cases, the compensation for a rapid process was primarily to increase the jury group size.

Swarm Mechanisms in the Assembly and the People's Court

Being a large gathering that solve problems, both the Assembly and the Court utilize several swarm mechanisms. Both resemble swarm problem solving in how problems are predefined before the meeting. Both institutions are not least highly effective in their emphasis on rapid problem solving. Both the Court and the Assembly had to make decisions within the limits of one day's work. Every Athenian jury had to arrive at its judgment by day's end, even when there were several cases per day. While the time schedule in the Court was strictly regulated, the Assembly had a bit more flexibility. Still, most meetings would only take half a day, but it could be extended to the whole day if deemed necessary. However, the work in the Assembly was more unreliable since it was done outdoors in comparison with the Court where work was done under roof (Hansen, 1991: 191).

If we compare the opportunity for deliberation in the Court with the Assembly, we see that the Assembly permitted some degree of deliberation prior to the meeting since the agenda was published a few days in advance. In contrast, the jurors had no opportunity to discuss issues in advance, since the cases were decided the day they met. In both meetings, rhetoric was important, as speakers or litigants would provide the only information to the large group before they voted. However, the Court allowed for significantly more time to the present multiple viewpoints. Speakers addressed complex matters by advocating different and mutually incompatible courses of action (Ober, 2008).

5.5 A Summary of Human Swarm Evolution

In this brief history of the origins of human swarm problem solving, we see how the ancient democracy in Athens emerges as part of a gradual evolution in human history, from minimal stranger interaction, to informal stranger interaction in premodern trade, and eventually to formalized

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patters of stranger interaction through democratic institutions. Ober (2008) claims that the key success factor in the Athenian democracy was how strangers were transformed into citizens who were connected to each other in "weak-tie" networks. In contrast to strong social ties, weak ties (e.g., when my friends are unlikely to be friends with one another) promote more effective sharing of information across the whole organization and it ensures cohesion. Small-scale networks with strong ties are usually very good at internal knowledge sharing, but they are poor at knowledge transfer to the whole network. However, the time dimension of large gatherings is important to consider. For instance, the Council of 500 shows that part of the success was due to giving individuals enough time to get to know each other, and then afterwards bring this knowledge back to their local deme. It institutionalized heterogeneous social interaction and established a knowledge-sharing culture across diverse groups of people in the polis who had been strangers to each other. Therefore, the Council became a meeting place that increased the likelihood of sharing best practices or new inventions in the territory.

One could claim that interaction between strangers is at the core of human swarm problem solving because it enables collective problem solving in much larger groups. In the online setting today, the ability to trust unknown others is also one of main challenges in designing successful CI. A top solver in a virtual innovation teams illustrate how this can also be an exciting experience:

> *I have met people with varied interests, and we all like to step out of our little box that we are employed in. And you find that people regardless of their culture or the country they live in are all pretty much the same. It has been a mind-opening experience that has allowed me to go into areas I would never have been able to do before without going and getting a master's in something or some other college degree. I have learned a lot of things* (s.57).

Through collective work, the solver discovers how people actually are "pretty much the same," echoing the entire Athenian system that was designed to bring strangers together. The Athenians also had to "step out of their little box" and engage with other strangers. In this final section of the chapter, the origins of swarm problem solving will be summarized through the description of two subtypes of swarm problem solving. On one hand, *pinpointed swarm problem solving* refers to an attempt to find the one exceptional solution that stands out compared with other proposed solutions. In *synchronized swarm problem solving*, the solution lies in combining all the different contributions. Both types of problem solving predefine a problem and solve the problems according to a set of predefined interaction rules. The tasks and roles are also defined in advance, but the value of human diversity is utilized in different ways. Pinpointed swarm problem solving seeks one or a few winner solutions from some of the contributors, while synchronized swarm problem solving includes all contributions as a part of the winner solution.

5.5.1 The Evolution of Synchronized Swarm Problem Solving

As the historical examples in this chapter illustrate, the story about ourselves is very much a story about our ability to solve problems in increasingly larger groups. Swarm problem solving emerged as a new type of collective problem solving, different from collaborative problem solving, in its ability to solve problem with a minimum of deliberation.

Group hunting represented a breakthrough in how humans could more effectively acquire food by working together in large groups. Like with group hunting among other carnivores, it is essential to coordinate actions through simple behavioral rules that all individuals follow during the hunt. The hunt would build on synchronization in the sense that every contribution from individual hunters matters and is equally relevant. The actual group hunting consists of synchronized movements, which involve contributions from everyone. The rapid synchronization is built around simple behavioral rules. Each hunter will observe the actions of other "near-neighbor" hunters, and the collective action can be regarded as a navigational problem that requires synchronization of dependent contributions. This type of swarm problem solving can perhaps best be described as group sensitivity and resembles the performance of a sports team where each member responds to the behavior of the entire group. It is different from rule-orientated collaborative problem solving in its emphasis on embodied cognition and indirect coordination.

Early hominins would probably have used similar interactional rules, but there is also evidence that they could effectively plan the hunt in a specific environment, which would at least have required advanced forms of gestural communication. Each group had a shared understanding of the challenge, and that a successful output was dependent on contributions from everyone, during the preparations, the actual hunt, and the butchering. The outcome of the group effort would also be much more valuable than what a single hunter could achieve on his own.

The invention of voting systems in ancient Athens represents the historical development of a more advanced type of synchronization. The benefits of large groups had become more prominent in warfare with the hoplites, and majority voting attempted to use a similar mechanism in governing societies. Majority rule allow everyone to be part of a decision-making process by taking a stance on simple "yes" or "no" alternatives. An important advantage is the speed of collective decision and the clarity of outcome.

Methods that built on "numerical decisions" made it possible to involve a large group of people in time-efficient decision-making. In a historical perspective, it became increasingly difficult for larger groups of people to coordinate collective work when they settled in towns as they grew in size. Different voting methods made it possible to synchronize information from many individuals by effectively aggregating the opinions of increasingly large groups. A vote also represented an equal contribution from every individual. This was both practical and it strengthened the idea of all citizens being equal. The kleroterion, the lottery machine, is an interesting example of a technology that ensured fair and equal representation from all the different tribes in Athens.

Furthermore, the court system in Athens synchronized individual contributions in ways that resemble a "wisdom of crowd" approach. Sortition ensured diverse representation and frequent rotations of participations reduced misuse. Oaths and anonymous voting ensured independent opinions. The prohibition against discussions between jurors illustrates the dedication towards individually independent judgments. All jury groups were very large, with a minimum size of 201, and even larger in the most important legal cases. This shows the presence of the idea that if many individuals vote, more accurate and fair decisions can be made.

Human swarm problem solving gradually evolved into more complex types of synchronization, beginning with dependent contributions in group hunting and then later being transformed into formalized voting systems that synchronized independent contributions. Today, the digitization of numerical data make it possible to utilize synchronized swarm problem solving in new ways. The online setting makes it easy to collect a large number of individual contributions within a short time period. One example from the previous chapter is Deliberative Polling, which illustrate how political discussions between representatives from the whole populations are synchronized into a final aggregated quantitative result. Another example is the Delphi method that aims to aggregate a comprehensive solution through several rounds of voting by using supermajority rule. When votes or judgements are stored in an online system, this makes it possible to collect asynchronous contributions within a limited time frame. For example, citizen science projects like Galaxy Zoo enable volunteers to

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do different microtasks and the results are afterwards synchronized through different averaging techniques. Crowdfunding sites like Kickstarter illustrate synchronization by donating money to different projects. The use of money permits more differentiated contributions than equal voting. The main difference today is that the voting and the aggregation of results are conducted automatically.

5.5.2 The Evolution of Pinpointed Swarm Problem Solving

Because pinpointed swarm problem solving attempts to identify the best solution among many other proposed solutions, it is likely that this type of problem solving motivated human groups to broaden their outreach by communicating with strangers. The establishment of premodern trade systems is one example of how humans began to communicate beyond their own band. This trade primarily exchanged valuable artifacts across long distances and established social practices that made more knowledge sharing possible, leading to new types of problem solving *between groups.* This extension in outreach through trade provided access to a much larger degree of informational diversity, and increased knowledge sharing would further amplify the human capability to solve different problems collectively. Strangers were increasingly regarded as potential resources in a trade network. Similar artifacts like the Venus figurine have been found across large areas, indicating the presence of shared myths and values among many different groups. As a rudimentary form of pinpointed swarm problem solving, premodern trade solves the "problem" of getting access to valuable artifacts that other groups own. The key factor is the ability to trust strangers. Strangers were gradually becoming something different because human self-awareness was emerging.

The next important milestone in pinpointed swarm problem solving can be located to the Athenian democracy, which developed institutions that opened up for a multitude of pinpointed swarm problem solving practices by bringing diverse people together.

While premodern trade (and large gatherings) started as informal exchange of knowledge and resources between groups, the Council of 500 in Athens stands out as an example of a carefully designed plan to utilize all the knowledge in a large population in a more effective way. This institution functioned as a "sensor network" by establishing social ties between individuals from all over the Athenian territory. Groups who previously had been strangers to each other were brought together within the framework of a common identity.

With time, a line of human interaction has evolved from no stranger interaction, to informal stranger interaction, and then to formalized stranger interaction through intentionally designed social networks. This first happened in the Athenian institutions that aimed to bring together people who were dispersed over a wide territory. Every tribe was represented by one third of coastal demes, inland demes, and city demes, and representatives from all these tribes worked together solving public problems in Athens for a period of one year. The rotation of councilors every year was designed to continuously link together new groups of people. By being together, the councilors would learn about other demes. The geographically representative network maximized environmental information and strengthened the capacity to utilize sources of information from a large segment of the Athenian population.

With the emergence of a global online setting, the "territory" has become so much larger, but the goal is still to utilize expertise to pinpoint the best solution. Both innovation contests and the citizen science game Foldit illustrate how companies and academic communities reach out to a large number of unknown others in an attempt to identify the single best solution (see Chapter 2). Although there are specific individuals or small group who produce solutions, it is the informal knowledge sharing and performance of the whole Foldit community that makes the continuous production of pinpointed solutions possible.

Another interesting example from the offline setting are hackathons. A large group of individuals meets in an offline setting to solve a problem with a short time period. There will be predefined specific goals or objectives, but the problem-solving process will be more reminiscent of a marketplace or bazaar. It is characterized by a large physical setting where many informal interactions are happening at the same time in a transparent environment. When information is "offloaded" in the environment, others can potentially get access to the same information. There is a loose control of the interactions, but all participants share the conception that they must solve the challenge within a short time period. Although people who meet in this context are strangers to each other, they are still interested in the same topic, which makes it easier to interact with each other. A multitude of qualitative contributions is produced and some are expected to be relevant outputs that identify the best solutions. These will be awarded prizes at the end of the hackathon.

The IdeaRally is another example of an innovation contest that is organized as a large gathering, bringing together competent strangers together from all parts of the world (see Section 2.2). In this setting with many parallel ongoing activities, a number of different solutions can be developed at the same time, but only some will be selected in the end. A large pool of expertise provides a wider access to ideas compared with a small group with limited expertise. As we can see, there is today more interest in finding out how one can utilize large gatherings to identify the best solutions within a short time period.

In ancient Athens, pinpointed swarm problem solving was also used in different types of contests; voting in the Assembly was used to award citizens prizes and honorary decrees such as the best rethor of the year, or a prize to the best executive group of 50 in the Council. It illustrates that competitions were to some degree used to motivate performances of societal value. Modern CI will also utilize the same mechanisms through innovation contests. By involving unknown others or outsider expertise, this can potentially increase idea diversity. It can be compared to finding the "needle in the haystack" by recruiting a large number of contributors. Only the persons who think they can solve the problem will respond to the call. In this approach, companies pick the best solutions instead of the best people:

> *If you look at it from the point of view of a company they can spend a lot of time interviewing people to try and put a team together. They give them salaries and maybe they come up with the solution and then again maybe not. Instead of them going out and trying to find the best people to solve the problem, they can get a lot of people solving it and then pick the best solution rather than trying to pick the best people.*

The person who provides the best solution may differ from problem to problem. When the problems are complex, the person who provides the solution can be unexpected. The solvers are not necessarily where you might expect them to be. By recruiting a large number of potential problem-solvers, this increases the likelihood of identifying a better solution because the diversity of proposals increases. Another example of pinpointing solutions is by using online leaderboards. For example, the Foldit game use many leaderboards to motivate participation and provide information about the solutions that are currently the best ones (see Section 2.3).

Furthermore, another example of pinpointed swarm problem solving in ancient Athens is the annual ostracism vote. If there were more than 6,000 votes in the first voting round, the person with the highest number of votes in the second round was exiled. There was no deliberation, only the vote. Although this voting system pinpoints the worst person, the logic is the same as voting for the best solution or person. By getting rid of one person, it was assumed that this would be beneficial for the Athenian society in general. In modern CI, there are not so many similar examples. However, disaster management resembles ostracism in first maximizing environmental information about an area, and then pinpointing the worst area that is most in need of help.

From a systemic perspective, ancient Athens was able to design a lottocratic political system that created many "winners" all the time. Most of the public positions, such as appointments of a magistrate (public official), juror, or councilor were based on selection by lot. Any citizen had the right to participate in decision-making, serve in public office, and could join the lottery. Most individuals would eventually win this lottery because there were so many citizen positions. Even the Council of 500 organized their work as a lottery. Leadership was rotated among 50 persons from one tribe each month. They were pinpointed to rule through random sampling. All groups would eventually "win" the honor of being leaders. By letting most councilors get the opportunity to be in charge, they would also be motivated to learn more about the Athenian governmental system. In addition, a majority of the councilors would through a daily lottery win the opportunity to be "president of Athens" for one day.

Historically, the challenge of finding the right person that can solve a problem has not been easy. The ingenious invention of Athens was instead to enable everyone to become "winners." The rotating system allowed more citizens to be part of the democratic institutions in Athens and increase their knowledge through active participation. The constant rotation ensures diversity, inclusion, and fair selection of candidates. It stimulates "heterogeneous social interaction" through the design of a multitude of groups and meetings between people who did not know each other from before, but still would engage in important societal work together. In the previous chapter, Deliberative Polling comprise a modern example of lottocratic selection, which appears to be underutilized today.

Note

1 Kleroterion – machine that selected the leaders of citizens of Athens. https://www.youtube.com/watch?v=1DhgkqJCIBA

CHAPTER 6

Human Stigmergic Problem Solving

6.1 What Is Stigmergic Problem Solving?

6.1.1 Background

What is stigmergy? The French entomologist Grassé coined the term "stigmergy" in the 1950s. The term is formed from the Greek words stigma "sign" and ergon "action," referring to individual actions that leave signs in the environment, and determine subsequent actions by others. Stigmergy usually describes how many individual agents are able to coordinate collective action only by leaving information in a shared environment (Parunak, 2005). The basic principle of stigmergy is extremely simple; traces left by agents in the environment provide feedback information to new agents (Theraulaz & Bonabeau, 1999). When one agent leaves a trace in the environment, this trace will even stimulate or motivate others to do subsequent work. The aggregated collective work serves the purpose of being externalized information that ensures that new tasks are executed in the right order. The complete solution will gradually emerge when different individuals interact with the "evolving information" in the environment at different points of time (Rezgui & Crowston, 2018).

Stigmergy can also be explained as a feedback loop that does not require any direct communication between the individuals because all coordination is done through the traces of information left in the medium. When information remains available, it can guide new agents at any later point of time, and there is no need to be present at the same time. Nor is mutual awareness a requirement since every individual works independently of each other. The individuals do not even need to know that other agents are participating in the work. The collective actions are materialized in the environment and function like a shared external collective memory (Heylighen, 2011, 2015). For example, an ant colony will record its collective activity as traces in the physical environment, and this helps

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them organize their collective behavior. Information can be stored in the environment in several different ways, as gradients of pheromones, material structures impregnated by chemical compounds, or by spatial distribution of colony elements. These traces of the collective activity function as "stimulants," both by directing and constraining the individual behavior of the ants. New actions are triggered by the perceived recent changes in the trace (Theraulaz & Bonabeau, 1999).

The notion of stigmergy allowed Grassé to solve the "coordination paradox," the question of how social insects could collectively tackle complex projects like building a nest. The notion of stigmergy highlights that it is possible to generate robust, intelligent behavior at a system level by following very simple behavioral rules. Compared to traditional methods of organization, stigmergy makes minimal demands on the agents. There is no need for a plan or overall goal, individuals only need to know the present state of the activity (Heylighen, 2015; Parunak, 2005; Rezgui & Crowston, 2018). The two basic requirements in stigmergy are that the agents can recognize the right conditions to start their work, and that they can access the medium in which these conditions are registered. These agents are goal-orientated in their attempt to maximize "fitness," "utility," or "preference." The underlying mechanism is local trial and error or variation and selection, where two interacting agents mutually adapt their actions, until they reach an acceptable "coordinated" pattern. This local pattern is then adopted by neighboring agents until it includes the whole system. A global order will spontaneously emerge out of local actions, illustrating that intelligence does not reside in each individual agent, but in the interactions among the agents and the shared dynamical environment (Heylighen, 2015; Parunak, 2005; Rezgui & Crowston, 2018). It has even been suggested that stigmergy is the only way a large distributed population can solve collective problems if it has a limited amount of computational resources (Parunak, 2005).

If one observes each insect separately in a colony, they do not seem to be involved in a coordinated, collective behavior. However, they interact indirectly through medium, and both physical and geometrical constraints will influence the choices of the colony. Social insects use a large variety of olfactory, tactile, visual, and vibrational messages, as well as multi-modal combinations of these in their communication. In general, these messages can be divided into three groups. First, some messages require direct contact between individuals, being local in both space and time. Second, some signals are local in time but not space, typically alarm signals. Third, some messages, building on stigmergy, are local in space but not in time (Feinerman & Korman, 2017).

6.1.2 Quantitative Stigmergy

Moreover, in stigmergy it is common to distinguish between quantitative and qualitative stigmergy. Quantitative stigmergy refers to perceived conditions that differ in strength or degree, and where stronger traces typically elicit more intense or frequent actions. Two or more actions are performed on the same object or task, and the stimulus-response sequence comprises stimuli that do not differ qualitatively from each other like gradients in pheromone fields. It is only the probability of others performing the same action that will change. A stronger trace will, over time, lead to more frequent actions by increasing the number of individual contributions, resulting in a more intense overall activity. Both ant trail laying and termite nest building use quantitative stigmergy (Heylighen, 2011, 2015; Theraulaz & Bonabeau, 1999).

In ant trail laying, ants discover a range of different food sources independently, and stigmergic mechanisms effectively select the closest source to the nest. If the path to the food source is short, the traffic will be sufficiently intense for the pheromonal trace to remain. However, if the distance between a food source and the nest is long, the time interval between the trips of two foragers may exceed the evaporation latency of the pheromone and the trail disappears. The time scale of pheromonal communication will depend on chemical evaporation times and vary between species and tasks. Depending on the distribution of food, the same behavioral rules may produce very different collective behavior. Individual ants will refine and amplify complete ant trail structures that other ants have made (Feinerman & Korman, 2017; Theraulaz & Bonabeau, 1999) (Figure 6.1).

Another example is termite nest building, which is performed without a plan (Figure 6.2). The individuals will locally interact with features of the structure by adding building material to them. Termites may add mud to the same pillar, or several individuals will push the same load of mud. Soil pellets impregnated with pheromone are used to build the pillars in two phases. First, pellets are deposited randomly until one of the deposits reaches a critical size. If the group of builders is sufficiently large, the coordination phase starts, and pillars or strips begin to emerge. The higher the emerging heap of mud is, the stronger the trace will be. This makes it even more attractive, strengthening the probability of more mud being added, thus creating an amplifying effect. The workers are stimulated to continue the building process through a positive feedback mechanism (the snowball effect), since the increasing amount and accumulation of material

Figure 6.1 Leafcutter ants following the same trail when carrying leaves back to the nest, photo Ricardo Riechelmann/EyeEm/Getty Images ©

Figure 6.2 Cathedral termite mounds near Adelaide River, Northern Territory, Australia. The termite mound structures are approximately 100 years old and can stand up to seven meters in height. The mounds are made with a combination of soil, mud, chewed wood, and saliva. The life of the termite is a constant race against rain because a heavy downpour can ruin part of the mounds. Therefore, the termites will always be rebuilding their mounds, photo Yvonne van der Horst/Getty Images ©

reinforces the attractiveness of deposits through the pheromone on the pellets. A spatiotemporal structure emerges from a random spatial distribution of soil pellets (Feinerman & Korman, 2017; Heylighen, 2011, 2015; Theraulaz & Bonabeau, 1999).

Once the structures are created, they are stabilized through negative feedback, mainly pheromone decay and competition among neighboring pillars. When pheromones are deposited on the building materials, it adds a temporal dimension to the physical structure because pheromones evaporate over time. If the number of builders become too small, the pheromone disappears and the amplification mechanism stops. This self-organizing system can result in several different stable states. In the ant trail laying, this depends on the initial conditions (path dependency). The collective behavior can also change completely at a critical density, like at some point in the nest building; no pillars will emerge below the construction, only above it. When building and extending a termite hill, no final goal will be reached as the maintenance will be part of an ongoing long-term project (Feinerman & Korman, 2017; Heylighen, 2011, 2015; Theraulaz & Bonabeau, 1999).

6.1.3 Qualitative Stigmergy

Qualitative stigmergy refers to conditions and actions that differ in kind rather than in degree. It differs from quantitative stigmergy in that individuals respond to qualitative differences in the type of stimuli; a different trace will stimulate a different type of action. Actions are performed automatically in the right order, since an action will not be started until the right condition is in place.

In nest construction in the solitary wasp *Paralastor sp*, it is the completion of one stage that provides the stimulus that begins the next stage (Figure 6.3). The wasp begins with the excavation of a narrow hole, and only when the nest hole has been completely lined with mud will the wasp begin the construction of a mud funnel above its entrance. This funnel is built in five distinct and highly stereotyped stages from a series of mud pellets. Stage 1 involves the building and application of a series of mud pellets until it reaches a length of 3 cm. At Stage 2, the wasp ceases to build upwards, and by adding more mud to one side, it begins the construction of a uniform curve. The end of each stage of building will provide the stimuli that initiates the next building stage. Coordination of the collective behavior will always build on the previous consequences of building actions (Theraulaz & Bonabeau, 1999).

Figure 6.3 Potter wasp building mud nest,
São Paulo, Brazil, photo Kassá/Getty Images ©

A second example is nest building in the wasp *Polistes*. Building decisions are based on perceived configurations of previous construction that direct the collective work. Here, several building actions may happen in parallel, and actions will be performed on separate, independent parts of the medium. One advantage is that different wasps can then do the same work (Figure 6.4). Nor does a wasp distinguish between its own or others' work, making it possible for a new wasp to continue with the ongoing nest construction work at any stage. This can potentially result in conflicting actions when they are performed simultaneously. However, cells are added according to specific simple buildings rules, such as the rule in which the wasps tend to finish a row of cells before initiating a new row. For example, the probability of adding a cell to a three-wall site is about ten times higher than in the case of a two-wall site.

Experimental studies have shown that if a stimulus is presented at the "wrong stage," it automatically leads to a redundant structure. It is the architecture itself that constrains the building activity and prevents its disorganization. Since the sequence of the tasks is imposed, a single individual does not need an overview of the complete of task. A new cell is added based on several templates that best characterize the current local shape of the nest (Theraulaz & Bonabeau, 1999).

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Figure 6.4 Two hornets building a nest together by making hexagonal cells, Mana, HI, United States, photo Craig Damlo/Getty images ©

6.1.4 Sematectonic Stigmergy

Furthermore, it is possible to distinguish between sematectonic and marker-based stigmergy. In sematectonic stigmergy, the structure of the domain itself will provides sufficient signals for coordinating the collective behavior without any need for special markers. A new action is triggered by "the current state to the solution" which is the accumulated activities of prior agents. This mechanism is present in the aforementioned example of nest building in the wasps *Paralstor sp* and *Polistes*. Another example is ants who cluster corpses in their cemeteries, directed by variations in the density of the corpse distribution. This is quantitative sematectonic stigmergy, where collective decisions, are made by individuals who follow gradients in this field, avoiding repellers and approaching components (Parunak, 2005). A classic example of quantitative sematectonic stigmergy is the creation of human trails. Humans wear down vegetation on routes that are used frequently, while the vegetation will grow again if an old path is not used. This example illustrates that all actions count whether you choose to walk along the path or not (Parunak, 2005).

6.1.5 Marker-Based Stigmergy

In marker-based stigmergy, coordination is built around a signaling mechanism where a mark is explicitly left with the intention of being a signal. Unlike sematectonic stigmergy, which is a response to an environmental modification, marker-based stigmergy does not make any direct contribution to the work in it itself. Here, ant trail laying is a relevant example, in which ants leave a trace of pheromones, a chemical signal, as marks when they return to the nest after they have found food. Each ant has the disposition to move towards the scent left by other ants. When there are few ants, the scent has little effect on the collective behavior of the group. However, when there are many ants, and each of them moves towards the strongest scent and at the same time lays down their own scent, trails of scent to the food begin to emerge. So the stronger the pheromone trail, the larger the probability of a response. Gradually, an extensive network of pheromone trails will connect the nest to the surrounding food sources. Shorter paths collect more pheromone, so the network and the collective "external memory" will continuously become more effective (Heylighen, 2013; Marsh & Onof, 2008).

Another example is how animals leave marks in the terrain, often communicating their presence to other conspecifics. The most basic message is a sign that informs others that, "I'm here." This mark will typically give information about the identity of the animal and its relative dominance (Giuggioli, Potts, Rubenstein, & Levin, 2013). A number of mammals will be marking the environment with glandular secretions, urine, or feces (Figure 6.5). Besides the function of informing other conspecifics, marks may help individuals orient themselves in their area.

In animal groups, marking is also done by the whole group in their area. They leave more marks at much-visited sites such as junctions, dens, or zones where individuals from other groups may be encountered (Theraulaz & Bonabeau, 1999). Likewise, human marker-based stigmergy will leave some kind of signal that informs others about their actions. For example, humans will tend to improve trails with markers such as direction signs, illustrating how sematectonic stigmergy is often combined with marker-based stigmergy that reinforces the preferred actions (Parunak, 2005).

6.1.6 Human Stigmergic Problem Solving Is Solution-Centered

Obviously, stigmergic mechanisms will be present in many types of human problem solving. As with insects, human individuals do not need to have a

Figure 6.5 Cheetahs scent marking their territory together, Masai Mara in Kenya, photo Mike Powles/Getty images ©

complete overview of the work, the problem, or the solution. According to Rezgui and Crowsten (2018), information on how to improve human collective work can also be communicated through the current state of the work itself. Coordination signals can be elicited from the ongoing shared work. Tasks depend on each other and build on previous work when it has been stored. The implication is that problems depend on the current status of the solution.

Parunak (2005) suggests the binary distinctions in quantitative vs. qualitative stigmergy, and sematectonic vs. marker-based stigmergy, can also be used in the analysis of different types of human stigmergy. In quantitative stigmergy, signals follow a single scalar, whereas in qualitative stigmergy, the signals form a set of discrete options. In marker-based stigmergy, the signs consist of special markers that agents deposit in the environment, while in sematectonic stigmergy, individual actions respond to the current state of the solution (Parunak, 2005).

In this chapter, the analysis is inspired by these stigmergic dimensions. For example, in human qualitative stigmergy, a preliminary part of a solution will be stored in the system or medium, and individuals will then respond to the unfinishedness in the solution in different ways. New actions will be triggered in an attempt to come closer to a solution. If many versions of a solution already exist, human quantitative stigmergy can be used to rate the most optimal solutions. In the online setting, solutions will continuously be compared with each other. Here, the aggregation of a large number of individual reviews will help direct attention toward the best solutions.

Furthermore, the chapter suggests that human stigmergic problem solving is primarily solution-centered and emerges through four distinct problem-solving mechanisms:

1. Rating complete solutions
2. Reestimating the solution
3. Completing solutions
4. Adapting complete solutions

These four subtypes of stigmergic problem solving are further explained, both through the introduction of new examples and by analyzing previous examples from Chapter 3. In the final section, the four problem-solving mechanisms are related to the different stigmergic dimensions (quantitative vs. qualitative, sematectonic vs. marker-based).

6.2 Rating Complete Solutions

6.2.1 Search Engines and Collaborative Filtering

Because of digitization, more information is available than ever before. In Chapter 3, several examples showed how knowledge products or "complete solutions" are being published openly, including research articles, open textbooks, and videos (e.g., YouTube). These solutions are typically complete in the sense that they are of direct value without any need for further modification. Quite a lot of knowledge products, like videos published on the online platform YouTube, are automatically included in a larger collection of similar types of work. Most knowledge products will remain available for a very long time. For example, when an instructional video is published to help a specific individual in an online community, it can also be relevant to other new viewers at any later point of time. However, because new knowledge products are being published constantly and everything is stored, this increase in published solutions need to be filtered. The sheer size is overwhelming and requires new ways of sorting and finding relevant information. Key questions are: How do we decide what we need to know, how do we find solutions that will

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address our need, and how do we evaluate what solutions are most relevant?

Today, it is the search engines that help us find and reuse the best solutions others have made. They select and rank solutions, and ultimately define what knowledge is of value today. The web became search-centric in the mid-2000s. Although people still use the phrase "surfing the Internet," they no longer move from site to site through hyperlinks like in the 1990s (Halavais, 2018: 30–31). Search engines are built around three components – the crawler, the indexer, and the front end. First, information about webpages is gathered from around the web. Second, all this collected data is evaluated according to their relevance to a particular set of keywords. Almost every modern search engine extracts key terms to create a keyword index of the web by an "indexer" (Halavais, 2018: 19). In the index of a printed book, one gets an overview of all the page numbers where all the keywords appear in the book. On the web, this strategy is not effective because much of the material on the web may be spam and intentionally misleading. Search results need to rank content according to how relevant it is. Algorithms will typically rely on hyperlinks to assess how relevant specific web pages are according to a search term. This is used to create an index, the "secret recipe" of a search engine, which crawls the web and creates a database of indexed material, which every individual search will be built upon. Third, in the final step, the search engine will present the processed results of a query at the "front end." The results are usually ranked in a simple list that display the most significant hits, providing a clear prioritization of the most relevant solutions. The results are designed to reveal possibilities without overwhelming the user (Halavais, 2018: 19–25).

Google became the most popular search engine because they were the first to recognize that the number of links could be used as an estimation of how good a web page was. When one page linked to another page, it indicated that the content was worth reading. Hyperlinks were not just connections, but rather votes on the relevance of a web page. A large number of links indicated that a page was particularly relevant. For example, according to one estimation, Google claims the median number of backlinks to the first three sites to be 1,210, while the hundredth site receives 61 backlinks, and the last site receives none. However, not all backlinks are necessarily of equal value. Therefore, Google assigned a PageRank to each page in the search engine's index, calculating the number of sites pointing to the page as well as estimating the "popularity" of these sites by also calculating the number of links these sites had. More weight is given to links from popular sites. PageRank provides a way for the web community to tacitly vote on the quality of a page. Google also extracts keyword information from the text on the backlinks, so that relevant content on these pages have an impact too. For example, if a web page is linked to from a site with many visitors; this popular page is "weightier" than other backlinks (Halavais, 2018: 108–116). If somebody publishes a solution, it will often be located by a search engine, and when more people link to an answer because they find it relevant, it is ranked higher in the search results.

In large part, the design of search engines is determined by our limited span of attention. Although there has been an enormous increase in the production and access to information and knowledge, the human capacity to consume information is still the same (Halavais, 2018: 112–114). Because of the existence of billions of webpages, it is not possible to present them all equally. Therefore, search is as much a process of ignoring as it is of presenting. Gaining attention has always been important, and the search engine is changing the ways in which attention is concentrated and distributed (Halavais, 2018: 99). Over a period of two centuries, mass media like radio, newspapers, and television sent out the same message to the public, setting the agenda and directing people's attention to what was considered worthwhile information. However, on the web, the attention becomes distributed because of all the options that are available. Because of the increased use of participatory media, the fight for people's attention is now harder than ever before. Attention is increasingly regarded as a valuable commodity. The visitor of a website is someone who gives you attention in return for information. In addition, this ability to consistently attract attention is something advertisers want because it can produce revenue. Here, the search engine is the tool that select some of these winners who get a lot of attention. In one example, an online diamond retailer called Skyfacet.com was selling jewelry worth about 3 million each year, but a change in Google's ranking algorithms removed the site off the first few pages of results for popular queries about jewelry. The result was that sales dropped by 17 percent in three months. While sales in an offline setting is about location, in the online setting, it is all about getting attention through search engines (Halavais, 2018: 112–114).

In the recent decade, data from social media platforms have also increasingly been used to inform and rank search results. In "social search" or search personalization, the search engine results are re-ranked according to that person's search history and the interests of the person's larger social network. In addition, people increasingly search for information via social media platforms instead of using open search engines. Platforms like Facebook and LinkedIn filter information from the rest of the web. For example, in a study in 2014, equally many found and read news articles on Facebook as on open-ended search engines. On social media, users not only find information, but they can identify who shared the information and connect with this person if they want to. The platforms even offer their own search engines, and in 2016, Facebook handled more than 2 billion searches per day from their search box (Halavais, 2018: 76–78, 89–90).

On one hand, most information is ranked automatically through our collective behavior on the Internet, but in addition, many systems today let individuals actively rate complete solutions. For example, there are dedicated Community Question Answering (CQA) sites, markets for answering questions that involve people with particular expertise. Some examples are Stack Overflow, Quora, and Yahoo! Answers. Generally, these sites allow individuals to ask a question, and anyone can rate the various answers that are provided. Points can also be awarded, and the market is largely reputation-based. All of these systems attempt to gain expert opinion without the costs of finding and hiring an expert. For a single question, that expense is frequently overwhelming. In many cases, the questions are practical and quite simple to answer (Halavais, 2018: 92–93). These sites build on the assumption that many individuals pose the same questions at different locations, but with the help of search engines, one can save time by effectively finding and reuse solutions that others already have provided. However, if a problem is difficult to understand or conceptualize, it may be much easier to ask an expert directly,

Another type of "sociable search" centers on the aggregation of explicit user-centered evaluations of content. They index ratings or measure how a community evaluates a web page instead of indexing the web pages. For instance, collaborative filtering harness information from explicit reviews performed by a large group of users who visit a site. Those who share similar interests can discover relevant material with very little individual effort. A "front page" of options is presented based on criteria provided by the user. Preferences in one area gives information about other topics that may be of interest, and the aggregated opinions of similar peers guide the user to new relevant resources. Homophily is one label that is used to describe the tendency of like-minded people to "flock together." If two people have similar backgrounds and preferences on some matters, they are likely to have similar tastes in other areas, and this can easily lead to a self-reinforcing congruence. By explicitly taking into account the searchers' social networks, results can be even more effectively ranked (Halavais, 2018: 82–88).

Reddit is one example of a collaborative filter site that explicitly let user votes decide what web pages get the most attention. This site covers a large variety of topics that allow the community to vote on the most interesting links and comments. Although Reddit does not actively seek to establish an online community, it is possible to publish comments. However, a major challenge at the site is how to reduce the "groupthink" of group filters, and limit unintended or intended bias. The algorithms that determine what appears on the front page need to be regularly changed because of attempts to manipulate the feed. One alternative strategy to cope with spam and bad, off-topic comments is to let users vote on comments. The website Slashdot even created a meta-moderation process that permitted voting on the moderators' votes. Every search engine depends on trust because the searchers will always perceive a threat of being either intentionally or unintentionally mislead. In traditional search engines, this will always be a challenge because the user will not know how the search engine works. However, in a system like Reddit, the transparency of all the activities creates trust. Being aware of how others use the system increases the overall trust in the system (Halavais, 2018: 84–88).

6.2.2 Different Rating Methods

The quality of complete solutions published online will be closely connected to how others value or rate the work. When a knowledge product is reused by others, the digital traces will always aggregate simple statistical metainformation, such as the number of visits. Many online sites also let users actively rate solutions in different ways, but typically with simple voting methods. For example, features such as subscription counts, ranking, likes, and dislike counts in YouTube provide an indication of the popularity of posted content and how well it is received (Lee et al., 2017). Systems will usually allow any viewer to rate a video by registering a "like" or "dislike" rating by using the "thumbs up" approval icon or the "thumbs down" approval icon. Viewers can also favorite videos as a way of "spreading the word" on videos (Postigo, 2016). The simplicity of this assessment system increases the likelihood of receiving feedback from more users. However, it may be difficult to interpret why people like or dislike a video. Some may also press "like" on everything they read. Although one study finds that some of the features in YouTube (e.g., recommendations, searching) allow learners to find relevant educational videos in an effective way, it is important to be aware that many views does not automatically imply high quality or credibility (Lee et al., 2017).

In online platforms like Reddit, the quantitative results of simple voting, like upvoting or downvoting, will have a direct impact on what information gets the front page of attention. These voting systems allow transparent voting, by letting new individuals see how others have voted before they vote themselves. This transparent quantitative rating will be part of the assessment when deciding whether one will use time reading an article or viewing a video. If a large number of votes are given, such rating systems aim to reduce bias and provide a fair and precise assessment of the quality of a knowledge product.

Another important way of understanding popularity on YouTube is through the number of subscribers each channel attracts. The "most viewed videos" and "most subscribed channels" represent different types of engagement, the most viewed has the greatest outreach, but the most subscribed has most engagement. The increasing number of channels with more than a million subscribers is indicative of the growth of YouTube. In 2010, there were only five such channels, while in 2016 there were 2000. The most subscribed channels are dominated by "YouTube stars." These stars aim to be authentic and create a community by interacting with the fans. Today, the subscriber count is considered to be a measure of audience engagement and return visits. It is considered the key metric that can generate revenue from sponsorship and merchandising (Burgess & Green, 2018: 87–92).

The subscriber will have an overview of their favorite channels and automatically be notified whenever a new video is added to these channels. This feature promotes more viewing and is very important in getting consistent views. If the viewers are not happy with the channel, they can stop subscribing. For instance, video game commentators, will use a lot of effort to both get subscribers and not lose them. They both compete against each other in getting subscribers, but at the same time they share them with each other. Top commentators will often favorite each other's videos, promoting their channels to each other's subscriber bases. The most popular commentators also have each other on their respective channels as guest commentators, or provide links to other commentators on their own channel. This reciprocity strengthens the relationship between gameplay commentators and help both channels grow (Postigo, 2016).

Typically, most sites will provide a collection of many comparable solutions that are ranked against each other. The aggregated quantitative rating will often be used as a part of ranking system that provide a lot of attention to a few persons or solutions. Today, these network gatekeepers are often labeled as "influencers," and they have a huge impact on the information flow in the system and what gets attention. They choose what information is valuable by connecting networks or clusters of individuals and information to one another (Halavais, 2018: 66–68, 87–90, 106).

Furthermore, most rating systems include qualitative data, in the form of comments or reviews of knowledge products. Although fewer persons will write comments compared with giving likes, they still play an important role in providing additional metainformation about the quality of a solution. When the comments are shared openly like in YouTube, viewers can read all the comments that appear at the bottom of the web page. The number of comments will increase over time, and make the aggregation of comments increasingly valuable and relevant. Still social participation will usually be minimal with a majority of comments being very short (Klobas et al., 2019). At some sites, the comments invite to more lengthy reviews of books (e.g., Amazon), movies (e.g., Internet Movie Database) or homestays (e.g., Airbnb). In general, comments can provide more detailed information than a quantitative scale, including both strengths and weaknesses. In addition, reviews of open textbook are important (see Section 3.2). Since the online version of the book is free, there is more skepticism regarding the quality. Open reviews make the quality of the textbook transparent and add supplementary information, in contrast to traditional textbooks (Pitt et al., 2019). Many amateur online communities are also built around informal peer review, like for instance, fan fiction communities (Black, 2008). In other contexts, such as science, peer review is still not open and done anonymously. This intends to ensure honest feedback. Open public comments could be valuable, but scientists appear to be reluctant to publicly criticize someone else's work (Nielsen, 2011: 179–180).

In relation to stigmergy, the rating of complete solutions can be seen upon as a human marker-based stigmergy, which today has become essential in organizing the abundance of human knowledge in the online setting.

6.3 Reestimating Solutions

In the US presidential election in 2016, all the polls got it wrong when Trump surprisingly won the election. This spurred an interest in

Table 6.1. *A comparison between the election results in the swing states in the US 2020 presidential election and the results from a prediction market*

Swing states	Actual result of the US presidential election	Predictions made at PredictIt the day before the election (November 2, 2020)
Georgia	Biden winner. Margin 0.2% (49.5% vs. 49.3%)	Trump winner (61¢)
Arizona	Biden winner. Margin 0.3% (49.4% vs. 49.1%)	Biden winner (52¢)
Wisconsin	Biden winner. Margin 0.7% (49.6% vs. 48.9%)	Biden winner (70¢)
Pennsylvania	Biden winner. Margin 1.2% (50% vs. 48.8%)	Biden winner (61¢)
Nevada	Biden winner. Margin 2.4% (50.1% vs. 47.7%)	Biden winner (74¢)
Michigan	Biden winner. Margin 2.8% (50.6% vs. 47.8%)	Biden winner (69¢)
North Carolina	Trump winner. Margin 1.4% (50.1% vs. 48.7%)	Trump winner (56¢)
Florida	Trump winner. Margin 3.3% (51.2% vs. 47.9%)	Trump winner (60¢)
Texas	Trump winner. Margin 5.6% (52.1% vs. 46.5%)	Trump winner (74¢)
Ohio	Trump winner. Margin 8.0% (53.3% vs. 45.3%)	Trump winner (72¢)
Iowa	Trump winner. Margin 8.2% (53.2% vs. 45%)	Trump winner (76¢)

alternative ways of predicting how the US 2020 election will end. Many looked to prediction markets, which allow individuals to buy and sell "shares" on whether a future event will happen or not. In the recent 2020 US election, PredictIt, a well-known prediction market, set Biden at 61¢ and Trump at 44¢ ("Who will win the 2020 U.S. presidential election?," 2020).

The market suggested that Biden was most likely to win, which he eventually did. Since Biden was the favorite among the bookmakers, this may not seem so impressive. However, what is remarkable is that the prediction market also picked the correct winner in all swing states, with the exception of Georgia (Table 6.1).

Biden won a number of swing states, where PredictIt had also priced him as the most likely winner, like Pennsylvania (61¢), Wisconsin (70¢), Michigan (69¢), Nevada (74¢), Arizona (52¢). It is interesting how the

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market estimated a close race in Arizona with a Biden win at 52¢, and it did also actually end with a very narrow winning margin to Biden at 0.3 percent. The market also correctly predicted a most likely Trump win in swing states North Carolina (56¢), Florida (60¢) Texas (74¢), Ohio (72¢), and Iowa (76¢). However, the prediction market is not perfect. In Georgia, Trump was predicted as a winner at 61¢ with Biden at 40¢. Here, the extremely tight race ended with Biden winning with a margin of only 0.2 percent. In sum, the prediction market showed an impressive accuracy that few experts would have been able to match.

Although political betting is illegal in US, PredictIt is an exception because it is primarily used by academic institutions for research purposes. The website has between 110,000 to 120,000 "funded accounts," and around 1,000 of them are highly active users who trade as a part-time to full-time job in terms of their trading volume. The site is highly regulated, individuals cannot use more than $850 on an individual bet, and only 5,000 traders can be in one specific "market" (Mashayekhi, 2020).

In this section, I will look closer at the stigmergic mechanisms that make this performance possible. Prediction markets are basically a crowd decision system, which use a market mechanism, often real money, to aggregate information from a large numbers of individuals. Individuals are invited to buy and sell contracts of predictions on the outcome of a future event. These virtual shares will typically pay one dollar if an event happens or a candidate wins the election and nothing if otherwise. The initial price of the contract is 50 cents. The aggregated effect of all the individuals who buy and sell the contracts will be the equilibrium market price of the contract. This price will change during the period up towards the time of the event, and the latest price is presumed to represent the current best guess about the probability of the event occurring. A contract trading at 60 cents implies the crowd believes there is a 60 percent chance that the event will occur at that given point of time. If circumstances change, and individuals change their mind and think that a political candidate will not win after all, they can sell (or "short") the contract, and take the profit or loss before the event has happened. When the trading in the market changes, the market price will be adjusted accordingly (Buckley & O'Brien, 2017). Evidence suggests that prediction markets can outperform sales projections, journalists' forecasts, and expert economic forecasters, and often it even performs at least as well as opinion polls (Atanasov et al., 2017).

As a type of stigmergic problem solving, it is the fluctuating market price that provides the crowd wisdom. It represents the collective opinion of the group, which is constantly being *reestimated.* During the entire betting period, the price can be regarded as an estimated solution that gives the best information about the likelihood of an event happening. At a collective level, the forecast is built on letting everyone participate on equal terms (Buckley & O'Brien, 2017). Traders are motivated by profit, so if they obtain new and relevant information, they act quickly in the market. The probability of the solution will therefore be continuously reestimated. Both the price availability and the price history promotes transparency during the process, illustrating that knowledge and opinions can be shared openly in this system (Atanasov et al., 2017). In prediction markets, individuals exchange information by placing orders, while in polls, the design let individuals make solo predictions. Since the value placed on the assets is set in an open market of buyers and sellers, participants are informed and socially influenced by each other through various market indicators (e.g., movements in prices, trading volume, volatility). The process is therefore different from the focus on independent contributions in the classical wisdom of crowd approach (Surowiecki, 2005). The collective problem-solving process is much more dynamic because of continuous aggregations made by multiple parties (Tindale & Winget, 2019). Economists have highlighted that the latest price reflects all information available to market participants. Prediction markets are designed to produce continuously updated forecasts about uncertain events (Atanasov et al., 2017). They can also cover multiple options of mutually exclusive alternatives, like all the candidates in a presidential election race (Buckley & O'Brien, 2017).

The first modern prediction market was the Iowa Electronic Market (IEM), which opened in 1988. Historically, prediction markets have been used to forecast elections, but many organizations are now also interested in using such methods to gather information from employees, both in risk management, product sales, project completion, or idea generation (Buckley & O'Brien, 2017). Today there are numerous markets, with PredictIt being among the most popular. Here, people can also discuss predictions and provide arguments about the current prices on specific events.

A number of studies find that prediction markets can provide more accurate forecasting than other aggregation methods like polls. It appears that several crowd wisdom mechanisms are present. *First*, participants are encouraged to search for relevant information and actively use that information to their benefit. It is therefore likely that more individuals will make informed contributions. The market incorporates differences in forecaster knowledge and skill. *Second*, the market price provide an automatic and continuous aggregate of the collective opinion. This is more effective than repeated polling and shows how prediction markets can provide updated information over extended periods. *Third*, prediction markets can easily scale to very large groups, and it will still work well when a majority have little relevant information because the few well-informed participants will be more motivated to increase the trading. If some participants are very confident, they will just buy more contracts. *Fourth*, participants can be anonymous which is important since social interaction can have a negative effect on the betting. *Finally*, bias is less of problem since unbiased participants can profit by exploiting others' biases. If somebody wants to manipulate the price, the prices will be corrected within a relatively short amount of time because participants wanted to profit from contract mispricing (Buckley & O'Brien, 2017).

However, one should be aware that prediction markets also fail. In the 2016 US presidential election, Trump was priced at 22 cent at PredictIt, but he still won the election. One explanation can be systematic bias among the participants using prediction markets. They are typically well educated and among the upper income groups. Another possible explanation is that traders sometimes move into a bubble, they became convinced of the inevitability of Clinton winning (Graefe, 2017).

Another type of dynamic forecasting is prediction polls. Here, individuals place predictions on future events, but they make probabilistic forecasts, either independently or as a team. The participants can change opinions during the betting period, and as in a prediction market, will receive feedback after the event is over.

In one study, the prediction poll addressed geopolitical issues like "Will any country officially announce its intention to withdraw from the Eurozone before April 1, 2013?" More than 2,400 participants made forecasts on 261 events over two seasons. Here, forecasters in teams outperformed the individual forecasters. The online teams comprised 15 persons and these teams both shared and discussed different issues, but they did not need have to reach consensus. Instead, they made individual predictions, and the team score was based on the median forecaster. The teams would have information about the forecasts of their teammates. Every team also had an overview of accuracy scores for each member and a separate leaderboard, which compared performance across teams. Both the use of individual leaderboards (within teams and across independent forecasters) and team leaderboards (across teams) created a significant level of gamification in the design. The competitive features between the forecasters are assumed to strengthen motivation, and there are many learning opportunities in the process. However, teams were not allowed to talk with persons in other teams. The statistically aggregated forecasts also gave more weight to the most recent contributions and the best performers (Atanasov et al., 2017).

In this study, the team prediction poll performed better than prediction markets, especially in the first phase of a prediction period. It is likely that both motivation and learning processes have played a role. The design offers a complex mix of intrateam cooperation and interteam competition. Teams would share information, learn of each other, and motivate each other to update their forecasts more regularly. This strategy is especially effective when the number of active forecasters is small (Atanasov et al., 2017).

Dynamic forecasting can also be used to filter irrelevant solutions. In online innovation contests, the best solution must often be identified among a large number of proposals. There may be hundreds of irrelevant ideas that are time consuming to review (Klein, 2017). One example is Google's charitable 10 to the 100th project. More than 150,000 suggestions were submitted and Google had to deploy 3,000 employees to filter all the ideas, putting the process nine months behind schedule (Lykourentzou, Ahmed, Papastathis, Sadien, & Papangelis, 2018).

The most typical crowd-filtering strategy is majority voting, which is used by Threadless, for instance. Anyone can vote on the best T-shirt designs and the most popular ones win prize money. Another alternative is multiple voting, which gives each individual in the crowd a certain number of votes to allocate to the ideas they prefer (Garcia & Klein, 2017). However, recent studies have shown that the crowd can be effective in filtering proposals by removing irrelevant ideas. In one study, the crowd was assigned to assist a review panel in a contest by removing irrelevant ideas and keeping the best solutions. In the Diverse Bag-of-Lemons (DBLemons) strategy, each participant is given ten lemons (corresponding to 19 percent of the idea corpus) and asked to identify the worst ideas instead of the best ones. By using a dynamic ranking system, participants can vote at different points of time. It is also possible to view how previous users have ranked the ideas. In addition, algorithms "force" reviewers to compare more diverse ideas with each other. The results show that each participant only had to look at approximately 50 percent of all the ideas to include all the best proposals, illustrating the time efficiency of this strategy. (Lykourentzou et al., 2018).

DBLemons is partly inspired by studies of the portfolio effect, which claims that if you add more diversity to your investment, you take on less risk. People who are exposed to just a few ideas initially appear to get fixated on them, which can impede successful problem solving. The finding underlines the importance of designing diversity procedures across domains in crowd decision-making (Lykourentzou et al., 2018). DBLemons resembles prediction markets in that each voter can view how previous users have ranked the idea, but it is different in that one does not have to choose the winner, but only remove the losers. This approach represents an innovative way of involving the crowd because it makes the individual task much easier and still highly effective. When the number of ideas or the amount of shared knowledge is huge, effective removal of noise becomes increasingly important.

The accuracy of crowd forecasting shows signs of a new type of CI that builds on decentralization of expertise. The stigmergic mechanism in dynamic forecasting provide a transparent environment that let individuals learn from each other and build on this knowledge through different types of gamification. The result is that a diverse group of people is able to quickly synthesize all their knowledge, represented by a quantitative indicator in a scalar measurement, like a price or score. This gives everyone an accessible overview of the aggregated collective opinion of the best solution, which is being constantly reestimated.

6.4 Completing Solutions

In this section, it is proposed that a third type of stigmergic problem solving is directed towards "completing solutions." It is characterized by new work, which build on the current unfinished version of a solution. In Chapters 2 and 3, several examples illustrate how a large amount of people can develop such complex knowledge products through asynchronous contributions in an online setting, such as the Wikipedia project, argument mapping, and open databases.

Wikipedia is considered to one of the best examples of this type of human stigmergic problem solving in an online setting (Heylighen, 2011). Most of the collective work is done on separate articles where new modifications build on the current state of the specific article. All the articles can be regarded as a collection of separate attempts to complete a solution. All contributions leave "traces" in a shared medium that enable new actions to build on previous ones. This stigmergic mechanism is present when edits in Wikipedia made by one individual trigger new edits made by another person. Other users can then again continue to work with the aggregated traces of others' work at any later point of time. This introducing a high degree of flexibility into the work.

Moreover, some online environments also let participants discuss how the work should be done. For example, in Wikipedia, every article is attached to a separate talk page that allows anyone to discuss the coordination of the work. Some of the most active authors might discuss specific issues with each other, while others may just briefly leave a comment or make suggestions on how to improve the article. The discussion is asynchronous and there is no guarantee that anyone will respond to a request, but all posts are archived and made easily accessible for anyone at a later point of time. However, a significant amount of the work in a Wikipedia article will be done without explicit coordination. For example, in one study of a Wikipedia article, about four fifths of the edits are done by editing the content in the article; while the remaining part were discussions on the talk page (Rezgui & Crowston, 2018).

Even mistakes can be valuable because they "trigger" others to make corrections, both minor spelling, but also misinterpretations of the content. Different types of errors, vagueness, or lack of information will stimulate different types of improvement (Heylighen, 2011; Heylighen, 2015 #483).

Corrections in Wikipedia can also be done without knowing how the complete article should end up looking. Each individual will only perform actions according to that person's interests, skills, or background knowledge. Normally, the more "confident" an individual is about the correct answer, the more it will be stimulated by the condition, and the quicker it will begin working (Heylighen, 2011, 2015). For instance, a spelling error triggers a proofreader in Wikipedia, while an imprecise article about Viking ships motivates an archaeologist to add new content. Because of the wide access in the global online setting, a diverse group of people with different expertise can easily make contributions based on their skills. Any contribution counts, everything from minor proofreading to major revisions. Over time, the quality will emerge through continuous attempts to improve the collective work.

Part of the coordination success in Wikipedia may be due to how discussions in specific areas are linked to separate articles. The structure is easy to grasp, minimizes the chances of redundant discussions, and makes it time efficient to join the discussion. By using a watch list feature in Wikipedia, editors can also keep an overview of all recent changes (Rezgui & Crowston, 2018). This modularized structure enables millions of article projects to move forward in parallel where all simultaneously aim to complete a solution.

Furthermore, completing solutions can be about "filling in the missing part" of a solution. This can be a bird observation in the eBird database or adding a new argument to an argument map (see Chapter 3). Here, many persons contribute with different pieces to complete map that aims to provide a fair and accurate overview of a solution. When a new contributor needs to position a new argument into an existing map structure, it is necessary to read some of the arguments already published. These argument maps can be used to support and organize complex political discussions, but usually a moderator will need to help organize the map and approve comments.

According to Bullen and Price (2015), the abundance of online information challenges us to develop a new form of literacy that make us better able to grasp the interconnectedness between many different problems and potential solutions. Collective argument mapping may be a help in describing complex problems. In one example, College of Contemporary Health's (CCH) Obesity used DebateGraph, an argument map in an attempt to create a more comprehensive and coherent visual representation of the obesity policy space. The obesity problem is rapidly increasing, and by 2030, it is expected that approximately 40 percent of the world's population will be overweight or obese. Obesity is a complex issue and needs to be analyzed from a range of different perspectives. At the same time, healthcare professionals and policy makers face an ever-expanding amount of data that needs to be synthesized and understood. The argument map includes causes, impacts, interventions, evidence, and barriers to change.

The goal of the Obesity DebateGraph is to help all stakeholders better understand the complexity of the problem in a larger societal context, and facilitate dialogue and critical thinking across the community. Here, the mapping system aims to integrate all kinds of information resources within the same map. It can also be used as a dynamic tool to update new information. The aim is to provide an overview of the most important resources and the current debates in the field (Bullen & Price, 2015). However, when the structure in the map becomes more complex, it is a challenge to sustain a complete overview of the collective work.

Another similar example is how the Climate CoLab organized innovation contest within the framework of a contest web that includes a family of related contests. This web aims to covers a broad space of possible solutions, by organizing a large number of proposals into a complete taxonomy. The taxonomy covers different parts of the problem, and every category is mutually exclusive from each other. This strategy centers on dividing a complex problem into many small parts so individuals can more easily make different contributions. Because all the work is transparent and accessible, the community of participants can also be challenged to combine these partial solutions and create a more comprehensive solution (Malone, 2018: 182; Malone et al., 2017).

6.5 Adapting Complete Solutions

6.5.1 Background

It is suggested that a fourth type of stigmergic problem solving is directed towards "adapting complete solutions." This type of problem solving aims to reuse and modify existing solutions. In Chapters 2 and 3, there are several such examples. One example is the integration contests hosted by the Climate CoLab, which require that new solutions must build on previous winner solutions from the innovation contests. All winners can participate in a new contest and the contestants are challenged to combine their own and others' work in developing an integrated proposal (Malone, 2018: 173; Malone et al., 2017). A prominent example of this type of problem solving is open source software projects. According to Nielsen (2011: 57), the most basic characteristic with open source is that programmers don't have to start from scratch, but can build on and incrementally improve what others have developed. The open distribution of code to anyone stimulates programmers to build a publicly shared information commons. Originally, the great programmers would write their programs largely from scratch within a very short period. In stark contrast, the best programmers today will instead know how to quickly reuse code from the commons, and assess what additional code they need to write from scratch. One could claim that every new solution indirectly builds on the work of thousands of other programmers. The advantage is that problems can be solved faster and more reliably compared with working from scratch. As the size of the information commons grow, the quality of the collective work will in general also improve (Nielsen, 2011: 57–59).

6.5.2 Open Textbooks

A more recent relevant example is the production of open textbooks, building on Open Access policies and the OER movement (see

Chapter 2). Today, there is an increased interest in the production of textbooks that anyone can access both because they can support education for all and possibly also maintain and improve the quality of these books (Al Abri & Dabbagh, 2018). Many open textbook projects build on a complete version that has already been published and which only needs minor modifications to be adjusted to a new context. Because open textbooks are usually published with a Creative Commons license, other textbook authors or educators can modify the original textbook so it better fits the local educational context. It is possible to both remix, adapt, combine, and add content. Because the open textbooks are digital, they can also easily be accessed by anyone. In a recent UK report, the "American" version of the open textbooks was not seen as barrier to their usage despite issues around language and other contextual issues. The license permits both minor and major changes. Among UK academics, there is considerable interest, not only because of cost savings, but even more because of the freedom to adapt and develop textbooks (Pitt & B., 2019: 1164).

Furthermore, new open textbooks movements are being established in other parts of the world. For example, in March 2016 the first Open Textbook Summit in Africa was hosted in Cape Town (Wiens, 2016). In the pilot project Open Textbooks for Africa (OT4A), the objective is to support the adaption of currently available open textbooks and the development of new textbooks that display African knowledge to the world. The cost of textbooks represents an even larger economic cost for students in the Global South (Wiens, 2016). In one example, a group of physics teachers at the University of Cape Town revised an open textbook in physics originally written by American authors and published through OpenStax (Wiens, 2016). In the topic, history of astronomy, the authors have replaced images of an archaeoastronomical site like Stonehenge in England with other similar sites in Egypt and Kenya (Merkley, 2016). In addition, this shift to an open textbook will save 150 first-year South African students 12,000 dollars at one institution over one academic year. Some of the textbook content has been changed to better fit with an African context (Wiens, 2016).

Today, there are more textbooks being published that build on adaptation of other textbooks. A core textbook is adapted to new language editions, and several different types of curriculum. Additional content about local, regional, or national preferences is included. The adaptation of material can also make more content accessible for people with disabilities. Students can even contribute. The book format is more flexible, and it is easy to reduce the size of the book and integrate it with other media resources. These books are often published with a Creative Commons license that allows for easy modification of the original version without needing to ask for permission. In this way, new solutions can be adapted to different contexts as a part of long-term collective knowledge advancement.

6.5.3 Internet Memes

Internet memes comprise another example of adaptation of solutions, but with a purpose that is very different from textbooks. An internet meme can be defined as a group of digital items that share common characteristics of either content, form, and/or stance. In the popular culture, it usually describes the propagation of items such as jokes, rumors, videos, and websites from person to person via the Internet. A central attribute is that they spark user-created derivatives articulated as parodies, remixes, or mashups. One example is the video "Gangnam Style" performed by South Korean singer named PSY, which became the first YouTube clip to be viewed more than one billion times in 2012. In addition to watching the clip, thousands of people also created and posted their own versions of the video imitating the horse-riding dance from the original video, with videos such as Mitt Romney Style" and "Arab Style" (Shifman, 2014).

The memetic content is simple, typically conveying one uncomplicated idea that imitates the original video in some way. Usually, some degree of repetitiveness complements this simplicity. This can be highly repetitive lyrics and melody (e.g., "Leave Britney Alone"). The repetitiveness may trigger active user involvement and make it easier to remake video memes. In other memes, repetition will be about imitating a well-known person, and others may again imitate these "imitations" (Shifman, 2014: 78–88). Humor is often important, but it can be "quirky and situational," including bizarre translations and wacky teenagers. Some memes belong to specific subcultures that share their own language and symbols (e.g., LOLcats, rage comics). This culture flourishes on specific sites such as 4chan, Tumblr, and Reddit (Shifman, 2014: 118).

The memetic form is the concrete manifestation of the message in the meme, including the visual/audible dimension and the genre-related patterns (e.g., animation). The video will often be filmed in one single shot, making it time efficient to create. The visual effects are simple with little or no editing work. For example, the meme "Leave Brittney Alone" only required a white piece of cloth, a camera, and a modicum, making it possible to make a new version with limited resources (Shifman, 2014: 78–88).

Previously, mass-mediated content would often be transmitted simultaneously from a single institutional source to many people. Memes are different because they spread gradually through many interpersonal contacts. The producers of memes are aware of each other because the content is circulated, imitated, and transformed by many different users. Memes should be understood not just as single entities that propagate well, but also as groups of content units with common characteristics and shared values in a digital culture (Shifman, 2014).

The memetic content will usually invite others to reuse and share the original work. Because most of the content is user-generated and reflect the opinions of a layperson, people will tend to react more to the memetic video compared with a professionally made video. It will often be perceived as more meaningful to respond to a peer than a celebrity. It is also more likely that other peers will comment on the new video responses, and thus reinforce a stronger sense of community (Shifman, 2014: 75–76).

In addition, because amateurs produce the videos, they will usually be textually incomplete or flawed, compared with a professionally made video. Paradoxically, a "bad" video production can make a "good" meme because inconsistencies often stimulate further spread and dialogue, active user involvement, and recreation of content. The unpolished, amateur-looking videos motivate people to address the puzzles: what is missing, or how bad it is. The memes become part of a socially constructed public discourse that include diverse voices and perspectives (Shifman, 2014).

Another attribute with memes is that they easily become popular because they are interlinked with each other. A new version of a specific video will draw attention back to the initial memetic video in a reciprocal process. This increases the likelihood of appearing in YouTube's suggestions bar as a highly relevant search result when viewers search for the initial meme. This is particularly important with user-generated content and amateur videos that do not necessarily receive many views. The metadata with viewer statistics and comments will constantly be aggregated and displayed to all users. This information is increasingly becoming an influential part of the process itself – with people considering it before they decide whether to remake a video, (Shifman, 2014: 32–33).

In the political domain, internet memes open new types of democratic discussions in the online setting. It is an accessible, cheap, and "enjoyable" way of voicing one's political opinions. It allows for the creation of multiple and diverse opinions. Major political events often spur a large number of commentary memes, which are used for political advocacy in different ways. Social media allows for new types of political participation, especially among younger citizens. This was first demonstrated in the 2008 US presidential election campaign, when massive amounts of politically oriented user-generated audiovisual content was created. Clips such as "Obama Girl," "Wassup," and "Yes, we can" attracted millions of viewers. The political campaigners produced only a fifth of the most viral videos, while interest groups and other nontraditional actors produced the rest. Popular videos were also transformed into memes, addressing and advocating issues with both humor and seriousness. (Shifman, 2014: 51–52, 120–126).

Another example is the "Pepper-Spraying Cop," a meme originating from November 2011, when students gathered as part of the Occupy Wall Street protest. When they refused to move, two police officers reacted by pepper-spraying a row of still-sitting students directly in their faces. Shortly after, videos documenting the incident were uploaded to YouTube, generating negative reactions in the public opinion. A photograph in which one of the officers was spraying the students quickly evolved into an internet meme. In the aftermath of the protest, the image was photo edited into a large range of contexts, spanning historical, artistic, and pop-cultural-oriented backgrounds (Shifman, 2014: 51–52).

Two main groups of memes were produced. The first group of user-generated images focused on political contexts. For instance, the police officer is shown pepper-spraying iconic American symbols such as George Washington, the Constitution itself, and other freedom fighters across the globe. All these new meme versions tell the same story, that the police brutally violated the basic values of justice and freedom (Shifman, 2014: 51–52).

The second group of memes is pop-culture oriented and shows the police officer pepper-spraying icons such as Snoopy and Marilyn Monroe. Some of these versions show an entirely different use. In one case, the pepper-spraying cop is used to criticize Rebecca Black – a widely scorned teen singer and internet phenomenon. The memetic content can also lead to stance alternations. While the politically oriented versions are mainly sardonic, the tone in the pop-culture-oriented ones is more playful and humorous. The "Pepper-Spraying Cop" meme shows a diverse type of diffusion and evolution (Shifman, 2014: 51–52).

Furthermore, memes can be part of grassroots action that links personal stories and political issues in an attempt to empower and mobilize citizens. A protest like the American Occupy Wall Street was not backed by a strong formal organization, but rather by digital networks. The slogan in the Occupy Wall Street's "We are the 99 percent" meme refers to the argument that 1 percent of the American population controls the country's financial wealth. The memes showed a person holding a handwritten text depicting a gloomy personal story. People would show their agony with a serious facial expression and by holding "I am the 99 percent." The stories could be about not affording medication or struggling to provide for children. The combination of repetition and variation turns these personal stories into a larger political issue. The misery is not just a personal problem because the collective network of memes show that the system has failed (Shifman, 2014).

On the one hand, a meme is unique, and on the other hand, the new version will signal membership in a large community that use similar messages. The multitude of new versions also helped promote the topic on the mass media agenda, drawing more attention to the movement. The popularity of the "99 percent" meme even generated a countermeme: the 53 percent meme. Conservative activists introduced a rhetoric with an opposite stance, bringing in conflicting information, underlining that only 53 percent of American people pay income tax. It illustrates how a stance in the meme can either imitate a certain position or introduce an alternative perspective based on the same idea (Shifman, 2014).

Memes play an important role because shared slogans communicate easily across large and diverse populations. Personalized content is also shared in large-scale, fluid social networks across the globe by ordinary internet users. The power in the memes lies in the message not just being standardized content distributed to everyone, but instead being personalized and adapted so individuals can tell their own stories. The community is simultaneously both local and global (Shifman, 2014: 127–129).

6.6 What Is Human Stigmergic Problem Solving?

6.6.1 Solution-Centered Collective Problem Solving

In stark contrast to swarm problem solving, human stigmergic problem solving is centered on the improvement of solutions, and not predefined problems. These solutions can be improved by rating, reestimating, completing, or adapting them. These solutions change continuously, whether it is a new individual rating or a new edit of an unfinished draft. Problems are relevant to these solutions, but they do not constitute the premise for this type of collective problem solving.

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In stigmergic problem solving, it is assumed that solutions exist independently of the problems. As pointed out by Von Hippel and Von Krogh (2015), one should be aware that there already exists a wide range of solutions in the environment. They use a story to illustrate their point: An employee visits a trade show "just to see what is new." There, the employee discovers a new payroll-processing software, and thinks it might be relevant to use in his firm: "I wasn't thinking that we had any payroll-processing deficiencies, but now I recognize that we do, and that this technology might make this work more effective." It is the new solution that creates a need. The formulation of a problem, that the payroll system in his firm is not as effective as it should be, is formulated after the solution has been discovered. In the solution–need pair there is no initial independent problem identification. One could describe the inferior previous arrangement as "a problem," but this is only possible to do post hoc after the discovery of a new solution (Von Hippel & Von Krogh, 2015). With the online setting, these "trade shows" are everywhere because so much information is stored on the Internet.

Many more solutions are available than ever before. They are stored as a collective memory in the online setting, which makes it possible to easily find previous solutions, reuse and modify them at any point of time. A solution can be used to solve many different problems for different persons at different points of time. The solutions range from complete independent solutions, estimated solutions, to very incomplete solutions. The environment functions like an external memory that registers and stores a proposed solution or part of a solution. When stored in a digital format, solutions can be reused in many intended and unintended ways. As the examples show, it opens up for the production of many different versions of an existing knowledge product. This happens as a distinctly asynchronous problem-solving process, contrasting human swarm problem solving that stresses a rapid and synchronous response to a specific problem. If the traces of the work (solutions) are shared openly, they can be reused in many different ways in the future.

The problem of free riding is almost removed because it requires little additional effort or cost to leave traces of your work in the online setting. "Free riders" are here defined as individuals who benefit from others' efforts without doing anything in return. An answer to a problem stored openly in an online setting will not only solve a specific time-restricted issue in a local context, but the solution will automatically become part of a huge collective "map" of interconnected knowledge. Open sharing often demands very little extra work. For example, if someone posts an answer to

Table 6.2. *An overview of the four different types of stigmergic problem solving*

	Sematectonic vs. marker-based stigmergy	Quantitative vs. qualitative stigmergy	Examples	Similarities with other animals
Rating complete solutions	Marker-based	Quantitative (actions performed on the same action)	– Reddit (collaborative filtering) – YouTube	Ants: Gradient following in a single pheromone field
Reestimating solutions	Sematectonic (marker-based)	Quantitative (actions performed on the same action)	PredictIt	Ant trails
Completing solutions	Sematectonic (marker-based)	Qualitative (actions performed on separate parts of the medium)	– Wikipedia – Argument maps	Wasp nest construction
Adapting complete solutions	Sematectonic (marker-based)	Qualitative (actions performed on separate parts of the medium)	– Open textbooks (revising) – Memes (remixing)	Termite nest building (decisions based on combinations of pheromones and the construction work as it is)

a problem in a discussion forum or makes a video response that demonstrates how to solve a practical issue, many other people can at a later point access this "frozen" solution and reuse it. On the Internet, mutual interaction mechanisms like tit-for-tat (e.g., "prisoner's dilemma") do not function in the same way as in the offline setting. In this way, the web itself can be regarded as a shared memory with solutions that are left as permanent traces in the online setting (Heylighen, 2011, 2015).

Table 6.2 gives an overview of the four different types of stigmergic problem solving that have been discussed in this chaper and what type of stigmergic mechanisms they build upon.

The table shows that "completing solutions" and "adapting complete solutions" (remixing and revising) primarily build on qualitative stigmergy, while "rating solutions" and "reestimating solutions" build on quantitative stigmergy. Human stigmergic problem solving will also often combine aspects of sematectonic stigmergy with supplementary marker-based stigmergy that produce relevant metainformation.

6.6.2 "Rating Complete Solutions" as Marker-Based, Quantitative Stigmergy

Because an enormous amount of knowledge products is being stored in an online setting, it is essential to develop mechanisms that can rate the quality of all these contributions. On one hand, the rating of these complete solutions can be regarded as marker-based stigmergy. Users will actively "mark" knowledge products, by providing different types of metainformation, like qualitative comments and quantitative ratings. Videos published on YouTube automatically map user behavior by generating reading statistics, but users can also actively choose to like, subscribe, or comment on a video.

On the other hand, these assessments and reviews will change over time. The aggregated metainformation about the solution will often be displayed as a rating result, whether this is number of likes, subscribers, or the frequency of knowledge sharing (e.g., retweets). In science, number of citations is one such rating mechanism. All of these build on quantitative stigmergy.

At a macro level, this metainformation compares and ranks a collection of solutions according to their quality and relevance. When there are a huge number of alternatives, a rating system provides a collective assessment and filtering of the available solutions. Algorithms in search engines also give much weight to these user ratings when they index and rank knowledge products. Like with the ant trail-laying systems, the rating systems attempt to provide the shortest route to the best solution through the enormous amount of digital information that constitute our human collective memory.

However, because so many solutions are produced online, only a few will be visible in the search engines. One challenge with top-rated solutions is that the most popular ones are not necessarily the best one. The structure of the web follows a winner-take-all distribution that amplifies attention towards a few solutions, while many remain unnoticed. Because of positive feedback, the initially most promising solutions will grow very quickly, while the rest will be lost. Without already being on the ranking list, it may be difficult to initiate interest in a solution because few persons will know about it. Search algorithms tend to increase the current imbalance and reinforce existing networks of popularity. Their lack of transparency also makes it more difficult to understand why some solutions get more attention (Halavais, 2018: 102–115).

6.6.3 "Reestimating Solutions" as Quantitative, Sematectonic Stigmergy

"Reestimating solutions" is a type of stigmergic problem solving, which centers on different types of dynamic forecasting. A market mechanism typically gives continuously updated information about the probability of a collective outcome. While "rating complete solutions" builds on marker-based quantitative stigmergy, "reestimating solutions" utilize quantitative, sematectonic stigmergy. The market price or the "voting leaderboard" is considered the most accurate indicator of the solution. Individuals can access the aggregated prediction of the entire group, which is continuously updated (e.g., PredictIt, Kickstarter). Based on their individual background knowledge, they can choose whether to engage or not. At an individual level, single individuals make estimates or bets, which vary in performance, but at the collective level, the aggregated fluctuating market price is considered to cancel errors and provide the best predicted estimate of a solution. Both "rating complete solutions" and "reestimating solutions" are similar in giving individuals access to transparent updated information about the crowd opinion at any time.

6.6.4 "Completing Solutions" as Qualitative, Sematectonic Stigmergy

"Completing solutions" is another type of stigmergic problem-solving which manifests itself in the urge to fill in the "missing part," like a piece of the puzzle in an argumentation map, or missing data from a geographical area in an eBird database. The perceived incompleteness of a solution triggers the motivation to make new contributions. However, the individual does not have to know what the final solution should look like. This mechanism builds on qualitative, sematectonic stigmergy.

Stigmergic actions stimulate their own continued execution via the intermediary of the marks they make. The completion of one task triggers a new task. The motivation will be to fix something that is missing, by "filling something out," "fixing an error," or "creating new order" (Heylighen, 2015). The "shared material" is itself regarded as a type of communication that allows for coordination independent of prior planning, norms, or explicit discussions (Rezgui & Crowston, 2018).

It echoes the construction work of bees, who are also automatically triggered by a special "configuration of incompleteness" in the solution. In their construction work, a type-1 stimulus triggers action A by individual 1. Action A will then transform the type-1 stimulus into a type-2 stimulus that triggers action B by individual 2. This mechanism allows for effective indirect cooperation between individuals (Theraulaz & Bonabeau, 1999). Like the bees, a contributor on Wikipedia will first begin to contribute when recognizing the right start conditions that correspond to that individual's background knowledge. The solution is mediated through a draft version that is changing over time. Further work is stimulated by the current state of the incomplete document with its limitations and errors that stimulate further modification. Each author is stimulated by what previous authors have written and use this information to either add, revise, or remove content (Parunak, 2005).

The contributors build on others' work by removing, adding, or correcting existing content. Anybody can change almost anything, and there is no editor who divides the tasks. On a macro level, this type of stigmergic problem solving can also involve large complex, self-organizing system with contributions from individuals distributed all over the globe. One example is the eBird database or the global network of Wikipedia articles. In these systems, thousands of people make independent contributions according to their interests and competence without any centralized control. Large projects will often be modularized, making it easier to participate in a smaller separate part. Based on their expertise, individuals make relevant contributions of different size, only coordinated indirectly through an online environment.

This type of collective work is also reliant on appropriate digital technologies like a wiki or an argument map technology. Several systems combine sematectonic stigmergy with marker-based stigmergy that permit asynchronous reflective communication about the ongoing collective work. In Wikipedia, this includes discussions of content, wording, and structure on the talk page of the different articles. The transparency of this metadiscourse provides future contributors with an informal review of the quality of the article and information on how it can be improved. These discussions may emerge over a very long time, involving many persons who are unknown to each other and not even aware of the new contributions being made.

In addition, the active contributors in the community use much time discussing and developing policies and procedures on separate wiki pages. This explicit coordination constitutes a growing proportion of all the work being done in Wikipedia (Kittur & Kraut, 2008). On one hand, sematectonic stigmergy will be present in the editing of the Wikipedia article. On the other hand, marker-based stigmergy will be present on the talk pages that are separate but attached to each article.

6.6.5 "Adapting Complete Solutions" as Sematectonic, Qualitative Stigmergy

In adapting a complete solution, a part of the original solution is reused and some type of revision is done, which can both involve minor or major changes. Because information is digitized, it has become much easier to make multiple new versions of a knowledge product, whether this is a textbook or a meme. This adaptation builds on sematectonic, qualitative stigmergy, since the new solution is reliant on direct modification of the original content. This repackaging can be done through either revising or remixing a solution.

In revising the knowledge product, the entire content is modified. The original open textbook will be transformed into a new complete textbook, like when an open textbook is translated into a new language to make it appropriate for a local context. This customization process can involve both major and minor changes, parts of the original content can be removed, modified, and new content can be added. Adaptations of open textbooks will usually require expert contributions because the goal is to end up with a "polished" knowledge product that can be used in an educational institution. Because of the Creative Commons license, a new author can modify the text without notifying the original author. This license exemplifies marker-based stigmergy that permits flexible reuse of the original work.

When remixing a work, a new interpretation is created from an individual part of it. In memes, some part is retained, while other parts are substituted with a new version of the same content through editing an image or adding a new soundtrack. In an offline setting, memes will usually change both their form and content because it is almost impossible to retell something in exactly the same way. However, in the online setting, one can easily retain some part in its complete original form. For example, in the "Occupy Wall Street" memes, everyone made a meme with a written text saying, "I am the 99 percent" on the video clip. New versions followed the same "production or remix rules." The content will often aim to be unpolished, authentic, and emotionally laden, which increases the likelihood of getting response from others. This is an example of sematectonic qualitative stigmergy.

Furthermore, memes are interesting because the interlinking and sharing of content is important. The adaptation time is quick because many individuals post a video based on their first shooting. Because a large number of new versions are produced, one could claim that memes also utilize a type of sematectonic quantitative stigmergy. Since all memes are linked together in a network structure, they tend to get a lot of attention in search engines. If the memes are made as personal stories about a political issue, they can together represent a powerful political statement (Shifman, 2014).

6.6.6 Improvement of Solutions as the Basis for Human Stigmergic Problem Solving

This chapter has intended to show how human stigmergic problem solving process is solution-centered. It builds on a version of a solution that already exists, either partially or complete, and aims to improve it by rating, reestimating, adapting, or completing it. These solutions may be relevant in many different ways, like a video or a Wikipedia article, which can be used to help solve problems for many different persons at different points of time. Consequently, a specific problem is not defined in advance, but can instead be regarded as an offspring of a solution. The solution is offered to anyone as part of a shared collective memory that emerges over a longer period.

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CHAPTER 7

The Origins of Human Stigmergic Problem Solving

7.1 Background

As already addressed in the previous chapter, the basic unit in stigmergic problem solving is the production of a "materialized" solution that in some way can be stored and reused. Today, the digitization of information and the invention of the Internet represents a revolution in both the scale and types of such solutions that now are available. If we look back in history, the storage of human knowledge has been a major challenge. Improvements and technological innovation have been essential in increasing our ability to solve problems collectively. In order to better understand the basic mechanisms of stigmergic problem solving, this chapter briefly describes the invention of writing and the printing press, two of the most important historical achievements. In human cultural history, most researchers agree that these two technological transitions resulted in a significant improvement in our collective external memory system which led to major economic, social, political, religious, epistemological, and educational change (Donald, 1991; Ong, 2013).

The last major transition in stigmergic problem solving has unfolded itself in recent decades with the invention of the Internet, which enabled new types of large-scale collective problem solving (Lévy, 1999). Today, information can be shared with more people than ever before and across time in an unprecedented way. Compared with prints, it is very easy to technically copy and reuse all kinds of digital content without any additional cost. An important catalyst is the declining price of storage of information. The different types of human stigmergic problem solving from the previous chapter illustrate how human stigmergy is increasing in complexity and evolving into new forms in the online setting.

However, the historical analysis in this chapter will move back in time to examine the basic rudimentary mechanisms in human stigmergic problem solving. This is a type of collective problem solving that follows a long

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historical line of technological development, with two milestone achievements. The invention of writing initiated a "reuse revolution," which the printing press transformed into a "copy revolution." The chapter explores how stigmergic problem solving evolved from a simple form into increasingly complex forms, which in the final section is labeled as frozen and fluid stigmergic problem solving.

7.2 The Invention of Writing

The invention of writing can be regarded as the first example of human stigmergic problem solving. Before writing, human sharing of knowledge was always limited to shared practices and verbal communication, but now it became possible to store information for a much longer time independent of the original writer. This transition represented a major advancement in the establishment of a collective memory because information could now be stored and reused, not only for a longer time period, but the information could be transported in the environment.

Writing was invented as a symbolic system that could support the limited memory capacity of humans. Without any transfer or storage of knowledge, there is always a risk that valuable information will be lost. For thousands of years after the Agricultural Revolution, human social networks remained relatively small and simple because they were very difficult to organize without being able to store information. Knowledge sharing happened through verbal communication or observational learning. In order to develop a larger and more complex society, it became necessary to invent a more effective information sharing system (Fischer, 2003: 28–29).

It was the ancient Sumerians, who lived in today's Iraq, who first invented such a system between the years 3500 BC and 3000 BC. Sumer's expanding society needed to invent new ways to administer and manage its raw materials, manufactured goods, workers, planted fields, tributes, royal and temple inventories, incomes, and expenditures. Human memory was no longer enough, and a writing system was invented to process mathematical data with the help of two types of signs. The number of signs was a combination of base-6 and base-10 numeral systems, giving signs for 1, 10, 60, 600, 3,600, and 36,000. The other type of signs represented information about people, animals, merchandise, territories, dates, and so forth. The writing combined numerals with pictograms and symbols to describe facts and figures and identify commodities. The first texts were economic documents, used for accounting such as recording the

Figure 7.1 Inscribed clay tablet from third millennium BC. Proto-Cuneiform clay tablet with seal impressions: administrative account of barley distribution with cylinder seal impression of a male figure, hunting dogs, and boars ca. 3100–2900 BC. Sumerian, Mesopotamia, probably from Uruk (modern Warka), photo Raymond and Beverly Sackler Gift, 1988/The Metropolitan Museum of Art

payment of taxes, the accumulation of debts or the ownership of property (Fischer, 2003: 22–33; Harari, 2014: 136–140). The system gave the same type of information, "so and so many of such and such a commodity." Because writing was time consuming, the outreach was limited to a very small reading public, but the practice was still important for record-keeping. The writing was done on clay tablets, an abundant material in the Middle East, which was easy to work on (Figure 7.1). Clay makes it easy to erase information and preservation is simple because the clay only needs to dry in the sun or one can bake it (Fischer, 2003: 22–33; Harari, 2014: 136–140).

In another system from the same period and area, numerals were made by pressing the round end of a reed stylus vertically into the clay. The first written texts were partial scripts, as the system of material signs could only represent specific types of information within a limited area. Writing did not intend to copy spoken language, but was instead used in areas where spoken language was inefficient (Fischer, 2003: 28–36; Harari, 2014: 138–144).

Between 3000 BC and 2500 BC, more signs were added to the Sumerian writing system, and it was gradually transformed into a full script that we today call cuneiform. The individual signs in this early writing system gradually became separated and independent from the eternal world of objective phenomena. The signs became stylized, making it easier to produce diverse texts and prolong the spoken word in a multitude of ways. By 2500 BD, kings were issuing decrees, and some were even writing personal letters. Within a thousand years, phonetic writing has made itself the most fundamental tool for Mesopotamian city-states growing into powerful empires (Fischer, 2003: 28–36; Harari, 2014: 138–144).

Systemic phoneticism as a complete writing system evolved over a long period of time. Fischer (2003: 33) claims that all other writing systems and scripts are derivatives of a basic original idea that emerged between 6,000 and 5,700 years ago in Mesopotamia. This idea of systemic phoneticism spread both east to the Indus and west to the Nile, and played an important part among other rising civilizations (Fischer, 2003: 32–33). Obviously, the writing systems evolved, and with time, the number of symbols was gradually reduced, making the symbols more abstract. The early clay tablets show at least fifteen hundred different pictograms and symbols, each representing one concrete object. In the "sounding out" or phonetization of "foot," "hand," or "head," human writers and readers were acknowledging the unique relation between an object, its graphic representation, and its phonetic value or cue. Because abstract ideas or names were difficult to grasp, their meaning also referred to a concrete object. For example, a "mouth" could mean both mouth and speech, and weeping combined the two concrete pictograms "eye" plus "water." Over time, the pictograms became more standardized and abstract, but with the same phonetic value. At one point, the object itself was often no longer recognizable in the pictogram, but the pictogram's relation to the object and its phonetic value would still remain. The pictogram had become a readable symbol, but these symbols still only covered a small area of system-external referents (Fischer, 2003: 29–30). This was still not complete writing, but a rich system of reminders that met the immediate demands of its users. Graphic symbols became signs of a writing system first when the phonetic value of a symbol was no longer bound to a system-external object within a system of limited, similar values. A person could then read a sign for its sound value alone within a standardized system of limited signs, this representing the birth of complete writing and systematic phoneticism(Fischer, 2003: 32–33).

At first, Sumerian systemic phoneticism was of minor importance, used to transcribe foreign words or phonetically sounding out hard-to-identify signs that held several possible meanings. From the early fourth to the early third millennium BC, most Mesopotamian writing remained essentially pictographic, with only limited phoneticism. However, by 2600 BC, phonetic writing had increased, and the fifteen hundred symbols had been reduced to about eight hundred pictograms, symbols, and signs. Logography (whole-word writing, including homophonic) and phonography (exclusively phonetic writing) did not fully develop until about 2400 BC (Fischer, 2003: 32–33).

In Egypt, writing was taken in around 3000 BC, but instead papyrus was used as a writing material. Papyrus is a kind of paper made by pounding strips of the plant Cyperus papyrus into sheets. It is thin, light, flexible and easily stored, and thus offers significant advantages compared with the bulky clay tablets. The ink dried easily, making the writing quick and it required less surface area per word than cuneiform wedge syllables. Papyrus writing continued in Egypt until the first few centuries AD. The Egyptians developed another full script known as hieroglyphics that can represent spoken language more or less completely (Fischer, 2003; Harari, 2014: 138–144). Hieroglyphs compose a writing system with more than 1,000 distinct characters, including both ideograms (representing a whole word or idea in a single sign) and phonograms (representing either an alphabetic sound or a group of consonants). This advanced writing system was used in formal inscriptions on tomb and temple walls. However, a simpler version known as hieratic was used for the multitude of everyday documents required by the bureaucracy. One only had to use 450 signs, hieratic was quicker to write and more economical of space (H. Wilson, 2019).

Both in Sumer and pharaonic Egypt, the invention of writing was combined with the simultaneous invention of new techniques of archiving, cataloguing, and retrieving written records. The scribes, who could write, became the most important social group (Figure 7.2). They were also able to find and reuse information by using catalogues, dictionaries, calendars,

Figure 7.2 Egyptian scribes managing granaries when reaping the corn. The scribes record quantities of harvest wheat, probably for tax purposes. Tomb of Menna. Detail from the frescoes in the vestibule, XVIII dynasty of Amenhotep III in Luxor. Original ca. 1400–1352 BC, photo Z. Radovan/Bible Land Pictures/AKG/NTB

forms and tables (Harari, 2014: 144–145). Each scribe had his own writing kit; it was a slate palette with two shallow cups for holding red and black ink cakes, and it also had a thin wooden brush case and small water jug. An ancient Egyptian scribe wrote much in the same way as we do with watercolors today. Scribes trained young boys at special schools, thus introducing the world's first formal educational systems. Scribal education in the hieratic script required training for five or six years (Fischer, 2003: 46–50; Wilson, 2019).

With time, an entire social class of scribes arose, most of them employed in agriculture. An essential activity was record-keeping, making and updating of lists. Scribes measured the fields for taxation purposes, checked deliveries of harvested grain, and weighted precious metals. They helped illiterates draw up contracts, letters, inventories, and wills, and made agreements and intentions permanent and binding. The scribes became the world's first lawyers. To become a priest or lawyer, a scribe would need even more training and learn more signs. Lawyers had to be familiar with civil and religious laws and have knowledge of previous official records, which were administered by archivists. Doctors also compiled their own collections of recipes and treatments, and many copied content from texts found in the temple library. Egyptians believed that the transformation of speech to writing made the words real and true (Wilson, 2019).

The written word was without doubt the vital precondition for the development of much more complex societal structures such as the dynasties. Egypt's kingdoms united a few centuries after the hieroglyphs' were taken in use. The way we write today and even some of our signs are the descendants of ancient Egyptian founders (Fischer, 2003; Harari, 2014: 138–144).

The invention of writing made it possible to save solution to collective problems. It emerged as a need in societies that wanted to expand in size. A collective memory was the basic precondition for the collective organization of more complex activities. It made it possible to reuse information in a much more flexible way anywhere by anyone. In addition, systematic phoneticism opened up for another way of producing ideas beyond verbal information exchange.

However, until the invention of the printing press, human stigmergic problem solving was limited because it was very time consuming to copy existing knowledge. Papyrus and paper, which allowed for more substantial writing, decayed with time. The access to knowledge was also limited because only a few people could read. Therefore, it is uncertain whether writing had any substantial impact on human cognition since such a small percentage of people in the population would know how to read and write. However, it is worth noting that Plato, in Phaedrus, criticizes the activity of reading because it weakens our ability to remember (Halavais, 2018: 38).

7.3 The Invention of the Printing Press

In the long term, the writing system and practices gradually improved. The symbolic systems evolved into the alphabet and the Indian numerals we use today. These symbols were much more flexible since they could represent "almost anything." However, the writing material still posed significant limitations in the cumulative accumulation of knowledge. Clay tablets made it possible to write only a very limited amount of information. Although papyrus was lighter and could store more information, it would gradually be corrupted. It was also time consuming to copy information because scribes had to write every new book copy by hand. Consequently, much knowledge was lost because written texts were not copied. When goldsmith Johannes Gutenberg invented the printing press around 1440, it solved many of these problems (Figure 7.3). It drastically reducing the cost of printing books and removed the need for human scribes. It opened up for a new type of collective knowledge advancement across countries and among a broader part of the population. Before the time of printing press, copying texts happened seldom, now mass copying became the new norm. This "copy revolution" resulted in the reuse of existing knowledge, but it also opened up new ways of improving our knowledge.

7.3.1 Mass Copying of Printed Information

Even before printing was invented, the shift from parchment to paper as a cheaper writing material had contributed greatly to the writing of more letters, diaries, memoirs, and notebooks. Writing was important for merchants and literati. However, texts still needed to be duplicated by hand, making it both time consuming and expensive. Since the invention of writing, preservation had been the major challenge. Before printing, no manuscript or document could be preserved for long without undergoing corruption. All documents were vulnerable to moisture, theft, and fire, and their loss was inevitable. While stone inscriptions endured, papyrus or paper records crumbled, giving rise to the rule: "Much is preserved when little is written; little is preserved when much is written." If one wanted more than one record, scribes would always have to copy the text. Copying of manuscripts was dependent on both the support and shifting demands of local élites and the availability of scribal labor. As a result, only a few books or texts could be copied, enriching a few areas while many others were forgotten. The perseverance of the antique heritage could only be very limited in scope (Eisenstein, 1980: 113–114, 217–218).

With this background, possibly the most important feature with print is preservation of knowledge. With printing, the durability of the writing material became much less of a problem. The new strategy was not to store knowledge by locking books down in vaults, but instead to produce and distribute a multitude of copies beyond the reach of accident. Preservation was achieved by quantity, using abundant supplies of paper, instead of expensive high-quality skin. Although printed paper still decayed with time, the mass production of books made it unnecessary to think about preservation (Eisenstein, 1980: 114–116).

The enormous increase in circulation show evidence of the instant success of printed books. By the end of the fifteenth century, after 50 years of printing in workshops in 236 European towns, at least 35,000 editions

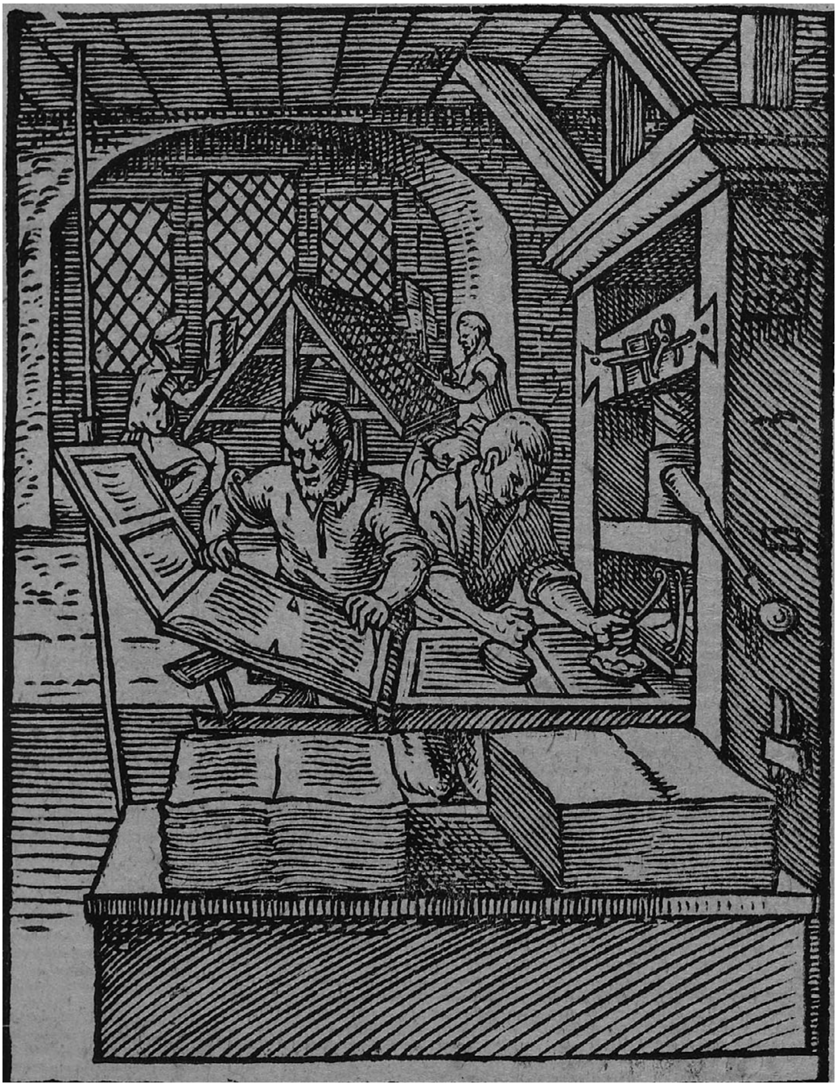

Figure 7.3 *The Printer's Workshop*, 1568. One of 133 woodcut book illustrations, showing the interior of a printing press. In the foreground, two men working at the press, the right man applying ink onto the letterpress matrix, the left man taking off a freshly printed sheet. In the background, two men seated in front of type drawers, holding a composition stick. In the foreground, two piles of printed and blank sheets of paper. Credit: From Panoplia by Hartmann Schopper. (Frankfurt-am-Main, 1568), Photo © The Trustees of the British Museum

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had been produced, amounting to 15–20 million copies. (Febvre & Martin, 1976: 186). During the sixteenth century, between 150,000 and 200,000 different editions were published. With an average of 1,000 copies per edition, between 150 and 200 million copies were published. During this period, books were made accessible to anyone who could read (Febvre & Martin, 1976: 262).

The quantity of book copies established a new type of permanence in knowledge production. The new idea was that valuable information could best be preserved by being made public. This idea ran counter to tradition, but it was the necessary precondition for early-modern science and Enlightenment thought. This mass copying of books also resulted in a democratization of the access to knowledge. Many more people could now learn both old and new knowledge by reading books (Eisenstein, 1980: 114–116).

In the first phase after the invention of the printing press, the primary focus was on saving and reviving ancient texts and ideas. It is important not to forget that the printer and the bookseller worked for profit. Fifteenth-century publishers only financed books that would likely sell enough copies to raise a profit. The Latin classics that were most popular continued to be those that had been most popular in the Middle Ages. Up until fifteenth century, printing also helped circulate those humanist texts that had been most commonly used in the Middle Ages as an introduction to classical literature. Among them, the most popular translations into the vernacular languages were the works of Aesop and Cato. As such, the immediate effect of printing was to increase the circulation of those manuscripts that were already popular. This increased the volume of some selected works and let other texts be forgotten (Febvre & Martin, 1976: 249, 253).

Before 1500, 77 percent of the books were printed in Latin. In other languages, there were typically translations of the whole Bible into German, Italian, French, Spanish, Flemish, and Czech. Religious works dominated, with 45 percent of the total production, including not only the Bible, but also numerous other books needed for Church services. Both clergy and laypeople wanted Books of Hours (devotional work) and local priesthoods made breviaries and missals. Of other books, medieval and contemporary literatures comprised 30 percent, and books about law and scientific subjects comprised 10 percent of the total production. There were few editions of the great classics of medieval philosophy or theology because the reader group was limited to students and teachers at the universities (e.g., Bologna, Cologne, and Paris). These books were commentators of the Bible, like William of Ockham and Aquinas (Febvre & Martin, 1976: 249–251).

Printers sometimes hesitated to publish scientific works in Latin because the reader group was very limited. In science, many texts remained available only in manuscript for a longer period than in any other field. The number of authors getting into print on scientific subjects rose each year, but the majority of works had no lasting scientific interest because it was within practical astrology. Most of the extensive "scientific" literature written in the vernacular and intended for a mass market was medical remedies, prognostication, and astrological tables. Works dealing with practical astrology were particularly popular in both fifteenth and sixteenth century among a large group of readers including lawyers and merchants. At the same time, the most original mathematical work by Nicolas Chuquet (1484) remained in manuscript. There was an absence of objective critical sense and there were few advances in scientific theory. However, printing helped draw public attention to technical works in architecture, agriculture, and machines. It was not before in the middle of the seventeenth century that the first reviews of research appeared. Although early printing certainly helped scholars in some fields, it did not in general strengthen the acceptance of new ideas or knowledge. Even the new geographical discoveries tended to be ignored, and only after 1550 did the situation change (Febvre & Martin, 1976).

The first decades of the sixteenth century were similar to the fifteenth century, with religious work dominating. Religious books continued to be popular in the vernacular languages, including different illustrated devotional works like Books of Hours. Many more bibles were also published, including specific translations of parts of the Bible, especially of the Psalms, the Apocalypse and Job. Devotional literature, particularly mystical works, amounted to one-sixth of the entire output. For example, Thomas á Kempis's *Imitation of Christ* was the most frequently reprinted work of all (after the Bible) down to recent times. However, because of the overall increase in book production, the proportion of religious works decreased and classical texts kept increasing. For example, in Strasbourg in the fifteenth century, more than 50 percent of all books were religious, while fewer than 10 percent were by classical authors. This changed in the period from 1500 to 1520, with only 27 percent being religious and 33 percent being either Latin or Greek texts or work by contemporary humanists. The different works of Virgil, printed 161 times in the fifteenth century, came out 263 times in the sixteenth century, in addition to the innumerable translations (Febvre, 1976 #1298).

If we look at the beginning sixteenth century, there is a significant increase in the diversity of the books being published. Books were increasingly published to support collective knowledge advancement in a range of different societal sectors. In addition to the clergy, students and the upper classes, the bourgeoisie also began to form their own libraries (Febvre, 1976 #1298: 78, 88). For example, book became very important in the legal profession. The number of lawyers increased steadily, and they needed access to law collections. Lawyers and royal officials also had their private libraries. Sixteenth-century members of the legal profession were an important group among booksellers. While churchmen were declining in relative importance as purchasers of books, lawyers, members of an ascending social group, became steadily more important. Their importance as booksellers' clients was especially high in Paris, the seat of government and of the courts of appeal, where the legal profession numbered 10,000. Of 186 Parisian collections listed between 1500 and 1560, 109 belonged to lawyers and royal officials, and only 29 to clergymen. Few soldiers owned libraries, but a surprising number of merchants, tradesmen, and artisans owned books, sometimes in large numbers. These included haberdashers, weavers, drapers, tanners, grocers, cheesemongers, hawkers, locksmiths, pastrycooks, skinners, dyers, shoemakers, and coachbuilders (Febvre & Martin, 1976: 263–264).

Furthermore, people gained interest in fiction, especially moralizing narratives like romances of chivalry. In Spain, Amadi de Gaule became immensely popular in 1508, and numerous new stories were produced in the following years. A wide reader group was interested in history, but rather legendary histories like the legend of Troy than objective historical accounts. In this period, stories were printed that could pass as national epics (e.g., King Arthur). These books were often illustrated and published in vernacular languages, targeting merchant customers and the wealthy bourgeoisie. In addition, there was an enormous increase in elementary grammars in Latin, showing the rapidly increasingly interest in learning how to read among the population. (Febvre & Martin, 1976).

The book fair was also a great gathering place for ordinary people, and a large number of the popular books was sold here such as almanacs, prophecies, popular storybooks, often illustrated with woodcuts, were all on sale (Figure 7.4). As the book production increased, systems were invented to provide a better overview of the total production. At the Frankfurt Fair, catalogues were used to give visitors an overview of the books available. These were forerunners of the innumerable bibliographies, which are nowadays produced at regular intervals. Catalogues of books

Figure 7.4 Martin Luther's translation of the New Testament, 1524. Luther's first translation of the New Testament arrived in September 1522. This 1524 edition was printed by Melchior Lotter in Wittenberg, Germany. Its most stunning distinction is the 44 woodcuts made by Georg Lemberger in what is known as Fürstenkolorit. In this type of illumination, the woodcuts are colored and heightened with gold, suggesting this Bible was created for an aristocrat. Luther downplayed the importance of priests, arguing that the divine text was straightforward enough for everyone to read and understand, Image Courtesy Museum of the Bible Collection. All rights reserved. © Museum of the Bible, 2021

were already from 1470, and it eventually evolved into a general catalogue of all the books available there. They became important among publishers in making the titles they produced more widely known (Febvre & Martin, 1976: 230–231).

Book learning represents perhaps the most important social revolution in European history. Previously, book reading had primarily been the activity of old men and monks, but now it gradually became the most important activity in the daily life during childhood, adolescence, and early manhood. The middle class had access to a richer and more varied literature. With the support of the Church, schools were established to teach people how to read the Bible. Because of schooling, more people could acquire knowledge and skills more effectively in a range of different sectors. Textbooks were invented to support students

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at different levels of learning, both in Latin and law. Print also made it possible to mass copy multimodal texts that combined letters, numbers, and images, thus enhancing knowledge production in several different areas (e.g., technical literature). However, increased literacy also widened the gap between literate and oral cultures in the population (Eisenstein, 1980).

In comparison, the era of the Internet has not brought the same need to upgrade the skill level in the larger population. The shift in popularity towards images and videos offers an easier alternative access to information, and may have reduced the dependency on reading skills. Anyone can videotape behavioral skills accompanied by verbal instructions. However, because the number of knowledge productions has increased exponentially and access from the online setting is immediate, the primary challenge today is to find the best solution. This involves the ability to search after information and identify the optimal solution in an effective way.

The process of remembering has been outsourced to the web. A search may involve an attempt to learn something new, or it can be an attempt to refind information that has been used before. Search engines have often retained a history of individual's searches. On the web, the traditional way of remembering a site was to bookmark it, but users are now instead increasingly conducting the same queries in web search engines, making the process of remembering linked to search in new ways. The aim is now to predict what information individuals need. By analyzing conceptual similarity among documents in our collective memory, it is possible to automatically suggest relevant solutions without even needing to do a search (Halavais, 2018: 43–55).

Compared with the printing press, the Internet reduces the importance of remembering yet further. When learning by reading became more common with the invention of print, it significantly reduced the role of mnemonic aids like rhyme and cadence. The nature of the collective memory was transformed. In the age of scribes, reading and writing had been closely connected to oral communication, but now reading was increasingly done as an individual practice. Book learning transformed the knowledge acquisition practices, allowing craftsman outside universities to teach himself new skills. Nor did students need to follow their master in order to learn a language or academic skill. Gatherings became less important, while bookshops, coffee houses, and reading rooms provided new kinds of communal gathering places (Eisenstein, 1980: 66,132).

Figure 7.5 Book frontispiece from 1679. Portrait of Jean-Baptiste Tavernier (1605–1689). Tavernier was a seventeenth-century French gem merchant and traveler. In 1675, he published Les Six Voyages de Jean-Baptiste Tavernier from his six voyages to Persia and India between the years 1630 and 1668. Credit: State Library Victoria, Australia

Today, this tendency is further reinforced because people can gain access to the world of knowledge from home and do not need to visit libraries to borrow books.

With printing, publishers and print dealers also began to deliberately promote the authors and artists. Title pages and booksellers' catalogues would include portrait heads of authors and name, birthplace, and the personal histories of the author. The self-portrait acquired a new permanence with its print-made immortality, and it increased the drive for fame. Personal celebrity became related to printed publicity (Figure 7.5). Increased standardization strengthened the appreciation of individuality (Eisenstein, 1980).

Contemporary writers who had their names attached to hundreds and thousands of copies of their works became conscious of their individual reputations and authorship took on an altogether new significance (Febvre & Martin, 1976: 261). Today, the famous knowledge producer does not need to be a virtuous writer, but can be anyone who can write a blog or publish a video, illustrated by the popularity of a growing amount of YouTubers or TikTokers, the influencers who have become the new famous persons. With the online setting, publishing is always possible, but the issue will rather be how to get attention among all the different voices that are present. Videos without many views will not show up in the search results, and will fail to produce any revenue.

Furthermore, the invention of printing also led to a change in the style of writing. When authors began to compose with the new presses in mind, the act of writing became separated from performing before a live audience. Consequently, literary compositions became less impulsive because all works would go through additional stages of copy-editing (Eisenstein, 1980: 121, 234, 322). Interestingly, the popularity of the video productions today can be interpreted as a revival of "live writing" in a new form. The original impulsivity in knowledge production is to some degree returning in the meme culture and amateur vernacular productions (see Section 6.5).

Before the advent of printing, anyone could copy manuscripts. The author needed a Maecenas or a patron to finance the writing. After the introduction of printing, this arrangement did not immediately change. Printers, like the copyists before them, had no monopoly in the texts published, and they would usually print ancient text. For many committed humanists, the problem of making a living was of pressing immediacy. To ask money from the bookseller was not yet common practice before the late sixteenth century. A new practice that was quickly adopted of printing was to acknowledge the patron at the beginning or end of the book. Gradually, however, it became normal for authors to sell their manuscript to a bookseller for a specific sum (Febvre & Martin, 1976: 160–161).

When an early printer made a book, there was nothing preventing another printer from bringing out the same work if he wanted to. At first, this created few problems since classical and medieval texts were already well known in manuscript. The need for texts was so pressing that many separate editions of the same text could appear simultaneously without prejudice because the market could absorb all that were produced. As the competition between the publishers gradually sharpened, it became increasingly important to sell at a low price. There was a growing temptation to reprint a work that had just been brought out by someone else, especially since the pirate could easily copy an edition page for page and did not have to pay anything to the author. Because of the lack of international law governing copyright and publishing, pirated editions could, for example, be smuggled into France from Dutch printers. This led publishers who were planning an important book to increasingly seek monopolies from government authorities in the publication and sale of a title over a certain number of years. Large profits could be gained in having monopoly to the publication of the works of the main Church Fathers, and of service books. In addition, the publishers sought out new work to publish (Febvre & Martin, 1976: 160, 240).

In the eighteenth century, booksellers prolonged their privileged rights in a book. They bought manuscripts and enjoyed a permanent monopoly over the right to publish a book once they had the bought the manuscript. Occasionally, they built great fortunes while the creators of those fortunes were left in penury. It was not before the end of the eighteenth century, that authors achieved legal right to their work through the recognition of copyright, which gives the author an exclusive ownership for a fixed period. The profession of author developed little by little (Febvre & Martin, 1976: 163–166).

It was only after printing that terms like plagiarism and copyright began to hold significance for the author. In contrast, some of the CI projects today illustrate a movement back to shared authorship and free access. This includes both the use of Creative Commons licenses (e.g., open textbooks) and the free sharing of research through Open Access. Draft versions of articles in Wikipedia may resemble plagiarism because information is copied from other sites, but the content will usually be revised beyond original recognition within a short period. All the collective work is part of a Knowledge Commons ineligible of any personal ownership (Loveland & Reagle, 2013). In a historical perspective, encyclopedias have always relied heavily on previous editions. The nomenclature – or list of words – has always been reused as a basis to establish a new encyclopedia. Borrowing or "pirate copying" has been a common way of knowledge sharing between different encyclopedias, including direct copying of portions of other encyclopedias' content. There are numerous examples of this practice from the eighteenth century. In this sense, Wikipedia does not represent a completely new production model, but is also a continuation of how encyclopedias always have been made (Loveland & Reagle, 2013). A major advantage with collectively owned knowledge is that information can be reused and improved much more rapidly, thus increasing the pace of innovation in society (Nielsen, 2011:

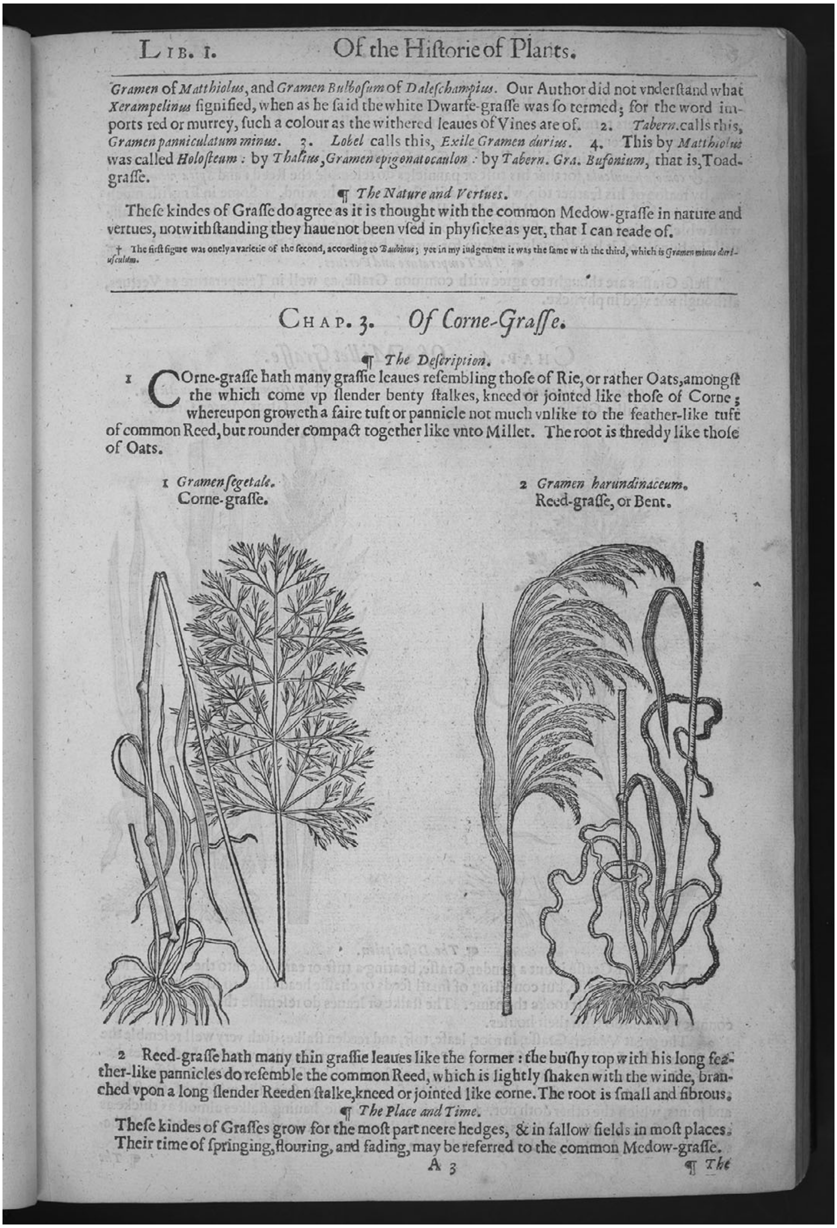
59–60). In collective projects like Wikipedia, there are no "authors," just contributors or editors (Wikipedians) It illustrates that some types of knowledge production in the online setting downplays the importance of individual authorship.

7.3.2 Flexible Modification of Printed Information

The New Formats of Printed Information

With the printing press, new types of books and printed information contributes to increased diversity in the accessibility of knowledge. The book format becomes more varied. Initially, the earliest printers copied manuscripts and tried to make the books resemble these manuscripts. However, as printed texts multiplied, the book was no longer a precious object that one could only find in a library. People also wanted books they could transport easily and use anywhere at any time. Therefore, a large number of books were produced in small formats, especially devotional works like Books of Hours. In addition, popular tales and classical authors were added to the "portable collection" from the end of the fifteenth century. Overview of all the content in the book became important, and both pagination and chapter headings were introduced (Febvre & Martin, 1976: 78, 88).

Before printing, images were seldom used to demonstrate points in technical texts or texts about nature. Early readers lacked plant guides or bird watcher's manuals. When scribes made duplications, it was more than enough work to copy the words, and in the course of centuries, ancient texts would gradually lose their original illustrations. With the printing press, fields like architecture, geometry, geography, and life sciences experienced a major boost because images could now be included in the books (Figure 7.6). Many tools such as banderole, letter-number keys, and indication lines were invented to make it easier to combine images with texts in the printing process. This was especially important in technical literature that described the relationship between words and things. It also became much easier to set up mathematical tables, and images inspired an entirely new genre of textbooks that used images for didactic purposes (e.g., Comenius to instruct children). Some even claim that the "printed image" was more important than the "printed word." Perhaps, most importantly, the printed book made possible new forms of interplay between letters, numbers and pictures that by far exceeded the separate value that these symbolic representational systems had (Eisenstein, 1980: 54–55, 68–70, 264).



Lib. I. Of the Historie of Plants.

Gramen of *Matthiolus*, and *Gramen Bulbosum* of *Daleschampius*. Our Author did not vnderstand what *Xerampelinus* signified, when as he said the white Dwarfe-grasse was so termed; for the word imports red or murrey, such a colour as the withered leaues of Vines are of. 2. *Tabern.* calls this, *Gramen panniculatum minus*. 3. *Lobel* calls this, *Exile Gramen durius*. 4. This by *Matthiolus* was called *Holosteum*: by *Thalius*, *Gramen epigonatocaulon*: by *Tabern. Gra. Bufonium*, that is, Toad-grasse.

¶ *The Nature and Vertues.*

These kindes of Grasse do agree as it is thought with the common Medow-grasse in nature and vertues, notwithstanding they haue not been vsed in physicke as yet, that I can reade of.

† The first figure was onely a varietie of the second, according to *Bauhinus*; yet in my iudgement it was the same with the third, which is *Gramen minus duriusculum*.

Chap. 3. *Of Corne-Grasse.*

¶ *The Description.*

1 Corne-grasse hath many grassie leaues resembling those of Rie, or rather Oats, amongst the which come vp slender benty stalkes, kneed or jointed like those of Corne; whereupon groweth a faire tuft or pannicle not much vnlike to the feather-like tuft of common Reed, but rounder compact together like vnto Millet. The root is thready like those of Oats.

1 *Gramen segetale.* Corne-grasse.

2 *Gramen harundinaceum.* Reed-grasse, or Bent.

2 Reed-grasse hath many thin grassie leaues like the former: the bushy top with his long feather-like pannicles do resemble the common Reed, which is lightly shaken with the winde, branched vpon a long slender Reeden stalke, kneed or jointed like corne. The root is small and fibrous.

¶ *The Place and Time.*

These kindes of Grasses grow for the most part neere hedges, & in fallow fields in most places. Their time of springing, flouring, and fading, may be referred to the common Medow-grasse.

A 3 ¶ The

Figure 7.6 Printed illustrations in John Gerard's *Herbal History of Plants* from 1633. This is the most famous English herbal, first published in 1597. Credit: Gerard, J., Davyes, R., Johnson, T., Priest, R., Dodoens, R. & Katherine Golden Bitting *Collection on Gastronomy* (1633). *The herball: or, Generall historie of plantes*. London, Printed by Adam Islip, Joice Norton and Richard Whitakers. Retrieved from the Library of Congress, Washington, DC, United States. www.loc.gov/item/44028884/

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Figure 7.7 *Theatre of the World, 1570.* Theatrum Orbis Terrarum (Theatre of the World), is considered to be the first true modern atlas, written by Abraham Ortelius and originally printed on May 20, 1570, in Antwerp, World Map. Credit: Ortelius, A., Diesth, A. C. & Llwyd, H. (1570) Theatrvm Orbis Terrarvm. Antverpiae: Apud Aegid. Coppenium Diesth. [Map] Retrieved from the Library of Congress, Washington, DC, United States, www.loc.gov/item/98687183/

Early printing was definitely most valuable for descriptive sciences such as natural science and anatomy because of the new opportunities to include illustrations in books. One result was that the human anatomical structure became widely known. Both botanists and zoologists who had previously struggled to understand local plant species in ancient texts would now also instead turn to direct observation. In 1520, the first work illustrating flora was published and became the prototype for all subsequent works. These books were read by enlightened and curious amateurs and not only scientists. One of the most distinguished of all printers, was Blaeu, the pupil of Tycho Brahe, who founded an important publishing house Amsterdam and made tremendous progress in the production of atlases (Febvre & Martin, 1976: 154, 277–278) (Figure 7.7).

Before printing, in the age of scribes, the advancement of learning had primarily been regarded as a search for lost wisdom. The transmission of written records was a constant struggle against the gradual corruption of paper copies. No technique could permanently record and store information for subsequent retrieval. Therefore, the first phase of the printing revolution centered on accumulating and preserving these old records. However, readers soon discovered that most of the ancient maps, charts, and texts were outdated, and map publishers, for example, soon began to publish genuinely new and improved editions. Over this period, there is a gradual change from saving corrupted copies and lost knowledge to the publishing of improved editions in all scholarly fields. Systems of charting the planets, mapping the earth, codifying laws, and compiling bibliographies were all revolutionized before the end of the sixteenth century. The old Hellenistic achievements were first copied and then, within a very short time, they were improved. New and philosophical ideas of progressive change were now emerging. David Hume, a prominent philosopher, claimed that the main advantage of printing was that it could continually improve and correct works in successive editions. A growing number of themes was associated with limitless progress instead of the older "decay of nature" theme. This was especially prominent in large collaborative reference works, where a series of new and augmented editions offered the promise of enlightenment. When a new version was published, it would remain available for correction, development, and further refinement by successive generations. There was a total shift in focus, from attempts to save and retrieve scattered fragments of previous work, to building complete new versions in most areas, spurring the many intellectual "revolutions" that happened in this period (Eisenstein, 1980: 112–113, 124). For example, the printing press helped establish a community of scientists who could reuse knowledge more effectively by communicating their discoveries through scholarly journals. Scientists developed norms on how to use correct references and cite published work. This made it easier to build on earlier work through a system that provided a chain of evidence (Nielsen, 2011: 59).

Furthermore, the press printed thousands of handbills and posters intended for the public. Many of them provided information about current events such as a festival or ceremony. Posters could provide information about condemned and proscribed books. This was the first literature of information, the ancestor of the modern newspaper (Febvre & Martin, 1976: 289–290). In the seventeenth century, the first newspapers were invented, creating an entire new field of providing up-to-date information to the public. They did not only provide information about what was happening in society, but they also gave critical reviews of politics and other issues. From then on, it became more important to be a newspaper editor than an orator in a public square (Eisenstein, 1980: 132).

Amplifying the Number of Translations

Another very important part of the printing revolution was the enormous increase in book translations into the vernacular languages. The first half of the sixteenth century saw exceptional economic prosperity and literate humanism. In this period, the printing press made the Greek classics available in not only Latin and Greek, but translated into vernacular languages and made available for all who can read. Virgil, Ovid, and historians like Caesar were popular, making the translations more important than the original works. For example, Plato was not published in Greek before in 1578 and was primarily known through Latin and French translation. This was a period when scholars brought together ideas of representative thinkers in an attempt to make permanent the works of creative spirits in all fields (Febvre & Martin, 1976).

The growing book trade stimulated publication in the national languages for economic reasons, and ended up fostering the rise of the vernacular languages. Printing had a huge impact already in the sixteenth century. Its presence in some linguistic groups ensured revival and continued expansion, while its absence resulted in some provincial dialects becoming less important. The preservation of a given literary language would often depend on printed catechisms or Bibles. These books materialized the difference between a separate "national" language and a spoken provincial dialect. Printers also homogenized languages by standardizing spelling, syntax, and idioms for millions of writers and readers, paving the way for the more deliberate purification and codification of all major European languages. These written languages stimulated the emergence of nationalism as opposed to Latin. A "mother's tongue" learned "naturally" at home would be reinforced by a homogenized print-made language. When learning to read, the child would first meet a standardized version of what the ear had first heard. This movement was amplified when schools began to teach reading skills by using vernacular language instead of Latin language (Eisenstein, 1980: 117–118).

The Church also wanted to spread their religious ideas more effectively by mass copying the Bible and liturgical texts. Especially Luther and the Protestant Church discovered that printed religious texts could help them gain support for the movement. More than anything, Protestantism was a "book religion." Between 1517 and 1520, Luther's 30 publications

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probably sold well over 300,000 copies, making a huge impact on the spread of these religious ideas. Protestant doctrines stressed Bible reading as necessary for salvation and did generate a pressure toward literacy and incentives to learn to read; while the Catholic Church worked in the opposite direction, with the priest reading for all (Eisenstein, 1980: 303, 333–334, 422). Nevertheless, print also led the Catholic liturgy to become more standardized and fixed in a form that would remain more or less the same for the next 400 years. The Church could insist on uniformity because everyone could use the same liturgical texts. Because the Latin language was retained in all Western countries, the same texts could be recited and the same ceremonies performed throughout the Catholic world. (Eisenstein, 1980: 313–314).

Furthermore, Luther exemplified how new types of printed information could be used to communicate political information in a much more effective way. Flysheets and posters were used as a part of this propaganda campaign in Germany. In 1517, Luther's Theses were printed as flysheets and distributed throughout the country within only 15 days. Luther wrote his *Appeal to the Christian Nobility of the German Nation* (1520) in German, not in Latin, for it was intended for the widest possible audience. Sermons, tracts, and vigorous polemics were immediately reprinted throughout Germany. Catechisms were cheaper and easier to understand and produced in even greater numbers than the Bible, which shows the first example of a truly mass readership and a popular literature within everybody's reach. The tracts were easy to transport, well-printed, with clear, bold titles within beautiful borders decorated in German style. The resounding name of Martin Luther was placed at the front, often with his portrait, which contributed to him rapidly becoming famous. Because of this text production, all Germany caught fire, and pamphlets came out on all sides, ridiculing the Pope and monks with illustration and caricature. The capacity of the press to influence public opinion was revealed in this period (Febvre & Martin, 1976).

It did not take many years before most rulers became aware of how influential books could be. For example, in France, until 1534 printers and booksellers who dealt in Protestant books could count on immunity, and they would seldom be harassed. After this date, the French king began pursuing, arresting, and executing printers and booksellers who had distributed the "false works" of Luther. The King must suddenly have understood the importance of the book in propagation of heresy. In January 1535, he even forbade any book to be printed within the kingdom on pain of death by hanging. However, it was impossible to enforce, and one month later, 12 Parisian printers were instead appointed to publish "those books which are necessary and approved for the public good." The French authorities had little success in their policy of repression through the book trade. French printers seem to have carried on working uninterruptedly. It just resulted in a growing underground trade in banned books and an increasing amount of literature with an outward appearance that was orthodox but in reality was a vehicle for heretical propaganda (Febvre & Martin, 1976: 309–311). Not so differently today, we see how information on the Internet is politicized and some governments even try to censor information.

Just as printing favored the growth of the Reformation, it also shaped modern European languages. Slowly, all the major Latin literature became generally available in vernacular languages. In 1549 in Paris, 70 of 332 books were printed in French, but this had increased to 245 of 445 books in 1575. The market gradually favored the literary language of the nation and Latin declined fully in the late seventeenth century. Luther also played a decisive role in the development of German language through his translation of the Bible and the catechisms he wrote. In order to be understood by the people of both Upper and Lower Germany, he simplified the spelling and standardized the grammar and vocabulary. In the period from 1518 to 1525, Luther wrote one third of the total amount of books published in German. Nor did Luther's translation of the Bible decline during the second half of the century. During the whole period of Reformation, books produced were predominantly in German. Afterwards, Latin made a recovery and German did not triumph until the seventeenth century (Febvre & Martin, 1976).

By the seventeenth century, languages in Europe had generally assumed their modern forms through a process of unification and consolidation, whereby one single language was written within fairly large territories. Spelling also became fixed and came to correspond less and less with pronunciation. The establishment of centralized national monarchies in the sixteenth century further reinforced this process. Latin managed to survive for a longer period because it remained the most widely used language of international communication. It was also popular in countries where foreigners seldom learnt the national languages like in Flanders, Germany, and England. In the eighteenth century, French took over as the natural international language of philosophy, science, and diplomacy, which every educated European had to know (Febvre & Martin, 1976).

7.4 A Summary of Human Stigmergic Evolution

7.4.1 The Invention of Writing

In the Stone Age, the process of copying solutions would always be limited to local communities, inhibiting a wider transfer of knowledge. There was always a risk of losing skills because the collective memory was only "saved" through embodied practices and active teaching across generations (see Chapter 9). This all changed with the invention of writing. It marked the beginning of human stigmergic problem solving, a new type of collective problem solving, that would forever change human lives. It made knowledge sharing transcend the limitations of time and space. For the first time, writing made it possible to separate information from the person, message from messenger. Solutions could now be stored and accessed by many other persons independently of each other. Although human communities have always attempted to reuse existing solutions, it is writing as a technological system that makes it possible to materialize solutions into a "frozen" form.

Both the invention of writing and the printing press spurred the development of more advanced societies. Writing coincided with the parallel invention of a number system that could support trade and transactions in ways that were more effective. All ancient civilizations were dependent on archiving, cataloguing, and retrieving written records. Scribes, clerks, librarians, and accountants could help people retrieve the stored information (Harari, 2014: 144).

Human were no longer dependent on their limited cognitive memory, and could begin to store records of their interactions in archives on clay tablets or papyrus. This was the rudimentary form of stigmergic problem solving, a technology that made it possible to save and copy human knowledge at a new and unprecedented scale. An externalized collective memory created the necessary condition for more effective collective problem solving in increasingly larger groups.

Although humans already had utilized stigmergy in trail systems, the invention of writing brought stigmergy to another level. This was a "metatool," built on marker-based stigmergy that not only allowed for sharing of information, but made knowledge creation possible through a new symbolic system. As a sign system, the invention of systematic phoneticism detaches the marks from its original relation to the surface when pictograms become more standardized and abstract. This evolvement is not a part of a grandiose mastermind plan, but emerges as small incremental improvements between language users over time. The accumulation of all

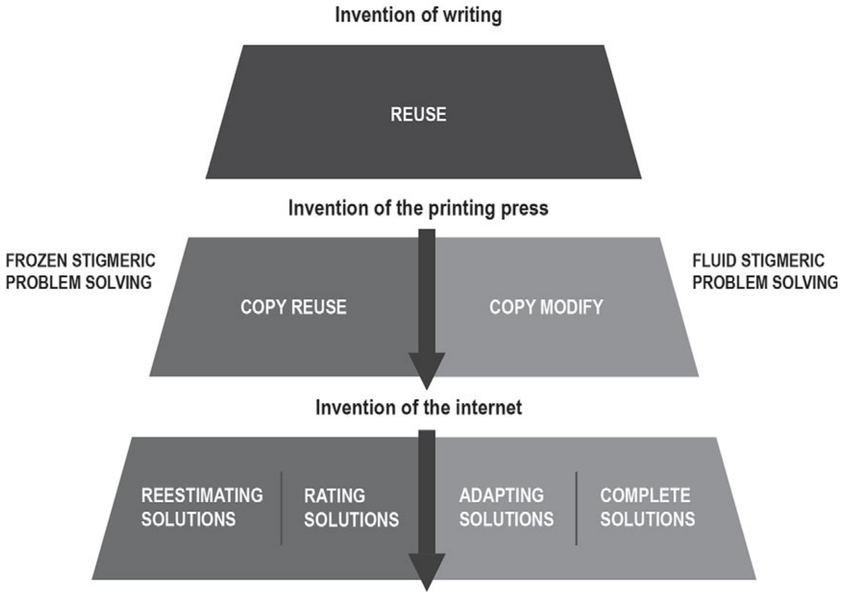

Figure 7.8 An overview of human stigmergic evolution through three different phases, author: own work

these local improvements is eventually the establishment of a coherent and flexible system that makes it possible for humankind to be more creative than ever before.

Solutions could now be represented as separate units of information that could be manipulated in their own way. However, early writing had significant limitations, particularly because of the writing material. It was time consuming to copy information, nor was it possible to modify information at a later point in time. Text written on a clay tablet could only be used in its original format. Papyrus permitted greater production of text, but it decayed more rapidly than clay.

This early writing can be regarded as a rudimentary form of human stigmergic problem solving because the process of copying a solution was nearly as time consuming as making a new solution. Only a few persons, the scribes, knew how to write and read, and it was not before the invention of the printing press that reading became a more common activity in a larger part of the population.

Figure 7.8 gives a brief overview of the history of stigmergic problem solving as it evolves over human history.

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7.4.2 The Invention of the Printing Press

The figure shows that human stigmergic problem solving originates from the invention of writing. This was a rudimentary type that made it possible to "reuse" solutions because written information could be stored. Knowledge could for the first time be exchanged across time and space because information was separated from the person.

However, it is the "copy revolution" of the printing press that enables full-scale use of human stigmergy throughout society. The reduced cost of making a book allowed for a much more flexible reuse and sharing of existing knowledge across wider geographical distances. All types of written knowledge could now easily be copied and made accessible to many more readers. As knowledge became materialized, millions of books spurred a major societal transformation. As a result, human stigmergy evolved into *frozen and fluid stigmergic problem solving*, two full-fledged subtypes.

On one hand, the mass production of identical copies made it possible for the Church and others to spread the same message to everyone. The act of copying information moved from a scribe and into a machine that could reproduce "frozen" complete chunks of information at an unprecedented pace. The large number of copies manifest a new type of quantitative stigmergy. Before the printing press, books would gradually be corrupted, but now this problem was "solved" by instead copying many books. *Frozen stigmergic problem solving* builds on these "copy reuse" practices in the printer workshops that made it possible to scale up knowledge production.

In the first years after the printing press was invented, the primary goal was to save ancient knowledge, and it led to a classical revival. However, it did not take long before printers began to produce other types of books, including not only religious works, but also storytelling books, books about law, scientific works, and technical books. Books were distributed over large geographical areas and became accessible almost everywhere. This radical increase in available knowledge made it possible for people to learn faster from each other. Knowledge sharing was amplified.

On the other hand, the printing press made possible a new type of fluidity or flexibility in the knowledge production. The content in books could not only be copied, but it could more easily be improved or adjusted to local contexts. Economic incentives made printers translate books into many different vernacular languages. This started with the Bible, but other areas were soon included. Classical works were translated from Latin to the vernacular languages. All these translations strengthened the position of the different European languages, and would with time contribute to more nationalism.

Moreover, the printing workshops made books in a larger variety of different formats. There were books in both large and small sizes, which made is easier for people to bring the book anywhere. Textbooks were invented to help people learn to read. The rulers also became gradually more aware of the political importance of controlling printed information, and leaflets and posters played new and important roles in providing information to the public. The invention of newspapers was part of this development.

Furthermore, the new book editions resulted in a gradual improvement of the accumulated collective knowledge in society. Scientific journals were established and sought to reuse and synthesize knowledge in a systematic manner through citing other's work (Eisenstein, 1980: 126). New scientific fields were born, centered on the revisions and improvement of previous work with an increased emphasis on corrections, reuse, and refinement. Printed books could include illustrations and figures, and this spurred the development of technical knowledge and the natural sciences. Stored solutions in books could be modified and used to solve new problems. In this historical context, *Fluid stigmergic problem solving* emerges as a new type of stigmergy that builds upon new "copy modify" practices. It marked a shift away from the need to save old, corrupted books to instead acquiring updated knowledge in the most recent edition of a book.

Before the printing press, fluid stigmergic problem solving would evolve as a slow and unplanned process. Although writing as a symbolic system improved gradually over time, it primarily evolved through irregular modifications in the practical use of symbols. With printing, books were being published regularly in new editions, as a planned improvement of a previous version. This strategy spurred innovation and collective knowledge advancement, and all the new editions created a sense of constant progress.

7.4.3 The Invention of the Internet

The next major transformation of human stigmergic problem solving is the recent invention of the Internet and the digitalization of information. While the success of the printing press is about making identical copies at a low cost, this cost is almost completely removed with the invention of the Internet. Solutions can now be permanently stored in an online setting; the problems of information decay are removed. A book can now be copied and reused in an infinite number of ways. In a historical perspective, *frozen stigmergic problem solving* has become more important than ever before, the sharing of knowledge now transcends both geographical-spatial limitations and time-limitations.

Anyone with access to internet can easily make his or her own public contribution, amplifying the democratization of knowledge production. Many amateurs are today sharing their practical knowledge openly, for example in videos that demonstrate their skills (see Section 3.3). This sharing is not motivated by money, but by a desire to share. Viewers or readers have become reviewers, both through the traces of their online activity and the ratings they actively give. This marks a transition from the age of the printing press with books creating a new type of impersonal connection between authors and the readers because they became unknown to each other (Eisenstein, 1980: 66, 132). Before the Internet, a few production facilities made a huge number of identical copies of information to the population, but there were few feedback loops. Reviews of knowledge products were written in newspapers and magazines by just a few persons (Benkler, 2006).

In contrast, the online setting reconnects the producer and the viewer in a completely new way. Solutions are now attached to their actual use because readers leave digital traces. This has led to the evolution of new subtypes of stigmergy such as "rating complete solutions" and "reestimating the solution." Active user evaluations of the quality of a solution have become much more important, including different types of metainformation, like comments or quantitative ratings. These aggregated digital traces are used by algorithms to determine what attention a specific solution gets.

From one perspective, the user evaluations become a part of the solution when ratings and reviews are saved as attached metainformation. These comments add relevant information to the content and can provide an important peer assessment of the quality. Viewers can also interact with each other through the meta-feedback. Nor will these ratings be "frozen" because they change over time and add a certain level of fluidity to this type of stigmergy. Even in prediction markets, the fluidity of the market mechanism contributes to the "frozen" solution through constant reestimations.

Furthermore, the Internet amplifies *fluid stigmergic problem solving* and transforms the previous "copy modify" practices into two new subtypes, "adapting complete solutions" and "completing solutions." Both utilize qualitative stigmergy in enabling contributions to build on each other.

While the printing press opened up for the adaptation of new book editions and translations, these processes are now scaled up at an unprecedented scale. Open textbooks make it possible to modify and translate the original version into multiple new versions. For instance, in the Global South, the adaptation of an already existing textbook can make it easier to produce them at a lower cost. The book is no longer a printed unmodifiable material artifact, but in digital format it can instead be regarded as an open-ended solution that can easily be adjusted to new contexts (see Section 3.2.3). Another example is political memes, which illustrate how modified versions become part of a community of similar types of work. Many amateurs will be involved in copying and modifying the original meme (e.g., image or sound).

The second type of fluid stigmergic problem solving is "completing solutions." It is born out of the digitization of information and characterized by collective work on draft versions of knowledge products. It makes it possible to coordinate complex projects with a huge number of participants such as open databases, argument maps, open source software, and Wikipedia. These processes are built around a transparent production environment and asynchronous communication. This allows for flexible participation, where errors are regarded as valuable because they trigger others to "fix" the content.

If we compare our internet society today with the Sumerians, one could claim that we still face the same challenge as our ancestors in how to store human knowledge in an optimal way. The Creative Commons license system illustrate how the knowledge production is changing. Both "copy reuse" practices and "copy modify" practices can now be performed without needing to ask the author for permission.

Although the Internet has democratized knowledge production, we are still struggling to organize our collective memory. Even when information is stored openly, it is not necessarily easy to find relevant information. When solutions compete for "attention," there are many losers, perhaps too many. In this system, the mechanism of rating solutions become essential, but is the crowd majority always wise? There is a risk that cumulative cultural evolution ends up being a fight about whom gets to be on the top of the "billboard."

CHAPTER 8

Collaborative Problem Solving

8.1 Background

As already mentioned in the first chapter, an important strand of CI research addresses problem solving that involves direct interaction in smaller groups or teams. A number of these studies have identified a general ability of a group to perform on a wide variety of tasks, indicating that groups, in the same way as individuals, also have a general intelligence (Malone, 2018: 32; Woolley et al., 2010, 2015). Although the individual intelligence of the group members is relevant, both the correlation between the average and maximum intelligence of the group members and the group's CI is only moderately strong. Factors such as group satisfaction and group motivation are not significantly correlated, adding more uncertainty to what group processes are most important (Malone, 2018: 33–34, 41–42).

Woolley et al. (2015) suggest that CI involved in collaborative problem solving in smaller groups is influenced by a complex interaction of both bottom-up (e.g., interpersonal skills) and top-down processes (group structures, norms, and routines) during problem-solving. Malone points to the importance of the three following factors: (1) individual intelligence, (2) working well with others, (3) cognitive diversity (Malone, 2018: 41–42). At present, studies both cover offline and online settings, but we still know little about the factors that influence on CI processes or this collaborative problem-solving ability. However, current CI studies suggest that at least four group factors are important for collaborative problem solving:

– Working well with others
– Cognitive diversity
– Equal participation
– Joint coordination

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These four factors will be analyzed by reviewing current CI studies directed towards small group collaboration, and other relevant publications by well-known CI researchers. In all these areas, there is also extensive research from outside of the CI research context, but it is out of the scope of this chapter to address these.

Instead, case studies from virtual teams in online innovation contests are included because they represent authentic problem solving in a highly relevant CI context (IdeaConnection). In some contests, individuals are handpicked for the teams. Sixteen experts are divided into three or four teams and these teams are then given 12 weeks to compete against each other in solving the problem. In this contest format, seekers only receive a few high-quality good solutions. This reduces review time compared with innovation challenges that include hundreds of submitted ideas, many of low quality. In the teams, participant motivation is also often high, since the chance of winning is greater. In addition, a facilitator supports the team in the problem-solving process (IdeaConnection, 2019a, 2019b, 2019e). The data from these teams provide insight into how advanced collaborative problem solving in the online setting can emerge in a natural setting.

8.2 Working Well with Others

Several CI studies find that that the ability of the group members to work well with others is important. This factor is typically measured as social perceptiveness by tests like "Reading the Mind in the Eyes" (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001) that requires that the test person judge others' emotions from looking only at pictures of their eyes. Group members vary significantly in how well they perform this task, and the average social perceptiveness score of the group members has been found to have a significant positive influence on the group's CI. It indicates that social perceptiveness is a measure of a person's social intelligence (Malone, 2018: 33–34, 41–42).

Interestingly, one study shows that the social perceptiveness was equally good at predicting collective intelligence in both face-to-face groups and online groups (Engel, Woolley, Jing, Chabris, & Malone, 2014). The result is surprising because the online groups could not observe each other, but only type text messages. It suggests that social perceptiveness is predictive of much broader interpersonal skills (Woolley et al., 2015). For example, the skill that enables you to read emotions in people's faces may perhaps make you sensitive to guessing what other people are feeling, even when they are only experienced through written text in an online setting (Malone, 2018: 37). Alternatively, the social perceptiveness may have something to do with qualities in the group interaction, such as active listening skills.

There is still significant uncertainty around the relational dimension in CI. The reason is that the c-factor is not predicted by several other factors that typically predict well-functioning groups, such as group satisfaction, social cohesiveness, and psychological safety concerning interpersonal risks (Woolley et al., 2015). In addition, few CI studies examine group interaction data and lack ecological validity, since they are experimental studies. For instance, there may be important differences between time-limited ad hoc groups and permanent groups. It is also likely that both specific individual relational skills and specific qualities in the group interaction are important. Top solvers in innovation teams in online innovation contests are assumed to inform our understanding of this relational dimension in collaborative problem solving and the types of group interaction that are important in CI.

8.2.1 Being in a Symmetrical Group Relationship

First, the perception of the group relationship appears to be important. Some solvers explicitly state that the team relationship evolves through the collaboration in itself. They highlight the unusually symmetrical collaborative relationship with less group hierarchy in the online setting. One solver states:

> *In the academic world, like everywhere else there is also ego and self-promotion. But when you work in a team environment, it is very important to keep an open mind and to be critical but also respectful. It is a very delicate balance to maintain. Some collaborations just do not work because people don't want to change their minds. But when you have a successful team, it is like magic, because when people are interacting with each other to learn and teach each other, a great trust develops. These are teams of equals and there is less hierarchy.*

According to the solver, this "team of equals" emerges when people learn and teach each other during the group work. Interestingly, the solver claims that this process of learning and teaching together creates "great trust," which allows groups members to be both critical and respectful (see Section 8.4). Other solvers underline how learning and group relationships are intertwined. One solver says, "The fact that there is always something to learn from other team members makes me look forward to meetings every time." The joy of learning together is an important part of the motivation. Another solver highlights the multidisciplinary team effort, "One of the challenges I recently worked on was completely out of my field, and the interest there is getting to know people from a different discipline and to see how they interact, how they work together and what their strengths are. That's really what I enjoy, I think, most of all."

If valuable peer learning is present, this has a positive influence on the group's ability to work well with each other in these high-performing teams. However, there are also challenges in the group dynamics. One solver explains:

> *The discussions are fun, usually anyway. Of course, when you meet people online that you've never met before you will get along well with some, but others are going to annoy you a little if they hog the conversations. Some people don't know when to be quiet and listen. So that's when the skills of a facilitator really come to the fore.*

This solver's statement suggests that listening skills are important. If the group struggles, a facilitator will help support the process.

8.2.2 Interest in Meeting People Who Are Different

Second, several solvers report that they enjoy being together with the others in the team. One solver says, "A lot of the time you meet interesting people with interesting occupations just by working in a team." This statement suggests a curiosity and interest in meeting new people that might be of special importance in this type of collaboration between people who do not previously know each other. Another solver describes it as both fun and interesting to learn about others' different cultural backgrounds, "It is nice to see how various team members with different backgrounds come up a solution to particular challenge in a novel way. We usually have fun times during meetings and exchange cultural backgrounds to get know each other well." Another solver also underlines the joy of being in a good team, "The different personalities, the experiences and the conversations. Then there is the camaraderie, which is incredible." Here, the term "camaraderie" is used, perhaps indicating a close relationship that is not friendship, but closer to just being engaged in group work. A third solver even misses the team afterwards: "And you know, when the whole thing was over I missed talking to the team. We got to know each other more than just as co-workers. It was nice. I really did miss the whole process when it was over." When the solver misses the team, it indicates positive feelings towards work, but also that many do not keep contact after the work is over.

Furthermore, some underline the excitement of getting to know people with a different background and expertise; one solver even describes it as "love":

> *I love it and I love meeting all the different people. I am working with engineers, chemists, physicists and mathematicians and they all come at these problems with different philosophies and with a different academic background. They are giving different slices of their own expertise. I think it is extremely synergistic and it keeps me on my toes. I have to be sharp so I can debate with different experts on an equal level.*

The solver describes how motivating it is to meet people with different academic backgrounds. Some solvers establish long-term relations with other solvers, both by expanding their social and professional networks:

> *Yes, and there's also 'c' and that is I get to meet lots of interesting people. For me it is meeting those people and putting them in my network so when I am faced with a new challenge I call them up. I launch companies with my networks. I'm always looking for good people, those personalities that really mesh well with me and vice versa and have skills that complement my own.*

This solver is explicit about the goal of finding people who have relevant expertise and can be part of a future network. In authentic settings, some solvers will want to work well with others because they have a strategic interest in establishing long-term business relations.

If we compare all these statements, the excitement of meeting different people stands out. One solver even describes team members as typical extroverts, "I also found people to be very, very open, and very accommodating. I think people who do open innovation by default are quite open minded." Solvers are motivated by getting to know new people. The social dimension of "working well with others" points to both specific personality characteristics and group characteristics, such as being in a symmetrical group relationship.

8.3 Cognitive Diversity

Another important factor in CI research orientated towards collaborative problem solving is *cognitive diversity* (Woolley et al., 2015). Here, the emphasis is not primarily on the different types of information other persons can bring to the table, but it is about the different thinking styles and perspectives that individuals use when they solve a task. Cognitive diversity is especially valuable in creative problem solving, which relies on new perspectives. Today, there is more interest in examining how groups of diverse problem solvers can outperform groups of more homogeneous high-ability performers (Page, 2017). Several areas provide strong evidence of diversity bonuses. One example is in academic research, where the percentage of teamwork has increased steadily in nearly all areas. For example, in social sciences, 20 percent of the papers were coauthored in 1960, and in 2000, this numbers had increased to 50 percent of the papers. Teams also perform better in science with coauthored papers earning more citations (Wuchty, Jones, & Uzzi, 2007).

The value of cognitive diversity will also depend on variation in perspectives (Page, 2017). For example, one top solver states that different backgrounds in the team can help produce more ideas:

> *Overall, it was a great experience working on the team. I do like to work with other people, and the one challenge that I've worked on so far, required a lot of theoretical work that needed expertise in many fields so I don't think one person could've solved it successfully. The challenge needed various backgrounds [...] In the group you hear many different points of view which gives you more ideas and helps you to think of things from different perspectives.*

When hearing "many different points of view" this can stimulate idea development. Another solver even actively seeks to increase cognitive diversity by wanting to work with individuals that think differently:

> *They have to be able to work with me. There's a wonderful saying a couple of guys in my network and I came up with – if we think the same about everything, if we think identically, one of us is redundant. I want people who challenge me and look at problems in completely different ways than I do and look for solutions in their realms of expertise and experience that are dramatically different from mine. People that come into my networks are very diverse and extremely different.*

The statement illustrates that some persons appear to be more aware of being with others who "look at problems in completely different ways than I do." The emphasis on perspectives that are "dramatically different from mine" indicates an attempt to maximize cognitive diversity. However, some CI studies indicate that the most collectively intelligent groups are those that are moderately diverse in cognitive styles. If the cognitive styles in the group are too diverse, group members communicate less effectively with one another (Aggarwal, Woolley, Chabris, & Malone, 2015; Woolley et al., 2015).

An effective team must be able to share idea and acknowledge dissent. They also need to feel safe, respected, and validated. These conditions are important in groups that are able to combine and improve ideas (Page, 2017). For example, one solver highlights how the team is able to refine solution:

> *Overall, my view of IdeaConnection is that it is a great innovation because when somebody thinks alone they might think their idea is great but it may not be. When you are a part of a team if your idea is not quite there you can correct it as others are contributing. And when everyone is giving their opinions you get a very good refined solution in the end. It also connects people from different walks of life. I've been able to work with people from India, Canada and the Netherlands at the same time. I think the IdeaConnection concept is great.*

In good teams, ideas will be continuously corrected or modified through contributions from every group member. Another solver explains how cognitive diversity enhances individual learning: "I also learned a lot about other disciplines, other ways of thinking through a problem, styles of writing, styles of solving complex issues, and how to integrate our different perspectives into a coherent whole." The individual learning is not only about acquiring knowledge of other disciplines, but about observing how others solve problems.

Furthermore, research studies have found a connection between cognitive diversity and identity diversity (Page, 2017: 171). *Identity diversity or social category diversity* refers to distinctions that are made between people who are like me (in-group) and people who are not like me (out-group), typically involving factors like, gender, nationality, ethnicity, or age, but also "non-visible" characteristics like sexual orientation. While most people intuitively acknowledge the value of functional background diversity, it is less obvious that socially diverse groups can have the same effects. First, identity diversity can be a source of cognitive diversity because individuals with more different backgrounds will bring in more variation in experiences that likely also increase the cognitive diversity. However, this is not a hard-and-fast rule; two persons with different identity do not automatically bring different cognitive perspectives to the table, nor does two persons from the same identity group automatically bring identical cognitive perspectives. There will always be some degree of both cognitive and identity diversity in a group. Still, it is important to assume that identity differences among group members like gender and race can promote cognitive diversity because one will then also be more open to approaching the same problem in different ways.

A second benefit of identity diversity is simply that persons who observe differences on the surface tend to assume that there are more cognitive differences in the group. This prompts them to seek out this information.

For example, including women in a group with only men is one way of stimulating cognitive diversity in groups. Difficult decisions often benefit from diverse representation. The mere presence of identity outsiders can change the behavior of the identity majority and potentially enhance group performance. Even if a person who is "different" does not bring in more cognitive differences, the mere presence has been shown to change the behavior of the group's members (Phillips, 2017).

One important reason is that people work harder in identity-diverse environments compared with homogeneous environments in their attempts to benefit from cognitive diversity. In this context, the groups are more positive and accepting towards alternative viewpoints. Studies show that persons who interact with individuals they perceive as different expect that it will require an effort to reach agreement (Phillips, 2017).

Studies have also found that racial diversity can promote critical thinking. For example, one study compared homogeneous groups of six white jurors with mixed groups comprising four white and two black jurors. The white jurors in mixed groups raised more novel case facts, identified more missing evidence, and were more accurate in the discussion compared with whites in homogeneous groups. One possible explanation is that individuals in heterogeneous groups expect more disagreement to be present in the group, and therefore examine the case more thoroughly. The perceived presence of identity diversity decreases conformity to socially similar others in a group and makes it easier for everyone to speak up with more confidence (Phillips, 2017: 233–235; Sommers, 2006).

Just being exposed to diversity can change the way you think. In contrast, it may be more difficult to utilize cognitive diversity if there are no perceived triggers from identity differences. A group of individuals with similar identity traits will easily create stronger expectations of consensus. Group members care more about maintaining relationships and harmony if they are together with identity-similar others (Phillips 2017). When hiring people, we have a tendency to falsely believe that people who share our identity are smarter and more capable. For example, studies show that biases range from 5 to 25 percent for salary offers. Small biases can also accumulate to form large biases, such as when a person needs to pass ten biased hurdles to reach the top of a company. These biased decisions can also be unintended and unconscious and may trigger nepotism (Page, 2017: 213–215). A striking example is a study which found that, when homogenous groups were outperformed by diverse groups, the homogenous groups still reported greater confidence and effectiveness (Phillips, 2017: 233–236; Phillips, Liljenquist, & Neale, 2009). People will filter both what they are saying and how they hear information, depending on who they are talking to and who is sharing that information. Individuals are often cautious in their support for diversity because they fear potential downsides. Studies show significant resistance against identity diversity because it is likely to result in more conflicts, disagreement, and questioning of one's own perspectives and opinions. These challenges require hard work that group members do not necessarily want. There is also a risk that outsiders are not respected or do not speak up because they do not feel welcome in the group. More identity diversity can cause discomfort, a lack of trust and mutual respect, communication barriers, and greater perceived interpersonal conflict. It can undermine the commitment to a group's goal, and it will not always be possible to observe immediate benefits. If some group members are more respected than others, group norms must also be reorganized to ensure that everyone's ideas are presented (Phillips, 2017).

On the other hand, if the group members become too similar to each other in cognitive style, they will lack the variety of perspectives and skills needed to perform well (Aggarwal et al., 2015; Malone, 2018: 36; Woolley et al., 2015). If groups become too similar, they risk becoming echo chambers, and reinforce each other's existing opinions. Members may become more interested in getting along than critically evaluating each other's ideas. For CI, it is crucial to bring in a sufficient diversity of perspectives (Woolley et al., 2015).

Organizations typically attempt to utilize cognitive diversity by combining it with functional background diversity (Page, 2017). For example, several of the solvers highlight the value of multidisciplinary diversity:

> *So on a previous challenge on the prediction of the fate of organic chemicals in soil, the seeker was looking for a model and we had a statistician on the scene and without a statistician we would've been dead in the water. But the statistician didn't know any chemistry and didn't know how these things degraded. So separately we would've been useless but together we were a good team.*

This solver claims the problem could not have been solved without the different academic backgrounds in the team. Another solver explains the value of including geographical diversity in an online setting:

> *For instance, we had people from South America, Canada, the U.S., and so having people from different climates provided insight into different crops, times of year, soil types, just real on the ground practical information. If you had just a number of folks in a university in one particular city it might be difficult to get all those types of insights.*

In this case, informational diversity is utilized because individuals from different parts of the world can easily participate in the problem-solving process. One solver also emphasizes the importance of complementary rather than overlapping expertise:

> *I think the difference is that the challenges at IdeaConnection tend to have a group of people who probably wouldn't be working together in the sense that they have complementary rather than overlapping expertise. So you're now putting people talking together who think differently and also have a different primary dataset on which they're basing what they're talking about. So you have a much more widely read community in lots of ways at that point.*

All these examples illustrate how the online setting makes it easy to design teams that would not normally be working together. These groups build on both multidisciplinary and multicultural diversity, which can potentially utilize cognitive diversity in new ways.

8.4 Equal Participation

Equal participation is another important factor for CI in collaborative problem solving. Several studies shows that equality of communication and work contribution among group members is important, both in face-to-face and online groups. When one or two people dominate the conversation, the group is on average less intelligent compared with groups that have a more evenly distributed participation and conversational turn-taking (Engel et al., 2014; Malone, 2018: 35–36; Woolley et al., 2010, 2015). One argument is the fair sharing of the workload. Another is that equal participation aims to utilize diverse member skills by involving everyone. However, group dynamics will often hinder this openness because group members think their opinion is irrelevant or they may fear disapproval from others (Landemore, 2013; Sunstein, 2006). In a classical experiment, Stasser and Titus (1985) showed that groups discussing a political problem are often surprisingly bad at using all the information they possess. Sometimes, group discussions even lead to worse decisions.

In the experiment, three written profiles of fictional president candidates of the student government at a university were created. The profiles contained information about the candidates' policies on issues of interest to students like dorm visitation hours and local drinking ordinances. They deliberately constructed three profiles so that one of the candidates was clearly more desirable than the other two. In the first version of the experiment, each student received complete profiles of all three candidates,

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and, not surprisingly, 67, percent of the students chose the best candidate. When students were then divided into small groups of four persons, the support for the best candidate increased to 85 percent (Nielsen, 2011: 69–70).

However, in the second version of the experiment, the researchers altered the profiles so that each student only received partial information about the three candidates. Some of the positive information about the best candidate was removed, and in addition some of the negative information about the undesirable candidates. Every group member would therefore receive information that suggested that one of the undesirable candidates was better than the best candidate. As a result, 61 percent then individually chose the undesirable candidate. Afterwards, students were divided into small groups of four with all information available about all three candidates. Still, the support for the undesirable candidate increased from 61 percent to 75 percent and the support for the best candidate decreased from 25 to 20 percent. It showed that groups were not sharing information in an efficient way, and they performed worse than the average member in the group. In a 1989 follow-up of the same experiment, the researchers found that the main weakness was that the group spent most of their time discussing information they had in common and did not use time exploring all available information. When several members had negative information about the best candidate, this was perceived as more important than the positive information held by only a single member. Groupthink ignores information from others even when most students think it is important to pool information from everyone. Another follow-up study found that asymmetrical relationships amplify the negative influence on group decisions. Unique information held by low-status members was much more likely to be ignored (Nielsen, 2011: 70–72).

Although few CI studies provide any detailed characteristics of equal participation in collaborative problem solving, the design of cognitive diversity will obviously be relevant. Groups who emphasize the value of a diversity of perspectives will strive to involve all group members (Phillips, 2017: 237–242). If we look at the online innovation teams, several top solvers also mention the value of equal participation. One solver states:

> *We all had different contributions which is what made it fun and stimulating. I looked forward to our discussions together. We did phone conferences and the team was so respectful of each other's backgrounds. We really worked hard to incorporate all our backgrounds into the final product. And I felt the theoretical portion which I contributed was honored as much as the technical content. The way we worked together was a wonderful experience and an example of how to truly collaborate and listen to each other.*

Here, the solver emphasizes that all contribute, but differently. The team is "respectful of each other's backgrounds," honoring each other's work and tries to "incorporate all our backgrounds into the final product." The ability to "listen to each other" is an important part of this process. Here, equal participation is about cognitive diversity by respecting and listening to others in the group. Because these teams are multidisciplinary and each individual has unique competence, it might be more obvious to let everyone voice their opinion. Another solver also describes how equal participation involves having different roles and tasks in the group work:

> *In the first way, as it went along we started to naturally fall into different roles on the team and I think that helped. Initially as four team members, we were trying to split things equally into four, and then, I think, we would get kind of frustrated if two people held up their end of that bargain and two people were lackadaisical about it or maybe procrastinating a little bit. Whereas, eventually we ended up where we naturally fell into distinct roles.*

This solver explains that the teams initially split the work into four identical parts, but this still led to some persons doing more work than others did. If some individuals are free riding, this can threaten the group work. With the support of the facilitator, the team managed to reorganize the work.

Because 12 weeks is a short period to solve a scientific problem, building trust in the virtual team is crucial. Solvers will often need to work with tasks that do not fully fall under their own expertise. Some will need weeks to understand the basic terminology, which can potentially create difficulties in sustaining the work because members work part time. Others may quit before the project is finished. When the solvers work in teams, a typical source of conflict will be members who do not do their part of the task. Nor may there be enough time to solve all relevant issues in the team meetings (Arnold, 2019a; Hossain, 2018). In order to design equal participation, it is necessary to understand "what people want to achieve" and how they can contribute to the group. However, the mix of expertise can also be challenging, as one solver states:

> *So it got better as I got to understand where the other people were in their careers and what their background was in terms of whom should work on which part of the project, who should be working together, and who should be editing things in terms of making sure that everything is coherent. It got easier as it went on. There was a lot of standing off at the beginning.*

In this example, the work improved when the group found out who should work on which part of the project. It underlines the importance

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of explicitly discussing tasks to ensure equal participation. Regarding this issue, the solvers highlight the importance of the facilitators:

> *He [the facilitator] submits the solutions, which is good, and writes them up. He wants to get contributions from everybody. It's like, say you're the foreman of a jury, and everyone has to vote, the foreman wants to get everyone's opinion. It's the same thing here; a facilitator makes sure everybody contributes. And he'll delegate the work and so on.*

The prominent role of a facilitator illustrates that teams will often benefit from a skilled person who can help organize the work in an effective way. It is likely that these groups to a much larger degree would have failed, like in the Stasser Titus experiment, if they were left to self-organize. Equal participation is without doubt an important design principle in collaborative problem solving that builds on CI, as numerous empirical studies and case stories show. It is not a principle that groups will automatically organize themselves around.

8.5 Joint Coordination

The fourth important CI factor in collaborative problem solving is joint coordination. Current studies find that the amount of spoken communication is important, both in face-to-face groups and written dialogue in online groups (Engel et al., 2014; Woolley et al., 2015). It is possible that more communication stimulates a stronger shared practice and more joint coordination of the problem-solving process. Previous sections highlighted both cognitive diversity and equal participation. However, there needs to be a balance between maintaining divergence and establishing a common understanding or shared goal. If the group share a body of knowledge and strategies, it is more likely they will resolve disagreements (Page, 2017: 173; Phillips, 2017). However, we need to better understand how this joint coordination can be achieved in collaborative problem solving. The data from the innovation teams suggest that at least four different coordination mechanisms are relevant:

1. Establishing a shared understanding of the problem
2. Planning the process
3. Staying focused on the shared goals
4. Ensuring the conversational flow

These coordination processes are heavily influenced by a facilitator who supports the process (Arnold, 2019b; IdeaConnection, 2019d). Without this person, it is likely that this type of coordination will become more difficult.

8.5.1 Establishing a Shared Understanding of the Problem

First, it is important to establish a shared understanding of the problem. In the first phase, teams may ask for clarification of the problem to make sure that they avoid misunderstandings. One solver explains how the group approached the seeker, asking for more information:

> *Yes, and I thoroughly believe in spending some time on analyzing the problem because the solution doesn't come out of thin air. It comes out of looking deeply into the problem, the context, what has been done in parallel industries or what has been done before. The more information you have, the easier it is to hone in on the right solution. I find the meeting with the seeker a very important part of the solution, because we really need to listen to them and try to learn from their experience. As a team we have experience, but not experience of these direct problems. Therefore, the more we can learn from the seeker the easier it is for us to come up with a solution that will match their needs.*

Here, the solver underlines the importance of listening to the seeker to really understand the problem. New solutions will usually build on versions of solutions that already exist. A solver even looks at this clarification process as a way of stimulating the development of new ideas.

8.5.2 Planning the Process

Second, it is necessary to outline a plan for the teamwork. In the innovation teams, the facilitator will be important in ensuring this is done. The facilitator proposes an outline that help the group members divide the tasks. One solver explains this process:

> *Right away the facilitator came up with an outline that she felt would answer the challenge and we took parts of that outline that were most appropriate to our backgrounds. This outline was so helpful and I just adapted my theory to my parts of the outline as did the other two solvers. We divided that outline in about five minutes. It was painless.*

By providing a structure and time plan, the joint coordination work becomes much more efficient.

8.5.3 Staying Focused on Shared Goals

Third, it is important to stay focused on the shared goals. In the innovation teams, the solvers underline how the facilitator helped the team stay focused:

She was more of a moderator than a Facilitator because sometimes the conversation would veer off into what I would call unproductive areas. Having the Facilitator there cut the conversation short and kept us focused on trying to get things done in the time we had allocated. I think that part was very critical for me because my time was limited.

The facilitator kept the group on track by stopping "unproductive" conversations, which is important because time is limited. Another solver illustrates how the group is highly focused on finding a solution and nothing else:

Well, it's much different than being part of groups in a company. I think everybody is much more focused on the solution rather than focusing on building their career or getting to lunch or other distractions you have in a small group in a company. So the focus is much more laser-like and directed. It is very pleasant to work with such focused people and experts in all of their fields. Everybody I've worked with is an expert in their field and it's good to get a glimpse of what they're doing at the cutting edges of their fields.

Although the group is diverse, with group members from many different fields, the group is still very goal orientated. When all efforts only need to be directed towards the cognitive effort of solving the problem, performance can increase. In addition, a solver states that the facilitator helps summarize the work, "The facilitator helps a lot. First of all, the facilitator looks at the problem and focuses us on it. And he communicates all our hopes and solutions into a coherent summary. And we look at the summary and see a trend in the thinking. The facilitator helps us to come up with the solution." By having a person summarizing the collective work, this can potentially help the group synthesize their efforts.

8.5.4 Ensuring the Conversational Flow

Fourth, it is important ensure the conversational flow. One solver says:

A fundamental part of any team is the facilitator. They are responsible for half of the team's success by keeping the pace and rhythm and solving any relationship problems if they come up. The other half is due to the team's technical background and having the time and the will to do the job.

Here, the facilitator is vital in keeping up the pace and sustaining the discussions. Part of the challenge is that individuals work differently, as one solver states, "Then, the other challenging part of it, I think, was just learning to work with people that you didn't know previously. We all seemed to have different styles of working and different styles of communicating. But by the end, I felt good about the way we handled it and the way we ended up coming together." This group struggled because they wanted to work and communicate in different ways. However, they managed to come together and agree on a shared group strategy. Another solver also emphasizes that the facilitator is important when such conflicts are present, "You need somebody to have that authority in the team, especially when one person says this way is right, and someone else says the other way is right." It is important that the facilitator help settle disagreements in an impartial way. This reduces the likelihood of new conflicts and sustains the conversational flow in a better way.

CHAPTER 9

The Origins of Collaborative Problem Solving

9.1 Background

This quasi-evolutionary account of the origins of collaborative problem solving builds primarily on research by the evolutionary psychologist Michael Tomasello (2008, 2016). It assumes that the ability to engage in collaborative problem solving is the most important reason why humans have been successful in evolution. Early humans gradually developed these skills, which made them uniquely different from other great apes. It is suggested that this process first began as closely intertwined mutual collaboration, which built on the evolution of more advanced forms of gestural communication. Three communicative motives are described, which are important in the development of the first type of collaborative problem solving. The human joy of collaboration is highlighted.

In the second part of the chapter, two antecedents to a collaborative culture are described. The establishment of a community of learners was essential in being able to transfer knowledge between individuals and across generations. Equal participation, building on reciprocity and norms, was also necessary to develop more effective types of collaboration. In the summary, this evolutionary account is compared with the modern examples of collaborative problem solving from the previous chapter.

9.2 Antecedents to Mutual Collaboration

Humans are different from other animals because they depend on each other in social relationships and benefit by helping each other. At some point in human evolution, the hominins who were able to collaborate gained an adaptive advantage over others. Collaboration represents a move away from great apes' total reliance on dominance as a way of settling disputes. Individuals had to become less aggressive if they were to forage together and share the spoils. Probably, ecological circumstances could

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have forced humans to forage together with a partner or else starve. It likely began with the emergence of the genus *Homo* around 2 million years ago (Tomasello, 2016). In this period, early humans began mating via pair bonding, which resulted in sibling recognition. When males began recognizing their offspring in the social group, they became less aggressive towards them. Humans are the only great ape that practices collaborative childcare. Individuals who are not parents will also help to feed and care for children, a tendency that may have evolved because of collaborative foraging (Harari, 2014: 10–11; Tomasello, 2016: 42–43).

Compared with other primates, humans are unique because they can walk upright on two legs, making it easier both to observe game or enemies on the horizon. More importantly, this permit the hands and arms to be used for a range of other purposes, like throwing stones or signaling. In this period, humans began to produce new tools. However, the disadvantage of walking upright is that the hips become narrower, which constricts the birth canal and favors earlier births. Compared with other animals, human babies are born underdeveloped and will need support for many years. Mothers could hardly forage enough food when they had needy children. It was therefore much more convenient to raise children by receiving help from other family members and neighbors. Over time, the most successful groups would be those that managed to share the spoils in a mutually satisfactory manner (Harari, 2014: 10–11; Tomasello, 2016: 42–43).

It is likely that humans first began to collaborate in dyads or small groups through mating, hunting, or coalitionary quests for dominance. Prosocial motivation for helping and sharing with others began in mutualistic activities in which an individual who helped her partner was simultaneously helping herself. In these groups, individuals depend on each other in an immediate and urgent way, and cheating or free riding is therefore unlikely. This mutualistic collaboration is characterized by symmetrical stability and is distinctly human. It represents a move from one person dominating over another to a larger degree of complementary symmetry in doing a task (Tomasello, 2008: 7–8, 13–16).

9.2.1 Mutual Collaboration Originates from Gestural Communication

According to Tomasello (2008), it is plausible that humans' skills and motives for shared intentionality initially emerged through mutualistic collaborative activities. When two individuals act together jointly, they naturally attend to the same situation. However, joint attention is not enough; the individuals must also know that they are attending to the situation together. Great apes do not engage with others in this type of joint attention, whereas human infants, quite amazingly, do it from before they are only one year old (Tomasello, 2016).

In evolution, these joint intentional activities would have started in the immediate close interaction between individuals, beginning with the gestures of pointing and pantomiming. When two individuals are working toward a joint goal in close interaction, both benefit by helping each other. Giving and receiving help will be easier when both parties engage in a closely intertwined collaborative activity. In this context, helping behavior might naturally develop as a way of facilitating progress toward a joint goal. The basic cognitive skill that is required is recursive mindreading, which implies that we both know we are cooperative.

This joint attention also makes communication toward a joint goal possible. Communicators and recipients can then interact cooperatively to get the message across. In stark contrast, two chimpanzees will never spontaneously carry something heavy together or make something together. Although apes understand that others behave intentionally according to their own goals, they do not form joint goals with others. They understand their own action from a first-person perspective and that of the partner from a third-person perspective, but they do not, like infants, have a bird's-eye view of the entire interaction. They lack an understanding of roles, which makes them unable to switch roles in an activity (Tomasello, 2008).

Young human children, but not great apes, form joint goals and take on individual roles that constitute important parts in the collaborative success. The role is impartial and partner independent; it can be applied by anyone irrespective of personal characteristics or social relationships. They communicate with each other in an attempt to coordinate the collaboration, showing that they have a "bird's-eye view" of the collaborative activity. They are able to change roles in ways that show that they are aware of individual perspectives. In the collaborative activity, it is the successful execution in itself that matters. While great apes operate according to an individual instrumental rationality, early humans were able to form the joint instrumental rationality of a pair (Tomasello, 2016).

It is proposed that vocal language first came into existence as a support to existing collaborative activities that were regulated by gestural communication. Conventional languages (first signed and then vocal) built on gestural communication. One argument that supports the view that human gestural communication is the "building block" of collaborative problem solving is that great apes have much more advanced gestural communication than vocal communication. Vocalizations are genetically fixed and only display specific emotions, but gestures are learned and apes can use them in a relatively flexible way in different social contexts.

However, early humans were also able to develop more advanced types of gestural communication through pointing and pantomiming. Both these gestures can provide the recipient with useful information if it is considered trustworthy. Pointing is based on humans' natural tendency to follow the gaze direction of others to external targets, and pantomiming is based on humans' natural tendency to interpret the actions of others intentionally. To communicate nonlinguistically, humans use the pointing gesture to direct the visual attention of others, and they use iconic gestures (pantomiming) to direct the imagination of others. It is likely that these two unique gestures made mutualistic collaboration possible. They arose as ways of coordinating the immediate collaborative activity more efficiently, initially by requesting that the other do something – with compliance asserted because it helped both participants (Tomasello, 2008).

Pointing is arguably the best candidate of the first gestural act that transformed humans' ability to collaborate in the immediate common ground of the mutual interaction. If we look at pointing in infants, there is evidence of a shared intentionality even before language acquisition begins (Figure 9.1). Infants are able to request things or share experiences and emotions with others. Humans are also the only primates that have highly visible eye direction, and indeed even human infants tend to follow the eye direction over the head direction of others, whereas great apes instead tend to follow the head direction. It suggests that eye contact must have had a more helpful function than a competitive function (Tomasello, 2008).

Furthermore, the communication in pointing and pantomiming is explicit, making it impossible to hide from the message without ignoring it. By letting the information "out in the open," this strengthens the interpersonal feelings of joint commitment and the trust between the parties. For example, studies of young children show that they are committed to collaborative activity through to the end; they even stay to help their partner after they have received their part of the share. When they engage in a collaborative activity, they will also be more eager to help another child, in comparison with other children with whom they have not collaborated. When the payoffs are identical, children prefer to solve the task together with others versus doing it alone. Chimpanzees do not behave like this, which suggests that human altruism toward nonfriends originates from mutualistic collaboration. The powerful interdependency mechanisms made it possible for humans to extend their sense of sympathy

Figure 9.1 Smiling baby girl pointing at a unicorn figure, photo Westend61/Getty Images ©

beyond kin and friends to include their collaborative partners (Tomasello, 2016).

Is this powerful interdependency present in verbal communication too? If we fast-forward in time and look at how top solvers in innovation teams solve problems together, there are several examples that illustrate the close intertwined collaboration between individuals. One solver states, "We arrived at the solution after throwing ideas back and forth. After one member came up with a really elaborate idea we built on that and grew it into the solution." The statement suggests a process whereby ideas constantly move around in the group, being co-created and synthesized in new ways. It illustrates that verbal communication can also be a part of similar types of mutual collaboration.

9.2.2 Three Communicative Motives

Furthermore, Tomasello (2008: 87) proposes that the following three communicative motives were essential in the evolution of humans' unique forms of collaborative activity:

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- Requesting help or information: "I want you to do something to help me."
- Informing others: "I want you to know something because I think it will help or interest you."
- Sharing feelings: "I want you to feel something so that we can share attitudes/feelings together."

All these three motives are basic social motivations connected to helping and sharing, and they emerge early in a child's development (Tomasello, 2008: 83).

Requesting Help

The first and most obvious human communicative motive is requesting help – getting others to do what one wants them to. It is similar to intentional communicative signals that all apes have, but instead of ordering the other what to do, humans often request help. This can include hints or polite requests, but will be significantly different from ape imperatives. Since humans like fulfilling requests of others, this will often be enough (Tomasello, 2008: 84–85). In collaborative problem solving, requesting help will be valuable in many different ways. If we look at verbal communication, a top solver in a virtual innovation team illustrates that naive questions are valuable for all parties:

> *The team interaction is interesting because the other folks on the team did not have the same kind of technical background. So their naivety or their lack of experience allowed them to ask questions and maybe even question paradigms that someone who does have the technical background would not do. And I saw value in that.*

This statement underlines the value of unexpected questions from individuals who lack experience, but still bring in more cognitive diversity. It shows that help is not only about transmission of information, but it can challenge the helper to rethink his own perspectives.

Informing Others

The second uniquely human communicative motive is to help others by informing them of things they find useful. Here, the gesture of pointing is limited because it cannot inform about things displaced in time and space. Instead, iconic gestures like pantomiming are more effective because more information is present in the gesture itself. Sometimes, individuals will even offer help to others when the information is perceived as irrelevant by the recipient (Tomasello, 2008). When informing others through verbal communication, the communicator can also use this as a strategy to "think aloud." For instance, a solver in an online team illustrates the importance of expressing unfinished thoughts:

> *I think explaining your reasoning out loud to somebody else is an incredibly good way of deciding whether there's a basic flaw there. When you talk out loud you certainly hear yourself and say, "I'm not saying that, am I?" whereas if you think it, it sounds perfectly reasonable. So I don't think it's really very different.*

The solver explains how the act of informing can help detect flaws in your own thinking. Informing others is not only helpful for the recipient, but also for the communicator. Thinking aloud will typically emerge as an important element in spontaneous discussion in dyadic collaboration (Baltzersen, 2017).

Sharing Feelings

The third basic communicative motive is an expressive or sharing motive that refer to people simply wanting to share feelings and attitudes about things with others. It can be a child who points to a dog to share the enthusiasm for the dog. It expands the social bonding with others and strengthens group membership. In verbal communication, it is present through gossip about all kinds of things (Tomasello, 2008). In this type of motive, it is also important to cope with negative feelings. A solver in an online team exemplifies the importance of critique:

> *For me, it is more accurate to say that I don't necessarily have a clear idea of the solution when I start, or if I do it often changes. Sometimes, you may be in love with the first thing that comes into your mind and you say to yourself 'Oh, I'm so brilliant'. But you have to be critical of yourself as well and try to find the holes in it. I have done one challenge on my own and the rest have been in a team environment. One of the values of working in a team is the critique. It is better to hear the critique from your colleagues before you submit a solution than hear the critique from the seeker.*

Here, the solver highlights the value of giving each other critical feedback in the teams.

9.2.3 The Joy of Collaboration

All three communicative motives assume that getting the message across will be mutual beneficiary for all parties involved. If a human communicator requests help (all other things being equal), the recipient will want to help, and if the communicator offers information, it is mutually assumed that the information is useful. Finally, if the communicator wants to share attitudes, they assume that the sharing will be interesting to the recipient. When the communicator overtly signals his intention to communicate, both parties try to ensure that the communicative act succeeds (Tomasello, 2008: 88–91).

A fascinating consequence of these communicative motives is that the collaborative activity is often in itself perceived as rewarding. In one interesting experiment, children between one and two years old were compared with juvenile human-raised chimpanzees on four collaborative tasks. Two tasks had a specific goal, and the two others were social games without a goal other than playing the collaborative game itself (e.g., the two partners using a trampoline to bounce a ball up in the air). The human adult collaborative partner was instructed to stop doing anything at some point to determine the commitment to the joint activity. The results showed that the chimpanzees were able to synchronize their behavior relatively skillfully in the instrumental tasks, but showed no interest in the social game. Most interestingly, when the human partner stopped participating, the chimpanzee never made a communicative attempt to reengage the partner even when they had previously been highly motivated in the instrumental tasks. They only participated in the tasks in an individualistic manner. In contrast, the human children collaborated in the social games and they even transformed the instrumental tasks into social games by placing the obtained reward back into the apparatus to start the activity again. It showed that the collaborative activity itself was more rewarding than the goal. When the adult stopped participating, the children actively sought to reengage the person, suggesting that they had a shared goal (Tomasello, 2008: 177–178).

If we look at modern examples of mutual collaboration, several of the top solvers are also motivated because they enjoy the teamwork. One solver states:

> *It was extremely stimulating and it pushed me to seek and elaborate information and knowledge that otherwise I would not have sought. Working on and building on the ideas of other contributors was extremely enjoyable. The plurality of perspectives on a certain idea can open new directions of thoughts and, ultimately, stimulate the creativity.*

This solver underlines the joy of "building on the ideas of other contributors." It illustrates how motivation is closely connected to the co-construction of new and unexpected thoughts. Another solver even expresses the paradox of enjoying the uncomfortable, "So it supplements your knowledge with other people's knowledge. You work with people that are out of your comfort zone which I really enjoy because it pushes you to do more research into a challenge and push back against other people and really make innovative kinds of solutions." The examples illustrate the positive feelings that emerge through the collective work in itself.

9.3 Antecedents to Collaborative Culture

How were humans able to extend beyond mutual collaboration and create collaborative cultures that permitted transfer of knowledge across generation? If we compare chimpanzees and humans, a major difference is that chimpanzee groups are not able to accumulate knowledge over time. In contrast, humans use cultural artefacts and engage in practices that other humans have invented before them. This learning across generations opens up for further improvements and refinement of artifacts and practices (Tennie, Call, & Tomasello, 2009). In this part, I examine two core components that enable such a collaborative culture.

(1.) A community of learners who utilize observational learning (social learning) and explicit teaching
(2.) Equal participation (equal sharing)

In combination, it is assumed these unique processes enabled the cumulative cultural evolution of knowledge across generations (Tennie et al., 2009). These issues will be further explored in the following sections.

9.3.1 The Emergence of a Community of Learners

When did we as humans become a community of learners? Researchers claim that our evolutionary story as tool users can provide some degree of answer to how this happened. Stone toolmaking (knapping) is a complex skill integrating demands for planning, problem solving, and perceptual-motor coordination within a collaborative social context (Pargeter, Khreisheh, & Stout, 2019; Stout & Hecht, 2017). However, if we look at the first stone toolmaking which began approximately 2 million years ago by *Homo erectus*, this knapping only involved simple hammer techniques that required less demanding manual skills. *Homo erectus* had adjusted to the upright walking position and could use their hands in completely new ways, but stone tools were still used in a simple way for a

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Figure 9.2 Regular flint handaxe from Boxgrove, West Sussex, England. From the Acheulian period. The typical tool is a general-purpose handaxe. Credit: © The Trustees of the British Museum

long time. Therefore, it was not necessary to invest much time in skill learning (Pargeter et al., 2019; Stout & Hecht, 2017).

However, about 500,000 years ago, skill-intensive biface-thinning techniques emerged, providing powerful evidence of a new capacity of learning among early humans. Boxgrove, UK is one of the richest and the oldest handaxe sites in Europe (dated ca. 524–478 BC) and it provides evidence of a handaxe production with smaller, thinner, more regular and symmetrical forms (Figure 9.2). The cores and flakes have been carefully shaped, revealing the use of knapping techniques such as soft-hammer, percussion, and platform preparation that are comparable to how modern experimental knappers work (Pargeter et al., 2019; Stout & Hecht, 2017).

Knapping is a practice which removes flakes from a stone core by using precise and controlled ballistic strikes with a handheld hammer (typically stone, bone, or antler). Only a small error in the strike will ruin the process. Expert knappers need to possess complex perceptual-motor skills, understanding the relationships between the force and location of the strike and how to position the core. Such a skill must not only be executed, but also observed and evaluated (Stout & Hecht, 2017).

Furthermore, training time is essential. Paleolithic foragers would have had to balance the costs and benefits of making and maintaining technology against the need to find food, avoid predators, and reproduce. Tool production time and foraging efficiency were obviously important factors to consider, but one study highlights instead the costs of skill acquisition as another important factor. In the experiment, modern participants were trained to make stone tools. The study shows that ∼200 hours of deliberate practice is required for refined handaxe production. The knapping learning curve follows a well-known "power-law of practice" that is common in both informal (sewing and cooking) and formal (biology and chess) learning. There were rapid initial increases in knapping skill followed by diminishing returns as performance approaches a local optimum. Although 200 hours in total might not appear to be a long time, other extra activities like the preparation of raw materials (e.g., spalling) and knapping tools (e.g., billet production) also had to be done (Pargeter et al., 2019).

Knapping is more of a flexible skill than one specific type of action. One needs to learn how to link effective means to appropriate goal-orientated action in many different ways depending on the specific task. In comparison, it is much easier to learn Oldowan knapping because it allows for more errors (Stout & Hecht, 2017). Learning the skill also requires extended investment in deliberative practice, directed toward improving performance through sustained effort and attention despite setbacks and frustrations. It requires discipline and self-control and is not necessarily enjoyable or rewarding in the short term. Learners must continuously check the actual incorrect outcome with the predicted outcome, and engage in a lengthy process of behavioral exploration to assess task constraints and refine skills. The largest neural and cognitive demands do not occur during the expert performance of the stone tool, but instead during the process of learning how to make stone tools. The working memory is taxed more heavily during the acquisition of expertise (Ericsson, Krampe, & Tesch-Römer, 1993; Pargeter et al., 2019; Stout & Hecht, 2017).

There is no doubt that making late Acheulean style handaxes requires both time and effort and a certain level of cognitive and affective learning. In addition, if the skills are only mastered by a small percentage of the group, they are vulnerable to loss. If the learning costs are high, it is less likely that others will acquire such skills. However, in a culture of teaching and learning, such a complex skill would more easily be maintained. The skills of making these tools suggest that hominid cognitive and technological complexity was going through a major transformation in this period. It suggests the presence of what could be the first advanced community of learners. Knapping skill acquisition involves the copying and high-fidelity production of stone tools, and probably required a community that encouraged collaboration, sharing of knowledge, and intergenerational reproduction of complex skills (Pargeter et al., 2019; Stout & Hecht, 2017).

If humans began to teach each other how to use these stone tools in this community, it is also likely that they developed the first human culture (Pargeter et al., 2019; Stout & Hecht, 2017). In general, explicit teaching is considered to be essential in cumulative cultural evolution. Teaching is present in all human societies, but it is not a common activity among chimpanzees or other nonhuman primates. Both children and adults are sensitive to teaching in their imitation of others. Teaching also involves a certain degree of altruism, in that the adult instructor needs to spend time and energy to ensure that a child acquires certain skills or knowledge. Children automatically trust adult teachers and are eager to change their behavior, in a way that chimpanzees apparently are not (Tennie et al., 2009).

Archaeological evidence cannot demonstrate a particular form of teaching, but the knapping skill requires the use of complex techniques that even modern humans will struggle with if they do not receive explicit instruction. The tools provide evidence of a more complex learning and teaching practice that involved both individual practice and social support (Pargeter et al., 2019; Stout & Hecht, 2017). Instruction could have been given as intentional demonstration, communicative gestures, or some type of linguistic instruction. As in apprenticeship learning or coaching, skill acquisition practices involve a combination of social learning opportunities like observation, instruction, and motivated individual practice (Stout & Hecht, 2017).

If we compare humans with apes, an important difference is that humans are able to learn socially of the actual actions performed by others (process copying), not just the results produced on the environment (process copying). Humans are effective in copying others' behavior and this begins early with the infant who imitates mom when observing her. Children do not only imitate to acquire more effective behavioral strategies in solving instrumental problems, but they also imitate for purely social reasons. In acquiring linguistic conventions, children are not only motivated by communicative efficacy, but by a desire to do it in the same way as others do. They conform to the group and imitate others simply because they want to be like them. The evolutionary basis is very likely identification with the group, motivating conformist cultural transmission and more faithful reproduction of behavior. In modern humans, one example is our tendency to follow fashions for no apparent instrumental reason (Tennie et al., 2009).

In contrast, chimpanzees learn how or where a box works, but they are not attentive towards the actions or the behavioral techniques that are used. For example, when chimpanzees observe someone using a tool, they tend to focus on the effect being produced in the environment, but they pay little attention to the actual bodily actions of the tool user. Instead, they use their own behavioral strategies with the goal of producing the same environmental effect. Thus, they reconstruct the product rather than copy the process leading to it. They solve problems by themselves and are reluctant to adopt any new behavioral strategy if they already have one that works. Consequently, the cultural traditions of nonhuman primate species do not seem to accumulate modifications over time. Chimpanzees are in a way reinventing the same wheel again and again through emulation learning (Tennie et al., 2009).

Humans are different since they can pay attention to the actual behavior or behavioral strategies of a demonstrator, and these processes must have been very important among the community of learners in Boxgrove. As part of a toolmaking practice, one type of observational learning would likely have aimed to copy the observed actions of others through a process of matching or "motor resonance." This requires the ability to translate visual and auditory information of another's actions to appropriate motor commands for one's own bodily actions, probably also attempts to copy bodily postures and gestures. This skill learning requires a significant level of general intelligence since a number of subtasks must be organized into a coherent mental program (Stout & Hecht, 2017). This copying of processes also enables the further modification and improvement of artefacts and practices across generations (Tennie et al., 2009).

9.3.2 Equal Participation

Obviously, there will be norms present in a human collaborative culture. Adults will expect that children behave in certain ways. Children do not only understand that something is done in a specific way, but also that this is how things "should be done." At some point in children's development, they expect that other persons ought to respond or help as requested, and they become offended if this does not happen. They begin following norms that regulate social behavior. In contrast, nonhuman primates show no signs of making normative judgements. Nonconforming behavior is not punished. In contrast, even three-year-old human children object if others do something the "wrong" way, and teach the offender how to do it the "right" way. This normative dimension does not only arise from explicit teaching, because when children observe adults, they will often think that everyone else should follow the adult behavior shown to them. This normative dimension of social learning strengthens the faithful transmission of knowledge skills across generations, reinforcing group identity and conformist transmission (Tennie et al., 2009; Tomasello, 2008: 133).

An important question is how sanctions and social norms have evolved. Mutual expectations of helpfulness are not norms because they have no punitive force, but they are one step in that direction (Tomasello, 2008: 208). Tomasello (2016: 49–50) claims that the emergence of a sense of fairness and justice originates from the joint intentionality as effected by a collaborating dyad. To coordinate collaborative activities, humans evolved skills that enabled them to form joint goals. Both the self and the other were recognized as important in the collaborative enterprise, and this mutual respect led to the emergence of genuine morality. In this new cooperative rationality, it made sense to depend on a collaborative partner. Individuals who were able to act together dyadically as a joint agent "we" were also able to structure their individual roles and perspectives. Over time, they developed a common ground understanding of ideal roles such as in stone knapping teaching. This practice eventually evolved into socially shared normative standards that specified what either partner must do in their specific role of being a teacher and a learner (Tomasello, 2016).

Reciprocity occurs widely in nature, but there is a difference between emotional (or attitudinal) reciprocity and calculated reciprocity. Mammals and especially primates, show *emotional reciprocity* because of their ability to form long-term emotion-based social relationships. Chimpanzees show positive affect toward those that help or share with them and with whom they engage in long-term social relationships. They can also feel sympathy for each other. Individuals form emotional bonds with those who help them and then they naturally help kin or "friends." The origin of this type of reciprocity is probably based on offspring bonding to those who succor or protect them. However, this does not explain the mechanisms that lead individuals to form friendly social relationships with nonkin.

Calculated reciprocity is a very different type of reciprocity, building on an implicit contract or rule like "we each keep track of who has done what for whom and stop cooperating if we are giving more than we are getting."

If I help you on one occasion, you will help me on the next occasion, as far as we benefit of it in the long run. This classic tit-for-tat reciprocity requires that we obligate ourselves to a future course of action, which only humans are capable of. Except long-term social partners, there is very little evidence that great apes engage in any exchange of favors. For instance, one experimental study found that randomly paired chimpanzees did not preferentially help an individual that had just helped them over one that had not (Tomasello, 2016).

This morality of fairness is confined to the human species. It is characterized by a sense of responsibility or obligation: "I do not only want to be fair to all concerned, but one ought to be fair to all concerned." Collaborative partners will be accountable for their actions by invoking interpersonal judgements of responsibility, obligation, commitment, trust, respect, duty, blame, and guilt. Humans also show resentment or indignation against unfair others. In contrast, great apes do not appear to have a sense of fairness in dividing resources, and they exhibit no sign of so-called retributive justice. Nor was free riding any problem initially among early humans. The number of individuals available was the same as the number needed for foraging success, but at some point, they would not allow others to get the spoils.

The simplest way of sharing is to let participants get equal shares and nonparticipants get nothing, and indeed, young children have a very strong tendency to divide the spoils of a collaboration in this way. Studies even show that young human children, but not great apes, share the spoils of a collaborative effort even when one child is given the opportunity to take everything. Young children also modify their own cooperative behaviors depending on whether others are watching. One explanation can be that early humans' collaborative activities took place in the context of partner choice in which potential partners evaluated others for their cooperativeness.

We also know that almost all contemporary hunter-gatherer groups are highly egalitarian. Dominant individuals are quickly overrun by a coalition of other individuals who are superior because of their group size. In a group hunt, the catch is almost always shared with others, not only in the immediate families, but more broadly in the social group at large. These social norms are usually very strict, and sanctions are used if they are not followed (Tomasello, 2016).

In contrast, the chimpanzees act according to the principle of "first come, first served," not equal sharing. The logic behind "tolerated theft" among chimpanzees is that if the possessor chooses to fight the harasser for the meat actively, he will likely lose more of the food to others nearby who will continue eating. The best strategy is to eat quickly all that he can, and allow others to take some meat to keep them happy. Hunters will obtain more meat than latecomers because they are the first at the carcass (Tomasello, 2008: 183). If there is a competition over food resources, collaboration will often fail. In one experiment, a pair of chimpanzees were presented with out-of-reach food that could only be obtained if they each pulled on one of the two ropes available simultaneously. First, when there were two piles of food, one in front of each participant, there was a moderate amount of synchronized pulling. However, when there was only one pile of food in the middle of the platform, making it difficult to share at the end, coordination fell apart almost completely. These findings demonstrate that chimpanzees are only able to synchronize activities when there is no quarreling over the food at the end. Although chimpanzees sometimes help humans, they do not help others if they themselves have a chance to obtain food (Tomasello, 2008: 183–184).

If we look at our human history, the arguably first type of formalized collaboration that emphasized equal participation were the collegial boards in ancient Athens. In the fourth century BC, the Athenians began to annually select some 700 magistrates. A lottery picked 600 hundred of them from the citizenry at large, while only 100 were elected in the Assembly. Most of these magistrates served on collegial boards, typically comprising ten persons with one representative from each tribe. All members were on equal footing, and there was no formal leader of the group. Decisions were based on discussions amongst the members, and if they disagreed there would be a vote and the majority decision bound all. These magisterial boards worked with public affairs according to the board's constitutional charter, such as leading armies, maintaining oversight of public festivals, and disbursing welfare payments. Service on most teams was intense for its duration, but it was limited to a single year. This reduced the risk of harmful strategic behavior. Selection by lot guaranteed that team members would bring in a large variety of different personal perspectives. Together with a background culture that emphasized formal equality in respect to public speech and vocal dissent, these features would likely create conditions that allowed for equal participation through the inclusion of all group perspectives (Hansen, 1991: 237; Ober, 2008).

Even today, public discussions in democracies are reliant on equal participation. Because these conversations invite to conflict and can be deeply uncomfortable, they require formal and informal rules of engagement. According to Schudson (1997), what makes conversation democratic is not free or spontaneous expression, but equal access to the floor, equal participation in setting the ground rules for discussion, and rules designed to encourage focused talk. The insistence on equality and a social order that creates a certain level of publicness are core components in the democratic conversations.

The emphasis on equal participation and debate is also an important part of modern collaborative problem solving in virtual innovation teams. A top solver in a team explains:

> *We sometimes have to go through a lot of argument, a lot of debate. I remember I was in agreement with another solver but the other two were not in full agreement, and everyone had to make their case as best as they could in order to convince the rest of the team. I think that was really challenging.*

The disagreement was solved by letting everyone make their case in order to convince the rest of the team. In the interview, this solver follows up and underlines the learning value of the process ("But I believe the amazing thing is that we learned a lot") and the individual effort that members put into such type of work ("you try to come up with the best out of yourself.")

If we look back at the magisterial boards, some historians claim that as many as ten individuals were selected just in case somebody turned out to be incompetent or unreliable. Although some individuals must have been incompetent, there are surprisingly few examples of complaints or people actually being dismissed. Moreover, when a magistrate was brought into court, the charge was usually bribery or corruption, not incompetence. According to the sources, the administration appeared to have worked satisfactorily in the lottocratic system with the support of a small group of clerical staff. Because the lottery was voluntary, candidates would usually be motivated to work in the administration, and the tasks would typically not require a high level of specialist skills (Hansen, 1991: 238–244).

The tasks in the board were based on the laws and decrees, and the magistrates were accountable for the funds they had used. Accountability procedures were strict, and all of them were assessed on reputation for character and conduct of life, rather than competence. Before leaving office, the magistrates also had to undergo a formal review (*euthuna*) of their work during the year. A special emphasis was put on the public funds (Hansen, 1991: 238–244). Gaining a good reputation as collaborators has probably been an important motivation early in evolution, too (Tomasello, 2008: 324–325).

Furthermore, even in virtual innovation teams, solvers highlight the value of being among "equals":

> *There is ego, but it doesn't feel like you are in a workplace because we're not climbing a ladder. We all receive the same reward for a successful solution, the recognition is the same. So there is no distinction for the reward. That's actually the perfect way to do it. As equals, all of our names go on the final proposal. So there's no way to stand out amongst your peers in that team.*

The solver highlights the importance of receiving the same recognition for the group work. The description of being equals is contrasted to workplaces where there is a lack of a symmetrical relationship.

What appears important in all types of equal participation is being able to tackle disagreements and still acknowledge each other. The magisterial boards were organized to encompass these tensions, and so do modern innovation teams. A top solver illustrates this attitude when he is asked whether he is bothered by his ideas being critiqued:

> *That's a fine line. Your ego can suffer because you might think to yourself, "OK, the other team members don't value me or don't value my solution." But if people are conscious of these feelings and provide clear argument that comes from a sound base, then we can tolerate criticisms. We are rational people in this industry. If it's just hand waving and you say it's not going to work and don't tell me why, then I might get offended.*

In this type of collaborative problem solving, it is vital to accept critique and not think that this means that your opinions are unappreciated. If proposals in the group are refused without argumentation, it may create negative feelings. Interestingly, the emphasis in collaborative problem solving should be on the quality of the arguments and not the persons making them. It indicates the importance of having discussion rules that can control emotions and enable the best argument to win through a fair and open discussion.

9.4 A Summary of the Evolution of Collaborative Problem Solving

The evolutionary analysis of collaborative problem solving in this chapter points to two distinctly different subtypes of collaborative problem solving. First, mutual collaboration points to what can be labeled as *elaborative collaborative problem solving*, building on the sympathy between collaborators and the presence of immediate helping behaviors like request, informing, and the sharing of feelings. In this type of collaboration, embodied interaction will be important. There is also a joy of being part

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of the collaboration in itself. With the flexibility of verbal language, this collaboration moves forwards as a spontaneous, rapid and open dialogue where individuals co-construct thoughts and think aloud. In general, the elaborative aspect of this type of problem solving does not follow a strict organization of the collective work, but members can join or interrupt conversations at any time in a more flexible way (Baltzersen, 2017). The stories from top solvers illustrate how different types of elaboration play an essential role in innovative problem solving. As the solver stories show, the open exchange of ideas enables persons to build on each other's thoughts and trigger them to move the discussion forward. In this intertwined collaboration, individuals both make requests for help and inform each other, in ways that are beneficial for both parties. In this context, help will also be related to how different tools mediate and display shared information in a common working space (Baltzersen, 2017). These group processes should be examined in more detail to better understand CI.

Second, the evolutionary analysis of collaborative culture points to the emergence of what can be labeled as *rule-governed collaborative problem solving*. It is likely that the transition from mutual collaboration to collaboration in larger groups involved the invention of norms. As mentioned by Tomasello (2016: 2, 9–10), the dilemma is that in most situations that require fairness, there will typically be present a complex interaction of the cooperative and competitive motives. On one hand, sympathy can be regarded as pure cooperation building on mutual interdependent collaboration. On the other hand, fairness represents a cooperativeness of competition in which individuals seek balanced solutions to the many and conflicting demands of multiple participants' various motives. Finding a satisfactory balance between cooperation and competition is the basic challenge of a complex social life. Competition is related to individuals' power and dominance in contesting resources. It requires some type of contract or rule to be solved. Therefore, the morality of fairness is much more complicated than the morality of sympathy (Tomasello, 2016: 2, 9–10).

In this quasi-evolutionary account, it has been suggested that rule-governed collaborative problem solving emerged through two key practices, skill acquisition and sharing of food. The findings at Boxgrove show that collaborative cultures may have emerged very early in human history. Stone tool learning required deliberate practice, with a minimum of 200 hours training. This skill acquisition is more cognitively demanding than the expert performance in itself. Individual training, observational learning, and explicit teaching would probably have been necessary to acquire the necessary skills. In this community of learners, tools would have been refined and improved over time and across generations.

Second, it is likely that hunter-gatherer groups were important in the development of equal participation as a social norm. Equal participation, with its emphasis on calculated reciprocity, represents a significant move away from the dominance of a few individuals in groups. From an evolutionary perspective, equal sharing of food required increased control of emotions and the establishment of norms that kept free riders out. A fair sharing of spoils also opened up the possibility of greater role differentiation in groups; not everyone had to participate in the hunt.

The democracy in ancient Athens was one of the first institutions that formalized equal participation as an important principle in collaborative problem solving. The collegial boards of magistrates were chosen by lot. It ensured both a fair selection and a large degree of cognitive diversity. This diversity of perspectives increased the likelihood of utilizing all relevant contributions. The conversational culture in Athens also allowed citizens to be critical and discuss uncomfortable topics.

Even today, the CI research still underlines the same principle of equal participation as a key success factor. This is important not only in innovation teams, but also in group discussions in Deliberative Polling. As mentioned by Schudson (1997), a democratically oriented conversation is not primarily spontaneous or free, but essentially rule-governed; civil discussion is guided by a conception of equal participation.

Chapter 6 outlined three key topics in CI research related to collaborative problem solving: 1. Working well with others, 2. Cognitive diversity, and 3. Group organization. Table 9.1 gives an overview of how these three topics connect to elaborative and rule-governed collaborative problem solving.

First, regarding the ability to work well with others, the analysis shows that rule-governed and elaborative collaborative problem solving build on different types of morality. Both create a symmetrical relationship, but while elaboration centers on interactional symmetry, the rule-governed approach seeks equal participation. Since elaboration builds on close interthinking, there is present a strong degree of mutuality when individuals build on each other's ideas in the ongoing talk. This leads to the establishment of a shared understanding, or a "we," which dissolves the separate individual positions. This interactional symmetry creates sympathy, which therefore increases the acceptance of unequal contributions. In rule-governed collaboration, the morality of fairness demands that everyone adheres to the shared collaborative norms.

Table 9.1. *A comparison of elaborative collaborative problem solving and rule-governed collaborative problem solving*

	Elaborative collaborative problem solving	Rule-governed collaborative problem solving
1. Working well with others	– The morality of sympathy: pure cooperation.	– The morality of fairness: cooperativeness of competition.
	– Interactional symmetry. Equal contributions are not so important.	– Contribution symmetry. Equal contributions are important.
	– Emotional reciprocity is important. Quality in the close proximate relations is important. Social skills are required.	– Emotional reciprocity is not so important. Social skills not required to same degree.
	– Ideas are co-constructed throughout the process. Collaboration is integral to the complete process.	– An element of competition is important. Balancing many perspectives and conflicting demands of multiple participants.
2. Cognitive diversity (How are contributions combined?)	– Not possible to identify separate contributions. The degree of individual contributions may vary because they are so intertwined.	– Including all separate contributions (Either anonymous or personally identifiable). More distant and complete units of contributions.
	– Co-ownership of ideas.	– Stronger ownership to ideas "my idea and your idea." One challenge is coping with negative feelings when "your idea" is criticized.
3. Group organization	– Emergent self-organizing group structure. Depends on the particular contributions in the process. No preplanned organization.	– Planned group organization with shared understanding and joint goals. Ideally, everyone follows the same group rules or norms.
	– Challenge: Not being able to elaborate on the ideas because rules need to be followed strictly.	– Challenge: Free riders.

Further research should more closely examine what "the ability to work well with others" actually implies in different types of group interaction. Woolley et al. (2015) find that interpersonal skills will be important in this type of problem solving. However, the top solver reports from innovation teams also illustrate that individuals can develop relations during the collaborative activities as they unfold. From this perspective, "the ability to work well together" should not only be analyzed as an individual interpersonal skill (see Chapter 6), but as something that emerges through the interaction itself. The inherent joy in participating may also strengthen group relationships.

Second, cognitive diversity can be achieved in two different ways in collaborative problem solving. On one hand, in elaborative collaboration, it will be part of the immediate co-construction of thoughts. On the other hand, in rule-governed collaboration, the ideas will typically first be proposed as separate individual contributions or ideas before they afterwards are combined into a coherent group solution. In this context, it becomes more challenging to criticize each other's contributions because ideas become more individualized. Collaborators need to learn to control their negative feelings when they are criticized.

Third, group organization is closely related to rule-governed collaboration in that it is organized according to prespecified rules that every group member needs to follow. This will typically become more important as the group size increases in order to ensure that all contributions are equally valuable. The morality of fairness will enforce sanctions on free riders. In contrast, elaborative collaboration will put less emphasis on organizational rules and greater emphasis on conversational flow, interruptions, overlapping talk, and the constant efforts of recombining and modifying ideas.

CHAPTER 10

Intelligent Engagement

10.1 Background

One of the most fascinating aspects of CI is the assumption that citizen participation can be the same as citizen expertise. Right after the invention of the Internet, Lévy (1999) claimed the meeting of minds in the online setting could potentially liberate us from the social and political hierarchies that have inhibited humanity's advancement. The Internet allowed for the strengthening of alternative grassroots communities compared to government institutions and corporate interests. Democratic societies could benefit greatly from this new kind of collective intelligence (Lévy, 1999). These ideas were further amplified with the emergence of Web 2.0 a decade ago, offering the vast majority of the population new opportunities to produce knowledge and join in public conversations about their own society. For the first time, people could easily engage in deliberation across national borders and traditional socioeconomic differences. Barriers to artistic expression and civic engagement were removed and people could openly share and connect with each other. Many envisioned the rise of new and prosperous human practices. Most importantly, parts of this new culture honored diversity in a completely new way because race, class, gender, or age was of less importance and individuals were not as constrained because of a lack of financial resources or traditional hierarchies in the offline setting (Jenkins, 2009). It is from this culture and these values that CI gains popularity. For instance, when peer production is described as a core modality of CI, it highlights how individuals increasingly participate in knowledge production activities in open decentralized networks, typically without receiving any economic incentives (Benkler et al., 2015).

In general, most of the large CI projects in this book follow this line of progressive philosophy in its emphasis on open and inclusive participation. Wikipedia was established in these early days of the Internet, back in 2001. Many citizen science projects are open for participants to join without

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having any special expertise or formal qualification. Personal interest is sufficient; age and socioeconomic background do not matter. Even young teenagers have contributed on Wikipedia and FoldIt. The wide outreach made possible by the global online setting increase the likelihood of recruiting more individuals from all over the world. These projects embrace this techno-optimistic participatory culture where everyone, for the first time in history, can share their opinions and knowledge at an unprecedented scale.

However, today one might ask if the citizen expert is just another mythical figure? Will crowd power lead to chaos and the delegitimization of expert knowledge? Although both open science and open democracy are movements that include citizens in new ways, most of the examples in this book are far from mainstream. A decade after Web 2.0 and the high hopes of a better society, there is a strong sense of disillusionment across the globe. The technological optimism has faded away as dark participation is on the rise, along with its echo chambers, trolling, and fake news (Quandt, 2018). This current "Zeitgeist" stands in sharp contrast to the early days of the Internet when many hailed its potential emancipatory powers.

Still, there are some positive signs, largely scattered around the world. There is more interest in reforming democratic institutions that can involve citizens in new and better ways (OECD, 2020). A key question is how this intelligent engagement can be designed. CI projects look differently in their community structures, indicating that there is no single answer to this question. From one perspective, many of the projects are built around separate individualized work or brief social encounters. A team in an online innovation contest engages in close interaction and collaborative problem solving for a short period. Many individuals are also primarily motivated by economic rewards since they are competing against each other. Both human swarm problem solving and stigmergic problem solving allow individuals to solve problems with a minimum of direct contact. A contributor in a citizen science project may have no contact at all with any of the other participants. Some of the wisdom of crowd approaches are even designed to reduce the amount of social influence. Although social media encourage direct contact and a community structure, an online video platform like YouTube is designed around a much looser community structure between the producers and the subscribers or followers.

The large differences in invested participation, even within one single community, have led scholars to describe social interaction in the online setting in other ways. James Paul Gee (2005), introduced the term "affinity space," claiming that online participation was more loose compared with the offline setting. These social structures point to CI as being centered on individualized work in a "detached networked individualism" (Wellman et al., 2003). A number of CI examples in this book are also built around temporary participation, such as hackathons, Deliberative Polling, and individualized innovation contests.

Mulgan (2018: 102) claims the character of "we" is often missing in much of the literature on CI because of this focus on aggregating separate contributions. Some of the most successful projects like Wikipedia offer evidence of the importance of community norms and the development of solid institutions. The FoldIt community is another example of a citizen science project that is completely dependent on long-term contributors. Most peer production projects also fail if they are unable to attract a community (Benkler et al., 2015). In complex problem solving that require sustained efforts over time, there will usually be a need for an institution or community.

In this chapter, I address several different types of intelligent engagement, with a special emphasis on CI in the political domain. New types of citizen engagement are emerging, such as mass activism, mass voting, and mass deliberation, all considered vital components in a democratic society (Anderson, 2006). In addition, the transparency of the collective work makes new types of asynchronous engagement possible. The final section also discusses various types of dysfunctional engagement that pose a threat towards successful citizen participation.

10.2 Mass Deliberation

There are several examples in this book that show how participants with different levels of expertise come together to solve problems together over a longer period. One example is the Polymath project that builds on a collaboration between academics and amateurs with an interest in mathematics (see Section 3.2). Today, there is an increased interest in how the deliberative democracy can be strengthened by utilizing CI. Public authorities are experimenting with ways of involving citizens from the whole population to come together to discuss complex policy problems. A key issue is that participatory governance must be institutionalized as part of permanent decision-making structures in democracies (OECD, 2020).

Citizens' councils, assemblies, and juries are often called "deliberative mini-publics." They typically recruit randomly selected citizens to meet, deliberate, and produce informed recommendations to public authorities. Deliberative mini-publics can be implemented in many different ways, and various initiatives demonstrate that there is not just one way of doing it (Chwalisz, 2019). For example, the use of citizen assemblies is gaining popularity. A body formed by citizens deliberates on an issue of local, national, or international importance. Like in Deliberative Polling, the members are randomly selected. Two early examples originate from British Columbia and Ontario, where citizens were assigned to deliberate on a proposal on electoral reform during a period of an entire year. In the case of the British Columbia, the proposal that the citizens eventually made received 57 percent of the vote in the whole population, just below the required 60 percent threshold, even though there were virtually no resources for a campaign before the vote (Fishkin, 2018: 164). Another similar example is the Citizens' Initiative Review in Oregon. A panel of 20 randomly selected citizens are invited to deliberate on a ballot initiative or referendum. They meet for three to five days, both to deliberate and be informed through expert presentations. Then the panel members write a Citizens' Statement that appears in the official voters' pamphlet to every registered voter. The pamphlet intends to be an informed guide and cover the topic of the vote in an objective way (Gastil & Knobloch, 2019).

Fishkin (2018: 7, 184), the inventor of Deliberative Polling (see Section 4.4), claims we need to transform democracies so everyone can be involved in deliberative activities. Although this type of mass deliberation is still primarily a theoretical idea, there are a few very interesting examples that points towards a new type of democracy. Both the recently established Citizens' Council in Ostbelgien and Better Reykjavík, the participatory governance platform in Iceland, build on the assumption that many citizens can be directly involved in governing a democratic society. These two examples are presented in more detail as they illustrate CI in the political domain.

10.2.1 Citizens' Council in Ostbelgien

Today, the Ostbelgien Citizens' Council is regarded as the most advanced example of a permanent deliberative democracy. Nowhere are citizens so consistently involved in institutionalized decision-making systems. Ostbelgien is Belgium's German-speaking community, a separate linguistic region and the smallest federal entity in Europe (Chwalisz, 2019; Van Reybrouck, 2019). In 2019, all parties in the parliament of Ostbelgien agreed to form a new democratic institution that would supplement the Parliament and the Executive. Here, the 80,000 citizens would be given a permanent voice. The new democratic institution includes both a permanent institution, the Citizens' Council, and a temporary institution, Citizens' Assemblies or Citizens' Panel, ("The Ostbelgien Model: 2019).

The permanent Citizens' Council is composed of 24 people who participate for a period of 18 months and convene once a month. Members have been selected from three different groups. Six are randomly selected from a previous Citizens' Assembly held in the region, six are politicians — one from each political party; and twelve are randomly selected citizens from the whole population in Ostbelgien. Every six months, eight members are replaced with randomly selected citizens in a rotation system (Cesnulaityte, 2020).

The Council sets the agenda by choosing up to three issues the citizens' assemblies are to work with. In advance, citizens, parliamentary groups, and the government have brought ideas to the Council. In 2019, citizens formulated several of the 20 proposals the Council received. The entire population in Ostbelgien were then allowed to vote on what topics they found to be most important. The council discussed the two most popular topics after the voting round and ended up selecting one topic that the first temporary Citizens' Assembly was assigned to work with (Cesnulaityte, 2020).

Furthermore, the Council decides the size and duration of the temporary Citizens' Assembly. Up to 50 randomly selected citizens can participate and they must meet a minimum of three times over three months. They can also invite experts to help them learn about the topic. Their role is to produce a recommendation, which is sent to the parliament, who by law are required to debate the issue at least twice and give a detailed response. The Council also monitors the parliamentary debates and ensures that the agreed-upon actions are implemented. Still, the recommendation from the Citizens' Assembly is not legally binding since the Belgian constitution grants all power to the parliament (Chwalisz, 2019).

Any person living in the region can be drafted, if they are more than 16 years old and do not hold political office. The members in both bodies represent the population in terms of gender, age, education, and residence. Those who participate have their costs covered and receive a small honorarium ("The Ostbelgien Model:" 2019; Van Reybrouck, 2019).

While Deliberative Polling only involve a couple of hundred individuals, the "lucky winners" of a random sampling process, the Ostbelgien example is interesting as it over time involves a large percentage of the population. In the summer of 2019, 1,000 randomly selected citizens were invited in the first round. Ten percent were willing to participate, which was considered a satisfactory response rate. In this final group of 100 individuals, participants were randomly selected, controlling for demographic background so it reflected the population of Ostbelgien (Cesnulaityte, 2020).

This rotation system makes it possible to include a wider proportion of the population to participate in democratic decision-making. It is inclusive, but not by letting everybody participate at the same time. Citizens fulfill their civic duty by participating intensely for a short period, knowing that fellow citizens will make similar contributions at another point of time (Chwalisz, 2019). A positive effect of involving a large number of citizens is increased political interest in society as members are likely to discuss political issues with families, friends, and peers. These new democratic systems are to a large degree inspired by how ancient Athens also used rotation and random sampling as core mechanisms in their democracy (see Section 5.4).

It is more uncertain if such deliberative institutions can succeed if applied on a larger scale. Landemore (2020) suggests that major democratic reforms of the representative democracy should build on deliberation by lot and rotation on a massive scale. When citizens are regarded as competent voters, they are challenged to engage more directly in political decision-making. Like in the Ostbelgien example, small deliberative groups like citizen assemblies or other mini-public structures can be given a more prominent position in democracies, "To my mind the deliberative ideal should be, ultimately, 'many connected brains' seamlessly and almost simultaneously exchanging information and arguments in ways that are costless and frictionless, resulting in enlightened individuals and enhanced collective intelligence" (Landemore, 2020). The citizen assemblies are organized as randomly appointed small groups which can deliberate independently of each other. Compared with elections, random selection maximizes diversity and representation from the larger population. Fishkin also proposes a new democratic model that involve both the use of Citizens' Assemblies and Deliberation days where small groups all over the country discuss different political issues through online communication. This type of participation can facilitate powerful learning processes and engagement in societal development (Fishkin, 2018).

The evaluation from Ostbelgien will be important in further attempts to scale up mass deliberation. It challenges us to rethink both the role of politicians and the relationship between governments and citizens. Citizen assemblies can be used to better connect the voice of the citizen experts with decisions made by elected politicians. The big question is still how these processes can be scaled up in size.

10.2.2 Better Reykjavík

Today, a number of local municipalities experiment with governing models that crowdsource citizen ideas on how to improve living conditions. One example is the Santander City brain, an online platform managed by the city council of Santander in Spain, which invites citizens to propose ideas regarding how to make the city better (Ismagilova et al., 2019). Another long-lived online platform is Better Reykjavík. It still provides a continuous dialogue between the local government and the public.

As already mentioned, the economic and politic crisis in Iceland in 2008 triggered Icelanders to begin to experiment with several new types of online participatory governance. There was a massive decline in trust in the existing political institutions. Therefore, the new initiatives focused on letting citizen opinions become more accessible to politicians. Online participatory governance was possible since as many as 95 percent of Icelanders were "regular users" of the Internet and there were few concerns about the digital divide, which was present in most other countries (Lackaff, 2016).

In 2010, grassroots activists launched Better Reykjavík as an open innovation platform. Here, citizens could express their ideas and comment on issues regarding services and operations of the City of Reykjavík. From its beginning, the project was "institutionalized," as it was endorsed by a new political party, the Best Party, which won the Reykjavík municipal government election (Lackaff, 2016). Better Reykjavík evolved from a previous initiative called the Shadow City (Skuggaborg), which was created by grassroots activists shortly before the Reykjavík municipal elections in May 2010. Each of the eight political parties could use a "branded" section of the site to connect with potential voters, and describe their political priorities so citizens could engage through debate and voting. While most of the parties did not use the site, the exception was the supporters of "anarcho-surrealist" comedian Jón Gnarr's Best Party. This party switched the agenda and instead encouraged citizens to help set the agenda by using the site, and approximately 1,400 citizens joined.

When the Best Party won the election in 2010, this created a high awareness of the platform. Consequently, the developers were asked to create a website devoted to soliciting the opinions of the citizens of Reykjavík. Better Reykjavík was opened, and the coalition parties in charge of the city encouraged citizens to use the site to share their priorities for the new government. More than 5,000 users joined the site in this early phase, representing around 10 percent of the population who voted at the city election (Lackaff, 2016).

Within months after the launch of the site, several of the highest-rated ideas from the Better Reykjavík site were placed at the top of the policy agenda listed on the Best Party website. The first four years, over 70,000 people participated and discussed over 1,800 policy proposals and ideas. Of these proposals, 450 received formal consideration from the municipal government, and as many as 350 proposals have been implemented (Lackaff, 2016).

If we look at the specific technical features in the platform, it resembles a simplified argumentation map by letting each idea be organized with two columns that invite others to write pro- and contra- arguments on the issue. Ideas can be proposed both in text format and as video presentations. Registered users can both comment on other's ideas or support them by voting, using a "thumbs up" or "thumbs down" rating feature. There is also an aggregate list ordered by the number of votes it has received. Over time, a body of proposals emerges, and each idea can be refined through discussions with other citizens.

Anyone can also view the open forum. Although the municipality will not formally respond to all ideas, a significant number is addressed each month. Each month, a committee in the municipality discusses the top-rated ideas. These ideas are considered public property and can be freely used in further policy decisions.

In 2012, Reykjavík started using the same site to support its participatory budgeting initiative Better Neighborhoods. The first three years, the city has used nearly USD 8 million to the best ideas submitted for neighborhood improvement. Only residents who live in the neighborhood can cast votes. Because of its sustainability, Better Reykjavík is arguably the most successful example of institutionalized open innovation in an online setting. In 2014, the Best Party was dissolved, and a new government was formed, but the new parties still decided to continue using the Better Reykjavík platform for the next four years, and the site is still in use today (Lackaff, 2016).

It raises the question why this initiative has been so successful compared with so many other similar projects that have failed. One important reason appears to be how it rapidly became normalized or institutionalized as a continuous channel for communication between citizens, policymakers, and public administrators. The initiative was implemented quickly; the project attracted a lot of attention. It was given meaningful resources; received both financial and political support. The goals of the project were also clearly defined. Iceland had already much focus on e-government through providing online services to the citizens. In 2013, 96 percent of Icelandic households had internet broadband, and 81 percent of citizens used e-government services (Lackaff, 2016).

Contrary to other similar projects run by public authorities, the platform is developed and maintained by a grassroots nonprofit organization. Both vTaiwan (see Section 11.3) and Better Reykjavík are unique because the technological innovation come from grassroots activists, hackers, and entrepreneurs, not politicians and government officials. From the beginning, this ensured that key participatory values were part of the project like transparency, accountability, and direct communication between citizens and the government (Lackaff, 2016).

When the City of Reykjavík in 2011 entered into a formal partnership with the Citizens Foundation who maintain the platform, participatory governance was made a mandatory component in the partnership. If the city council wants to use the platform, they have to address the top five priorities posted to the site each month, in addition to the top priorities in each of the 13 topical categories (tourism, operations, recreation and leisure, sports, human rights, art and culture, education, transportation, planning, administration, environment, welfare, various). Consequently, during the years afterwards, tens of thousands of citizens have used the platform, and city committees have formally evaluated hundreds of these citizen-submitted ideas (Lackaff, 2016).

Since the platform is open source, it has very little costs. Disruptive users or trolls have not been a problem, even though the platform is linked to social media networks like Facebook and Twitter. The connection with other social media make it easy for users to more quickly and easily engage in ideas by sharing, commenting, and liking them (Lackaff, 2016).

Better Reykjavík is one example of how citizen expertise is utilized in an online setting. One advantage is that the online deliberation is archived so all individuals do not have to be present at the same time. Asynchronous communication allows individuals to read the same content when it is convenient for them and at their own pace, which can potentially lead to greater inclusivity by making the deliberation more convenient. Landemore (2020) claims the online setting offers the potential to solve the longstanding democratic trade-off between group size (direct mass voting on predefined issues) and depth of argument (deliberation and discourse in a small group) for the first time in human history. A range of different communication types can be used, including both asynchronous and synchronous deliberation, verbal online deliberation, in addition to deliberation in an offline setting. In the online setting, activities in the mini publics, like in Ostbelgien, can be made transparent and open for feedback from the larger public.

10.3 Mass Voting

In the political domain, another way of utilizing citizen expertise is through mass voting. The most prominent example is how the Five Star Movement (5SM), an Italian political party, frequently let party members vote on a range of different issues. The 5SM was established in 2005 by Beppe Grillo as a grassroots movement against globalization. It recruited activists, mainly linked to left-wing associations, collectives, and NGOs. The five stars in the name refer to the core areas of interest during this period, including public water, sustainable transport, sustainable development, right to free internet access, and environmentalism. Today, the 5SM has become one of the largest Italian political parties. One important reason is that they attract many disillusioned voters from other political parties by claiming they will bring the citizens back to the center of decision-making process through new types of direct and participative democracy. Their long-term vision is to design a complete political system built around direct democracy, and the party implements similar ideas in the organization of member participation in their online platform.

Another reason why they are popular is their post-ideological approach to politics where policies are determined on an issue-by-issue basis. This ideological flexibility allows the party to address different topics in a strategic way according to new sociopolitical situations. Even the five pillars of the movement (public water, sustainable transport, sustainable development, right to free internet access, and environmentalism), that originally attracted disillusioned voters of left-wing parties from the anti-globalization movement, have gradually become less important, even though they still focus on environmental issues. On particularly important issues, they delegate the decision to online member voting, which is a rather unique characteristic among populist parties in Europe (Manucci & Amsler, 2018).

Their popularity emerges from a general distrust of other Italian political parties. Since they became the second largest Italian political party in 2013, the party has gradually become more institutionalized, occupying the center of the Italian political spectrum with its emphasis on "ideological flexibility" (Deseriis, 2017). However, the populist movement has been reluctant to form alliances with other political parties because they have been described as a corrupt group that are only interested in their own privileges (Manucci & Amsler, 2018). Therefore, the party has not wanted to describe itself as a political party, but instead as a new alternative way of organizing democracy outside of the traditional representative democracy in Italy. The party highlights the active participation of the citizens, and the role of political representatives as being spokespersons of the people. Politics is assumed to be about morality instead of competence, democracy should implement the people's will. When the movement gets 100 percent support, the citizens become the state and the movement will no longer need to exist (Manucci & Amsler, 2018).

Consequently, 5SM remains constantly attuned to the people's mood. For example, Europe was not a salient topic for the party until it participated in the elections for the European Parliament in 2014. The meta-discourse about direct democracy is also very important because it brings both left- and right-wing voters together. In order to remain popular, 5SM aims to capture the current social and political Zeitgeist (Manucci & Amsler, 2018).

Furthermore, the movement differs from traditional political parties because it does not cost anything to become a member. Nor are there any party congresses because this can lead to the formation of internal factions and strands, and the funding structure is also based on online micro-donations. In addition, there is frequent use of social media communication such as Meetup groups, Facebook groups, and other online groups that aim to replace the physical infrastructure of a traditional political party. This digital democracy seeks to establish a more direct relationship between ordinary citizens and their representatives.

The 5SM's also has a two-mandate limit for all its elected representatives that intends to prevent the ossification of a party establishment. It resembles the same limitations as in ancient Athens, where citizens could not serve on the same board two times (Deseriis, 2017).

Moreover, the Internet is seen as a transformative technology, which will ultimately undermine the autonomy of the political class, changing the political representative to become an executor of the popular body. The free mandate of the politician is criticized, being the cornerstone of representative democracy. Instead, 5SM introduce direct democracy measures such as online referendums and citizens' initiatives. The utopian vision of this digital direct democracy is nothing less than "the abolition of all political parties." It involves the demise of the professional politician, whose function will ultimately be replaced by the voluntary and temporary participation of all citizens in political life. The constitutive document of the 5SM also acknowledges the central role of the Internet in expanding participation in the political process. It claims not to be a political party, but instead aims to realize an efficient and effective exchange of opinions and democratic debate outside of associational and political party bonds. Instead, it is assumed that the value intends to be in the totality of the member network users (Deseriis, 2017).

The online platform Rousseau allows party members to have direct contact with the party in public office and be a part of decision-making processes on several different issues. The platform had 140,000 registered users in 2017 and is currently one of the world's largest online platforms for political participation. Here, members can select candidates via online primaries, vote on the party program, provide feedback to elected representatives on draft legislation, publicize local events, participate in fundraising, and submit their own legislative proposals. Members are repeatedly invited to vote on different sections of the party program (energy, education, foreign policy, labor, defense, and so forth). The members are also consulted on issues such as the expulsion of party members. For example, between 2013 and 2016, 19 Senators and 18 Deputies have left or have been expelled from 5SM, in accordance with the party's idea that politicians are mere "employees" with a temporary mandate, and who are continually monitored by their employers: the people (Manucci & Amsler, 2018). In addition, members and councilors can take relevant online courses on how the political system works and they can share experiences with others (Deseriis, 2017).

The online platform opens up for several functions typical of direct democracy and differs from similar political parties (German Pirate Party, Podemos in Spain) which to a larger degree emphasize deliberative nonbinding processes. In contrast, Rousseau (the online platform) reduces deliberation to a minimum and instead highlights member voting. However, the voting typically consists in filling out single-choice or multiple-choice questionnaires based on expert opinions published on beppegrillo.it. Although each expert's blog post receives many comments, the questions are based on the expert's initial opinion, and not on the collective discussion that unfolds on the blog. From this perspective, the 5SM executive group retains a high degree of control of the party agenda. There are no features in the platform that enable asynchronous communication between the members (Deseriis, 2017). This platform (Rousseau) is primarily an operational tool for frequent voting. This lack of in-platform discussion tools suggest that Rousseau privileges preference aggregation over processes of opinion formation; decision-making over deliberation (Deseriis, 2017; Manucci & Amsler, 2018). Deseriis (2017) claims this hybrid institutional arrangement that enables citizens to participate directly in policymaking does not reduce the autonomy of elected representatives, but on the contrary reinforces it and legitimizes it.

Scholars have struggled to explain what kind of political party MS5 actually is. One suggestion is that it is a new type of party, build around "techno-populism" as a political philosophy. The basic assumption is that the political competence required for collective problem solving is to be found in the collective intelligence or common-sense knowledge of the citizen-expert. For the first time in history, new technologies make it possible to involve all citizens in democracy. Politics is regarded as "problem solving," which leaves no space for ideological confrontation between rival visions of society. This technocratic conception of politics as problem solving is combined with technological utopianism, which assumes that the Internet will offer a more effective way of mobilizing collective intelligence compared to what can be achieved using traditional political parties. The movement vigorously supports a web utopianism that resembles CI in its assumption that the technological power of the Internet can dramatically improve the problem-solving capacities of human communities. Because it allows for broad outreach and unmediated communication, it can utilize expertise and best practices among dispersed individuals and communities. It is this dramatic increase in CI that in the future will make it possible to solve global problems such as climate change or the economic crisis (Bickerton & Accetti, 2018).

In the long run, the Internet will eventually lead to a more effective solution of common problems by mobilizing new forms of CI. The main difference from other variants of technocratic discourse is that political competence does not depend on a few entitled experts, but instead, the competence is spread out amongst the population at large, to the crowd.

By transforming citizens into experts, technocratic and populist elements are combined into a new techno-populist party type (Bickerton & Accetti, 2018). The technocratic dimension refers to the assumed existence of only one correct policy solution. Politics is seen upon as "techne" in the original Greek sense, implying that there exists right and wrong solutions to specific policy problems, regardless of partisan attachments. Disagreement is viewed as the result of errors on somebody's part, or self-serving interests at the expense of the common good. Therefore, politics should be designed as an epistemic endeavor in such a way that it increases the probability of finding the correct answers to the collective problems that societies face (Bickerton & Accetti, 2018).

Finding the right solution is a matter of competence, not ideology. Technocrats, experts, and professionals can replace professional politicians and make the political decision-making process more effective by making it more like how corporations are run. The people should be consulted about the general policy, while experts should implement the policy (Bickerton & Accetti, 2018). When there is a particular complex issue, such as the possible withdrawal from the Eurozone, it is first the duty of neutral experts to inform the people about the different options and initiate a collective deliberation. In the second phase, the will of the people is expressed by a purely majoritarian approach (Manucci & Amsler, 2018).

The importance of competence is also clear from the way the M5S recruits its political representatives. In the 2013 primary elections, candidates were not required to provide a statement of their political views. They only uploaded their CVs because qualifications are what matters. Politicians are "technicians" that are supposed to fix problems. However, this does not only include people with formal qualifications. Grillo famously claimed that if the 5SM was to win the national elections, he would put a housewife with three kids in charge of the Ministry of Finance, not a professor. Grillo's main argument was about competence because the housewife would have a much better understanding of financial issues because of her day-to-day management of her family's finances. It illustrates how citizens with practical knowledge are regarded as the best technocrats (Bickerton & Accetti, 2018). This notion of competence echoes the old Athenian democracy, which did not provide any formal schooling to its citizens, but they were still regarded as competent enough to engage in participatory governance systems.

The populist dimension refers to the assumed existence of only one authentic will, which is the will of the people aiming for the "common good" (Bickerton & Accetti, 2018). However, an obvious limitation is that the leadership of the party still formulates the agenda and decides which issues will be set out for mass voting. Some scholars claim that the members still only have a marginal role and that the political philosophy of the movement has not actually been implemented in practice (Manucci & Amsler, 2018).

Like other anti-establishment parties such as Podemos, 5SM describe the political space as a fight between the "virtuous people" and a corrupt political class. In common with populist parties, the M5S are anti-pluralist as well as anti-elitist. However, the political philosophy is criticized for leaving no room for debate and disagreement. With the strong emphasis on majority voting, one may also ask to what degree minority positions are respected within the party (Bickerton & Accetti, 2018).

10.4 Transparent Collective Work

If we look closer at the different CI practices, we see that transparency is often a basic precondition for collective work. The exception is human swarm problem solving that builds on independent contributions such as innovation contests or crowd averaging methods. Still, many CI projects seek different types of transparency. For example, the transparent knowledge production processes in Wikipedia ensures accountability as different versions of articles are stored and can be retrieved. This transparency makes it easier to settle disputes when interactions are saved. Open online databases also provide a high degree of transparency, by letting everyone get access to the information. The Polymath project save online discussions and make it easier to follow the line of a complex argument. In the first Polymath project, the discussions went over 37 days with full transparency. The storage of the problem-solving process make it possible to analyze the comments at a later point of time (Nielsen, 2011: 202). This transparent environment illustrates how a relatively large group can solve complex mathematical problems through asynchronous communication. The pace of these reflections processes is somewhere in between the qualities of the ongoing verbal discussions in an offline setting and the slow, long-term communication in scientific papers that last for years.

In addition, the transparency of the process provide insight into how scientific knowledge is produced. Outsiders can learn that false starts are a part of the process, and even famous mathematicians struggle and misunderstand issues (Nielsen, 2011: 202). However, since so much information is stored, it takes time to examine how knowledge construction processes have evolved, whether it is a Wikipedia article or a collective mathematical argument.

In the offline setting, the importance of transparent human interaction is connected to productive communities of practice (Lave & Wenger, 1991). Hackathons are typically organized as transparent offline environments, which provide many opportunities for observational learning (see Section 4.4). For example, one study of hackathons found that it was important that team members were able to collaborate in close proximity to each other in the same room. Then, they can then easily move between different activities, point to visible artifacts, and observe what other participants are doing. Participants learn from others by watching them code or by overhearing issues raised by others in parallel conversations. Whiteboards on the walls are sometimes used to sketch out ideas, make decisions, reflect on alternatives and do informal teaching on how to code. Collaborative writing tools such as wikis were used to make it easy for participants to share lists of software that most people would need during the work. Several participants also took pictures of the images on the whiteboards and later posted them to their team's wiki page. This made it possible to continue with unfinished work after the hackathon was over (Trainer et al., 2016).

A room in a hackathon will typically have both individual workstations and central worktables where multiple people can sit and work. There will also be breakout conference rooms where groups can work privately without distractions. This makes it easier to have impromptu meetings to address important problems. Depending on their interest, participants can flexibly move in and out of different groups at the hackathons (Trainer et al., 2016).

Hackathons are interesting because they show the importance of a transparent and open environment where both physical and digital tools support co-attention. On a micro level, the transparency of shared visual displays can help a group focus their joint attention towards a problem, whether the informational display is Post-it notes on a blackboard or text written on a laptop screen. Such artifacts can support elaborative collaborative problem solving and transparent group communication, as all parties have access to the same information (Baltzersen, 2017).

One interesting example of transparent dyadic collaboration is pair programming (e.g., eXtreme programming) (K. Beck, 2000). Pair programming is a software development method that lets two programmers do the work by sitting in front of the same screen, but with different roles. The person who is controlling the keyboard and mouse is called the driver, while the other member is the observer or navigator. The driver will write code, while the observer reviews each line of code as it is typed.

The observer also evaluates the problem-solving strategy (Umapathy & Ritzhaupt, 2017). Likewise, some solvers in online innovation teams highlight the value of working through a shared interface:

> *When you are given such a broad challenge, it is hard to know what level of detail to go into and how you want to put it all together. So there was a lot of back and forth work where the document grew and shrunk. It was this process between multiple hands that eventually pruned it down to something that really made sense.*

In the online setting, it may be even easier to work on a shared document in real time (e.g., Google documents, Office365). Both chat features and synchronous audio communication offer opportunities for explicit coordination on the same document. However, few CI studies have yet addressed such production tools that influence the collaborative problem-solving process.

10.4.1 Crowd Peer Review

Another interesting example of transparent collective work in larger groups in the online setting is crowd peer review, an alternative way of doing scientific peer reviews. Instead of doing a traditional peer review with a few reviewers, the editors of a journal invites a group of 50–100 expert reviewers to join the review process (Nguyen, 2018). Even though this is a new practice, there are indications that it can both improve the quality and speed of scientific publishing (Select Crowd Review, 2019). Benjamin List and Denis Höfler first developed the system in the scientific journal Synlett in 2017. In late 2018, Synlett had crowd reviewed 115 manuscripts and accepted 70 of them. There are still just a few other journals who have adopted the same method (e.g., SynOpen) (Nguyen, 2018).

The crowd peer review method follows a few specific steps. First, all the potential crowd reviewers receive a notification that a manuscript is waiting to be reviewed. They must then decide if they have the time and expertise to review that specific article. The reviewers who accept the invitation can open the manuscript and write anonymous comments anywhere on the document. They can also see each other's anonymous comments and are allowed to discuss them with each other. Usually, there will be both suggestions and edits in the manuscript after just a few hours. In one crowd peer review example, around 15 of 80 invited crowd reviewers ended up working on the manuscript (Nguyen, 2018).

The reviewers will comment on different aspects of the article and also recommend rejection or acceptance. By the time a reviewer starts, the manuscript will already have many comments. The first commenters will usually leave longer comments, while new reviewers are encouraged to simply write "agree" instead of rephrasing the same point. Late reviewers might focus on another part of the paper or the supplementary material. In this way, the review work is split up. One reviewer reports spending one to two hours reviewing each manuscript. Therefore, the reviewers will usually read more manuscripts compared with traditional peer reviewing. The crowd will normally reach an agreement whether to accept or reject the manuscript. Disagreements are communicated politely because all comments are submitted openly (List, 2017; Nguyen, 2018).

On average, the review period lasts two to three days. The editor will then read the reviewers' comments, make the final decision, and send the crowd feedback to the author. A major advantage with crowd peer review process is that the process is much faster. In a traditional peer review, only a few reviewers will write a critique of the paper and this process can take several months, while the crowd review will be completed within a week. Authors appreciate the speedy process. Editors will not have to send reminders to reviewers after the deadlines. Another benefit is the reduced workload for the crowd reviewers. There is also more flexibility because you can simply pass on a manuscript if you are busy (List, 2017; Nguyen, 2018).

Because of the large number of reviewers, authors will receive more diverse opinions and perspectives from the reviewers. In one experiment, 100 highly qualified referees were recruited and given 72 hours to respond. The crowd review shows that the authors received more comprehensive and detailed feedback. Overall, the experiment produced a fair and rapid editorial decision. In a traditional peer review with a few reviewers, the comments and arguments will be much shorter (List, 2017; Nguyen, 2018; Select Crowd Review, 2019).

Authors often say that the crowd's comments provide more detailed comments than those from a typical review. One author was surprised that the crowd corrected small errors that even copyeditors would not have discovered. The initial fear was that one might be flooded with responses and miss the comments that really matter (List, 2017). For example, one author says he once received a 76-page document compiling the crowd's comments on his manuscript and supplementary material. At first, the author was overwhelmed and unsure whether he had to respond to every single critique, but this was not necessary and the author had, overall, a positive experience. Regarding the quality of the collective work, a crowd reviewer claims that it reduces the likelihood of unfair or biased reviews that occasionally happen in traditional peer review. When reviewers can read and comment on other reviewers' comments in a transparent online environment, this can reduce bias and lead to better and more accurate reviews (List, 2017; Nguyen, 2018).

In the journal Synlett, four-day review periods are typical when weekends are included. The journal SynOpen has also started offering crowd peer review, but with a separate and smaller crowd of about 35 experts. Here, the crowd comments will usually close after two days. Based on the amount of submitted comments, this is considered the best point of time to make decision of whether to accept or reject a manuscript. One day is too short a time period because the reviewers have not yet been able to publish enough substantive comments, whereas four days of reviews can produce too many comments that risk overwhelming the authors (Nguyen, 2018). This mechanism resembles a quorum response in the emphasis on finding the right time to end the process (see Section 4.2).

Moreover, the reviewers seem to enjoy interacting with other peers, rather than just doing the review on their own (List, 2017). In such a transparent environment, one can learn by observing how others do the peer review. In Synlet per 2018, the reviewer group consists of around 80 members. The group of reviewers is more diverse than usual, including scientists in industry, academic faculty of all levels, postdoctoral researchers, research associates, and even graduate students. Graduate students are normally not allowed to review manuscripts, but in this collective process, it is less of a problem to include individuals with little experience who just want to learn how to do a review (Nguyen, 2018).

A possible disadvantage is that the process may involve more work for the editors and authors. If there are many review comments and suggestions on improvement, the editor must help the author prioritize the most important changes and make a reasonable effort. There is a risk that it may end up being too much work. One of the editors at Synlett was skeptical at first, but is now convinced about the quality of crowd reviewing. In traditional peer review, he would many times face a difficult decision when he received conflicting reviewer recommendations, sometimes with only a line or two of justification. With crowd review, the amount of comments make it easier to grasp the general consensus while disregarding irrelevant comments (Nguyen, 2018). However, a crowd report is typically harder to assess than three or four conventional reviews. The editor will therefore have more to read, but not necessarily feel that the workload is too burdensome (List, 2017).

10.4.2 The Icelandic Experiment

Transparent collective work is also becoming increasingly important in the political domain in relation to open democracy. One example is the Icelandic constitutional experiment. In the aftermath of the 2008 financial crash in Iceland, parliament organized a National Forum with 950 randomly selected citizens who were to deliberate and establish the priorities of a new constitution. Openness in the process was essential since it originated from several popular movements in the country that wanted fundamental change in the country. In 2010, the National Forum gathered for a one-day session with brainstorming and discussions that aimed to bring forward key principles and main ideas that should be included in the constitution. The careful selection of participants legitimized the process as they were considered to reflect the views of the population of Iceland. Many of the participants had no previous experience with politics, but still played an important role in shaping this important political document. Eight themes emerged from the discussions and the results were summarized and rendered into a "mind map" that was also made publicly available (Landemore, 2015).

This document served as an inspiration for the work of the Constitutional Council, comprising twenty-five elected members, who were assigned to draft a bill for submission to parliament. The Constitutional Council spent four months in 2011 writing the draft. The direct participation was most prevalent during this period. The 25 members regularly posted online, so the Icelandic people could read the different versions of the draft. In total, 12 drafts were posted, and anyone interested could post comments and send feedback using social media like Facebook and Twitter, or using regular email and mail. The text was produced progressively, by writing more text, sharing it openly, and then integrating the useful comments. The crowd was self-selected, so there were no mechanisms that could stop trolls or people who would post irrelevant comments. The crowd members also made comments independently from each other and not in collaboration with each other. To some degree, the crowd's comments shaped the substance and style of the draft although the details are not described However, the Council would retain final authority over the text. (Landemore, 2015).

In 2012, the draft bill, a nonbinding national referendum on the constitutional proposal was held and it secured a two-thirds approval. However, for different reasons the constitution was rejected by parliament in 2013. Still, the Icelandic constitutional experiment shows how constitution writing can both be more inclusive and transparent. The public was able to witness, observe, and thus make up their minds about the activities of the actors, and the actual drafters of the constitution were able to access the crowd opinion, when they found it necessary. Everything an individual wrote on the Constitutional Council's Facebook page could be viewed, commented on, and ranked (with likes) by other citizens as well. This made multidirectional communication possible. The process took place in the open, which is fundamentally different from traditional constitution writing done by a few selected persons behind closed doors (Landemore, 2015).

10.4.3 Crowdsourcing Bills of Law

Another example of transparent collective work is the crowdsourcing of bills of law in the Five Star Movement. A large part of their online platform, Rousseau, is dedicated to lawmaking. Four of the nine platform areas (Lex Members, Lex Region, Lex Parliament and Lex Europe) are dedicated to the drafting and discussion of bill proposals. This crowdsourcing channels a large part of the activity among the party members. Although some activities in lawmaking are left out, such as consulting expert knowledge and prioritizing certain bills, the platform still provides new opportunities for members to interact directly with party representatives (Deseriis, 2017).

If we look more closely at the process, it is divided into distinct phases. In phase one, members are allowed to draft a proposal for a bill of law. It is not only required with a brief description of the bill and of its stated objective, but also an analysis of preexisting Italian legislation on the same subject, and a comparison with similar legislation that may exist abroad. However, many of the proposals do not contain this information and a clear description of the proposal is what matters most, making the threshold of access quite low. Still, only 17 percent of the 6,223 proposals pass the screening phase, when a member of parliament (MP) assesses whether it meets four requisites: constitutionality, jurisdiction, financial feasibility, and consistency. The proposal cannot duplicate or contradict preexisting 5SM-sponsored bills. Consultation is not possible afterwards, which makes the evaluation process unverifiable (Deseriis, 2017).

The next phase is voting. Every two to six weeks, all registered users receive an email that invites them to vote on a new batch of proposals. Each batch will comprise around 100 proposals. Still, the voters are only given one day to review the proposals and cast five preferences. The email notification announcing the start of voting is usually just a few hours in advance. This is done because of security concerns, but obviously has a negative effect on the voter turnout, ranging between 12 and 15 percent of the members (Deseriis, 2017).

The two winning proposals that receive the highest number of preferences move to the tutoring phase. The tutor is an MP who is responsible for transforming a proposal written in a nonjuridical language into becoming an actual bill of law. Once the bill is finished, the MP uploads it to the Lex Parliament area in the platform together with a video presentation of the bill that both includes the original member who proposed the bill and the MP responsible for it (Deseriis, 2017). The members can then provide feedback on the bill for 60 days. The users have six options when they comment: addition, modification, objection, suggestion, defect of form, and off-topic comments. Members can also rate other comments in this phase (one to five stars), but they cannot reply to other comments. It enables a discussion between the members and the representatives, but not between the members, who alternatively have to use other online environments such as the Beppe Grillo blog, Meetups, or Facebook groups. Still, there is much activity in this phase. From 2014 to 2017, the 5SM Deputies and Senators uploaded a total of 324 draft bills, generating more than 70,000 comments (Deseriis, 2017).

No other Italian party has permitted this type of crowdsourcing in draft legislation among its members. However, one of the main challenges in this environment is the lack of feedback on the vast majority of the comments. Although many comments do not require a response, the rate of reply is only 5 percent, and the response rate varies a lot between different representatives. The MPs are supposed to use the most important comments to amend the draft bill, but this interpretation is highly subjective. After the discussions, each MP is also supposed to publish a copy of the revised bill that will be introduced in the appropriate parliamentary committee, along with a conclusive report that explains how comments from the members have been integrated. However, only 23 bills out of 324

(7.1 percent of the total) have reached the publication stage since 2014. The conclusive reports vary a lot in quality and only six of the 23 reports acknowledge how changes have been done based on member comments (Deseriis, 2017).

From a political perspective, the voting processes resembles a traditional wisdom of crowd approach in highlighting the important of making independent decisions. Fractioning and bias are avoided by speeding up the voting process when members are only given a day to vote. This makes it difficult for somebody to start a campaign for one of the proposals. If they are not already well informed on these issues, this may potentially be a weakness. Although the citizens of ancient Athens also just had one day to make their decision, they would still be present and listen to arguments for and against a case before they decided to make a vote. The sheer size of voting on 100 proposals seems daunting, but the voting design is perhaps built around the assumption that people already know what topics they think are important before the voting (Deseriis, 2017).

However, the last phase in the crowdsourcing process opens up for 60 days of commenting in which members can read each other comments and vote on them. This transparency permits some degree of deliberation. Although the party appears to struggle in responding to all the member proposals, this type of crowdsourcing is still an interesting new way of involving citizens in political decision-making. The political representatives can still choose what bills they want to bring into Parliament. In addition, they will have access to a wide range of opinions from the party members throughout the process (Deseriis, 2017).

10.5 Social Media Activism

Citizen activism is important in any democracy. This includes both community volunteering, civic protests, and a free press that is skeptical towards the state power (Anderson, 2006). These two mechanisms highlight collective actions and critical discourse as essential. The online setting opens up new types of informal deliberative discourse through the use of social media. However, most of the social communication is often built around short written messages, for instance on Twitter or Facebook. These platforms offer easy and efficient contact compared with an offline setting, but their potential for deliberation is more uncertain. Although there are significant challenges for informal communication in an online setting, some of the previous examples in this book illustrate how some discuss political issues in new ways. Two such examples are the use of vlog (see Section 3.3.1) and memes (see Section 6.5.3). Although the vlog is often used for entertainment purpose, it allows for a personal voice, which can also address political topics. Vlogs enrich the public discourse by providing an alternative publishing channel that can let individuals share their knowledge about uncomfortable and difficult topics that other media have not prioritized (Burgess & Green, 2018: 127). This can potentially offer other types of deliberative discourse in society. Memes have definitely played a part in political activism and demonstrations. Although counter-memes are produced in some cases, the degree of deliberation appears to be limited. The memes primarily reinforce existing political stances rather than promote discussions between groups with conflicting perspectives. The brief format with an emphasis on images and videos is not ideal for citizens who seek deliberation on political issues. The emotional communication can motivate activism and attract other individuals with like-minded opinions. Although memes have engaged the public, there is a risk that the simplicity of the communicative message can amplify extremist attitudes. Since memes often build on intentional manipulation of authentic videos or images, one can also question whether it downplays the truthfulness of information.

Furthermore, an interesting common characteristic with several of the successful knowledge production projects is that they provide meeting places for their members in an offline setting. Several of the most successful projects, like Wikipedia, host regular conferences and workshops in which active members attend to get a stronger feeling of being part of a community. In Wikipedia, there are both local Wiki-gatherings and annual international Wikimania conferences. Although only a very small percentage of Wikipedia contributors attend, these people are some of the most important in the community. At these meetings, like-minded enthusiasts are acquainted, and this makes it easier to maintain contact afterwards.

Another example is from open textbooks, which today are promoted at several offline conferences around the world. At the University of British Columbia, there are now annual conferences about open textbooks. In one recent project (the UK Open Textbooks project), the objective was to adopt US-based open textbooks from OpenStax in the United Kingdom. Hard copies of these textbooks were displayed at conferences, exhibitions, and trade fairs. In addition, a number of workshops were offered at different higher education institutions. These workshops were hosted by the Open Textbook Network, a membership network that connects higher education institutions in their use of OER and open textbooks. One study showed that the workshops led 45 percent of faculty participants to adopt an open textbook afterwards (Pitt & B., 2019).

Moreover, the OpenStreetMap project is built around offline meetings. When Steve Coast presented his work at a conference, he discovered that many more people were interested in joining the project. With time, the joy of meeting other map enthusiasts has resulted in mapping parties where people meet in a physical co-location to go together and gather data (Neis & Zielstra, 2014). Studies have also shown that face-to face meetings in open source software development increase participation in follow-up work afterwards (Trainer et al., 2016). When people are involved in social activities like eating and drinking together, they establish trust and social bonds that are important for online work.

Although online communities can be viable on their own, one can ask if they are sustainable without any offline meeting places. For example, many of the online citizen science projects struggle, and one important reason appears to be a lack of strategy on how to use the offline setting too.

In political activism, there is also a discussion whether it can be built strictly around online activism. In general, online activism can be used in two different ways. On one hand, the Internet can be used to facilitate traditional offline activism strategies like the Arab Spring, which used social media to coordinate street rallies and spread news globally. Over the last decade, the use of Twitter and Facebook have become increasingly important in social movements like the Arab Spring (Murthy, 2013) and Black Lives Matter (Cox, 2017). Another study of mass civil disobedience in Hong Kong's 2014 protests finds that social media strengthened protesters' ability to mobilize and organize, on the Internet and in the streets. Social media were essential for short-term tactical maneuvering and constant information-sharing. However, the social media efforts did not persuade a durable majority of Hongkongers of the movement's legitimacy (Agur & Frisch, 2019).

In recent years, amateur video clips have become an increasing part of social movements, as people use their mobile phones to record demonstrations and protests as they are unfolding (Germain, 2020). For instance, both protesters and bystanders can now easily record graphic videos of police violence and publish them on social media. Authentic videos provide strongly emotional content that in some cases can trigger larger social movements. The most well-known recent example is the killing of George Floyd, in which a video recorded by a bystander led to worldwide protests against police brutality and institutional racism. It was a 17-year-old teenager who did not know Floyd who recorded what happened.

She felt she had to document it, but she is still struggling to cope with what happened, and the response to the video on social media, which included a mix of outrage, praise, and criticism. Some accused her for not doing enough to prevent the death, illustrating how tough it can be to publish such videos on social media (Nevett, 2020). If videos of demonstrations are published on social media in totalitarian states, individuals will also be easy to identify by the police.

In addition, activism can be organized only as a virtual activity. However, when people only meet online, it is difficult to build trust, commitment, and long-term interpersonal relationships. Hiding of personal identities and occasional participation may weaken the solidarity between members. The convenience associated with online activism, like distributing petitions without needing to go from door to door, has generated labels such as "clicktivism" or "engaged passivity" that describe a lack of commitment to the cause because members do not physically take part in protest marches. Some studies highlight that social media have led to more dispersed, temporary, and individualized forms of political action, being different from offline activism that typically centers around a single united group who share the same fate (M. Stewart & Schultze, 2019). For example, by using a hashtag, an individual can experience the feeling of being "part of something larger," without being physically present (Xiong, Cho, & Boatwright, 2019). Some have argued that this type of minimal-effort activism harms the public sphere in the long run. The e-movements are fragile and create a feeling of togetherness only momentarily, which inevitably dissolves as the algorithms direct attention towards new trending topics. Because members dedicate little time and commitment to a given movement, it is unlikely that a sense of community and solidarity will emerge between them.

Miller (2017), for example, claims that interaction in social media is primarily about achieving communion through passing the word along. Apart from the exchanging of information, it aims to promote social harmony through the maintenance of relationships. The conversational environment is built around limited forms of expressive solidarity. Others claim that online activism offers something new, a more personal and individualized participation, displacing the typical homogenizing processes that emerge through collective action in offline settings. In an online setting, shared experience (e.g., being a racial minority) or collective identity (e.g., a "person of color") is less important, which can also potentially recruit more people to the movement (M. Stewart & Schultze, 2019).

What is evident is that contemporary social movements are increasingly hybridizations of both online and offline practices. One interesting example is My Stealthy Freedom (MySF), a social movement protesting the compulsory veiling of women in Iran. It is built around two types of activism, the MySF Facebook (FB) fan page and the, White Wednesdays (WWeds) campaign (M. Stewart & Schultze, 2019)

The MySF movement began with Masih, an Iranian woman, publishing a photo on her own Facebook page where she was driving a car with her headscarf dropped to her shoulders. On the page, she invited other women in Iran to claim this freedom for themselves. Many responded, and this led here to make the MySF page on FB. The page centers on posting of anonymous photographs of women who have taken their headscarves off in a public place. This illegal act tended to produce powerful emotions including fear, stress, excitement, joy, and pride: "I was walking in the Shariati St. I took off my scarf. I was extremely scared; but I dropped the scarf to my shoulders and started taking selfies" (M. Stewart & Schultze, 2019). Some women attributed their ability to engage in this risky act to the obligation they felt towards the movement in general and a sense of duty towards Iranian women in general. This imagined solidarity is primarily connected to the production of the courageous hijabless photos on the MySF page. Each member is experiencing the activism by daring to do the same as the other photographers. The shared experience emerges as the members read, like, and comment on the posted photographs. Despite the offline practices of protest being performed individually, the members still felt a strong sense of "we-ness" and collective identity in the online setting, which is often typical of offline social movements (M. Stewart & Schultze, 2019).

In 2017, after three years, the site comprised around 2,050 photos, with hundreds of comments, likes, and re-shares. At this time, Masih launched a new campaign called White Wednesdays (WWeds). Women were challenged to wear white scarves and clothes in public on Wednesdays to protest against the veiling law. In addition, they were encouraged to capture their experience in short videos talking about their opposition to the compulsory hijab. This made it possible for the members to identify each other in public. Many joined this campaign because they were waiting for the next step (M. Stewart & Schultze, 2019).

In contrast, the White Wednesday campaign encourage weekly, physical meetings where activists showed their membership by wearing a white headscarf on a Wednesday. The Wednesday offline campaign distinguished itself from the Facebook campaign primarily in that the individual activists became identifiable. Fellow protesters could be identified by the white headscarves they wore on a Wednesday. Those who published videos or images on their personal social media pages were identifiable to the whole group. During the five months (May to October 2017) of WWeds's operation, Masih published around 310 videos and 120 photos. The campaign's "#WhiteWeds" hashtag also made it possible for activists to post their content on their own accounts, while maintaining the link to the collective (M. Stewart & Schultze, 2019).

This led to the development of different subgroups based on where they lived and what opinions they had. Wearing white on a Wednesday was not illegal, and may seem to be a minor practice of resistance, but it still required a considerable commitment to this once a week in everyday life. One would have to engage in repeated face-to-face encounters with family, friends, colleagues, and neighbors, some of whom might support the compulsory hijab. Those who posted videos on their personal social media accounts were likely to be personally harassed, physically threatened, and even arrested. The actions strengthened the individuals' sense of commitment to the protest and the inter-personal bonds between the activists. The activists shared a stronger physically embodied sense of what it is like to protest when the same act was performed many times, and this led to a stronger sense of solidarity (M. Stewart & Schultze, 2019).

These two types of activism in the movement were highly intertwined: the Facebook page preceded the offline Wednesday campaign, and the offline events were posted on the Facebook page afterwards. This case report illustrates that online social movements do not necessarily lack commitment and can be transformed into offline campaigns too. Online social movements are different because the participation is individualized across different physical places. This allows for more flexible participation, but risks strengthening feelings of loneliness and alienation. As this MySF illustrates, participants will often want to meet offline after some time (M. Stewart & Schultze, 2019). Compared with an anonymous online mode, campaign mode is much more dangerous because people become identifiable. Even today, the Iranian regime violate human rights by arresting members of the movement and sending them to prison (Alinejad n.d.).

10.6 Dysfunctional Engagement

Although positive intelligent engagement obviously is the main interest of CI, dysfunctional engagement that hinder CI also needs to be better

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understood. In the 1990s and 2000s, there were high hopes that the invention of the Internet would strengthen democracy and engage citizens in new types of civil debate. Some even expected people to become amateur journalists by publishing their opinions in political blogs, and this would strengthen the critical discourse in society. Among techno enthusiasts, the average user was idealized as a brave new citizen who could produce valuable societal knowledge. In stark contrast, the sharing of information on social media today is typically described as a "private" online behavior that has little interest for societal knowledge production or public news production (Quandt, 2018).

Although an enormous number of people actively use the Internet, online discussions show few signs of paving the way towards a better and more diverse society. People visit the same websites and prefer to read about just a few topics in the news. Surprisingly, one study even shows that newspaper readership is more concentrated online than offline. One important reason is the search engines that primarily direct attention towards a small number of top news providers (S. Hong & Kim, 2018). As a result, a tiny number of sites have a large number of readers while very few or none listens to the vast majority of speakers. When many fight for this attention, it has produced the opposite effect of reducing the overall capacity to be heard. Although everyone is equally able to publish content, money is still an important factor. Many professional web producers use sophisticated strategies, like search engine optimization (SEO), to move towards the top of the ranking list because of the market value of reaching a large audience. The web tends to pick a few winners who get all the attention. The popular vote has arguably become even more important, and this has not improved the political dialogue in society (Halavais, 2018).

Because search engines return a lot of information, we spend less time reading the information we find. We skim it and move quickly to the next distraction. The search process pushes us to collect information from more sources, but in far less depth and with few attempts to synthesize the information. Many people also place a lot of informational trust in the top hits on a search engine like Google, equally as much as traditional news media. There is a risk that the convenience of selecting the top hits make us less critical of information. For instance, there are popular delusions among the top ranked results. A search on a question like "Is climate change a hoax?" returns top results that refer to climate skeptics (Halavais, 2018). The ranking algorithms are concealed in such a way that people are not aware of the manipulation. This can potentially also help political parties win elections. In one study, Epstein and Robertsen (2015) found that biased search rankings can shift the voting preferences of undecided voters by 20 percent or more. Young people especially put a lot of trust in the search engines. There is an increased concern that the lack of informational control opens up the possibility of much greater manipulation. Another example is from the 2016 presidential US election, when a firm named Cambridge Analytica were able to develop detailed psychological profiles of American voters based on Facebook data. These were then used to produce a new type of politically inspired behavioral microtargeting that would tailor its pitches and messaging to different personality types (Zuboff, 2019).

Today, many are concerned that these online activities and especially clique formations represent a threat to democracy. The term "filter bubble" typically describes the polarization that social media platforms like Facebook create. Algorithms customize the user's online experience by presenting information that matches previous consumption behavior. The aim is to connect people with information they are likely to want to consume, but the result is that users are placed in a bubble in of personalized stream of content (Pariser, 2011; Spohr, 2017). A recent example is how social media amplified opinions about the US election being rigged, which eventually led to the storming of the United States Capitol.

Fake news has become a big problem on the Internet. Another example is how Facebook users in August 2020 were repeatedly spammed with fake posts warning them about the UK's Coronavirus Act. In Stoke-on-Trent in the UK, a headteacher even had to assure parents that their children would not be taken away to a secret location if they began coughing in class. Even though the posts were quickly fact-checked, they still circulated and even appeared as an autofill option when searching for "covid act" on Google. It illustrates how difficult it is to remove this kind of content when it first gains a prominent position in online social networks (Greenwood, 2020).

The reason this can happen is because links establish meaning across web pages, but they also make the web "chunky." Once cliques or clusters of websites are established, they tend to reinforce themselves. An individual might find site A by following a link from site B, and decide to link to both of them because they are similar. This increases the likelihood of a new person finding both site A and B. When looking for a friend or a product, these algorithms are usually experienced as convenient because they help you find friends you might know or products you might like. The feeds provide you with options that are assumed to be relevant (Halavais, 2018: 102). Filters on Google or the Facebook News Feed are prediction engines that constantly try to find out what you want next. Many individuals are not even aware that Facebook News Feed provides a highly customized online experience. This is an advantage when searching for a specific product or service, but it is not what you want in political discourse. Participants will tend to self-assemble into groups that share the same opinions on both Twitter and Facebook. It increases the likelihood of developing more extreme arguments because individuals are drawn towards ideologically homogeneous groups, instead of developing more broadly informed opinions. Most persons also tend to consume media that align with their beliefs and avoid content that has a different perspective. When individuals with the same interests cluster together, there is a risk that these groups become self-reinforcing or self-referential (Halavais, 2018: 102; Spohr, 2017).

Algorithms on social media, like those employed by Facebook, expose participants to information that already supports their existing beliefs. For example, in the 2016 US presidential election, the Facebook News Feed provided widely different information about the candidates depending on whether one was a conservative or liberal voter (Halavais, 2018: 141–143). In democratic political debate, you do not want a system that amplifies preferences you already have. If groups create their own environments and only read their own news, this leads to a more fragmented discourse and weakens the public agenda. However, empirical studies find that the filter bubbles today have a limited effect on the majority of the population (Zuiderveen Borgesius et al., 2016). Although there are some "echo chambers" that deny factual evidence, like neofascist groups, a large-scale study on Twitter found that the national social network in Australia is highly interconnected, with limited signs of filter bubbles (Bruns, 2017).

Another major concern is the abundance of fake news in the online setting. Over the last decade, algorithms on social media have tended to reinforce the attention towards some conspiracy theories because of the popular vote mechanisms. People will be curious about reading sensational information even when it is not true, which unfortunately leads some of this content into "winner positions" in the attention economy. Fake news will often also attempt to look like real news, with articles that create the same feeling of credibility as real news. Both images and videos can be manipulated in sophisticated ways. To strengthen the illusion of trustworthiness, there can even be a network of fake sites linked to each other (Tandoc Jr, Lim, & Ling, 2018).

Because of social media channels like Facebook, Twitter, and YouTube, it is easy for this type of content to bypass legacy media. Here, anyone can become a content producer and spread different types of misinformation, through memes or comments. Traditional news sites will usually have much better opportunities to control the content (Quandt, 2018). Part of the problem is therefore that social media have increasingly become intermediaries between news publishers and their readers, like the News Feeds on Facebook. All news will then look roughly the same and make it more difficult for users to identify what is fake news. Although thousands of content moderators who work for the company try to remove the offending content, this is a still a constant struggle because of the abundance of misinformation (Zuboff, 2019).

Nevertheless, a large study of 50,000 US users found that the vast majority of online news consumption is still done by simply visiting the home pages of the favorite, typically mainstream, news outlets. While the use of social networks and search engines shows some increase in the mean ideological distance between individuals, these same channels also increase individuals' exposure to material on the less preferred side of the political spectrum (Flaxman, Goel, & Rao, 2016).

Still, multimodal disinformation has become an increasing problem in recent years. Studies of Facebook show that people are increasingly interacting socially, with more use of images, GIFs, and emoji instead of words. As previously discussed, political memes reach large audiences on Facebook and Instagram, showing that the visual language of debate is becoming more important. There is no elaboration in this debate, but rather an interaction centered on giving or receiving likes, shares, and brief comments. Likes can be regarded as ideological badges that serve the purpose of marking tribal identification with a group. When information is shared between friends, most people tend to be more positive towards that type of political information (Greenwood, 2018).

Most users avoid debate and serious political comments on Facebook, but it is perfectly okay to share a humorous political meme as a way of entertaining friends or to restate a shared attitude. The result is a culture characterized by "clicktivism," which requires so little effort that is has raised questions whether it tells us anything at all about peoples' actual engagement. Most people find it easy to share something others have made, but they are more uncomfortable in writing something themselves (Greenwood, 2018).

In contrast, some smaller subgroups, like anti-immigrant groups, are highly motivated to write their opinions and will therefore often get a disproportionate attention in social media. It is much easier for extremists to find like-minded people in an online setting compared with an offline setting. In one example, an anti-immigrant meme was initially shared by the page of UKIP Brighton & Hove. Surprisingly, of the 45 people who made comments, a majority were middle-aged grandmothers. These women were also sharing memes about anti-animal cruelty, anti-Black Lives Matter protests, QAnon, anti-BBC proms and content in favor of Brexit. It shows that Facebook content from the UK and the US is intermixed, and it illustrates that if you first share a radical meme, the algorithms give you more of the same, with the risk of luring you into a vicious cycle of increasing levels of radicalization. A slightly racist granny can gradually turn into a "hardcore" racist with a twisted understanding of reality (Greenwood, 2020).

A range of states, political extremists, religious groups, and conspiracy theorists are interested in using the Internet to spread misinformation and propaganda. Even comment sections on established news sites can be targets for both trolls and strategic manipulators because they provide free access to a large audience. One example is how the *Guardian* identified a high number of manipulative user posts in their comment sections during the Ukrainian crisis. A large number of pro-Russian posts were linked to the Russian government, or at least their support groups in the form of an internet research agency in St. Petersburg. This type of political propaganda can be emotionally loaded, as with trolling, but it is also different because it plans to target specific groups through repeated manipulation over a longer period. Another strategy is the manipulation of journalists to write stories based on fake facts. For instance, this is done by distributing case stories that pretend to be genuine eyewitness reports. Strategic manipulators may also direct an attack towards a specific article, person in the article, or even the journalists themselves. One example is how right-wing commentators in Germany targeted journalists who had written articles about refugees. By writing a massive amount of comments, the goal is to influence the general public opinion about refugees in the whole society (Quandt, 2018).

To some degree, news sites can control such attacks through user moderation and authenticity checks, but this is far more difficult on social media sites. Although unstructured trolling and cyberbullying still is a problem that follows from the early days of the Internet, it is today the strategic manipulators, not the angry "lone wolfs," who are of greatest concern (Quandt, 2018).

Most CI projects will to some degree need to cope with the challenge of dysfunctional engagement. Wikipedia solves this both by using bots and content moderators. Others require login on their sites. At a macro level, the biggest challenge is perhaps that the large amount of fake news and untrue comments risk creating a general mistrust in the population towards information that may weaken journalism's legitimacy in the long term (Tandoc Jr et al., 2018). In addressing this concern, independent fact-checking has been adopted more widely as a strategy to help regain public trust (Brennen, Simon, Howard, & Nielsen, 2020; Ceci, 2020).

10.7 Summary

This chapter points to intelligent engagement through different types of citizen participation. This participation can be organized into two major types of engagement, close and loose engagement. Loose engagement focuses on individualized engagement with little direct contact, while close engagement involves frequent direct contact between participants. The examples suggest that both types of intelligent engagement are equally important, but they need to be carefully designed if they are to be successful.

Loose engagement will typically center on different types of indirect communication and coordination of the collective work. Crowd peer review is one example. The work is usually finished within three days after a certain number of comments have been collected. Flexible participation is important. Only the individuals who have the time and the relevant competence join. Task management is built around self-selection in a self-organizing system. Because the pool of reviewers is large, there will always be enough individuals to do the review. However, the participants will do the work at different points of time within the three days. Because the environment is transparent, comments will build on each other. New reviewers assess the comments that have already been published and identify how they can make new contributions. Individuals contribute with different types of expertise and try to supplement each other in the collective work. The engagement is centered on the work and can be characterized as loose because participants do not communicate directly with each other. When the work is over, the group dissolves and a new group will be established next time. Another example of loose engagement is how the wider public was involved in the work with the Icelandic constitutional experiment. They were invited to send in comments, but they did not receive any direct response from the group writing on the new constitutional draft.

Mass voting is another example of loose engagement. Members in 5SM are primarily invited to vote on different issues and the online platform is designed in such a way that it does not allow members to comment on each other posts. The party members vote on many different issues within a short time period to avoid strategic voting, factions, and social influence between members. This resembles a classical wisdom of crowd approach. In the online platform, members can read and learn from other comments, but they cannot discuss issues directly with each other. The disadvantage is the limited deliberation opportunities. Only making simple anonymous contributions such as in citizen science projects might also create feelings of being detached from a community.

However, the Polymath project illustrate that asynchronous participation allows for more flexible participation. Individuals can engage with different levels of intensity in the collective work. Another example is Better Reykjavík, the local municipality initiative that invite citizens to participate by sharing good ideas. The online platform is designed around asynchronous communication, but individuals can respond directly to others' ideas by writing comments. Most users prefer to upvote or downvote different ideas. The voting is important since the local government will respond to the most popular ideas in the platform. This is an example of participatory governance that promote both close and loose engagement, depending on how the citizens want to engage in the platform.

The movement My Stealthy Freedom illustrates how loose engagement gradually was transformed into a close engagement when members increased their activities in both online and offline settings. Individuals in this group displayed varying levels of engagement. Facebook made it easier for the members to support each other, but it also exposed members to greater risk of imprisonment. However, a goal with activism is to seek close engagement, which is a requirement for collective action and long-term political change.

One example that requires close engagement is the Citizen Council in Ostbelgien. In this small deliberative community, participants met frequently and engaged with each other in an offline setting. By getting to know new people with diverse backgrounds, this participation is expected to be both interesting and enlightening. The Council also engages the wider population by inviting the maxi-public to send in proposals on policy issues and vote on the ideas they think are most important. These proposals comprise the basis for the further establishment of citizens assemblies that are assigned to examine how these political problems can be solved. The close link between the mini-public and the maxi-public is an interesting institutionalized example of how mass deliberation building on close engagement can be designed.

Most of the examples in this chapter center on citizen empowerment. Both the Ostbelgien citizen council, Better Reykjavík, social media activism on Facebook and the 5SM share the ambition of wanting to empower citizens. All invite citizens to participate in political action, but in different ways. Even 5SM have designed crowdsourcing processes around bills of law that are intended to combine both deliberation and voting, although the degree of success appears to be somewhat limited. New channels are being invented that let citizens communicate their concerns more easily and have closer contact with politicians. These votes count, as they comprise recommendations that either the local government or parliament are required to follow up. The rotation system in ostbelgien ensures that a majority of citizens will be invited to participate in government at least once in their life time.

However, there are significant challenges in these systems. Only 10 percent of the invited citizens in Ostbelgien choose to participate, which may indicate a relatively low interest in this type of direct democracy. The low numbers also raise concern about how representative these citizen politicians are. Only a small percentage of the 5SM party members choose to vote on the case-to-case mass voting events that the party holds. This type of self-selection is nearly always unrepresentative and can easily lead to a distorted form of inclusion. Some are empowered more than others are, and special interests or the most vocal can even outperform the majority (Fishkin, 2018: 15). Still, the invitation in these systems is given to many and is built on the notion of equal participation. There is a sense of refreshing openness in these initiatives even though many choose not to participate.

However, from a normative point of view, one can question whether the emergence of techno-populist parties ought to be considered a good thing for democratic regimes. 5SM highlight majority rule and reject the legitimacy of political opposition with its emphasis on technocratic problem solving. A vital part of democracy is centered on the critical discourse and respect for minority opinions (Bickerton & Accetti, 2018). 5SM highlights a political life in the online setting with a future ideal built around constant mass voting, but it is far from certain if this is enough for citizen involvement in democracy.

Online activism has been criticized for clicktivism or lack of engagement. The culture of liking and sharing memes on social media risks impoverishing intelligent engagement, and gives growth to echo chambers from the sofa at home. Algorithms do not require elaborative arguments. Still, My Stealthy Freedom shows that social media like Facebook can play an important role for people in totalitarian regimes because it is often difficult for such regimes to ban global enterprises that are used for many different purposes.

This chapter points to a number of ways that citizens can be more involved in politics. More of our lives are happening in front of screens, and online engagement is becoming increasingly important. The examples from this chapter show that intelligent engagement can be designed in new ways that utilizes both an offline and online setting.**

CHAPTER 11

Intelligent Contributions

11.1 Background

What are collectively intelligent contributions? Obviously, the specific answer to this question will depend on the context. If we look back at the different CI projects in these chapters, we see that CI tasks and the production of content is organized in many different ways. For example, tasks can be done as separate contributions from scratch or in sequence by building on previous contributions. The importance of making separate independent contributions is prominent in many of the contest formats in innovation contests and when aggregating micro contributions in citizen science projects (see Section 2.3). The tasks will typically be performed within a relatively short period on equal terms. Originally, this approach was underlined by the wisdom of crowds literature (Surowiecki, 2005). However, the examples in this book show that dependent contributions that build on each other are equally important. The shift from independent contributions to dependent combined contributions is exemplified by the crowd peer review mentioned in the previous chapter. Traditional reviews will typically involve a few reviewers who do this work independently, but in crowd peer review a much larger group of reviewers build on each other's work. By increasing the size of the group, the relative size of the individual contribution becomes much smaller, and the problem-solving time is drastically reduced. The "many eyes principle" helps improve the quality of the work.

In reality, successful CI projects may even include phases of both separate and combined contributions. For example, if we look to simple microtasks like the correct classification of images in Galaxy Zoo or in Snapshot Serengeti, this type of work is done in parallel with, but independently of, others. By letting several persons do the same task many times, the number of errors are reduced (Franzoni & Sauermann, 2014).

In the next phase, scientists build on these contributions when they write up the research paper.

Another characteristic of many large CI projects is that they build on task modularization. Individuals can work on separate parts of the collective work without needing to have a complete overview. In Wikipedia, every article is organized as a module. Therefore, contributors can easily choose to work on one or a few articles separately even when there are millions of articles. In video platforms, every video can be regard as a separate module that is connected with other videos through user ratings and "smart recommendation" systems. One individual will only be capable of viewing a very limited amount of the available information.

This chapter will further examine the mechanisms that in different ways can make contributions intelligent. Four core mechanisms are highlighted as especially relevant in producing high-quality CI:

1. Many different perspectives on the same work
2. The golden middle way is the best solution
3. Searching for the unexpected solution
4. Modularizing the tasks

11.2 Many Different Perspectives on the Same Work

Several of the CI projects in this book combine contributions by bringing in different perspectives on the same work. The Polymath project illustrates how different individuals can contribute through collective problem-solving processes in time-centric asynchronous discussions. Prediction markets show how different contributions are aggregated through a numerical value that represents the current state of a solution. Crowd peer review brings in a new approach in this area, when dozens of reviewers engage in the review of a single article. It challenges previous models that invite a few reviewers to do more in-depth work (see Section 10.4). The problem-solving period varies, but all these examples aim to utilize CI through the "many eyes principle" (see Section 1.2.3).

Collective writing of a Wikipedia article is an especially good example of the value of letting many different eyes focus on the same work. The article format is supposed to be relatively short and provide a valid and readable overview of a topic. When many contributors work on the same article, studies have found that the quality improves because of the diversity of perspectives and the reduced likelihood of making errors (Giles, 2005). Its trustworthiness is reliant on the use of good secondary sources, and transparent storage of the different versions of the article.

The contributors will perform many different tasks, including simpler tasks like removing spelling errors, fixing hyperlinks or adjusting the content to encyclopedic guidelines. A large amount of the work on Wikipedia articles is done without any explicit discussions on the talk page. A new edit may automatically prompt a new action by another editor. In a stigmergic perspective, the article is an unfinished "text solution" that trigger others to continue to work on it. This is possible because everyone has access to the current "synthesized" version of the article. This work is collective, with the individual author disappearing into the background. All the contributions melt into one coherent solution, which aims to provide a more accurate, and detailed description of the topic.

The person who starts writing a Wikipedia article will often frame the work for new contributors. The first-mover advantage describes a pattern where the initial text on a page tends to survive longer. There are usually fewer modifications of this content than later contributions. It appears that the first person that creates an article generally sets the tone of content (Viégas, Wattenberg, & Dave, 2004). The risk is premature alignment. Because of positive feedback, early choices can be amplified even when they are not good. One such example from a different context is the incident when users on the Reddit site mistakenly identified the bombers of the Boston marathon in 2013 (Halavais, 2018: 84).

However, the ideal is to include "fair" representation of all perspectives in a Wikipedia article. The transparency of the knowledge production process aims to ensure that many perspectives can be integrated in an unbiased way. The talk page attached to each article is important in promoting an informal peer review that can integrate a diversity of perspectives over time.

Although anyone can contribute, a relevant contribution requires some level of background knowledge about the topic in an existing article. Still, the tasks are simple enough to recruit a large number of volunteers. Since there is no time limit for this work, the articles will need to be updated continuously. Because of this, it becomes even more important to create an online community that motivates sustained contributions.

A positive spinoff of this approach is that it can lead to the production of slightly different versions of the same work, which are modified according to personal interests or a local context. This is common in open source software development, but also in knowledge production processes in

Wikipedia and open textbooks. For example, when an open textbook is translated into a new language, some of the content may be modified to better fit that specific culture.

Argument mapping is another example of how one can utilize many different eyes on the same work. The basic assumption is that deliberation should build on an informed and rational debate that include all relevant pro- and con- arguments. The interface in an argument map is designed so it can easily display a hierarchy of main arguments, sub arguments and explanations. Clusters of arguments are organized in a tree structure that provides a better overview of all the arguments. The final argument map aims to include all perspectives or positions in both a comprehensive and fair way.

In argument mapping, new contributors will add perspectives according to the existing structure, and they will have to adjust their arguments according to the missing parts in the map. Contributors will need to read other contributions in order to position their argument into an overall coherent structure. In contrast, online discussion forums are often overloaded with too large discussion treads and argument redundancy. Exposure to both pro and con arguments is assumed to strengthen the deliberative processes, which is important when dealing with a complex issue like public health or environmental issues. When the number of perspectives increases, it can potentially create better deliberations. An important design challenge is to be able to sustain the overview of the map when the number of contributions scale up (Klein, 2012).

The problem with a topic-centric technology like a wiki is that it aims to provide one single coherent answer, with the risk of oversimplifying the picture. It offers limited opportunities to deliberate on controversial topics. Since the goal is to include all relevant content on a given topic in one single article, this forces the authors to move towards the "least-common-denominator" consensus. In Wikipedia, the controversial discussions are found on the talk pages attached to the specific article, but this content may also become messy because of the time-centric organizations of the discussion thread (Klein, 2012).

A third example is online innovation teams, where team members have different eyes on the same work. One reason is that the problem requires a multidisciplinary team with different background, as one solver states:

> *The nature of the challenge was that there is a company out there that wants to get a broad overview of an area to see where they should invest in computational biotechnology. They want to know what should they be doing in the future and what are the general trends. In order to get a picture of that you need people*

with diverse backgrounds to really pull together this very big picture, and home in on the important things.

Team members with different backgrounds will be better able to provide a broad overview of the field. Another solver highlights how many different eyes help to further develop an idea:

But it's not just the matter of having ideas. I mean you can have an idea, but if you don't have a team to build it, it's only an idea. From the first time you say "wow this is it," there's a long haul to making it a reality. You know, the original idea isn't just "here's the solution X," it changes and become so much better for how the team molds and shapes it. The idea is enriched by the rest of the team.

The solver underlines how the team molds and shapes the solutions through elaboration, by continuously moving the idea work forward. However, there are challenges in sticking to one solution. Some teams have to submit several different solutions because they cannot agree on which solution should be further pursued. In contrast, in individual innovation contests, ideas cannot be further refined through elaborative collaborative problem solving.

Furthermore, the whole contest format in the Climate CoLab, described in Chapter 2, builds on the mobilization of many different eyes to help tackle climate change. For example, "integration contests" challenge contestants to combine previously proposed solutions that have been developed independently of each other. Because previous solutions are stored and published openly, this makes it possible to arrange new contests that build on these ideas. Both the proposals and the reviews are open and anyone can leave comments. The design of a transparent communication environment opens up the process to contributions from many different persons. By involving people from all over the world in collective problem-solving, the goal is to make people more aware of how such problems must be addressed from a local, but also systemic perspective.

All these examples illustrate how one type of intelligent contributions center on utilizing many different eyes on the same work.

11.3 The Golden Middle Way Is the Best Solution

If we examine different CI projects, many are similar in their attempt to find the best solution by balancing diverse contributions. It is assumed that the midpoint is the optimal outcome of the crowd opinion. This "golden middle way" or balancing of contributions can be achieved in several different ways.

11.3.1 Meeting at the Quantitative Middle Point

As mentioned in Chapter 4 on human swarm problem solving, many projects estimate a quantitative middle point as the best group contribution. The basic assumption is that a crowd can utilize more valuable information from a variety of sources compared with what a single individual can achieve. When this information is aggregated or combined in an effective way, "errors" or deviations from the optimal solution tend to cancel out if contributions are made independent of each other. If errors are randomly distributed and the group size is large, the law of large numbers ensures that the middle point provides an accurate answer (Surowiecki, 2005). Another example is a prediction market that use a market prize and individual betting to estimate the middle value of the crowd opinion (see Section 6.3). Deliberative Polling also illustrates that averaging can be used to aggregate crowd opinions in political decision-making (see Section 4.4).

An interesting paradox is that by maximizing a diversity of contributions, one increases the probability of aggregating the most accurate midpoint. For instance, one study that compared different crowdsourcing methods found that a crowd is wisest when it is maximally "diverse" in that its members are as negatively correlated with each other as possible (Davis-Stober et al., 2014). When adding a new member to a group, the best strategy is to select somebody who is maximally different from others. By adding a much less skilled, but more diverse member to the group, the group became more accurate compared with just adding a new member with higher but similar skills. This follows the logic that if all individuals provide very similar predictions, there is little extra value in aggregation. Especially if the crowd is small, it is more beneficial to add a new member who can bring in information that is more diverse. When the members become less correlated with one another, the wisdom of the crowd effect becomes stronger. This is even more important than ensuring that the individuals make their estimations independently of each other. The intuition follows the same logic as predictor variables in a multiple regression analyses that are very similar to each other. Adding a new predictor, which gives new information, helps the model even if it is poorly correlated with the outcome variable. In the presence of some skilled members, it becomes more important to add members with truly different perspectives, which also helps to avoid biased opinions (Davis-Stober et al., 2014). This finding supports the diversity prediction theorem, which underlines that crowd wisdom is maximized when judgements systematically differ as much as possible, not when judgements are independent and cancel each other out (L. Hong & Page, 2004).

11.3.2 Finding a Balanced Representation of All Sides

If we look at the content that gets attention today in the online setting, it is sensational rather than balanced content. According to Shifman (2014: 66–71), viral content is designed in a specific way to become popular. First, this type of content will often be funny, and it can be surprising, interesting, or practically useful. People tend to share content that arouses them emotionally. Positive stories can generate a feeling of being in contact with something greater than oneself, like natural wonders or people overcoming adversities. However, stories that evoke negative feelings of anger and anxiety can also become viral. The disadvantage with this trend is that rational arguments are left out because feelings are considered more important in making the content viral. Second, clear and simple news stories spread better than do complex ones. Jokes are more "sharable" because people can understand them quickly. Since the problem is simple, the solution offered is equally straightforward and easy to digest. However, the risk is that complex problems are oversimplified to increase the likelihood of making it viral. It is not necessarily the high-quality content that becomes most popular.

Still, there are some interesting examples of knowledge products that one could claim resemble a "golden middle way" in an attempt to include "all perspectives." For instance, Wikipedia articles show that it is possible to successfully synthesize content into coherent articles with competing or opposing views. One explanation may be the shared consensus norms like the "neutral point of view" policy that explains that contributors are not supposed to write an "objective" text, but instead seek a fair representation of all sides. The focus on using reliable secondary sources transcends the debate from being a question of whether or not to include specific content to asking how content should be included and with what sources (Algan et al., 2013).

Likewise, in argument maps that promote deliberation, it is important that different political views are presented in a fair way. Argument maps can perhaps complement wiki technology, which is not able to capture knowledge about contentious topics in an efficient way. In simple decision-making, people will perhaps automatically "meet in the middle." However, in complex decision-making where there is no simple correct answer, it may be more important to get an overview of the issues that divide people most deeply, or identify the best ideas for one specific issue and try to understand why it is like that. In a deliberative community, the goal will not only be to maximize the collective outcome, but also avoid that the minority feels alienated. This can undermine the decision and the future cohesion of the community itself. If discussions are to be experienced as fair and legitimate, the argument mapping tools must be designed to minimize regret rather than solely maximizing the majority outcomes (Klein, 2017). Still, one can question whether the organization of arguments maps into pros and cons risks polarizing the debate even when members have better access to all arguments.

11.3.3 Identifying Commonalities

Another interesting consensus-making approach is vTaiwan; it seeks to find the "golden middle way" by emphasizing consensual statements in the crowd. vTaiwan was established in the aftermaths of the Sunflower movement, a sudden three-week demonstration in 2014 by Taiwanese protesters who occupied parliament because of a trade bill that would bring their country closer to China. The protesters eventually backed down, but it raised another bigger question: how could Taiwan's government listen better? To find a solution, Taiwan went to the civic hackers who had been part of the protest and asked for help. They wanted to avoid something like this from happening again (C. Miller, 2020).

These civic hackers were organized in leaderless collective called gov (pronounced "gov zero."). They believed in radical transparency, building on the values from the open source software philosophy, by which everyone should be included in the decision-making process. Not only were they invited to give advice, but one of its members, Audrey Tang, was appointed the country's digital minister. A new group with a very different worldview was given political power in a way we have not seen before. The civic hackers saw the main problem to be a lack of communication and information between the citizens and the government. Elections were too infrequent to give government enough information about what the public wanted, while referenda and debates split society. Instead of measuring division, the group thought one should instead design systems that could improve the communication flow and invent new ways of constructing consensus (C. Miller, 2020).

Although the Internet could offer a solution, it was also part of the problem in Taiwan. Online politics in Taiwan was polarized and primarily made people angrier. There were no platforms that let citizens express their preferences to the government in a constructive way. Like in the rest of the world, social media like Twitter, Facebook, and YouTube had turned the political debate into a game focused on capturing attention. The algorithms prioritize information that gets the most clicks, independent of how crazy it is. These platforms are engineered to keep you on the site, leading to content that provokes the strongest emotions. This amplified the politics of division and outrage rather than nuanced discussions or attempts to compromise (C. Miller, 2019, 2020).

In an attempt to create a new type of democratic process that pulled people together rather than split them apart, the civic hackers invented vTaiwan (the "v" stands for virtual). The environment let citizens, politicians, and others discuss proposed laws in addition to joining face-to-face meetings and hackathons. The political goal is to help policymakers strengthen the legitimacy of their decisions by not only letting citizen vote on questions posed by the government, but also by letting them pose the questions. If it succeeds, it is expected to produce something that the government can turn into new laws (Horton, 2018; C. Miller, 2019).

vTaiwan builds on open source tools, and one of the key parts is the Pol.is platform. The platform lets anyone share their feelings openly with each other, and it is possible to agree and disagree with others. It is also possible to upvote or downvote other people's comments. In this way, Pol.is resembles any other online forum. However, there are also some major differences, as many of the features are designed to bring the groups closer together. When the debate begins, Pol.is draws a map of the debate and shows everyone where they are positioned and where all the different knots of agreement and dissent are positioned. The upvotes and downvotes generate an opinion map of all the participants in the debate, clustering together people who have voted similarly. Even when there are hundreds or thousands of comments, it will be easy to identify like-minded groups rapidly in the map, and get an overview of where there are divides and consensus. The comment system is interesting because it can include a large population of several hundred persons and still stay coherent (Horton, 2018; C. Miller, 2019, 2020).

However, more importantly, the platform does not highlight the most divisive statements, but instead gives most visibility to the most consensual statements. Attention is given to the individual suggestions that find support across the different subgroups and not only in one cluster. After viewing the map, people will usually begin to draft comments they think can win votes from both sides of a divide, gradually bringing subgroups closer together. This specific design feature motivates a competition, bringing up the most nuanced statements that can win the vote of individuals across subgroups. Therefore, most of the participants will typically spend far more time discovering their commonalities rather than just discussing one particular sub-issue. Because of the visualization feature, people can also easily follow the crowd opinion as it unfolds. As such, the technological design in the platform builds on a conception of consensus rule and not majority rule (Horton, 2018; C. Miller, 2019).

Furthermore, because it is not possible to reply to comments, people lose interest in making divisive statements. This almost completely removes the problem of misbehavior. There are also fewer problems with redundancy in this method since only some statements will receive attention in the platform, and it is not necessary to include all statements like in an argument map (Horton, 2018; C. Miller, 2019).

Within a period of three to four weeks, most people will usually agree on most of the statements. This differs from politics when people often spend most of their time discussing their disagreements. By gamifying consensus, the platform is able to create a new type of unity in the process (C. Miller, 2020).

When people express their views, the online platform gives most visibility to those finding consensus across different subgroups. Groups become more aware of what they can agree upon, their hidden consensus. This is different from traditional social media, where algorithms often give primary attention to divisive statements or provocations that receive many comments (C. Miller, 2020). The case reports from Taiwan show that within a period of three to four weeks, most people will agree on most of the statements. While there might be half a dozen polarizing statements, there may be 20 or 30 statements that create broad unity. The success can be attributed to the fact that these commonalities are made more visible than the disagreements. The technology allows people to converge and form a polity. This is not done by resolving bitter disagreements in an online setting, but by pointing to a way forward by revealing the numerous areas most people can agree upon (C. Miller, 2019).

In one of the platform's early successes, the political issue was how to regulate the company Uber, who were in conflict with the local taxi drivers. Within a few days, the platform voters had moved into two large groups, one pro-Uber and one anti-Uber. The online debate covered anything from calls to ban Uber or let the free market decide. Then something surprising happened when both groups were still trying to attract more supporters. Some members began posting statements that everyone could agree were important, such as rider safety and liability insurance. Gradually, these recommendations were refined as individuals tried to get more votes. Eventually, almost everyone had come up with seven recommendations they could agree upon, for example, that private passenger vehicles should be registered. Underneath an angry debate about Uber regulation, everyone realized that they just really cared about safety. The conflict between pro- and anti-Uber camps had been transformed into a consensus that described how they could both exist, but on specific terms. After the online deliberation, the recommendations were discussed in a face-to-face setting with Uber, the taxi drivers, and experts. The different stakeholders had already been drawn closer to each other as the online debate had identified several "consensus items" – statements that most people agreed with. The government followed the recommendations from vTaiwan and let Uber operate, but only with licensed drivers (Horton, 2018; C. Miller, 2020).

Another interesting example is a conflict over whether drunk drivers should be beaten with canes. More than 10,000 voted on a recent proposal that advocated caning as a punishment for drunk driving and sexual assault, but there was also fierce resistance against this kind of punishment. The government challenged vTaiwan to find consensus where none seemed to exist, with groups both supported and rejected caning with emotional intensity. Initially, opinion was divided into three camps: one group each for and against caning, and a third group argued that the punishment should be more serve. Surprisingly, as in the earlier example, the crowd in Pol.is transformed the discussion. The consensus opinion that emerged had nothing to do with caning, but focused on political strategies preventing such crimes. The crowd had found out that "To cane or not to cane?" was the wrong question to ask. Instead, the group began proposing legislation including alcohol locks and confiscating drunk drivers' cars. This solution would not have emerged from a traditional online petition that only gave people the option of voting yes or no (Horton, 2018; C. Miller, 2019).

Still, there are several significant challenges in this new type of e-democracy. vTaiwan has mostly focused on digital issues and not yet on a national issue with entrenched polarization. Civil society needs to learn how to use such tools in cooperation with the government. A large part of the population is not comfortable with using such tools. Only 200,000 people have participated in the vTaiwan discussion. However, nearly five million of the country's 23 million inhabitants have participated on the new platform Join, which builds on a similar method that attempts to create a new public service culture (Horton, 2018). It is problematic to implement such systems on a wider scale when there is a group of people who do not use this type of technology. Young people are usually more tech-savvy, even though all age groups are increasingly using social media. One will perhaps need to use lottocratic methods to ensure demographic representation on important issues.

Another challenge is to incorporate these decision-making structures such that they become a permanent part of the government. When Taiwan's finance ministry decided to legalize online sales of alcohol, there was concern that online sales would make it easy for children to buy liquor. Alcohol merchants and social groups were just talking past each other, and in 2016, 450 citizens joined vTaiwan to deliberate on the issue. In just a few weeks, both sides discovered that they were actually willing to give the opposing side what it wanted, and they were able to formulate a set of recommendations together. Sales would be limited to a few e-commerce platforms and distributors, and purchases would be collected at convenience stores, making it very hard for children to collect them without arousing suspicion. One month later, the government incorporated the suggestions into a draft bill that it sent to parliament. However, because of a change in administration, the online alcohol sales bill was never implemented, showing the risk of "openwashing" – that such processes can end up only creating the pretense of transparency. Because the government can ignore the discussions, vTaiwan may eventually end up as a tiger without teeth. Many participatory governance projects around the world suffer from the same problem, thus making it difficult to gain credibility with citizens (Horton, 2018).

Public officials and politicians also need to regard online comments as something other than protests. They need to acknowledge the potential in mobilizing citizen expertise (Horton, 2018). Moreover, the experimentation continues. All government drafts of law are now subject to 60 days of public commentary that will be organized in a similar way as in vTaiwan. However, the survival of the platform still depends on the power of the ruling party (C. Miller, 2019).

The most important result of vTaiwan is that it shows that online deliberation is possible if the technology is designed in the right way.

Mainstream social media have largely failed in creating a real political debate because they amplify polarizing content. In contrast, consensus platforms can include both citizens and politicians in more constructive ways. By clearing away the divisiveness, systems like vTaiwan can help the crowd agree and give advice to the government in making laws and regulations (C. Miller, 2019, 2020). In the political domain, it appears that intelligent contributions should highlight consensus elements. The system's potential to reconnect people who are in conflict with each other provides evidence of a promising new approach that should be further examined in the future.

11.4 Searching for the Unexpected Solution

There are numerous examples in the history of science that shows us that scientists responsible for major scientific breakthroughs in a field tend to be marginal to that field. The marginality effect assumes that individuals in marginal positions have access to different knowledge than the actors who are at the center of the source problem field. This increases the likelihood of producing potentially novel solutions. The main reason is that they tend to ignore the prevailing core assumptions in the field of the focal problem. For instance, a study of "high impact" papers shows that they are different both in search scope, search depth, and atypical connections (Schilling & Green, 2011).

In the offline setting, this marginality effect will often not be present because only a limited group of persons have access to the problem. This all changes with the online setting that makes it much easier to recruit people. Several CI projects also aim to utilize this marginality effect by recruiting a large group of problem solvers to produce unexpected solution. For instance, online innovation intermediaries have even become a new business opportunity that seek to help problem seekers by hosting innovation contests. The open call for participation invites individuals from different scientific fields and with different backgrounds (age, institutional affiliation, educational pedigree) (Jeppesen & Lakhani, 2010). The expected quality depends on recruiting a large and diverse group that can produce enough unusual ideas, and increase the likelihood of solving the problem. In some cases, the solvers can even be amateurs with little formal education, as with the finalists in Climate CoLab (Malone, 2018: 181–182). Although most people will find it hard to solve a puzzle, many will still be able to recognize the solution when it is explained to them. The "aha-moment" can both occur when a solver reaches the solution, but also when the seeker is informed about the solution (e.g., "Aha I see it"). For instance, it's easy to recognize when someone has written a good software program. What often drives the work is the gap between the difficulty of writing programs and the ease of evaluating it. It's usually much easier to recognize the insight that solves the problem than actually reaching that insight (Nielsen, 2011: 74–75).

Regarding CI, it will be important to examine if contributions can be organized in ways that promote these unexpected "aha moments." In one study of Innocentive, an online intermediary, 166 problems were broadcast to a potential solver population of up to 80,000 individuals; 993 individuals submitted solutions. In total, 59 were awarded, showing that the solvers managed to solve approximately 30 percent of the problems. (Jeppesen & Lakhani, 2010). The percentage of solutions may appear low, but these problems were all very difficult to solve. The solution seekers were large companies with their own research staff who had not yet been able to solve the problem. The most interesting and surprising finding was that a solver had a greater chance of winning if there was a wide distance between the solver's field of expertise and the focal field of the problem. Successful solvers were often at the boundary or outside the expected field of expertise (Lakhani et al., 2007). The main reason is that the experts in the focal field had already failed to solve the problem. By announcing the problem as an open challenge, seekers were able to bring in individuals who would know the answer to similar problems in other domains.

If there already exists a solution in another field, a solver will not have to spend much time and effort in solving the problem. For instance, Innocentive arranged a contest for the Alaska-based Oil Spill Recovery Institute, asking for methods to deal with oil when it spills into frigid ocean waters. The problem was how to separate oil from water after they had frozen into a viscous mass. It was a chemist who came up with the solution. He had been working on a construction site, and realized that the same kind of vibrating devices that keep concrete from hardening prematurely could keep oil from congealing in cold water (Malone, 2018: 180–181). In another example, a firm's research laboratory did not understand the toxicological significance of a particular pathology. The problem had also been discussed with top toxicologists, without any success. In the innovation contest, the solution was surprisingly solved by an expert in protein crystallography who had no previous experience with toxicology problems (Lakhani et al., 2007).

The assumption is that a person or team can solve the problem, but with a radically different approach to the problem. The broad outreach increases the likelihood of finding an outstanding contribution or thinking outside the box. The invitation to participate moves into many different fields and sectors that would not previously have been invited into the problem-solving process. In the recruitment phase, the persons in the relevant crowdsourcing environment will read the announcement and do a preliminary assessment of the probability of solving the problem. Only the persons who think they stand a chance of solving the problem will respond to the call. Although the solution is unexpected to the seeker, the solver may happen to reuse a solution that already exists:

> *The first thing we did was a general literature search to see if anyone had done part of the challenge. And there was a lot of information already publicly available. What we did then was had a discussion online about which avenue would be the most fruitful, what do we need to do to expand what is already out there, and integrate it with other things that have been out there. You know there was no need to reinvent the wheel, in that case.*

Here, part of the work was about checking if anyone had already done the work before. The phrase "no need to reinvent the wheel" shows that the team could reuse solutions that were already publicly available. In recent years, it appears that an increasing number of challenges are less difficult to solve.

In general, the main weakness with online innovation contests is that ideas cannot be further synthesized or recombined after submission. The contest format hinders collaboration between competing individuals.

In comparison, science teams increasingly outperform individuals. They increase the probability of being extremely highly cited – in science and engineering, they are six times more likely to receive at least 1,000 citations than a solo-authored paper. These findings contradict a widespread belief that scientific, technological, and artistic breakthroughs originate from the minds of lone geniuses (Wuchty et al., 2007).

In recent years, team contests have also become more popular in online innovation contests. In the innovation model referred to in this book, a few multidisciplinary teams are invited to compete against each other. An important part of this process concerns the preselection of team members that are most likely to solve the concrete problem. Because of the online setting, it is much easier to put together a team of diverse multidisciplinary experts that cover a wide area of perspectives from all over the world. The teams that compete will work separately, and a facilitator is used to support the process in constructive ways (see also Chapter 8).

Some of the top solvers report that these group processes force them to move outside of their own focal field:

> *One of the challenges was pretty much in my field, although I think being in your field is difficult. That's because most of the solutions require you to think outside the box. You may have good ideas but you have become too entrenched in the concepts, knowledge and ideas of your field. It's harder then to think outside of the box which is really what new ideas require.*

This solver claims that one can easily become "too entrenched" in the perspectives of your own field. Likewise, another solver emphasizes the importance of keeping the mind open and "keep thinking about the problem, as the solution might come from anywhere."

In the previously mentioned Polymath project, comments from outsiders also stimulated top mathematicians to develop their ideas in new and unexpected directions, "something I found more striking than the opportunity for specialization of this kind was how often I found myself having thoughts that I would not have had without some chance remark of another contributor. I think it is mainly this that sped up the process so much" (Voytek, 2017). It shows that even chance remarks can trigger creativity. In this project, an unknown researcher who joined the project also brought in relevant competence from non-mathematical research (Nielsen, 2011).

Another solver emphasizes how an innovation team can do a longer ideation process:

> *Yes, I do both. Very often what I see is that as a standalone solver you basically come up with one or two ideas and go deep as quickly as you can, because you are alone. With a team, you can do a longer ideation process and I like it when people in a team very quickly list several ideas, even the craziest ideas. When you work in a team you truly think out of the box much more than when you are standalone. Secondly, when you work in a team you can go beyond just an idea because you have multiple expertise. You can really articulate much more because you are bringing multiple expertise and multiple thinking. You can really shape a solution which I think is much more attractive for a seeker.*

Because the team is multidisciplinary, it can both provide more creative and "crazy" ideas. The trend is toward greater use of teams by innovation intermediaries. For example, Innocentive, who originally only offered challenges for single individuals, now also offer team challenges. When only a few teams participate in a competition, the winning chances increase. In addition, one avoids the typical "creativity overload" problem in individual competitions that leads to a burdensome review of all the ideas.

Furthermore, some CI projects illustrate a community approach to finding the unexpected creative solutions. The community performance in FoldIt is an interesting example of how a game environment can produce unexpected solutions of high quality. This is done by motivating many users to participate and compete, but also share ideas in a friendly manner (see Section 2.3). Both the IdeaRally (see Section 2.2) and the hackathon (see Section 4.4) illustrate how a large group is recruited to intermingle in an attempt to produce an optimal solution. Within participatory governance, the Better Reykjavík project is another example that shows how the local population can be involved in generating creative ideas that are relevant to the municipality. Together, these examples illustrate that the search for unexpected solutions cover both an individual level, a team level, and a community level.

11.5 Modularizing the Tasks

11.5.1 A Modularization Strategy

A key challenge in many CI projects is how to organize and combine a large number of contributions in an effective way. In general, a modularization strategy is the most common way of organizing the collective work. The complete work is split into many small subtasks that can be performed independently of each other. Collective work on open source software is a classic example, which make it possible to do separate subtasks that still depend on each other. It is easier for participants to organize their attention around single issues that can be separated from each other. It is not even necessary to understand the whole project. Individual work can be done separately from all the other ongoing work, making it much easier to contribute. It may take a lot of extra time to get an overview of all the content or the complete discussion. Another major advantage with modularization is that it builds on the principle that any contributions matters, even very small ones (Nielsen, 2011).

Many citizen science projects that involve analysis of huge amounts of data build on modularization. They are designed as simple well-structured tasks of low complexity (e.g., Galaxy Open Zoo). The problem is clearly defined in advance, it can easily be split into small task pieces, and the criteria for evaluating contributions are well understood (Franzoni & Sauermann, 2014; G. Graham et al., 2015). In one classical example from 2002, NASA published photos of the surface of Mars on an open website so anyone could volunteer to help mark and classify craters. During the first six months, 85,000 users visited the site. In total, volunteers made 1.9 million entries during the project period. Normally, this type of work would require many months of work by a scientist or graduate student. The maps of Mars were divided into many small segments with a simple marking tool. This made it possible to modularize the tasks and split them into smaller components (or modules), which could be worked on independently before they afterwards were put together again. One microtask usually only required a couple of minutes' work. The users could therefore choose to either quickly mark one crater or work for hours with many craters. One study found that a small group of clickworkers did most of the work, while one-time contributors did 37 percent of the total amount of work. People contributed for the fun of it. Because the modules were independent of each other, contributors could choose when they wanted to contribute. This strengthened both user autonomy and flexibility in the project. The quality of the work was also high because the tasks were discrete and highly modularized. By averaging the coordinates of the user contributions, the results were assessed to be at approximately the same level as an expert scientist (Benkler, 2006; Malone et al., 2009). This example illustrates the potential in letting the crowd solve simple problems that have one correct solution. Benkler (2006) claims that the number of people who can participate in a project is inversely related to the size of the smallest-scale contribution necessary to produce a usable module. If the granularity of the modules is small and the required work effort is sufficiently low, there will be less need for extra "incentives" because individuals can more easily do it in their leisure time.

Another prominent example of modularization are the millions of articles in Wikipedia. In every article, contributions of any size matter. Thousands of persons will be working on thousands of separate articles in Wikipedia, but they do not need to know of each other. Still, articles will be linked together in the online environment. The size of the encyclopedia is much larger than printed encyclopedias, demonstrating how the complexity of solutions can scale in the global online setting. According to Nielsen (2011: 33,56), the ideal is to create a technological platform architecture that gives every participant an easy overview of how they can make the best contributions. This can broaden the range of expertise that can be used, making it easier for newcomers to join the project (reduce barriers to entry) and reduce the time needed to perform a task (Nielsen, 2011).

On the other hand, if projects become too monolithic, it is more difficult to get an overview of what is going on. This is why the Linux project put much effort into modularizing the collective work related to the development of an open source operating system. Many attempts to produce complex knowledge products have also failed because of insufficient modularization (Crowston et al., 2018). For example, although open textbooks can easily be reused and adapted, it has been very difficult to let a large group of people co-produce a textbook like in the Wikibooks project. Although the "big brother" Wikipedia is an enormous success, high-quality textbooks need to be both larger and more coherent, making the work more difficult for amateurs. Nor is it possible to have different writing styles, and one needs to follow local or national curriculum standards if the textbook is to become a part of the syllabus in colleges or schools. These guideline requirements have constrained the project's granularity, making it more difficult for outsiders to contribute (Benkler, 2006).

In ill-structured tasks, the specific subtasks are not obvious, contributions cannot be easily evaluated, and the problem space will first emerge during the work. When contributions build on each other and are highly interconnected, it is much more difficult to modularize the tasks (Franzoni & Sauermann, 2014). For example, the Galaxy Zoo Quench project illustrates how difficult it is to involve amateurs in writing a research paper together. One reason is that the different parts of a paper, like the introduction, the review, and the data analysis need to be consistent with each other. They cannot be treated as separate modules. The production of a coherent paper requires additional work in planning the writing process and revising the parts so they fit with each other. Only a few tasks in writing, such as proofreading, can be compared with galaxy classification that is done without affecting other tasks. The voice and writing style of the different sections needs to be similar. In addition, problems at a conceptual level are more difficult to identify and resolve. The project failed because it was unable to decompose the analysis into specific subtasks (Crowston et al., 2018). One alternative strategy could perhaps have been to enforce stronger centralized control with a coordinator who organized and modularized the work in advance.

Attempts to let a large group of people write a novel together have also failed. One example is the Million Penguins project, which recruited 1,500 persons to write a novel together with wiki software. This project never became a success because people were not able to work effectively together. A major difference compared with writing an encyclopedia is that it is very difficult to modularize a novel. Every sentence in a novel is to a much larger degree connected with all the other sentences in the overall story.

Different parts in the book will be connected with each other in intricate ways. Modularization may lead to dissonance and incoherence. Nor is the wiki software ideal at keeping an overview of longer pieces of writing and the relationships between them. On the contrary, it is a tool that is designed to work well for the collaborative writing of short, independent articles in a reference work (Nielsen, 2011: 53–54).

11.5.2 Modularization in Strongly Interconnected Content Structures

Depending on the complexity of solutions, the modularized task will either be part of a strongly interconnected content structure or a loosely connected content structure. Examples of strongly interconnected content structures are open database projects (e.g., Bird, OpenStreetMap) or collective argument maps. When the structure is predefined, contributor guidelines will usually be more precise. In open databases, contributors are given specific instructions on the type of information that is required. One recent example is participatory mapping in sustainability projects (Nicolosi, French, & Medina, 2020). In these modularized structures, each separate module is built from scratch, they will at the same time be part of a large collective knowledge construction, building on the others' work. The goal is to produce a richness and diversity that is still easily accessible for others. In addition, it will be relatively easy to get an overview of the complete collective work in these structures.

In eBird, every uploaded bird observation is a module that becomes part of a large database with all observed bird activities. In comparison with an argument, a bird database will not to the same degree depend on filling the missing gaps because users can upload their information independently of others. These databases are collections of information, where individuals can upload information separately from each other. A large amount of data is effectively aggregated because there is no need to coordinate information between the contributors. However, the missing data spots on the map are visible and provide volunteers information about what areas need to be further explored. In this way, new contributions can also build on previous contributions in these databases. One example is the Gulf Coast Oil Spill Tracker, a data visualization tool within eBird. It was a mash-up of several datasets that included the locations of the ten bird species of conservation concern and the current forecast of the oil slick. It provided a valuable source of timely information. In the year following the disaster, more than 4,000 birdwatchers along the gulf submitted over 110,000 checklists. These data were used to estimate the number of birds that died but were never found. It illustrates that baseline monitoring from leisure birdwatchers can be valuable in many different ways (C. Cooper, 2016: 46–47).

An argument map is another example of a tightly interconnected content structure. Each argument will typically represent a module, and it will either be part of a number of pro-arguments or counter-arguments. These arguments are organized in a hierarchical structure. New contributors will need to build on others' work by positioning a new argument within the framework of arguments that have already been published. The credibility of an argument depends on how it fits into a coherent map structure.

One challenge today is that most groups are better at producing more arguments that can reinforce their prior beliefs compared with finding counter-arguments. In the argument map, exposure to counter-arguments is assumed to lead to a possible change of confirmation bias. "Confirmation bias" is the empirically well-established tendency of individuals to seek out arguments that support a position they already hold. People tend to give more weight to the most striking pieces of information or simply to those pieces of information they already possess, instead of looking for relevant information that might be lacking. When group members disagree, they are most likely to find arguments for their own position, but this can be beneficial in an argument map as it provides more detail to specific arguments. Because people are usually competent at falsifying statements that oppose their views, this can be a useful skill that can be utilized in the map. If both parties participate in this process, it may contribute to the development of a more complete map with more in-depths explanations. However, if the argumentation map is skewed in one specific direction, there is a risk that deliberation can strengthen group polarization. Close attention must be paid to the how decisions are achieved when groups strongly disagree (Landemore, 2013).

11.5.3 Modularization in Loosely Connected Content Structures

Furthermore, some CI practices center on loosely connected content structures. Many knowledge products today, whether it is a text or a video, are published openly and become accessible for others. The work becomes a tiny module in an enormous network of interlinked information on the Internet. From this perspective, every video on YouTube is a separate module in a platform where the most realistic way of finding the video is by using its search engine.

However, one of the main challenges in the new global online environments is how to tackle the problem of information overload. While the traditional expert model built on the transmission of knowledge from a formal expert to many less knowledgeable others, the networked online environment illustrates how anyone with some skill or knowledge can share their knowledge openly with others. The problem is that both the number of experts available and the number of amateur contributions have become enormously large. Searching through hundreds of scientific papers that describe an issue is far too time-consuming for a single individual. While it is still possible to synthesize content in text documents, this is much harder to do with videos because of its multimodal properties. The most relevant videos will therefore need to be identified, and viewing many videos to select the most relevant is far too time consuming for an ordinary individual.

Today, search engines are considered the best option to solve this challenge of finding modularized information in a loosely connected content structure. These search engines require that citizens find and assess relevant information on their own. Although search engines like Google contain links to a large proportion of the web, only a tiny percentage is made easily accessible to users. Unlike television or even printing, it is easy for anyone to publish their opinion to a large, potentially global, audience, but this does not imply that anyone will pay attention to this "diversity of content." The assumption that computer networks are more democratic, and necessarily provide a greater voice to everyone, is misguided (Halavais, 2018: 101).

While the distributed nature of computer networking makes it less likely that a small number of interests can control it, this does not imply that the web is a level, uniform network. Most likely, any given contribution on the web will be lost in the flood of similar efforts. While search engines make it easier to find answers to specific questions, this is done at the expense of the larger, diverse world of information and opinions. Of the millions of blogs in the blogosphere or videos on YouTube, most get viewed by only by one or two people, while a small number get millions of hits, this being far from equal access to the greater web audience (Halavais, 2018: 101).

Paradoxically, search engines that can retrieve enormous amounts of information are today being criticized because they oversimplify the available information when they only display a limited number of hits. A search for "staph infections" will generate a hit of about 1,200,000 pages, as health topics are popular on the Internet. The first three results, which most users will check, are from mainstream, relatively well-respected sites, but in total only 234 results are displayed. It shows that an enormous number of pages are left out. When most people use a search engine like Google, they typically only check the top ranked pages. On one side, it is necessary to select only a few results because our attention span is limited. The goal of using the search engine is to avoid the "junk" on the web and provide higher precision in the search results of the search engine. However, the hyperlinked structure tends to send the searches along the same path to the same informational sources. The result is that general-purpose search engines overrepresent the central tendency and reduce the diversity of the information when they operate in the hyperlinked structure of the web. Even though the search tools are not intentionally designed to amplify a few top selections, the ranking systems are conservative and reinforce existing orders of authority. It is not a question of whose power they conserve, but rather that they tend to enforce a "winner-take-all" structure that is difficult to break free from. The network structure on the Internet is organized in such a way that a lot of attention is given to a few sites, while many sites receive no attention at all. The risk is that search engines amplify a global groupthink monoculture and makes it more difficult to find local cultures and practices. There is a naturally tendency to move towards monopoly: "one search to rule them all." This becomes a problem when large search engines are used by a very diverse set of users with different needs. It becomes more difficult to serve the interests of marginalized groups because a general relevance in search engine rankings does not necessarily match an individual query situated within a very particular aim (Halavais, 2018).

In the network, only a few links survive and are amplified, leading to concentrations of power and influence. This results in a fight for attention in the network structure. Virality itself is also highly persuasive; view counts inform viewers that many others find a message interesting, and this amplifies the spread of the message. If the author is already famous, it is more likely that people will share the work. In viral marketing, there are two types of preferred influencers – the "hubs," people with a high number of connections to others, and "bridges," people who connect between otherwise unconnected parts of the network. In marketing, it is much more important to get the attention of these highly connected individuals compared to just sending the message to "regular" users (Shifman, 2014).

11.6 Summary

If we compare the different value-producing mechanisms, they are all similar in their attempt to produce better solutions by integrating diverse contributions. Many CI projects are designed to include as many relevant contributions as possible in an attempt to capture the "complete complex picture" of a problem, either by combining all contributions or through selecting the single best contribution. However, the increase in informational diversity risks ruining the coherence by making the complexity overwhelming. Therefore, the intelligent contributions needs to be organized so they provide some kind of overview of both the processes and the products of the collective work.

Modularization of tasks is the most typical strategy to deal with the overview challenge. Another strategy is to remove the need for overview, like when independent contributions are harnessed in some "wisdom of crowd" approaches. Similarly, most innovation contests let individuals find optimal solutions independently of each other. The benefit is in the "stranger bonus" that is created when many proposals are generated. Here, the overview challenge will be how to effectively review all the proposed solutions afterwards.

If we also look at how knowledge products are modularized and accessed through search engines, it is evident that only a few "winner" solutions will get most of our attention. In an enormous, loosely connected network structures, it is very difficult, often impossible, for an individual to keep an overview of all the content. Algorithms do the work of selecting the best solution or narrowing down the individual choice to a few options. The disadvantage is that we know little of how the algorithms work, but convenience and time efficiency still make search engines the preferable alternative. However, there is a risk that popular hits are biased, and do not provide the best quality option, as many will fight for attention in the online setting.

Another way of coping with the challenge of information overload is to fuse all contributions together in the ongoing work, as when the complexity of a module in Wikipedia never moves beyond the size of one readable article. This makes it easy for an individual to have an overview of the content, and receive contributions over time. vTaiwan is another example of a decision-making technology (Pol.is) that enables individuals to easily keep an overview of discussions with several hundred participants. Improving the quality of deliberation in an online setting is a major challenge. The case stories from Taiwan illustrate that "consensus games" can transform disagreements. This is possible because all contributions are part of an emerging map structure that creates a visual overview of the debate, and the aggregated clusters of different positions.

In vTaiwan, the second phase is centered around an online competition between who can find the best “consensus solution”. Rapid negotiations are performed through up- and downvoting of different alternatives that resemble the honeybee dance in swarm problem solving. The crowd constantly chases the best consensus solution in its attempt to win votes. Part of the success appears to be how rapidly participants can change positions in the network structure, compromise, and move towards the “golden middle way.” In this process, the parties discover that they agree on more issues than they previously thought. The logic of communication is entirely different from the algorithms in social media platforms that are designed to maximize profit by reinforcing existing preferences.

In argument mapping, the CI design is very different in its emphasis on the construction of a comprehensive set of arguments. The hierarchical organization of the map assumes that all arguments can be linked together in a systematic and coherent way. New contributions should not be made separate from existing information, but rather adjust itself to the current state of the collective knowledge production. Previous contributions will also be checked and revised when many participants read the same information. Since there is no point in adding an argument or information that has already been made, this can potentially provide a better overview of a complex debate. The predefined structure in pro and con arguments aims to create a better overview of a complex debate and avoid that persons only stay on one side in the debate.

However, one can question whether the technological design overemphasizes a dichotomy between pro and con arguments, especially if the group needs to develop a solution that synthesizes or transforms the current debate. Still, the process of filling in gaps in an argument map may be educational and lead many individuals into new argumentative areas that they have not previously examined. This may result in an attitudinal change.

According to Landemore (2013), receiving complete information about political parties is not enough – there needs to be a deliberative discourse that builds on this informational diversity. The available information should create the foundation for a diversity of reasoning processes that include both pro and con arguments. This is important because individuals often fail to be self-critical towards their own arguments. In argument mapping, individuals are challenged to both find better support for their own beliefs and assess arguments advanced by others. If individuals want to convince others of a given proposition, they will be motivated to find good arguments that are likely to convince the listener.

When listening to arguments, individuals will want to evaluate the soundness of the arguments before they accept the conclusions (Landemore, 2013: 126–127).

One must also remember that many find it challenging to engage in political debate with others with whom they disagree. Most people, when faced with disagreement, will prefer to retreat to like-minded peers or avoid political discourse at all. Disagreement threatens norms of politeness and interpersonal harmony (Landemore, 2020). While vTaiwan aims to transform the discussions through consensus building, argument mapping appeals to the rationality of individuals in providing arguments that are more informed to all parties. In addition to the verbal offline discussions, argument mapping is reliant on the production of written arguments as part of a comprehensive framework. It enables individuals to compare arguments before decisions are made. One advantage is that this tool makes it easier to bring forward arguments from minority groups (Klein, 2017).

However, the major challenge is how to summarize the complexity and bring forward the most interesting questions and arguments in an effective way. Depending on the problem, users can be challenged to synthesize the argument map or refine proposed solutions in the final stage. From one perspective, one could claim that the technological design builds on utopian rationality. It is assumed that all arguments can be integrated into a coherent and logical map. However, it is important to be aware that the argument map is usually not a goal in itself, but primarily a support for informed discussions in an offline setting. For example, the final decision may be a vote on a few proposals (Klein, 2017).

If we compare all these examples, transparency is important in letting any individual access all information. New digital technologies aim to provide relatively simple overview in different ways. Both the consensus platform and the argument map are very different from an echo chamber in that they provide information about every individual as a part of the whole group. While the pol.is platform partially expects the crowd to reach consensus on some issues before they meet offline, the argument map technologies assume that consensus must be achieved in an offline setting. In the offline setting, vTaiwan recommends both meetings and hackathons, which can help lawmakers implement decisions with a greater degree of legitimacy. In the political domain, it is important to find the right balance between intelligent contributions in the interplay between an offline and online setting. vTaiwan has been used in 26 cases, with 80 percent leading to "decisive government action" (Horton, 2018), but the government is still not required to pay attention to the outcomes of those debates. Institutionalizing CI-practices is key, but the pace of implementing new decision-making methods or argument maps is slow. Often, power structures in the existing system will need to change, and some may question whether it is a good idea to transfer more political power to a large crowd.

CHAPTER 12

Intelligent Evaluations

12.1 Background

According to Mulgan (2014), there is a need for a new discipline that helps us to be collectively intelligent about our own collective intelligence. In bringing in this metal-level perspective, we are challenged to ask what this implies. If we look to individual learning for inspiration, we know that metacognition, or the ability to choose efficient learning strategies and evaluate your own individual learning, is essential among good learners (Flavell, 1979). At a collective level, the processes of planning, monitoring, and evaluating collective work will be equally important. Collective metacognition has been proposed as a term that describes how collective intelligence can think about its collective intelligence (Schuler, 2015).

Because of the digitization of information and the online setting, evaluations are also infiltrating almost every area of human life. The first section of this chapter describes the rise of the reputation society, which centers on evaluating persons. Online reputation is now not only important in human work settings, but it is at the center of our lives in social media. Individuals are constantly getting feedback from others in the form of quantifiable ratings of different activities.

The second section focus on evaluation of collective work. Digital technology makes it possible to design metacommunicative feedback loops in most group work and organizational work, sometimes labeled as triple loop learning (Tosey, Visser, & Saunders, 2012). This section discusses the potential of implementing a more systematic level of metacommunication in collective work.

The third section addresses intelligent evaluations in the political domain. One could claim that evaluations are at the core of any well-functioning democratic system. If we look back in time, the ancient Athenians were the first to institutionalize evaluations with the nomothetai. Today, the Citizens' Assembly in Ireland is a fascinating new way of institutionalizing citizen evaluations in democratic systems.

12.2 The Reputation Society

12.2.1 The Emergence of the Reputation Society

In recent years, scholars have suggested that that we are moving into a new type of reputation-centered society, largely triggered by how reputation systems have become important in an increasingly number of different online environments. In contrast to an offline setting, online individual reputation becomes visible in a new way when it is assumed to be measurable as a reputation score (Gandini, 2016).

Because social and socioeconomic interactions require trust, reputation can help actors make decisions in situations where they do not have direct knowledge of other persons. In online settings, trust becomes even more important when people do not meet in the same physical co-located setting. We cannot rely on local knowledge or word of mouth. If we do not have any previous knowledge of persons, this creates uncertainty whether they actually are reliable. Online reputation system has been designed to facilitate trust or remove the need for it. Reputation scores are typically used to assess how trustworthy individuals are, building on various types of digital data, both active user data like ratings and reviews, but also passive user data like interaction histories. Algorithms and metrics automatically aggregate the data into a one-dimensional quantitative score that describes an individual's trustworthiness (A. Wilson & De Paoli, 2019).

In a historical perspective, this new reputation economy emerged with the growth of a largely individualized workforce of knowledge workers, the freelancers and self-employed workers who very early began to engage in online social networks. In the late 1990s, the notion of self-branding and self-promotion began to spread as key activities for career development. Cultivation of a professional image became essential in the new knowledge economy, and the increasing popularity of social media amplified the importance of these self-branding practices. In this context, the notion of reputation takes a prominent position as a shared cultural conception of value that bridge the offline and the online setting. It becomes strategically important to manage reputation in the network of professional contacts, as it is decisive to get jobs. This new source of trust is not only reliant on interaction in an offline setting (Gandini, 2016).

In the online setting, reputation was reinvented as a new type of social capital by imitating the logic of trustworthiness used in the Google PageRank algorithm. The huge success of this search engine builds on an analogy between hyperlinks and academic citations; the idea that the "citation of the Internet," the link, was the most informational resource. The PageRank calculated the number of links pointing to one page from other pages. In a similar way, reputation was recreated as a performance metric that could calculate a reputation score by informing about the trustworthiness of individuals in a very easy and reliable way. Although reputation across online environments can be regarded as the digitization of word of mouth, it is also an economic asset. Reputation becomes an object, a form of individual social capital that includes both offline and online networks, and it represents an investment in social relations with expectations of economic return and future job procurement in an increasingly freelance-based labor market (Gandini, 2016).

Today, the number of freelancers in the economy is increasing, with as many as one of seven workers in the UK. In addition, wide varieties of economic transactions are now dependent on reviews and feedback systems with elaborate rankings and reputation scores of various sorts. This includes an increasing number of sharing economy sites within holiday accommodation like Airbnb and online retailers such as eBay. In these systems, personal reputation functions as a networked asset that favor some persons in economic transactions of information, services, or goods (Gandini, 2016). Most of the online systems that use reputation scores build on an economically orientated competitive logic, with an emphasis on methodological individualism.

These systems draw on data about a user's activities to produce information about that individual's standing in the online community. They resemble the point systems and leaderboards in online games, where the "capital" is the opportunities for gamers to "spend" these points in different ways within the game-world. The main difference from a game is that the scoring metric will typically combines many different types of data. Data can be generated directly from user's activities, such as frequency of visits, how much time they spend on the site, how many transactions they complete, how many contributions they make to a discussion, how many network ties they have, and so on. It typically also includes how others rate the contributions, through likes, up- and downvotes, or more specific assessments regarding helpfulness, reliability, promptness etc., and qualitative feedback like review comments (A. Wilson & De Paoli, 2019).

The metrics may be different depending on the online site. It often intends to serve as proxies for prior experience and personal knowledge that can predict future behavior. The different factors in a reputation system will typically be used to generate a numerical measure of the user's overall behavior/reputation/ranking within the relevant community. Reputation scores are aggregates or averages and the data can be weighted in a range of different ways. Scores are often also made public to other community members, so individuals can make decisions whom they want to interact with. In other cases, the scores will only be available to site administrators (or an automated process) and allow privileges or give access to services within the space (e.g., using star ratings or badges) (A. Wilson & De Paoli, 2019).

When reputation systems are intended to support transactions of a trading nature, an entity's reputation score depend on customer feedback about reliability, product quality, speed of response, etc. In other areas, these scores can include the number of contributions and other users' explicit evaluation of individuals. Users can judge others in a range of different ways, by awarding stars, writing feedback, favorite, up- and down-vote. Consequently, one can both accumulate and lose reputation, often spend it, and sometimes even speculate on it. However, it is difficult to defend against unfair assessments or being able to explain choices. Once a seller receives a negative rating, this can easily lead to more negative ratings because these systems tend to amplify biased up- or downward spirals (A. Wilson & De Paoli, 2019).

Furthermore, studies on eBay find that giving feedback is not motivated by altruism, but by an expectation of reciprocity. Users lose interest in receiving feedback once they have accumulated experience and a good reputation score. Then they will no longer need to elicit ratings form others by rating them (A. Wilson & De Paoli, 2019).

Reputation manipulation is also a significant threat against these systems. Unscrupulous participants may find ways to manipulate the reputation scores in dishonest ways so they can earn more money in e-commerce platforms. A well-established, high reputation can provide a better price. Similarly, participants may try to damage the reputation of others, leading to rivals losing customers (A. Wilson & De Paoli, 2019). When reputation is viewed as a currency or marketable commodity, it is exposed to the same problems as in financial markets, like questions of ownership, fairness, and control. Collusion is one threat, as a group of people contributes to boost or undermine a reputation score. Badmouthing can produce unfairly negative ratings and damage reputation, with negative economic consequences. Bots have also been linked with manipulation of reputation scores (A. Wilson & De Paoli, 2019).

12.2.2 *Online Reputations Moving into New Domains*

The reputation score systems are becoming increasingly ubiquitous, as they move out of business sites, into an increasing number of new domains. For example, many expert Q&A sites, which are primarily a discussion forum instead of a trading environment, have begun to employ reputation systems so that users asking questions can judge the trustworthiness of an answer, or community members can build up their own reputation as experts. Here, high reputation scores is motivated by kudos and honor, for example by receiving badges of achievement in the community. This can be regarded as a type of gamification, which motivates knowledge sharing in the community (A. Wilson & De Paoli, 2019). StackOverflow is one such example of an expert Q&A site where programmers can ask and answer questions relating to technical issues. Users can up-vote and down-vote others' questions and answers. These actions not only organize what is visible, but they also contribute to reputation building. In general, there are many more ways to gain reputation than to lose it. However, one loses reputation points if a post is flagged as offensive or spam.

Points can also be "spent" (transferred to another user) in a bounty system for those seeking quick answers to complex questions (A. Wilson & De Paoli, 2019). In addition, points are converted into privileges at the site: for example, once a user has 15 points, they can vote up a question or answer; once they have, 20, they can talk in a chat; once they have 125, they can vote down questions or answers; and so on. At 1,500 points, users are allowed to add new tags to the site (questions are tagged as corresponding to particular topic areas, such as SQL or Java); at 2,000, users can edit other users' questions and answers. At 10,000 points users gain moderation rights; at 25,000, they have access to the site's analytics. Thus, there are incentives to build one's reputation that go beyond the acquisition of reputation for its own sake, (A. Wilson & De Paoli, 2019).

Another area for reputation score systems is scholarly social networks for scientists. These measure a scientist's reputation and scientific impact (e.g., altmetrics) in new ways (Fecher & Friesike, 2014). For instance, ResearchGate aims to be the prime deliverer of scholarly reputation by designing reputational metrics that builds on a richer amount of data compared with only measuring the number of citations of an article, which has been the most important influence on a researcher's reputation regarding funding and career opportunities. Today, the scholarly workflow in the online setting of formerly hidden actions like reading, bookmarking, sharing, discussing, and rating are leaving traces online and offer new ways of measuring scientific impact. However, studies show that alternative engagement metrics, such as Q&A and follower data, can also lead to reputational anomalies (Nicholas, Clark, & Herman, 2016).

Proxy voting is another example of a reputation system in the political domain. In one proposed model, labeled liquid democracy, it is possible to transfer votes through a new type of flexible representation. In this alternative model, all members vote directly on all policy issues. Since the required voter competence is more demanding, voters can delegate their votes to a representative to vote on their behalf on a singular or several policy issues. These votes can even be further delegated to another representative, but can also be terminated by the original voter at any time. The voting model allows for area-specific representation instead of the typical political representation that intends to cover all policy issues. It enables voters to directly authorize experts to vote on their behalf. This allows for a more fine-grained account of political representation compared with the typical policy bundles political parties provide. In addition, the voting method is assumed to require a "reputation system" based on ranking and ratings. When experts have a transparent record of accomplishment, voters can easily assess the results of previous claims and use this information when they vote. Liquid democracy is proposed to be particularly relevant in legislative decision-making (Blum & Zuber, 2016).

In other areas a reputation score system might have potentially negative effects. Conventional reputation systems are loaded not just with the values they are designed for (trust, honest behavior, reliability), but also a more subtle value-system that is orientated towards a competitive, capitalist free market based on self-interested individuals. Individuals possess a capital that individuals can accumulate and lose it. This may be appropriate for an e-commerce website, but in other contexts, these systems may have potentially negative effects (A. Wilson & De Paoli, 2019). For example, in expert Q&A sites, knowledge sharing often builds on values like pride and commitment. There is less focus on promoting individual skills.

Although some of these sites operate with reputation scores, this is not necessarily at the expense of other actors who compete for the same resources. However, a potential disadvantage is that low reputation scores may have a negative psychological effect on individuals. One example is the discussion forums on the platform supportgroups.com, which is dedicated to users with financial problems, homelessness, anxiety, and other mental and physical health issues. Recently, it included an online reputation system so that users can acquire points when they publish comments in the forums. Since this environment attracts vulnerable individuals, reputation scores systems are particularly concerning since they can have a negative impact on users' self-esteem (A. Wilson & De Paoli, 2019).

In reputation systems that aim to create a supportive community of peers, it may be counterproductive to develop a quantifiable reputation system. Individualized ratings risk weakening community values and cooperative activities that are not measured by the system. While a market-based view of reputation may be desirable in a business-focused trading site, it may undermine important noncompetitive values on other sites (A. Wilson & De Paoli, 2019).

12.2.3 Reputation Score Systems in Social Media

Social media sites and professional networking sites encourage social interaction through likes, shares and mentions, and other comments. These statistical data are used to aggregate metrics, which also create individual reputation systems in the informal social domain. For instance, social influence today is increasingly regarded as something that can be measured through the number of followers you have on different sites. Reputation is becoming more important since we increasingly depend upon others to engage in transactions to employ us, befriend us, or listen to our opinions (Gandini, 2016).

In social media, people live continuously in the gaze of others through a range of informal assessments such as likes, friends, followers, and many other secret rankings. This system produces a stream of evaluative metrics that raise or lower one's social currency. As a consequence, self-presentation in social media has become an increasingly important part of people's life. The continuous "curation" of one's photos, comments, and profile with deletions, additions, and modifications, are all designed to maximize likes, being the core value indicator in this existential marketplace (Zuboff, 2019).

The most important psychological process in Facebook is "social comparison." It describes the influence from our social environment, when we tacitly apply evaluative criteria from our society, community, group, family, and friends. Ordinary young people are drawn into online communication that automatically triggers social comparison on an unprecedented scale. Both insecurity and anxiety increase when individuals constantly chase for positive feedback from others. The use of likes in social networks provide users with those variably timed dopamine shots, which further increase their efforts. A post with zero likes is not just privately painful, but it stands out as a kind of public condemnation. Still, most users are more eager for the reward than the fear of being humiliated (Zuboff, 2019).

In the social media life, there is no self independent of other's feedback. The likes provide a continuous assessment of one's value on the social market. In one study, one third of the women said that their biggest worry online was that they constantly had to compare themselves and their lives with others. The systems are designed to maximize the possible amount of users' time and consciousness, and the result are several types of emotional anguish such as addiction, boredom, distress, and isolation. Simple behavioral techniques are used, like variable reinforcement, which let the user receive small rewards every once in a while, in the form of likes and comments from others (Zuboff, 2019). Zuboff's descriptions may overemphasize the negative effects, but they are a reminder of the destructive effects reputation systems can have when they colonize new areas of human life.

In contrast, the original Internet, and some of the most well-known CI projects rely on what can be labeled as a deliberative reputational meritocracy. In these CI environments, a majority of individuals make minor contributions, while a small core does much of the work. These active contributors serve as leaders of the community and make the most important decisions.

In the online setting, these meritocracies originate from open source software communities (Castells, 2010). One example is the Linux operative system, where any change to the code of the central kernel can break the entire project. The founder Linus Torvalds and his "closest group" will decide which of the submitted modules are included in the upgrade of the software (Kittur & Kraut, 2008). Although Linus does not have a legal or technical authority, he has a persuasive authority. Anyone is legally free to do as they please, but the community is still built around a hierarchy of meritocratic respect, mutual recognition, and some kind of peer review system (Benkler, 2006). Here, the skills count regardless of age, sex, race, position, or qualification. Everyone is given an opportunity in a decentralized system where recognition is based on what you do and not who you were (Levy, 2001). Likewise, in one study of the Apache server project, a core group of 15 developers contributed 88 percent of the new lines of code, but did only 66 percent of the bug fixes, which was a less interdependent task. This finding indicated that low coordination tasks such as bug fixes was done by many different contributors, while high coordination tasks such as strategic planning was done only by a small group. The leader group set direction and provided a structure to which others could contribute (Kittur & Kraut, 2008).

While the reputation systems in social media are part of an individualistic, accumulative, and competitive paradigm, some of the large CI projects, like Wikipedia, build on a peer production community that honors hard work. Here, individuals with many different backgrounds will interact and build a common identity through their shared passion. Advancement in meritocracies are based on performance, rather than wealth or social background. In these reputation systems, achievements are displayed on personal profile pages. One example is the gaming community Foldit, which provide a multitude of statistics on the gaming performances. The login information on the site encourages users to register so they can get credit for the volunteer work ("You are an anonymous user and will not get any credit for your contributions. Sign in now!").

In the same way as in research communities, part of the motivation is about gaining recognition by peers (Himanen, 2001). Both Foldit and Wikipedia illustrate that even very young persons, like teenagers, can do important work in these communities. The main distinction between different subgroups in the community will typically be between newcomers and old-timers. In Wikipedia, there will be thousands of informal leaders who work on separate articles, depending on who does most of the work. Over time, some of the most active contributors can choose to move into strategic roles in the community (Kittur & Kraut, 2008).

Wikipedia is also interesting because of how deliberation is an important part of how persons are evaluated in the community. This includes the process of selecting individuals to become administrators or Wikipedians in the community. When a person is nominated to become an administrator, the evaluative deliberation will last for seven days. Anyone can ask the candidate questions, but no person can ask more than two questions each. This process let other editors get to know the candidate, and explore the candidate's motivation to become an administrator and if they understand their new role. An uninvolved third person, a bureaucrat, decides whether there is consensus to approve the request. The final judgement is not based exclusively on the percentage of support, but in practice one will usually need more than 75 percent of the votes because most candidates with less than 65 percent support are not approved ("Wikipedia:Administrators," 2020).

In contrast to the dominant trend of using reputation scores, Wikipedia still highlights "quality, not quantity." Because edits can vary in size and quality, edit counts are not an important part of the assessment ("Wikipedia:Edit count," 2020). However, all contributors will acquire a track record because it is easy to identify all previous actions in the environment. These actions will also be part of the assessment. Most active contributors will already have developed an informal reputation based on the work they have done. Some contributors even make their own personal profile pages that display the work they have done. Still, it is the deliberation and voting by members in the community that decides who is promoted to the most important roles in the community.

12.3 Evaluating the Collective Work

12.3.1 Shared Coordination

The digitization of information does not only open new ways of evaluating persons, but it also influences how we monitor and coordinate the collective work in a range of different ways. Some degree of coordination is necessary in all kinds of group work and evaluations an important success factor. From a theoretical perspective, intelligent evaluations will build on some type of metacommunication or metadiscourse, as it utilizes our human ability to talk about how we talk. This ability requires language and is likely to have played an important role in human evolution. Some even consider the ability to communicate about our own communication as a basic condition for successful human communication (Bateson, 1972). Explicit, shared coordination is important when small groups engage in complex tasks that require a high degree of synchronization between members. Studies from an offline setting also find that explicit metatalk is important in regulating small group work in professional settings (Baltzersen, 2013). It provides feedback loops that enable groups to evaluate their ongoing work. Here, collaborative

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problem solving differs from human swarm problem solving in its emphasis on such processes, like the need for joint coordination (see Chapter 8). If we look to specific CI practices, virtual innovation teams illustrate how metacommunication can be performed in efficient ways. For example, a top solver claims part of the solution is to ask for a clarification of the problem:

> *When we started this recent challenge we asked to have a conference with the client. We asked very pointed, detailed and technical questions, so that we could understand exactly what it was that they were after, because the challenge was not written in great detail. They were sort of vague and you're like saying, "Well if you don't want to answer this question that's fine, but if you tell us what's your bottom line, what is it that you want to get out of this, what is your product, or what is your goal, it's going to be a lot better, because if we understand that then we will be able to provide you with that solution." So in terms of this one, once we met and spoke with the client, it became pretty clear to me. I was like, well, I didn't know what the solution is but I was pretty sure I could figure it out.*

This is an example of metacommunication in the initial phase of the problem-solving process. A discussion with the seeker in this phase can help the group better understand the problem, and thus increase the likelihood of solving it. In general, many studies point to the importance of discussing and establishing good group norms early in the problem-solving process, even if the meeting is short. Some studies report that it helps handing out a written description of the rules of the discussion and read aloud the rules (Fishkin, 2018: 176; Grönlund, Herne, & Setälä, 2015).

Other CI researchers also highlight that collective work in large organizations need to build on metacommunication or reflective communication (Mulgan, 2018; Schuler, 2015). These processes are often connected to different types of feedback, such as second-loop learning (Argyris & Schön, 1997) or triple-loop learning (Tosey et al., 2012), which raises the awareness of how organizations learn. The notion of triple-loop learning assumes that intelligence operate at multiple interconnected levels; the first loop uses existing models to process data and perform existing work efficiently, the second loop generates new relationships or new procedures, while the third loop creates new ways of thinking. Participants reflect on how they think about the "rules," not only on whether rules should be changed (Mulgan, 2018: 156, 237).

However, when the group size increases, it becomes increasingly difficult to coordinate and get an overview of everything that's going on. For example, if only one person can talk at a time, it can be frustrating to be in a large group because it can take much time to let everyone be heard. When coordination requirements increase, this may reduce motivation. As Brooks Law states in the domain of software projects: "Adding manpower to a late software project makes it later." When the group size reaches a certain level, shared responsibility or control become a problem. The members will have to use relatively more time on procedural issues rather than substance or actually doing the task (Kittur & Kraut, 2008).

With the support of digital technology, direct coordination is possible in larger groups than what was previously possible. However, the exact threshold of the maximum group size is uncertain. A common rule of thumb for face-to-face groups is that the optimal group size is somewhere between five and ten people. If there are fewer, there is not enough benefit from diverse points of view. If the group size is above ten, coordination will take too much time. Even when groups make this extra effort, the difficulties of working together may outweigh the benefits of having more people (Malone, 2018: 184–186). Still, different digital tools can provide a better overview of the group work and make it easier for larger groups to work together in real time compared with what is possible through verbal discussions in an offline setting. Different tools can provide both qualitative and quantitative feedback that give a better overview of the ongoing work.

Several of the CI projects that encompass cognitive or informational diversity when they scale up in size face challenges with overview that needs to be tackled. In the Polymath 1 project that lasted 37 days, 27 individuals made 800 mathematical comments, in total they wrote 170,000 words. As the projects evolved, it became increasingly difficult and time-consuming for newcomers to join the project because of the amount of information they had to read.

Because the blog that was used in the Polymath project is a time-centric tool, new comments to a blog post were automatically listed below previous contributions. This chronological organization of the contributions made it gradually more difficult to get an overview of all the perspectives. Because the discussions were organized into several different blog posts with attached comments. The discussion is also becomes messier when both relevant and irrelevant comments are included.

One alternative strategy is to design statistical tools that can provide a simplified overview of the collective work (e.g., deliberation metrics). They can support coordination by making it easier for groups to evaluate their own work. Some CI research examine different types of metadiscourse tools, like to-do lists and chatbots that can prompt different types of group evaluations (Young Ji Kim, Gupta, Glikson, Woolley, & Malone, 2018).

In argument mapping, metadiscourse tools, termed deliberation analytics, aim to provide better overview of all the contributions in a large group. The system mines the traces of the group's activity and generate customized metrics that can give both the participants and moderators a better overview of how the map is evolving. Fisrt, the topology of the argumentation map (e.g., breadth and depth of the branches of the map) provides information about the maturity of the deliberations. This is a better proxy than metric algorithms like word frequency statistics. Second, the metrics notifies participants about issues they may want to resolve based on their previous interests, which both include their viewing activity and the content of their contributions. They can then choose to either rate the comment or add a new post. Users with similar topical interests are also clustered together in an attempt to motivate them to collaborate on a branch in the tree structure. Third, dysfunctional communication can be identified through a social network analysis of the interactions in the deliberation map, if there are tendencies toward groupthink (Fujita et al., 2017; Klein, 2012, 2017). This example shows how digital tools can provide support for formative assessments, making it easier to monitor the ongoing collective work.

Wikipedia illustrates how the evaluation of the collective work can utilize crowdsourcing methods. Every article has a talk page that enables a written metadiscourse of the collective work. The modularization of each article allows for a myriad of "content-focused" discussions on different topics. Participants can choose to only discuss the content and not write about it. These discussions can be regarded as open conversations about our own culture that anyone can join.

However, studies show that most of the work on a Wikipedia article will usually be coordinated by a small number of contributors. They typically solve the complex, interdependent tasks, for example on how to structure or organize the article so it becomes more cohesive. Explicit coordination is primarily valuable in work on articles when there are few contributors. It is usually more important in the early life cycle of an article when the direction is more uncertain and open-ended. There are also many simple, stand-alone tasks, which require little coordination. This can be tasks like fixing grammar, combating vandalism or creating links. (Kittur & Kraut, 2008).

In addition, there are a huge number of other special pages dedicated to discussing Wikipedia policies and technical issues. These wiki pages were

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not part of the original design of Wikipedia, but they have gradually emerged in line with community needs. Although many of these pages are only of interest to the Wikipedia community itself, they comprise the evaluation policy that ensures the sustainability of the online community (Nielsen, 2011: 52–53; Rijshouwer, 2019). Wikipedia is a particularly interesting case because it shows that citizens cannot only be knowledge producers, but also successful evaluators of their own collective work.

12.3.2 The Need for Coordinators

Another strategy in evaluating collective work is to utilize some type of centralized control, like appointing a leader or establishing a small core group that coordinates the larger group. Most of the CI projects have a coordinator. The titles vary, being a moderator, facilitator, or copilot, but they all aim to organize the problem-solving process in an effective way.

Most intermediaries in online innovation contests also use a facilitator to support both the seekers and the solvers. In Topcoder, every project is assigned a copilot who works with the seeker. The copilot manages the logistics, answer technical questions, and help the seeker in producing a realistic project plan. This involves giving an accurate description of the challenge, making sure that all deliverables are received and that the review process is done in a proper way (Topcoder, 2019b). The copilot is an elite member, and needs to have won a minimum of three challenges (Topcoder, 2019c). He earns money if projects are on time, and the outcomes are delivered with high quality (e.g., $40 for one challenge and $600 for another challenge) (Jefts, 2018). In *Innocentive*, the PhD-educated facilitators are primarily a support for the seekers, helping them to formulate the problem in an appropriate way while the facilitator in IdeaConnection is supposed to support the solver team in their work (see also Chapter 8). In this type of collaborative problem solving, the facilitator will help the team to do the work within the deadline and not stray off the topic.

In other CI projects, the moderators act more like project leaders. For example, in the Polymath project, Gowers, the founder, has usually been responsible for organizing the academic discussions. Successful Polymath projects have required a project leader to moderate and guide the discussion, and generally to keep the momentum going (Michelucci & Dickinson, 2016). In the first Polymath project, Gowers acted as a moderator, but there were few problems with internet "trolls" or people persistently posted distracting comments. Nor were well-intentioned but unhelpful comments a significant problem (Gowers & Nielsen, 2009). However, being a moderator can be very time consuming, and only a few people have done it so far. This is why there is usually only one Polymath project a year (Michelucci & Dickinson, 2016).

Furthermore, the coordinator will need to solve conflicts between contributors. They help solve disagreements on what content should be in the specific articles. For instance, a typical conflict in Wikipedia can be that writers follow personal preference instead of adhering to community norms. The moderators who guide and help new contributors are called Wikipedians (J. Beck, Neupane, & Carroll, 2018). They have expertise about the community norms and do a lot of the maintenance work, which is vital for the sustainability of the encyclopedia. They do not necessarily write articles, but spend much time editing the content and turning it into a more coherent resource. They serve as "protectors" of the encyclopedia in the sense that they cope with vandalism or others who do not follow the norms of the community. It is also important to ensure that users follow citation rules and copyright rules. It is these persons who transform the encyclopedia into being something more than a broad collection of individual contributions (Algan et al., 2013; Benkler, 2006).

In many online communities, conflicts arise because of poorly defined policies. This may even involve conflicts between moderators. This is why communities like Wikipedia have procedures and policies on most activities, including how to resolve or manage online conflicts (J. Beck et al., 2018).

The role of the moderator in argument mapping is also very important since several hundreds of participants may be involved. They organize the debate and cultivate the discussions by deciding which claims are acceptable and which need to be improved. They guide participants and monitor debates for duplicate claims, "fake" contributions, or abusive content. As the debate grows, moderators will also sometimes have to reorganize the entire debate (J. Beck et al., 2018).

Furthermore, moderators ensure that new posts are correctly structured and that authors follow the map conventions. Sometimes posts will first be given a "pending" status, and become available after they have been checked by moderators. This ensures that the map is well structured. One study found that two moderators were able to handle nearly 200 active contributors, with most posts (~85 percent) requiring no or only minimal moderator support. In some argument maps, moderators can automatically be notified about a conflict, or where users have rated posts without reading the arguments. Because moderators represent a potential extra cost, researchers are also exploring how one can crowdsource moderation work into a series of easy-to-do micro-tasks that every participant can do (Klein, 2017).

Although the role of the moderators is not to evaluate the merits of a post, some studies suggest that it is a challenge to take a "neutral" stance in the debate. Beck et al. (2018) identified adversarial beliefs and values as a common source of conflict between moderators. Some of these conflicts were not productive and undermined collaboration. In some cases, librarians were used to successfully strengthen the competence and position of the moderators. In general, these different CI projects indicate a need for coordinators because very few projects can rely only on self-organization.

12.4 Institutionalizing Critical Discourse

12.4.1 The Nomothetai

The use of evaluations is not something new in society. In ancient Athens, the citizens managed not only to invent democracy, but gradually they were able to improve these institutions by strengthening the critical and deliberative discourse. After the Peloponnesian War with Sparta, the Athenians briefly lost their democracy, but managed to reinstate it (in 402–401 BC). The citizens had experienced that a demagogue can win the votes in the Assembly regardless of the citizens' interest. Therefore, they established the nomothetai, a new institution that was devised to avoid this from happening again. In this new system, proposed changes in law, which was passed by the Assembly, could not become a law unless it was also approved by the nomothetai (Fishkin, 2018: 52–53, 203).

Nomothetai were probably recruited from the panel of 6,000 jurors who had sworn the Heliastic Oath. They were ordinary citizens picked by lot for a given day from among those who showed up. Their function was to examine proposals more closely than the Assembly could be capable of doing. The number of nomothetai varied according to the importance of the legislation proposed – probably at least 501, but for more important matters even 1,001 citizen jurors or more. A meeting lasted only a single day, and it is likely that the nomothetai could deal with more than one legislative proposal in the same meeting (Hansen, 1999: 167–169).

The laws were passed by a procedure analogous to a trial, hearing the arguments for and against the proposal. Legislation is assumed to be a revision or change of the law currently in force. A new legislative proposal is therefore regarded as an accusation against the existing laws. The author of the proposal for change will first speak as the accuser of the existing laws. Afterwards, the five advocates chosen by the Assembly defend the existing laws. When both have spoken, the nomothetai decide by show of hands. If the majority supports the proposal for change, it becomes the law in force (Hansen, 1999: 166–169). Some claim that this type of critical discussion and questioning is the very essence of democracy and is the most important precondition for the overall growth of knowledge and development of a prosperous society (J. F. Mueller, 2018).

At a societal level, the nomothetai served the purpose of being a security or democratic brake that could restore order and potential ill effects of voting in the Assembly (Fishkin, 2018: 52–53, 203). A new multistage institution was introduced that could have a critical and evaluative function regarding decisions that other democratic institutions had made. As a result, legislation became less casual, and it reduced inconsistencies in the legal code. From this perspective, it is the political norms and the design of institutions that afford democratic conversation and critical discourse; democracy has less to do with social norms and informal conversations on a micro level (Schudson, 1997: 305).

12.4.2 The Citizen's Assembly in Ireland

The 2017 World Values Survey shows a worrying shift in attitudes toward democracy. More young people, in both Europe and the US, are skeptical of democracy as a governing model. There is more political apathy than previous generations. People are less interest in joining political parties and experience that the political elites have become more detached from the people (Foa & Mounk, 2016, 2017; Micu, 2018). People also have less faith in public institutions. For example, in 1964, 76 percent of Americans had faith in the government to do what is right, but in 2015, only 19 percent were of the same opinion (Micu, 2018). In addition to the lack of faith in political institutions, there is increasing concern about the dysfunctional engagement in the online setting. This situation calls for new ways of involving citizens that reduce polarization and strengthen consensus-building processes.

As the nomothetai institutionalized new types of critical discourse after a crisis in Athens, there is a need for new democratic institutions today that can perform intelligent evaluations. The Citizen's Council in Ostbelgien, Deliberative Polling in Mongolia, and the Better Reykjavík platform are all interesting new examples. However, the paradigmatic case is the Citizens' Assembly in Ireland.

It is the first country in the world to hold three national mini-publics in quick succession. A representative sample of 99 citizens from the population are invited to meet and discuss important constitutional questions or complex political issues over a longer period. They are selected through random sampling from the whole population in the country. These assemblies have been established by Parliament, and they also make their final recommendations to the same institution. In the Irish context, deliberative democracy is being implemented as part of the wider political system in a systematic manner because of these citizens' assemblies (Farrell, Suiter, & Harris, 2019).

Most of the issues that the assemblies have worked with have later been set out for mass voting through a national referendum. Both the first Convention on the Constitution (2012–2014) and the Irish Citizens' Assembly (2016–2018) were essential in supporting national referendums for constitutional change, legalization of same-sex marriage in 2015, and removing the constitutional ban on abortion in 2018 (Farrell et al., 2019). This Citizens' Assembly was assigned to deliberate on five issues: abortion, the aging population, fixed-term parliaments, organization of referenda, and climate change policies. There was international pressure to change policies concerning abortion and climate change. Opinion polls also showed strong support for a liberalization of Ireland's abortion laws (Farrell et al., 2019). On highly contested political issues, a simple aggregation of votes through a referendum might not be the best option because many citizens will want to debate the issue. In the case of same-sex marriage and abortion, the Assembly helped break a political deadlock and were important in establishing public acceptance for change (Devaney, Torney, Brereton, & Coleman, 2020).

Input Legitimacy

If we look closer at the success behind the Citizens' Assembly in Ireland (2016–2018), several features ensured the legitimacy of the process. First, input legitimacy is crucial to ensure trust both in the political system and among the wider public. The government established the Assembly and invited citizens were randomly selected from the wider population. In total, 99 citizens and 99 substitutes were selected. Unlike the first Assembly, no politicians participated because they wanted to distance themselves from the controversial abortion issue.

The members were stratified according to sex, age, social class, and region. However, some reported too many participants coming from urban areas, which limited the discussion of climate challenges in rural areas. This illustrates the importance of inviting a large enough group to ensure sufficient representation.

Another challenge was the large turnover, with more than 150 individuals needing to be recruited during the 15-month period. Since the members did not get an honorarium, this had a negative effect on attendance (Devaney et al., 2020).

Throughput Legitimacy

Regarding throughput legitimacy, it is important that the discussions in the Citizens' Assembly are organized in a fair way. There were monthly weekend meetings. During these meetings, members used much of the time to discuss issues in groups of seven to eight persons. The group members were rotated, so every individual had to discuss issues with many different persons. The participants reported about challenging discussions with individuals who held other viewpoints (Devaney et al., 2020; Farrell et al., 2019).

Diverse groups are important because attitudinal change is more likely to happen when being exposed to views that are different from your own. Like in Deliberative Polling, a facilitator helped the group stay focused, be respectful towards each other, and ensure that every member had an equal opportunity to speak. These sessions were also closed, with no cameras or recording, so individuals could feel safe to state their opinion (Devaney et al., 2020; Farrell et al., 2019). The participants report being very satisfied with the format of the meetings, especially that the group rules ensured fairness, civility, and equality in participation. In addition, the participants were given some individual reflection time. A secretariat was also established to coordinate the process in a proper way (Devaney et al., 2020).

Before the meetings, briefing material was sent out that intended to be as objective as possible. During the meetings, legal, ethical, and medical experts had presentations, and when abortion was discussed, there were presentations by advocacy groups and personal testimonials by women (Farrell et al., 2019). The participants were satisfied with the presentations and praised those speakers who exemplified success stories from their own countries (Devaney et al., 2020).

In general, the participants experienced a significant level of learning by being part of the process. However, the group was given only two weeks to discuss a broad and complex question such as "How to make Ireland a leader in tackling climate change," and the participants report that this was too little time. If the topic had been more specific and involved a cost analysis, they suggest that the recommendations could have been more realistic (Devaney et al., 2020). These statements suggest an awakening of a citizen responsibility and an increased understanding of the complex trade-offs that need to be made in politics.

Furthermore, the wider public was invited to interact with the Assembly. All expert presentations were live streamed to strengthen public involvement and transparency in the process. A strong media presence amplified public awareness, and a dedicated website provided public access to all expert content, papers, and public submissions. On the topic of climate change, the public sent in more than 1,000 submissions, including 150 group submissions (including from nongovernmental organizations, sectoral interests, and representative groups). This shows a strong public engagement.

Although the participants were given some time to read the submissions, it is more uncertain to what degree they are able to integrate these comments in the deliberation. In the evaluation of the process, the participants suggest that a summary of the submissions would have been better to read. Nor were the submissions part of the presentations. However, the size of the feedback from the wider public illustrates the potential in connecting the citizens' assemblies with the wider society. If this is done more systematically, it provides an opportunity to enhance environmental literacy in the wider society. Environmental literacy seeks to empower citizens to make responsible lifestyle decisions. By more strongly involving the maxi-public in the process, it seems possible to design political systems that can promote mass deliberation, strengthen the communication with citizens, and motivate more sustainable behavioral change (Devaney et al., 2020).

Output Legitimacy

Output legitimacy is dependent on how the final recommendations are used in the wider political system, such as a mandatory follow-up from dedicated parliamentary committees. To complement this bottom-up form of governance, participants find it necessary with clear top-down political engagement to create policy coherence. This involvement also ensures that citizen efforts are honored.

In the Ireland case, an all-party parliamentary committee was established after the Citizens' Assembly to respond to the recommendations, and it delivered a report one year later in 2019. The committee was not obliged to pursue the recommendations, but it still endorsed most of the recommendations, with the exception of the proposed increase in carbon tax. To a significant extent, this report shaped the development of the government's Climate Action Plan, published the same year. The process illustrates how citizen involvement can be connected to the political decision-making system in new ways (Devaney et al., 2020).

It is also interesting that the random sample of citizens were able to move beyond self-interest to engage in collective decisions for the greater public good, which is a typical criticism against climate engagement (Devaney et al., 2020). Obviously, output legitimacy is threatened if the politicians do not accept recommendations they do not like or if they choose not to respond to the recommendations at all. Recommendations made by randomly selected citizens, who are neither elected nor experts, can raise accountability issues (Devaney et al., 2020).

Furthermore, in making the final report on climate change, the participants found it difficult to rank the 13 recommendations on climate change since they found all of them to be important. They suggested that their recommendations be complemented by further expertise, cost assessments, and evidence-based input, since they were not experts in the area (Devaney et al., 2020).

The Citizen's Assembly as an Intelligent Evaluation

These deliberative forums can provide valuable information about the citizen opinion on a political issue. These mini-publics serve the purpose of being "trusted information proxies" that can establish a more efficient communication between elected politicians and the public. Here, it is essential that the participants perceive the information dissemination, like the briefing material or presentations, as legitimate. If the whole process and the final vote is legitimate, it can help politicians make tough political decisions, for example on climate change, which require trade-offs and public support for action. From one perspective, the final voting on recommendations can even be regarded as an informed "micro-referendum" that can potentially lead to better decisions (Devaney et al., 2020).

Moreover, a Citizens' Assembly will provide insight into how people speak about the climate crisis, including their local concerns and shared values. This is different from an opinion poll or referendum, which aggregates opinions without deliberation. If the wider maxi-public is engaged, this process can shape public opinion, not just be used to develop a specific public policy. Deliberative processes are especially important in addressing complex public problems by involving citizens in the decision-making (Devaney et al., 2020).

A very important political goal in the climate crisis is to engage the public more strongly. Citizens' assemblies represent an interesting new way of involving citizens in building consensual solutions on environmental problems. Environmental literacy is not only about the dissemination of correct values and beliefs, but it requires a dialogue with audiences of different persuasions, knowledge, and levels of engagement. Identifying citizens' opinions on climate change can help politicians engage in dialogues that are more constructive. Those individuals in Ireland who have participated in the Citizens' Assembly also think this institution should become a regular part of a democratic system (Devaney et al., 2020).

In 2020, a new Citizens' Assembly in Ireland has been established to advance gender equality by bringing forward proposals that challenge the remaining barriers and attitudes that facilitate gender discrimination. Because of COVID-19, the meetings have been held online, and all video presentations are publicly available on YouTube (Farrell, 2019). This third Citizens' Assembly will provide important knowledge on how a new modern "nomothetai" can be organized through online communication.

12.4.3 Knowledge Commons

A significant challenge when implementing citizens' assemblies is how to cope with manipulative misinformation in the public sphere (Devaney, 2020). Therefore, the collective problem-solving capacity of this type of democratic institution depends on the quality of the publicly available knowledge. In a polycentric democracy with a range of different smaller institutions, like mini-publics and engaged maxi-publics, it is important that objective knowledge is accessible to everyone (J. F. Mueller, 2018). A strong knowledge commons with dedicated open access policies is crucial in facilitating societal innovation.

Already one hundred years ago, John Dewey underlined that print was necessary to create a true public, but it could still only serve democratic conversations. Democracies put a lot of effort into writing to secure, verify, and make public decisions. This greatly enhances the capacity of public memory and makes democratic talk civil, since democratic conversations will be oriented towards the explicit and transferable communications found in print (Schudson, 1997: 305). If we look at the face-to-face conversations in the citizens' assemblies, they also end up with a vote and a final written knowledge product that can be further used.

Many of the examples in this book show examples of how our collective memory is being strengthened through the digitization of information. According to Mulgan (2018: 170), any CI system is reliant on a rich informational knowledge commons. Commons are shared resources that are free for anyone to use, like water, forests, libraries, science, and also the Internet. In the offline setting, commons are usually vulnerable to over-exploitation of resources if property rights are absent. However, this is not a problem with digital information because it can be copied infinitely at a low cost. Today, the Creative Commons licenses institutionalize the flexibility of being able to modify knowledge products without needing to ask the original creator for permission. When products are instantly and easily modifiable, it is much easier to add value to the work through sustained collective efforts. A knowledge product can be adapted and modified by others into many different versions, whether this is an open textbook or a Wikipedia article.

An increasing number of policies today belong to the knowledge commons. As previously mentioned, this includes open access policies in science and open textbooks, both of which exemplify open knowledge production. Free textbooks can provide knowledge that is more easily accessible and can recruit more readers. Open data is another example of how more people can be given access to valuable information. Collective problem solving becomes more efficient when it draws on a body of common knowledge.

However, the largest video-sharing platforms today have commercial ownership. YouTube, the largest video platform in the world, shares video content openly, but they can also charge money for usage. These videos comprise the dominant cultural archive of our time, being an increasingly important provider of our cultural heritage. Until now, this platform has supplemented the role of state-based cultural archiving institutions like public libraries and museums, as well as media companies and broadcasters who want to involve users in new ways. However, because YouTube is a commercial enterprise and not a public one, they have no obligation to store these data in a way that serves society for the best. Until now, there has been little debate of the long-term implications of letting commercial spaces be responsible for some of the functions that public cultural institutions previously held. Today, libraries cannot re-archive material on YouTube, because of legal barriers such as copyright law and YouTube's Terms of Use. This issue becomes even more important when we know that an uneven or deliberately reshaped collective memory can have significant influence on people's conception of history and justice, and one therefore needs to ask who should be in control of it. For instance, people have used YouTube to publish eyewitness videos documenting conflict and human right abuses. Because YouTube frequently removes violent or otherwise "inappropriate" content, there is a risk that this sometimes may involve content of historical or political significance. In one case, footage of the Syrian conflict was removed because it was flagged as violent, but after protests from human right groups, it was later restored. States are today increasingly asking whether they should rely on YouTube, Vimeo, or Facebook to keep public records (Burgess & Green, 2018: 137–139).

Digitization of information has opened up a major movement towards a strengthening of our collective human memory. In the long term, this can lead to more innovation, but it appears that collective learning at a national level and global learning depend on the prevalence of a strong knowledge commons.

12.5 Summary

We are moving into the age of intelligent evaluation. Traces of online activities provide unprecedented opportunities to examine our personal behavior, our collective work, and discuss our political systems. At a group level, metacommunication is essential for good communication and these mechanisms can now be scaled up in new and innovative ways. On the positive side, the massive amounts of data provide an opportunity to discuss, deliberate, and learn. The digitization of information provides many interesting new ways of evaluating collective work. Feedback loops can support groups in coordinating problem solving more efficiently. Although third-loop learning in organization can perhaps not be planned, there are now digital tools, like argument mapping, that make it possible to support such reflective communication in new ways. The examples also show that most groups still need a coordinator to help organize the collective work.

Furthermore, online reputation score systems make decisions about whom to trust. In the sharing economy, these systems build on crowd assessments. They have been used to regulate sales and transactions successfully. Services are rated and reviewed, and these evaluations make it easier to find the right experts for the right job. The main attraction is definitely the time efficiency and simplicity of just having to rely on one simple quantifiable score. Many online communities also operate with lists of "top contributor" or "top reviewers" to motivate contributions.

Traditionally, reputation has been considered an "intangible asset" that is very difficult to measure, but this view is now changing. The emerging reputation society builds on the premise that reputations actually can be measured through online reputation scores. However, there is a concern that algorithms and metrics produce unfair simplistic evaluation scores, and we know little of potential negative individual effects of being a "low achiever." There is increasing concern around the negative effects of being evaluated all the time. In addition, the scoring systems can be manipulated, and it is possible to attack others' reputation. Furthermore, there is a growing awareness that the reputation system is overly centered on an individualistic, accumulative, and competitive paradigm. Nevertheless, reputation scores are being taken in use in new areas that have nothing to do with economic transactions.

In social media, evaluating other persons has become the new normality. It has led to increased psychological stress as people become more obsessed by constant social comparison. When living in the gaze of others, it is all about getting likes and followers in social media, risking the escalation of a self-interested narcissistic individualism. Zuboff (2019) warns that social media life is becoming a collectivist life in a human hive where individual autonomy is lost. Humans follow the group pressure of the herd and the computational certainty of the "smart" solutions that can replace deliberation and democracy. It is the youngest members of our societies that are most at risk as these destructive mechanisms foster them from early age.

The social media systems are designed to tempt persons to constantly rate each other. The like button also provides the most valuable behavioral surplus, as metacommunicative data are the most powerful predictors of human behavior. The more a user presses the like button, the more information Facebook receives about a person (Zuboff, 2019).

On the more positive side, deliberative reputational systems are assumed to potentially democratize and decentralize power mechanisms in society. The talk page on Wikipedia demonstrates how the crowd can engage in important critical discussions of the content in one of the most important knowledge sources of our time. Independent of social background, the most active members can gain respect and become leaders if they make important contributions. Quantitative ratings matter less. Peers evaluate each other through the transparent traces of their work, and together they formulate the community policy.

Furthermore, the Citizens' Assembly in Ireland shows how deliberative democracy can be utilized in new ways. Citizens are challenged to discuss highly contested political issues such as abortion and climate change. The deliberation period is usually at least one year and is key to transformative change. It shows how governments can get access to the opinions of an "informed public." Many of the activities are also shared openly with the general public, who are invited to engage with the Assembly. An important goal is to strengthen political interest on the issue in the broader community. (Devaney et al., 2020). A strong knowledge commons can provide a better basis for making informed decisions in this type of participatory governance.

A more fundamental question concerns the number of evaluations we need in a democratic society. Because we can collect more data, on both persons and work processes, does this also imply that we should do more evaluations? Can it be intelligent not to evaluate? Currently, the simple quantitative ratings are colonizing our society. There are infinite opportunities to produce evaluative data, and surveillance capitalists have learned to profit from it. These evaluations are primarily based on machine learning and hidden algorithms, which raises a number of questions: Who should design the evaluation? Who should have access to the evaluation results? Who should perform the evaluation?

However, in a democracy built on evaluation, it is not the quantitative ratings that really matter, but rather the tough and unpleasant critical discourses between citizens with different views. John Dewey once claimed that politics should be treated as a scientific evaluation. After implementation of a policy, the effects need to be evaluated and if the results are unfavorable, policies must change. Citizens were essential in evaluating these policies through voting in periodic elections, public opinion polling, and by giving public comments on proposed regulations (Anderson, 2006). Today, new types of intelligent citizen evaluation are being invented, such as the Citizens' Assembly in Ireland, which can likely strengthen democratic institutions in the future.

CHAPTER 13

COVID-19 as a Wicked Problem

13.1 Background

COVID-19 can be regarded as a wicked problem with long-term consequences we will struggle to cope with for many years to come. After the initial outbreak in Wuhan, China, in December 2019, the virus spread rapidly to other countries and the World Health Organization (WHO) declared it a pandemic in March 2020. The pandemic has led to economic and social instability. Because of the scale and the speed of infections, most countries eventually had to close down their societies, with a range of negative effects that we do not yet fully understand (Alford & Head, 2017; Moon, 2020). A number of systemic factors have had a negative impact such as economic loss, financial insecurity, unemployment, inadequate access to health services, school closures, and lack of social contact (Moreno et al., 2020; Pfefferbaum & North, 2020; Torales, O'Higgins, Castaldelli-Maia, & Ventriglio, 2020). According to projections released by the Congressional Budget Office (CBO), the virus will reduce US economic output by 3 percent through 2030, a loss of $8 trillion. Unemployment has also increased (Rushe, 2020). In the first outbreak, most European countries decided to shut down the schools, but they largely decided to keep the schools open during the second wave. One important argument is that a shutdown makes young people's futures and education another victim of the disease. Children from poorer backgrounds lose more and need more time to recover. There have been reports about children both losing physical fitness and showing mental distress when schools were closed. Low-income families have suffered more because they lack access to technology and space to work at home. Home confinement has been particularly difficult for vulnerable children. Schools are also important because they allow families to participate in the economy (Reynolds, 2020).

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Governments have had to cope with overwhelming policy challenges worldwide. All governments have been tested on how to prepare for, mitigate, and respond to the outbreak. The complexity and lack of knowledge of the problem creates ethical dilemmas (e.g., striking a balance between limiting the loss of lives as much as possible vs. maintaining a healthy economy) (Alford & Head, 2017; Moon, 2020). Previous studies of similar public health emergencies have shown that a large amount of emotional distress is produced in the affected populations, and this appears to be the case now too (Pfefferbaum & North, 2020). Studies point to an increase in additional mental health problems in the population, such as stress, anxiety, depressive symptoms, insomnia, denial, anger. This includes both those with preexisting mental disorders and previously healthy people. Many groups are particularly vulnerable, such as infected patients, their families, elderly, individuals with preexisting medical conditions, and healthcare providers who work directly with sick people (Pfefferbaum & North, 2020; Torales et al., 2020). One reason is the unpredictability and uncertainty of the disease. Another is that lockdown and physical distancing increase social isolation, loss of income, loneliness, inactivity, limited access to basic services, access to food, alcohol, and online gambling; they also result in decreased family and social support (Moreno et al., 2020). Both the fear of being infected and mass home confinement has led to an increase in anxiety and depression. However, we do not yet know how serious the long-term effects will be of this type of isolation (Moreno et al., 2020; Pfefferbaum & North, 2020; Rajkumar, 2020). Another negative effect is the lack of follow-up of long COVID patients (Gallagher, 2020). A recent study finds that half of the individuals who had recovered from acute infection were still experiencing persistent fatigue ten weeks after initial symptoms. A third were still unable to return to work. The fatigue was independent of the severity of initial infection (Townsend et al., 2020).

Furthermore, the outbreak has affected the general healthcare service in a negative way. In June 2020, almost half of US adults had delayed or avoided medical care because of concerns about COVID-19. This avoidance was more prevalent among vulnerable groups, including persons with underlying medical conditions or those with disabilities (Czeisler et al., 2020). Because of an increase in unemployment, people have had more problems paying for medical care (Abelson, 2020). In addition, people are facing longer hospital waits for other diseases in countries such as the UK (Triggle, 2020). In total, all these stressors have increased the risk of suicide (Pfefferbaum & North, 2020), and even "successful" countries like

South Korea report an increase in suicide rates (Ryall, 2020a). Although many international organizations like the WHO advocate stronger support on mental health measures, the economic breakdown has limited response opportunities at a systemic level (Moreno et al., 2020).

This chapter addresses three important strategies that have been used in the outbreak:

1. The test and trace strategy
2. Effective communication about the pandemic
3. Rule compliance in the population

I will particularly draw to Moon's (2020) analysis of the success factors behind the South Korean response. Although the country experienced a sudden surge of infected cases, it managed to get control over the situation within two months, and the country did not need to go into lockdown. In addition, the successful New Zealand response will be briefly presented. In the final section, the three strategies will be analyzed from a CI perspective.

13.2 The Test and Trace Strategy

After the COVID-19 outbreak, governments chose different measures to suppress transmission. The soft approach used only moderate mitigation measures. One example is the UK strategy, which initially aimed to obtain so-called herd immunity (Colfer, 2020). China chose a hard approach by using aggressive measures such as lockdowns, travel bans, and curfews in the Wuhan area. As conditions worsened, most countries shifted to a hard approach (Moon, 2020). However, the hard lockdown approach has huge negative effects on both the economy and people's mental health when they need to stay at home and social interaction is restricted. By contrast, the soft approach has a less negative impact on the economy, but more people get sick and die of the virus. Recent studies also point to herd immunity as not being a realistic alternative because antibodies fall rapidly after recovering from the disease (Ward et al., 2020).

An interesting third approach is the unique approach that South Korea chose and which many countries are now trying to implement when they are facing the second wave of the outbreak. South Korea experienced a surge in new cases in the middle of February 2020 in two provinces, but by taking a series of actions they were able to get control over the situation relatively quickly (Moon, 2020). Moon describes it as an agile-adaptive approach, as it is primarily centered on identifying each infected case as fast as possible through massive testing. Infected patients were isolated and digital technology was used to track these people's previous movements. At the beginning of the outbreak, South Korea tested around 4,000 people per million, while Japan only tested less than 100 per million. The massive preventive testing was combined with epidemiological surveys of each infected patient, which gave important information about the contagion speed. Several innovative practices, such as drive-through and walk-through testing stations were quickly adopted, which reduced testing time and enhanced the national testing capacity. Training centers and public institutions' facilities were used to accommodate light-symptom patients. This approach and the alternative solutions were successful in slowing down the contagion speed. Countries like Italy and France that did not increase testing eventually ended up with a hard lockdown approach because of the uncontrollable massive surges. In contrast, the massive testing was able to control the outbreak without extreme intervention measures such as lockdowns (Moon, 2020).

While the South Korean government has demonstrated innovative responses to the COVID-19 outbreak, it was equally ineffective in dealing with the MERS virus in 2015. Despite the surge of infected cases at that time, the government initially did not disclose all information to the public, such as where the patients were hospitalized. They wanted to avoid any unnecessary fear among citizens and potential reputation damage to the hospitals. This nontransparent position caused public outcry and tensions with the local municipality in Seoul that wanted to disclose this information. Eventually, this information was published, allowing citizens to assess if they had could have been exposed to the virus (Moon, 2020).

Later, the MERS white paper was published to document key lessons and policy recommendations from the experience. This led the South Korean government to upgrade the Korean Center for Disease Control and Prevention, which strengthened its autonomy and increased the number of the professional staff. The MERS experience was a failure, but the government used it to learn so they would be better prepared for the next outbreak. New procedural protocols were established to control and prevent new infectious diseases, and these would be helpful when the outbreak of COVID-19 happened (Moon, 2020).

Likewise, many governments have learned from the first wave when they are trying to tackle the second wave of the pandemic in the most effective way. Many countries want to avoid a lockdown and have aimed to develop a "test and trace" strategy, prioritizing community testing, case isolation, contact tracing, and quarantining of contacts of cases (Aleta et al., 2020; Kendall et al., 2020). The UK is one example of a country that has chosen to meet the second wave with a "test and trace" strategy (TTI) in combination with physical and social distancing. Based on evidence from South Korea, researchers recommended that the UK should implement TTI because it would make it possible to keep schools open (Panovska-Griffiths et al., 2020). TTI can be very effective in breaking chains of transmission, if three conditions are satisfied. The first factor is speed; there needs to be a quick turnaround of both case testing and contact tracing. Second, compliance is essential, as most people need to be willing and able to follow the guidelines like isolation and quarantine measures. The third factor is to maximize the coverage, in identifying as many cases as possible through high-precision population surveillance (Initiative, 2020). Because a large number of people show no symptoms when they are positive, testing must also be combined with physical distancing measures. However, a weakness with the testing strategy is that the test sensitivity estimates can be as low as 65 percent. Because of the high false-negative rates, testing must be combined with physical distancing measures. Still, this approach can be effective if the virus is not spreading too fast (R below 1.5) (Davis et al., 2020).

However, in mid-November 2020, the TTI was buckling because the cases were increasing too fast. Only one in four tests were received within the original goal of 24 hours. Only about 60 percent of the contacts of infected people were reached, far below the 80 percent considered necessary to control transmission. The proportion of asymptomatic cases poses a huge challenge, and if the numbers of infected case first begin to surge, a temporary national lockdown becomes the only option. TTI also depends on efficient coordination between national and local government, which may not be present (Neville & Dombey, 2020).

13.3 Effective Communication about the Pandemic

COVID-19 differs from previous pandemics in its mass media coverage. A wide range of news sites, public health sites, and universities (e.g., Johns Hopkins) provide open data, easily readable statistical graphs that inform the public about the current evolution of the pandemic. Anyone can easily access and read the confirmed cases and number of deaths in different areas. Local sites can also provide data on how many are hospitalized or have been tested. The numbers are continuously changing as they are being updated "in real time." In this sense, the coverage of the pandemic has to a large extent focused on numerical data, even though the statistics may be highly inaccurate, depending on how many persons have been tested.

Still, these data provide transparency and are important in making tough political decisions more acceptable. A study from South Korea shows that a majority of respondents checked this type of information multiple times a day. When South Korea in 2015 failed with MERS, they did not provide any information. This time the government has provided up-to-date statistics on infected cases and the fatality rate in an attempt to increase citizen engagement in anti-COVID-19 measures (Moon, 2020). If the numbers begin going down, this also provides positive feedback to citizens and will perhaps motivate them to continue to follow behavioral measures. If the numbers are going in the wrong direction, people will know that they have to increase their efforts to stop the virus. Statistics from the whole country may strengthen the feeling of the pandemic as a collective responsibility. During the first outbreak, these numbers were regularly part of the headlines of the online news coverage, and they were also important during the second wave. The statistics on the number of deaths and infected cases are reported daily and provide a continuously updated set of "scores" on the current development. It gives information about how well the crowd are performing. Still, the graphics do not include the rate of mental health problems or the unemployment rate. Although journalists report on these issues too, the pandemic indicators dominate the headlines.

Certainly, the online statistical data do provide an overview of the situation, and it is usually worse not to provide any public information about the development. During a crisis, people will seek out information to better understand what is happening. Fear of the unknown leads to higher anxiety levels in both healthy people and those with preexisting mental health problems. Misleading information via social media can increase stress. Therefore, it is important that public health authorities release updated information regularly (Torales et al., 2020). When there was a sudden surge of confirmed cases in South Korea, citizens were at first very disturbed. Many were disappointed by the poor judgement of the government, and the updated statistics amplified fear and distrust. However, in the long run, these data contributed to reducing fear and increasing public trust in the government. By displaying negative results, the government strengthened their credibility as an objective information provider, which was important in filtering fake news and misinformation around COVID-19 from social media (Moon, 2020).

Furthermore, there are examples of educational material being shared in effective ways during the pandemic. In one case, an infographic presenting intubation guidelines for use in operating theatres was published openly through an official website and social media. Because the material was open access, the use of the infographic spread very rapidly, resulting in 12 translations to other languages within a ten-day period. Some chose to adjust some of the content, and a large number of other health organizations also began to use the resource. One important reason why the dissemination was so successful was because an institution with a good reputation made the infographic, and the imagery was of high quality (Chan, Nickson, Rudolph, Lee, & Joynt, 2020).

Unfortunately, there is large amount of misinformation about COVID-19, particularly on social media (Pennycook, McPhetres, Zhang, Lu, & Rand, 2020). One study analyzed 25 million tweets over ten days to show that disinformation regarding the coronavirus was spread 7,000 times from 6,000 accounts. Almost all political activity was performed by right-wing governments or parties, one prominent example being the coordinated spreading of the China bioweapon conspiracy theory, which has made over 5 million impressions on Twitter users (T. Graham, Bruns, Zhu, & Campbell, 2020). In a recent shared statement, the WHO, UN and others claim that social media is currently amplifying an infodemic that undermines the global response to control the pandemic. There are deliberate attempts to disseminate misleading information to advance alternative agendas of groups or individuals. It can increase stigmatization and be harmful to people's physical and mental health. Misinformation is polarizing public debate on topics related to COVID-19, and amplifying hate speech. Instead, countries are encouraged to strengthen the support for science-based data to the public (WHO, 2020).

One recent study finds that, rather than being completely fabricated, much of the misinformation about COVID-19 involved various forms of reconfiguration, where existing and often true information is spun, twisted, recontextualized, or reworked. This reconfigured content has higher engagement on social media. There was less evidence of misinformation that was completely fabricated, and there were very few examples of "deepfakes." Misleading or false claims about the actions or policies of public authorities were most common (Brennen et al., 2020)

Moreover, the study finds that top-down misinformation from politicians, celebrities, and other prominent public figures is what creates the largest social engagement. To counter this, it is important that news media also publicize falsehoods and lies from prominent politicians which have been published in social media, in order to hold them accountable. Misinformation on social media that come from ordinary people generate far less engagement. Although independent fact-checkers have increased their work, it is not possible to check all problematic content because of the large volume. However, social media platforms are doing more work in targeting prominent figures, like when Twitter, Facebook, and YouTube in late March removed posts shared by Brazilian President Jair Bolsonaro because they included coronavirus misinformation. Still, a significant percentage of posts on Twitter, YouTube, and Facebook remain on the sites without warning labels. Independent media and fact-checkers play an important role in sorting false from true material. Since much of the misinformation is directed towards public authorities, it is more difficult for those institutions to address it directly (Brennen et al., 2020).

Still, social media play an important role in being a supportive public environment. One example is the COVID Symptom Study app, developed by Tim Spector at King's College London, which is the largest community monitoring of COVID in the world. Over 4 million individuals have voluntarily shared personal information and answered questions related to any underlying chronic condition. The app has been important in identify the problems of long COVID, which is now being increasingly acknowledged by public health authorities as a major health challenge (Ennals, 2020).

13.4 Rule Compliance

Rule compliance in the population is critical in the effective management of any infectious diseases, whether it is influenza or COVID-19. For instance, social distancing and individual sanitization are considered the best ways to prevent the spread of a virus. All countries depend on people actually following the behavioral rules, like physical distancing, hand washing, quarantine, and wearing masks. Even South Korea, which uses advanced surveillance technology, is reliant on voluntary engagement and cooperation. Therefore, public information campaigns about behavioral rules are essential (Moon, 2020). The major challenge is typically non-compliance with public health directives when people contract the disease, or that the general population ignore social distancing measures. The measures infringe personal freedoms, and can lead to financial losses, so they can easily trigger anger and opposition in the population (Pfefferbaum & North, 2020).

Regarding rule compliance, New Zealand stands out as an interesting example. The country experienced one of the lowest rates of infected cases and mortality among higher-income countries in the first wave of COVID-19. The government decided to try to stop the virus by enforcing border restrictions even before the first local case was confirmed. When infected cases were detected, they moved very quickly into national lockdown, within just a month. This strategy was combined with rigorous case detection, isolation, contact tracing, and quarantine measures. As a result, New Zealand could move out of lockdown earlier than other countries. Nor were high-risk workers and indigenous Māori people disproportionately affected in the first wave (Jefferies et al., 2020).

This early, intense response could have easily created anger in the population, which was a worry in many countries who used slower lockdown implementation such as Australia, the UK, and Italy. The decisive national leadership would not have been possible without rule compliance and cooperation from the population (Jefferies et al., 2020). The government communicated simple, clear health messages with kindness, and the population cooperated and followed the measures even when New Zealand were one of the first countries to implement lockdown. A research study shows that compliance with basic hygiene practices and trust in authorities was at nearly 100 percent. The population correctly understood important facts about the coronavirus and how the disease spread, indicating that the population was well educated. Nine out of ten practiced social distancing. They were aware of symptoms and the possibility of asymptomatic transmission. Nor did they believe some of the most common myths of misinformation, like for example that only elderly people were infected. Despite the country's success, there were economic tolls, with nearly one in five reporting economic difficulties, and the indigenous population being disproportionately affected (Thaker & Menon, 2020).

Rule compliance with respect to the wearing of facemasks has been an issue during the pandemic. The South Korean people quickly adopted the advice of medical professionals, and very few objected to wearing a mask. A majority of people even began wearing masks before the government recommended it. It was experienced as a sensible precaution, since Koreans were concerned about others not getting ill too. This is very different from some Western countries, where some parts of the population have not followed government rules (Ryall, 2020c). In the US, the wearing of facemasks even became a political issue. One study identified significant differences between Republicans and Democrats on coronavirus-related restrictions and safety measures. Thirty-one percent of Democrats expressed concern about other people not wearing masks, while only 5 percent of Republicans agreed. Democrats are much more concerned about getting COVID-19 and are more likely to say that people in their community should always wear a mask (Van Kessel & Quinn, 2020). Part of the challenge in some US states is that the mask mandate debate has been left to local authorities to decide because there has been no state mandate (Diamond, 2020).

A supplementary strategy to voluntary rule compliance is the use of digital surveillance tools. In South Korea, the government collected GPS data from individual mobile phones, which provided detailed information about the movement path of each infected patient prior to being quarantined. An app was developed that showed the places infected patients had visited (e.g., Corona Map). This included data mining of CCTV footage and credit card use (Moon, 2020). The track and trace system is widely credited with limiting the spread of the illness. The highly automated system effectively traced the routes and interactions of people infected with the virus and who they had been in contact with. The system was able to reduce tracking time from 48 hours to four hours. All crowded places the infected person had visited, like a gym or bar, were closed and disinfected (Ryall, 2020c). Those in quarantine use the app to report their symptoms and provide status updates to officials. A local government case officer checks in twice a day, and by using electronic wristbands, the government ensures that people are not able to break their quarantine (M. S. Kim, 2020; Moon, 2020). In contrast, preliminary data on England's test and trace programme showed that only half of those who were asked to self-isolate said they had complied with the rules (BBC, 2020).

Surveillance tools can be effective in enforcing rule compliance, but even though the app data are published anonymously, there are serious concerns about infringement on the privacy of infected patients. Governments face a trade-off between privacy and public safety in this emergency. What is interesting with South Korea is that a national survey found that a large majority of people (84 percent) support the surveillance strategy, apparently because people trust the system will be used to ensure their well-being (Moon, 2020). In many Western countries, this surveillance technology has been met with much more skepticism.

13.5 COVID-19 in a CI Perspective

This final section will more closely examine how the three governmental strategies mentioned in this chapter resemble different aspects of CI.

13.5.1 Transparent Information

First, this chapter has shown the importance of many different types of transparent information flow. Arguably the most effective governmental strategy that both contains the virus and simultaneously minimizes the "damage," is a strategy that resembles environmental sensing in its attempt to maximize information about the spread of the virus. The South Korean "test and trace" strategy illustrates an adaptive type of collective problem solving that made it possible to react quickly when infected cases were reported. The country managed to contain the spread of COVID-19 without a lockdown, while other countries were eventually forced to implement a hard lockdown with many negative effects. In addition, South Korea used mobile technologies to map the spread of the virus and inform citizens when necessary. A number of apps and QR-tracing at different hotspots made it possible to keep an overview of individual movements in the population. When infected cases were identified, close contacts could be easily identified, and people could move more quickly into quarantine. The constant testing and tracking of people who had been in contact with those who had been infected made it possible to contain the virus without shutting down society.

From a CI perspective, this approach resembles environmental sensing and human swarm problem solving in the attempt to maximize environmental information. When accurate information about the current situation is continuously updated, the government can be more flexible in their choice of strategy, depending on the spread of the virus. The disadvantage is the heavy surveillance of the public, for example, the highly effective quarantine rules, which still violate privacy.

Another aspect of transparent information flows is the sharing of all types of knowledge about the pandemic through the Internet. Most of the big news sites in all countries have provided citizens with updated statistics on the spread of the virus. From one perspective, these numbers provide feedback to the citizens on how well they are succeeding in following different behavioral rules. As the case of South Korea shows, it is likely that this type of transparent information increases citizen's understanding of the seriousness of the problem. From a CI perspective, this is an example of stigmergic problem solving. The constantly changing statistical indicators resemble how solutions can be "reestimated." A decrease in number of infected cases informs the crowd population that they are moving closer to the optimal solution. If the number of cases increase, people will know that they have to be better at following behavioral rules, such as social distancing measures.

There are also several other interesting examples of open online knowledge sharing during the pandemic. This includes preprints of scientific research papers and even online platforms that allow anyone to upload data about their health condition to a database, like the COVID Symptom Study. Such research-based initiatives provide important data about the pandemic, both regarding geographical differences in infected cases and in providing more information about how sick people are. This type of knowledge sharing can be interpreted as a type of stigmergic problem solving. However, the problem with misinformation during the pandemic, the so-called infodemic, illustrates how biased information can attract a lot of attention on the Internet. When people like or share information, they also sometimes look for information that is sensational or entertaining, but not necessarily truthful, with the risk of amplifying misinformation.

13.5.2 Citizen Responsibility

Second, citizen responsibility has been an important issue, since citizens have had to comply with behavioral rules enforced by the government. All governments are dependent on citizens' cooperation concerning some of these behaviors, such as social distancing measures and voluntary quarantines. The New Zealand approach was reliant on citizens actually trusting government's strategies. Most citizens report that they followed the behavioral rules. The challenge of getting people to follow behavioral rules is an example of human swarm problem solving, but the aim is to achieve homogeneous social interaction, whereby everyone complies with the same rules.

Governments have also regularly had to change their advice because the number of infected cases have changed. Clear messaging has been important, but this has been more difficult when there is a mix of mandatory requirements and recommendations. To maximize trust, many governments have chosen to let both politicians and health experts inform the public together. However, there have been tensions between politicians of different political parties and researchers. One example is the lack of clear recommendations on facemasks in the US, which created confusion among the citizens and reduced motivation to use a mask. Educating citizens is part of the process and if different advice is given, it can easily lead to more resistance.

In trust-based strategies, social norms among different groups in the population will be important. Solidarity during the pandemic is centered on all citizens following the same behavioral rules. One example is the expected solidarity across generations, in requiring young people to be careful to protect elders and other vulnerable groups. From a bottom-up perspective, the behavioral rules are more than just rules; there is a degree of sacrifice when everyone must restrict their own social life through physical and social distancing.

The paradox in a pandemic is that you also want less individual free choice and more conformity towards the correct behavior. Social conformity and pressure can be effective if the majority already follow the required behavioral rules. People who do not follow rules will quickly observe that they are a small minority. If people comment on others breaking the rule, this will create a peer pressure to comply. However, the effect can also be opposite if the majority in a group don't follow the rules. Rules on social distancing, like limiting the number of people who can meet at informal social gatherings, can be considered as "invasions" into people's private lives. These activities cannot be controlled and are dependent on citizens being willing to follow them. Peer pressure will be the most important mechanism against rule-breakers. If a group of people follow physical distancing rules, it will be quite difficult to break these rules, because if a person comes too close others will just move further away.

In an emergency, conformity is an advantage. This has been less of a problem in totalitarian countries, like China, where the population are used to following mandatory requirements. The South Korean government was also reliant on people using the health apps and actually seeking health services when they became sick. The citizen acceptance of surveillance technology to collect geodata has made it easier to contain the spread. Under normal circumstances, this technology would have created much more concern regarding privacy infringement. However, these behavioral rules will inevitably have many negative side effects. Even relatively "successful" countries like South Korea have seen a rise in the number of suicides in the last half-year (Ryall, 2020b).

13.5.3 Collective Learning

Third, collective learning at a system level has been important in dealing with the pandemic. South Korea learned a lot from the Middle East Virus (MERS) in 2015 a couple of years before the COVID-19 outbreak. Most decisions on how to tackle the outbreak were based on science instead of political decisions. Key initial disinfection decisions were primarily based on scientific evidence and standard operating procedures established after MERS (Moon, 2020). Their past failure in coping with that outbreak made them much better prepared than other countries.

Other countries that have struggled during the first wave of the outbreak have also tried to adjust their strategies in meeting the second wave. Many have adopted a test and trace strategy. However, the disadvantage is that if too many people are infected, the number of cases lead to information overload, which chokes the testing system. When this recently happened in Slovakia, they invented a new strategy by choosing to mass test most of the people in the country. This makes it possible to reduce the spread of the virus because most of the infected individuals are set in quarantine. It is then possible to regain control over the number of infected individuals. Public health authorities will get more accurate information on how and where the virus is spreading, making it possible to continue to trace the virus without going into a full lockdown. Other countries, like Austria, are adopting a similar strategy, which illustrates how countries are learning from each other at a rapid pace during the pandemic.

Concerning the vaccine development, it has not been possible to treat vaccines as global public goods. International actors like the WHO have tried to build an inclusive global distribution network, but the process has instead been dominated by "vaccine nationalism" and bilateral contractual mechanisms. Therefore, there is a risk that the vaccine distribution process will accentuate the economic and social divide between higher and lower income countries (Santos Rutschman, 2020). The vaccine race has largely been organized as an innovation contest with many different vaccine candidates. At present, nine candidates are in late-stage trials, while many more are in the earlier stages. A large variety of different types of vaccines are being developed, with teams working independent of each other. As with other types of human swarm problem solving, this approach increases the likelihood of identifying one candidate that is effective. Currently, a number of the vaccines show very promising results.

In addition, the pandemic has led to new policies that might have potentially positive consequences in the long term. In Spain, the economic crisis and poverty that followed the lockdown triggered the government to implement a guaranteed minimum income to all citizens. The European

Council has recommended that other member countries do the same to combat poverty and social inclusion. Although home schooling has been less of a success, people have realized that some of their work can be done at home and in this way, they can save travel time. This may also reduce pollution. It remains to be seen if these working habits will change permanently, but several big companies now say that workers can choose if they want to work from home.

CHAPTER 14

Motivation to Contribute

14.1 Background

If we think CI can benefit society, we need to understand how we can motivate individuals to engage in this type of collective problems solving. However, because CI covers such a broad area, including science, practical problem solving, and politics, this is a daunting task. Depending on the complexity of the task, the required skill level varies a lot. It ranges from innovation contests that often look for individuals with specific formal qualifications to citizen science projects that require simple image detection skills (e.g., Galaxy Zoo).

Furthermore, studies of motivation in peer-production communities identify a mixture of motivations, such as social status, peer effects, prosocial altruism, and group identification. Single individuals are motivated by a combination of different factors, and this mix will also vary (Benkler et al., 2015). Some citizen projects target specific groups who have advanced skills. This group has a strong intrinsic motivation if the activities are closely aligned with their needs and interests. However, it may be difficult to include volunteers with both high and low skills in the same project (Hecker et al., 2018). One exception is Wikipedia, which has managed to offer a wide range of tasks at different skill levels. In innovation contests, prize money will obviously be important, but other intrinsic motivational factors are also influential (Baltzersen, 2020). Studies of open source software communities (FLOSS) have shown that it is possible to combine paid and unpaid contributions without excluding intrinsic motivational factors (Benkler et al., 2015).

Still, most of the CI projects in this book typically center on noneconomic motivational factors. In a historical perspective, we have more spare time than ever before (Shirky, 2010). Many CI projects depend on this extra "time resource" because they rely on volunteering. However, the competition is fierce, from both social media and a range of entertainment services such as games and movies.

Motivational factors may also change over time. For example, in the original hackathons, individuals were highly motivated by the idea that they could produce something of value to everyone. However, in a recent study of a hackathon, only one third participated because they wanted to change the world (38 percent) to become a better place. Other motivational factors, like learning and networking or receiving recognition, were more important. It illustrates that motivation may change over time with each new generation (Briscoe & Mulligan, 2014).

Since CI covers so many different practices, some claim that it is impossible to describe CI motivation within a single coherent motivational framework (Benkler et al., 2015). However, a tentative model can still be useful as a guide to provide an overview of various motivational factors that are important. In this chapter, the following factors are discussed:

– Being immersed
– Being recognized
– Being part of a community
– Learning as motivation
– Economic motivation
– Making societal contributions

These factors are inspired by a typology developed by Baltzersen (2020) in relation to online innovation contests. Solver statements about their motivation to participate in online innovation contests are an important part of the content in this chapter. These data may be somewhat biased in the sense that they highlight positive motivational factors, since the stories have been published openly. However, because many of the profile stories display authentic names or usernames, there is no reason to believe that the published content is untrue. However, the demographic background of the participants is also very similar, a vast majority being male, middle-aged, and with highly qualified expertise. In addition, there are few examples from the political domain in this chapter.

14.2 Being Immersed

14.2.1 Being Immersed in Simple Tasks

If we look at motivational factors in different CI projects, it can be relevant to distinguish between low-level and high-level cognitive challenges. In CI projects, there is a wide range of relatively simple tasks. This can be an image recognition task in a citizen science project, rating the quality of a video on YouTube, fixing spelling errors in a Wikipedia article, stating your opinion in an argument map, or betting on the outcome of a political event in a prediction market. Most individuals can do these microtasks, and it will usually require a minimum of time and effort. Because they are simple, this increases the likelihood of getting more people to contribute.

These microtasks require a lower level of concentrated effort and can be done to relieve boredom for a brief period. Although most people may perceive an image recognition task on Galaxy Zoo as uninteresting, astronomy hobbyists enjoy this type of activity. Gamification designs can motivate individuals to do more repetitive tasks. In prediction markets, it is easy to place a bet on the correct answer and perhaps win money. In other systems, collective predictions on swarm platforms will take less than a minute. These low level-cognitive activities can often be done in combination with other activities (e.g., traveling to work or watching television) and it is important that they are perceived as interesting or entertaining.

Another issue is task variation. An individual might use most of the day to solve high-level cognitive challenges, and in the evening relax by doing some less cognitively demanding work on Mechanical Turk (Malone, 2018: 194). Simple tasks can be motivated by an urge to fix incomplete work. The open display of errors in Wikipedia can trigger somebody to continue the work, for example by fixing spelling errors. Although bots do many of the minor fixes today, there is still a range of tasks that humans need to do.

14.2.2 Being Immersed in Complex Tasks

In the CI projects that require advanced skills and a significant investment of time, it becomes more important to have a strong desire to solve the complex challenge and be passionate enough to sustain the effort over time. According to Levy (2001), programmers deeply appreciate the beauty of simple code that allow programs to perform complicated tasks. This esthetic motivation or individual flow keeps them going (Levy, 2001). When Linus Torvalds first created the Linux system, joy of the work was an important motivation (Himanen, 2001). Many solvers in online innovation contests also express positive feelings like enjoyment, excitement, fun, and pleasure (Hossain, 2018; Innocent et al., 2017).

In complex problem solving in online innovation contests, the economic rewards will usually not be sufficient to motivate participation because it is unlikely that one will win the prize money (Baltzersen 2020).

Although, some activities may be both boring and tiresome, the long-term goal is associated with pleasure. For example, one top solver emphasizes the joy of working with very difficult challenges, "I'm always driven to the next difficult problem and I like difficult problems. I like the worst kinds of problems. I want the worst problems in the world in front of me. That's what I want to work on every time." When being immersed in a task, even the "worst kinds of problems" are experienced as motivating. Another solver emphasizes the positive feelings of being immersed in the collaborative work. It forces him to move out of his comfort zone because he is working with new people and unusual problems. Citizens who meet unknown others in citizen assemblies will probably have similar feelings when they are assigned to work together with strangers in solving societal problems.

In addition, solvers in online innovation teams are motivated by the constrained timeline and the competition between a few selected teams. It pushes the group to work harder, as one solver highlights:

> *Everyone knows that they are working side by side with us – and only the best team will win. Of course the money is also a motivation, but the award offered in almost all challenges is not enough, alone, to keep the team working. The intellectual challenge, the will to win is the springboard and the glue that keeps the team running.*

The solver describes how the "will to win" is an important motivation that drives the challenge. The teams are motivated both by the difficulty of the challenge and the contest format.

14.3 Being Recognized

An important individual motivation in many CI projects is to receive recognition for the work that has been done. Several projects aim to build motivation through different types of leaderboards and ranking systems. For example, Foldit provides a ranking system with high scores and individual ranking score on profile pages. The leaderboards are assumed to strengthen individual motivation through the joy of competing. In online innovation contests, some are motivated by the possibility of outperforming their peers:

> *It was nice to have an award and money for the time that I spent. But the emotion was more interesting of competing with other people and then being the successful team. That gives you a lot of confidence, a lot of motivation and this truly was much more important to me than the monetary reward. Especially as this was my area of expertise, so I should be doing well.*

The primary motivation is to be the most successful team; it is less about the prize money in itself.

In Topcoder, another innovation contest environment, part of the motivation is to test your own individual skills and compare them with the top community members. It is possible to track progress on the leaderboards. An overview of the personal ratings is displayed on each member's profile, covering skill areas within algorithm, design, and development. The open display of performance statistics on personal profile pages, such as in Topcoder and Foldit, suggest that several CI projects are also part of the new reputation society dominated by quantitative measurement models.

Likewise, IdeaConnection has ranking systems displaying how much prize money different solvers have won. The prize money is a quantitative recognition of their skills. When winning an award in an online innovation contest, some solvers interpret the prize money as an indicator of how much the work is valued, as one solver states, "It made me feel that what I know is appreciated and that even large and medium companies need outside advice."

Formal author recognition is another motivational factor. In some projects, amateurs receive scientific credit, but this is done differently. In Foldit, two teams (Void Crushers and the Contenders group) which made significant contributions were mentioned as coauthors on a paper with lead researcher Firas Khatib and other colleagues in 2011 in the journal *Natural Structural and Molecular Biology* (C. Cooper, 2016: 120). A group name is used and not the individual names of the persons in the group, suggesting that this is more of symbolic gesture as it is less important for amateurs to get scientific credit for their work. Likewise, research papers from the Polymath project are usually written under a pseudonym (e.g., "D.H.J. Polymath"). This can be a problem for early career mathematicians who may want to participate in a Polymath project, but who receive too little merit or acknowledgment for the work. Although they can learn much by participating in the project, they will often have to prioritize writing ordinary research papers instead (Michelucci & Dickinson, 2016; Tao, 2014).

Using a list of authors can be another option, but in some cases, it will be difficult and time consuming to agree on the exact size of the individual contributions. Some may have done very little work. Still, Foldit researchers used a list of names to recognize amateur contributions in a recent scientific publication. More than one hundred players are mentioned by name at the end of the article (Horowitz et al., 2016). By giving

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scientific credit, this is one way of acknowledging the work of amateurs, which can perhaps strengthen their motivation.

Other amateurs are more motivated by being recognized in the working process. For example, in the Polymath project, amateurs are given the opportunity to work together with top mathematicians in the field. Some will be motivated by being in direct contact with famous scientists during the actual problem solving (Nielsen, 2011).

Moreover, in Wikipedia, peers recognize each other by giving each other different types of awards. For example, a "barnstar" is an informal award that anyone can give to anyone as a recognition of that person's work in Wikipedia. These awards have a positive motivational effect on the most active Wikipedians (Benkler et al., 2015). Another study of Wikipedians show that it is not altruism but reciprocity and social image that are strong motives for sustaining cooperation (Algan et al., 2013). The motivational logic in relation to author recognition is very different, since active users are motivated if others reuse or modify their work. For example, in one study, a contributor was very proud because somebody had translated his work on one article into a similar article in another language edition of Wikipedia (Baltzersen & Tolsby, 2008). It illustrates that peer recognition can manifest itself in several different ways. By contrast, if new contributors receive harsh treatment from experienced editors in Wikipedia, this will reduce the motivation to contribute (Benkler et al., 2015).

From one perspective, being recognized by peers is the same as receiving likes in social media. However, in CI projects, peer recognition is typically directed towards a substantial individual performance, and feedback from peers is usually sincere and honest. The use of likes in social media may be more casual, being part of a more detached "clicktivism culture."

14.4 Being Part of a Community

Several CI projects show that active members feel a need to meet each other to experience that they belong to the same community. Active participants will often get new and more prominent roles in the community, like becoming Wikipedians or facilitators in innovation contest systems. In Topcoder, some of the participants who get new roles are motivated because they engage daily in community activities. As one of the crowd workers says:

I feel Topcoder is an extension of my family right now, because I talk to members and Topcoder managers every day. It is like a real office for me. I spend the whole day talking about the project, challenge, and it is just for fun. Actually, the best friends that I already have are from Topcoder. They are from India, Romania, France, Italy... around the world. When I got started, I really liked this communication, because I felt I'm part of something. The communication of Topcoder, especially with the new members, is really good" [P7]. (Shafiei Gol et al., 2018)

The solver describes that they make friends from all over the world, and that it was like being part of an extended family. The close communication and friendships appear to be an important motivation for some of the highly skilled members who have core roles in the online community. Although Topcoder is built around contests, active members can still participate in ways that create a feeling of being part of a community (Shafiei Gol et al., 2018). There is also an increased awareness that it is important to offer a community space where members can interact and share ideas in between the competitions.

Long-term contributors will typically engage in social networks with others who share the same interest, including creative professionals (Brabham, 2013: 68). In the online setting, the motivation will be to connect with other persons who share the same interest or hobby, and it will be less about having a similar background (age, gender, education) or living in geographical proximity. Part of the process of belonging to a community is about becoming acquainted with other like-minded people. This peer production brings together people who would otherwise not meet. Users will both be motivated to find their tribe (e.g., being connected with people who share their interests) and by becoming a hero (e.g., having a substantive positive impact on a community they care about) (Klein, 2012).

Opposite, social conflicts can be devastating for sustained participation. For example, one of the top contributors in Foldit over six years quit because of a falling out with another player and the management. He was part of the successful Contenders team and had no formal background within biology, but still managed to make substantial contributions to research. He had been playing Foldit almost every night for six years. On his user page, he shows that he became really upset when the management decided to support a teenager instead of himself who had been playing for 30,000 hours (C. Cooper, 2016: 125). This example illustrates that when individuals join a project, they are first motivated by curiosity in science, but sustained activity is heavily influenced by social factors. It also illustrates the presence of an informal meritocracy in the player community, whereby player influence is based on player experience (C. Cooper, 2016: 126).

Furthermore, CI projects that build on long-time work over many years will typically arrange regular large gatherings where people can meet in an offline setting (e.g., Wikimania conference, mapping parties). These gatherings are important for the most active contributors, such as the Wikipedians, who become acquainted with each other and strengthen their experience of belonging to the same community. Another example is how active OpenStreetMap contributors participate in so-called Mapping Parties. Here, contributors meet at a certain location, get to know each other, and share experiences about their work. The main events are the yearly "State of the Map" conferences, which are held at several different locations (Neis & Zielstra, 2014).

In a study of a hackathon, the second most important reason to attend the hackathon was networking (82 percent), illustrating the importance of getting to know others and possibly learning something new from them (Briscoe & Mulligan, 2014). These meeting places are also important in that active members can acknowledge each other. The social contact is established through the shared interest in the work being done.

The importance of being part of a community is perhaps most evident in how many CI projects with weak community structures lose most contributors after a short time. When individuals work independently from each other, they feel alienated and more detached from the work. This makes it much easier to quit. Some of the simple citizen science projects that aim to collect independent individual judgements are vulnerable because there is less need for a community in the problem-solving process. A similar challenge is present in online systems that primarily crowdsource opinions through simple mass voting. One example is the Five Star Movement, which provides limited opportunity to deliberate, with the risk of reducing the motivation to participate. In other cases, like when somebody wants to modify an open textbook, the main goal is to make this process effective by removing the need to contact the original author (e.g., Creative Commons license).

Being part of a community can also be about branding. A video platform like YouTube still promotes itself as a community built upon authenticity, vernacular culture, and the accidental "viral" video star, even though most people are now realizing that it is all about business as usual. "Amateur content" is increasingly being produced by professional

YouTubers in the attempt to maximize the number of subscribers or views to increase the cash flow (Burgess & Green, 2018). Still, the success of YouTube illustrates how individuals can be motivated by wanting to be part of a "community" that is built around attractive community values.

What is interesting with Wikipedia is that individuals can be part of the community in many different ways. On one hand, an anonymous contributor can choose to improve an article without participating in any online discussion at all. On the other hand, the long-term volunteers are essential in the further development of the encyclopedia. They feel an ownership and commitment to make durable contributions and ensure that everyone follows the guidelines (Benkler et al., 2015). However, most contributors will not be active Wikipedians, but they will still be very important in contributing to the different articles. Perhaps this flexible participation structure is key to the success of the Wikipedia community. If so, CI projects should build communities that allow for both loose and close engagement.

14.5 Learning as Motivation

Learning as motivation is an important motivational factor in many CI projects. Individuals who engage in collective problem solving will often experience being part of a learning process. In innovation contests, solvers know they can learn more by participating in a difficult challenge. For highly skilled workers, challenging work is essential to stay intrinsically motivated (Shafiei Gol et al., 2018).

14.5.1 Individual Learning as Motivation

In hackathons, one of the most important motivational factors is learning. In the context of software development, life-long learning is especially important because new technologies are invented at a rapid pace (Briscoe & Mulligan, 2014). Similarly, a solver participates in an innovation contest to update his professional skills, "I have a background in pharmaceuticals so I wanted to learn more about plants and the environment. I have not been associated with that field for quite a while and I've always had an interest in it. So it was a way to be re-introduced to what's going on in the field and it was really rewarding." This is not a formal way of learning, but instead it happens through problem solving. It illustrates that solvers sometimes choose to work with challenges in areas where they do not think they can win a prize, but where they will instead improve their professional skills (Hossain, 2018; Innocent et al., 2017; Shafiei Gol et al., 2018). Others join to get a better overview of the general problems in the industry. One solver emphasizes that innovation contests enable him to work on problems that are different from his ordinary work:

> *They allow me to work on tons of problems that normally you can't do when you're in a big company. You're not allowed to go down the hall and work on a problem with another group that's way outside of your group. So challenges allow me to work with people that I wouldn't normally get to work with and tackle problems that I wouldn't normally get to tackle.*

The solver seeks out the problems he really wants to work with. In many CI projects, both passion towards the work and self-selection of tasks are important.

14.5.2 Collective Learning as Motivation

In many CI projects, individuals will learn from each other in the collective problem-solving process. For example, in the IdeaRally, several solvers highlight the learning experience related to participating in a transparent environment (see Section 2.2). University students also participate in Topcoder competitions to learn from the reviewer feedback they receive on their proposed solutions. Even when the environment is centered on competition, members still discuss challenges and share ideas with each other in online forums. In addition, the final competitors get to see the designs and the codes of the other finalists. Part of the award is this access to others' work, since it motivates members to keep improving (Shafiei Gol et al., 2018). Because many contestants will not win prize money, learning is arguably the most important motivational factor.

Furthermore, most of the top solvers in the online innovation teams are motivated by the learning opportunities in the group (Baltzersen, 2020). One top solver describes how the diversity of the learning experience is an important motivational factor:

> *The best part was the opportunity to test ideas and lines of thought against others who have distinct experiences and approaches. If any idea is really good the others will adopt it, because the whole team will harvest the benefits. It the idea is bad, or if a team member is not able to present it in a good way, it will be rejected. Every idea accepted or rejected is a window to observe and learn how to be successful in a multicultural, competitive world.*

The solver highlights how one can learn something of all ideas, and "the best part" is to be able to test you own ideas and receive feedback from other, indicating that individuals with advanced skills are highly motivated by being in intense learning processes. Another solver underlines the value of meeting new people:

> *I enjoy the challenge of a new problem and it heightens and improves my skills, not only being challenged with new and different things around the world, but also meeting new people and learning how to deal with different personalities. So I'm learning in the process and giving back some of my skills to people who may benefit from them. That's one of my main motivations in life.*

This solver appreciates the team process and learning how to deal with different personalities.

14.5.3 Transformative Learning as Motivation

In some types of CI, transformative learning can be a relevant motivational factor. Aida Berges, a contributor in the citizen science project Galaxy Zoo, is a 53-year-old stay-at-home mother of two living in Puerto Rico. She classifies hundreds of galaxies every week, and the work has changed her life forever: "it was like coming home for me." (Nielsen, 2011: 155). The project gave her an opportunity to follow her passion. It illustrates the potential outreach in an online setting, and allows individuals to be part of projects that previously would not have possible because of geographical and social constraints.

Some CI systems like Topcoder attempt to retain solvers by designing promotion opportunities within the environment, whereby it is possible to become a reviewer. Solvers can build up a reputation which can be beneficial for their career opportunities. Long-time contributors become part of the Topcoder Veterans Community that supports individuals in moving into meaningful civilian jobs.

Another example is the Climate CoLab, which hopes to create attitudinal change by motivating people to create good ideas on how to fight climate change (Malone, 2018) (see Section 2.2). Similarly, the increased use of citizen assemblies builds on the assumption that citizens will rise to the occasion when they are given responsibility. This will transform them into becoming more engaged citizens afterwards (see Section 12.4).

14.6 Economic Motivation

Even in the direct democracy in ancient Athens, payment was essential in motivating participation. However, a juror only got three obols (Greek currency) for one meeting, which lasted a whole day. This was far less than a day's wage, but it might have been the only chance for some groups to earn anything at all. The payment was enough to meet the necessities of a small family, and for the elderly, the invalid, and the unemployed. Many jurors were probably older citizens who could no longer do hard physical work, but they were still able to listen to speeches. Still, the payment appears to have been sufficient to ensure that enough qualified people turned up for allotment (Hansen, 1991: 183–189).

If we look at how the deliberative tasks are organized today, citizens also often receive an honorarium. For example, both the Deliberative Polling in Mongolia and the Citizens' Council in Ostbelgien give some payment and cover participants' costs. However, since the work is considered a civic duty, pay as an extrinsic motivation is not supposed to be important. Still, it may be essential in recruiting individuals from low-income groups.

In this book, it is primarily innovation contests that use economic rewards to motivate participation. Some successful solvers even regard this type of activity as full-time work, but the majority look at prize money as an extra bonus income (Baltzersen, 2020). The reward models are also different. Online contests such as IdeaConnection and Innocentive often give a large amount of money to a few winner solutions. The others get nothing. Because the challenge requires skilled expertise and because the likelihood of winning is relatively small, it is important that the size of the prize is big. In the team contests, the chances of winning is much larger, since only a few teams compete against each other. In contrast, the Topcoder model is different, as the rewards for IT challenges are often modularized into minor payments. In addition, timely and guaranteed payment is important because there are no traditional employment contracts or benefits (e.g., healthcare). The competition and selection of winners must be perceived as fair and transparent (Shafiei Gol et al., 2018).

Another important motivational factor in CI projects is self-selection of tasks. Freelancers will want to control their working hours and only register for contests that match the person's skill or interest (Shafiei Gol et al., 2018). It is also important that the solvers are able to find the appropriate challenges quickly. In general, these types of environment encourage hyperspecializaton. For example, somebody who is particularly good at designing user interfaces can do just that. When workers get to choose the tasks they want to do, it increases the likelihood of finding people who are really good at doing the tasks (Malone, 2018: 191, 195).

Another economic motivation is that the participation can strengthen career opportunities. By earning money, doing different kinds of work, learning new skills, and earning a rating, one can build a portfolio or CV that is relevant for future employment. Some technology companies even recruit persons directly from sites like Topcoder. In addition, many regard participation in the innovation contest environment as a new of doing professional networking (Arnold, 2019c).

Online communities struggle if they do not offer any career tracks. One example is the qwiki that was established by John Stockton in 2005. Inspired by the Wikipedia model, the goal was to invite researchers to develop the best collective resource on quantum computing. The resources would be constantly updated and cover material ranging from simple introductions of key concepts to detailed explanations of the latest research, including source materials, animations, and interactive simulations. There were high hopes of a new wiki science. Many professional scientists were also invited to join the work, but very few did any work at all. The majority of the few users who joined the project spent most of their time writing about their own research on the profile page. Most of them believed the potential was tremendous, but still none were willing to spend any time. After six years the project eventually stopped. Ambitious scientists were forced to pursue scientific publications and research grants. Moreover, the young scientists had to do the same, in the tough competitive environment of securing a scientific job. The science wiki did not provide enough scientific merit and offered no prosperous future careers. Wiki-science remains an unrealized dream (Nielsen, 2011: 176–179).

14.7 Making Societal Contributions

In ancient Athens, every citizen who had sworn the Heliastic oath was equipped with a personal “ticket.” It was a small bronze plaque, inscribed with the individual’s full name and mostly stamped (Figure 14.1). This citizen token or pinaikon served the function of being an “identity paper,” and it was used in the lottery machines in the People’s Court. Detailed study of most of the surviving plaques shows that the name of the original holder has been hammered out and replaced with another name. The plaques changed hands often because the composition of the 6,000 jurors changed annually. It indicates a competition for places to become a juror.

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Figure 14.1 A juror identity card or pinakia identifying citizen by names. Clay fragment with Greek inscription, fourth century BC. The identity cards list the name of the juror, his father, and that of his area (demos). When selecting jurors by lot, these plates or "identity tokens" were inserted into the kleroterion, the randomization machine. This fragment is located in the museum of the Ancient Agora, Athens. Photo John Hios/Akg-images/NTB

But what is most striking is that all the best-preserved plaques have been found in graves. It is a testimony to the unique mentality in Athens in this period, because in archaic times, most citizens would want weapons, not small plaques, in their grave (Hansen, 1991: 181–182). It illustrates how proud the Athenians were of their democratic system and the opportunity to make societal contributions.

Other successful CI projects build on a similar to have a positive influence on society. A top solver in an innovation contest is proud of winning a contest: "Being a winner was a reason of pride with the feeling to have provided important ideas to solve important problems." Although some of the CI projects require simple "boring" work, these persons may still be motivated because of the societal value of their work. A study of Galaxy Zoo, a citizen science project, found that the most important volunteer motivation is the opportunity to contribute to research, regardless of gender or age (Raddick et al., 2013). In large projects like Wikipedia, some of the simple "cleaning work" and moderator work done

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by Wikipedians will be important in maintaining the encyclopedia to a high quality. These individuals feel a strong sense of civic duty (B. Stewart & Ju, 2020).

According to Himanen (2001), the motivation among coders (hacker ethic) is passion or the desire to create something valuable together with others. Hackers believe that everyone in society should be able to interact with computers in the same way, since computers have opened up a world of opportunities that could potentially create better lives for people (Levy, 2001). Himanen (2001) emphasizes that these volunteers want to create something valuable for the community that shares their passion. Individual work is shared with the community so it can stimulate further knowledge development. In the political domain, it is interesting how both vTaiwan and Better Reykjavík emerge from this type of hacker philosophy. Even the Five Star Movement was founded on the concept of involving citizens in new ways of political life.

Today, this philosophy is present when amateurs share videos of their hobbies on how to solve different practical tasks. Individuals who are passionate about their skills and knowledge will often want to share them with a wider community. Instructional videos have a societal value, and the producers may also receive acknowledgment through views, likes, and comments from other like-minded people on the Internet. On an aggregated level, all this work helps to strengthen our human collective memory, but at an individual level, it is about sharing and being generous.

Although some individuals participate in projects to earn money, the large majority participate because they have extra free time. The basic requirement is "cognitive surplus," a term used to characterize the extra free time we have in addition to the basic obligations of life, like doing paid work or spending time with our family. It usually involves different leisure activities like being together with friends or doing a hobby. There are wide ranges of projects one can join, depending on the background skills. Several projects require specific skills and a significant level of individual expertise. The projects range from tasks that require no expertise (e.g., Galaxy Zoo), some level of expertise (e.g., Wikipedia) to advanced levels of expertise (e.g., IdeaConnection). The amount of time required also differs, from minutes (e.g., Galaxy Zoo) to months or years (e.g., Polymath). In complex challenges like innovation contests, solvers have to be available a considerable amount of time within a period of weeks. In contrast, very little effort will be required if you rate or comment on a published video. In work requiring some level of effort, most individuals participate because they are passionate about the work they are doing. This includes both low-level challenges (e.g., Galaxy Zoo) that require little time and more time-demanding high-level challenges (e.g., innovation contest).

Retirees is an example of an age group that have new opportunities to continue working. For example, a senior solver still participates in online innovation contests:

> *I love the challenge of a problem as it keeps my mind busy. I think I'm as creative as I ever was, and probably even more creative than I ever was, and I'm now seventy years old. It's the stimulus that folk like IdeaConnection provide for me to do that. If companies such as IdeaConnection weren't around it might have been more difficult for people like me to find an outlet for our creative energies.*

These contests are important because they are an "outlet for creative energies." This type of online work is not only good use of human resources in society, but it also enriches personal lives. It is attractive for both companies and the solvers, but one should note that these case stories only report from a tiny group of highly competent professionals. Even in citizen science projects that require relatively simple work, the volunteers are more educated than the average population, and the majority are middle-aged or old white men (Raddick et al., 2013). Still, the examples point to new opportunities for a more flexible type of crowd work.

14.8 Summary

The specific mix of motivational factors used in the design of a CI project depend on the type of person one wants to recruit. Obviously, there is a major difference between recruiting people to make small and simple micro-contributions and motivating highly skilled persons to spend a lot of time and work to solve a problem. In many CI projects, it will be important to design a community that can recruit a group of people that have different motivations. Table 14.1 gives an overview of the characteristics of different motivational factors that are relevant to CI projects.

In many cases, several of the abovementioned facts will motivate individuals. While some CI projects are clearly built around an online community (e.g., Wikipedia), other CI projects center on contests and short-term involvement in specific problems. It is more uncertain whether online communities can be successful in the long run without having any offline meeting places. In Wikipedia, contributions will require both simple and advanced skills. Therefore, it is important to design a

Table 14.1. *An overview of different motivational factors relevant to CI*

Motivational factors	Characteristics
1. Being immersed	– Simple tasks (high cognitive level) that require little effort. Be fun or relieve boredom (e.g., image detection in citizen science, proofreading in Wikipedia). – Advanced tasks (low cognitive level). Developing new ideas through intense work, like time-limited work in innovation contests or a Citizens' Assembly.
2. Being recognized	– Active contributors want to be recognized by their peers (e.g., Wikipedians). – Author recognition. – Positive feedback from prominent peer members. – Peer recognition through leaderboards.
3. Being part of a community	– Active participants will be part of a community, involving both citizen science (Foldit) knowledge sharing (Wikipedia) and online innovation contests (Topcoder). – Active participation in offline setting (e.g., Wikimania, mapping parties, Citizens' Assembly). – Flexible participation that also allows some individuals to make anonymous separate contributions.
4. Learning as motivation	– Individual learning: (e.g., innovation contest like Topcoder, Citizens' Assembly) – Collective learning: Learning from others in transparent environments and through discussions (e.g., IdeaRally, crowd peer review, online teams in innovation contests, Citizens' Assembly) – Transformative learning: (e.g., becoming a citizen scientist, innovation contest winner, or Wikipedian).
5. Economic motivation	– Payment, rewards, and prize money. – Providing future career opportunities (e.g., profiles pages that display your work, develop portfolio for future employment). – Flexible participation. Work autonomy and self-selection of tasks according to your own interest and competence. – Trusting the system. Safety becomes more important when commitment is higher (payment, personal security, employment).
6. Making societal contributions	– Utilize all human resources in society in both political and scientific domain. – People living in remote areas can work in an online setting. – Proud of doing important work (e.g., participatory governance in Citizens' Assembly, innovation contest, citizen science, sharing passion).

community where peers recognize and honor each other. The examples from the innovation contests illustrate how solvers can both be motivated by economic rewards and intrinsic motivational factors such as being immersed in the task. Solvers are also motivated because they learn through participation, being passionate about both the collective problem solving and the opportunity to make societal contributions. In some cases, like in innovation contests, there is a trade-off between competitive structures that privatize the knowledge production and the community structures that facilitate open knowledge sharing.

CHAPTER 15

The Intelligent Society

15.1 Background

This book has shown that CI has been important throughout our history. This is not only a story about how we have been able to cooperate in increasingly larger groups, but also about how we have gradually improved our ways of solving problems together. It all began with intimate collaboration in dyads, and with time we gradually learned to solve problems with unknown others through human swarm problem solving. Our collective problem-solving abilities were further developed when we learned how to improve our tools, and it excelled when we learned how to store knowledge. The invention of writing enabled new types of knowledge sharing, and the printing press opened up the possibility of stigmergic problem solving at an unprecedented scale. The story of CI is not only about group size, but even more about our extraordinary ability to improve our ways of solving problems together.

With the invention of the Internet, CI is evolving into new and even more sophisticated forms. Because of mass communication, large-scale cooperation is now possible in previously unimagined ways. One of the most successful CI projects is Wikipedia, which illustrates how content production can be coordinated at a massive scale and with a diversity that is unimaginable without an online setting (Benkler, 2006; Castells, 2010). Originally, Pierre Lévy (1999) coined the term "collective intelligence" as a new, universally distributed "global brain" that is constantly evolving and in which all humans are part of the same environment for the first time in our history. The fundamental premise is that no one knows everything, everyone knows something, and all knowledge resides in humanity. The global brain assumes that solutions already exist; they only need to be rediscovered through search engines or other tools. Like all major social transformation, the basic feature relates to how our perception of space and

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time changes when geographical restrictions are removed and when the problem of information decay disappears.

In the mid-2000s, we witnessed an enormous growth of previously private "vernacular creativity" becoming a part of the public culture through online social media, blogs, photo sharing, and videos. This new "participatory culture" (Jenkins, 2009) was associated with liberal and progressive ideologies about popular culture. Amateurs could actively participate in the creation and circulation of new content, and some foresaw the rise of a new culture centered on citizen engagement and democratic knowledge production. Technological change would lead to mass democratization, perhaps best illustrated by *Time* Magazine's announcement that the "Person of the Year" in 2006 was you. The techno optimism sought to revive a lost folk culture that could transform individuals and communities from passive consumers to co-producers and knowledge producers (Burgess & Green, 2018). The goal in the Cape Town Open Education Declaration from 2008 is to create a world where "each and every person on earth can access and contribute to the sum of all human knowledge." It echoes Levy's vision of CI in its aim to make human knowledge accessible to anyone, independent of his or her economic income. Both open science and open democracy are children of the same ideas.

The main goal of the first part of this book was to describe mechanisms in three basic types of human collective problem solving that are all relevant for CI. What the analysis has shown is that many of these mechanisms are surprisingly similar with other animal groups. If we understand them better, we might also be better able to use them to solve our collective problems.

However, while technologies have made communication easy, there is no evidence that social media has improved our life quality. Although people have access to more knowledge than ever before, many seek misinformation or no information at all. More people are well educated, have more spare time and better writing skills, but they have still not become "hobby scientists" or "hobby politicians." With a few exceptions, the commercial tech companies dominate the Internet, and we are today witnessing the rise of alternative societal models that build on algorithms and machine intelligence. Zuboff (2019) claims that this new instrumentarian power or instrumentarian intelligence has already become the dominant societal power. This final chapter describes the basic characteristics of this intelligence. It will be shown how it differs from civic intelligence, a societal intelligence that builds on CI.

15.2 Instrumentarian Intelligence

Instrumentarian intelligence is already here. Techno optimism is back, but it is no longer about Web 2.0, but big data. For the first time in human history, massive amounts of behavioral data are being collected in all areas of our life. By using the power of machine intelligence, the goal is to reveal the hidden truth of who we really are as humans. All large tech companies, with Google and Facebook at the forefront, are pursuing more of this human behavioral surplus because of the knowledge it can provide. Today, the companies are even colonizing the world of things through digital sensors, surveillance cameras, and facial recognition technologies. A richer set of data can provide an even better prediction of human behavior. The ultimate goal in this surveillance capitalism is to replace the mystery of the unknowable market mechanisms with certainty, mapping out the graph of everything. Human experience is today being reborn in the market as behavior: the fourth "fictional commodity that is different from land, labor, and money, still largely unregulated by law" (Zuboff, 2019).

A fundamental assumption is that humans are nothing more than a moving object surrounded by social fabric that can now be constantly monitored. Complex social phenomena can be analyzed as aggregations of billions of small behavioral transactions. For example, automatically aggregated Facebook ads build on data from a wide range of online activities, including what users explicitly share, favorite, and like. When users voice their opinion, the real value is the behavioral surplus it generates that makes the algorithms even more precise. The News Feed function in Facebook is a secret predictive algorithm, consisting of more than 100,000 data elements of behavioral surplus that continuously estimate a " personal relevancy score" as it not only scans your and your friends' behavior, but what everyone else that you follow does (Zuboff, 2019).

In return, the individual is offered social connection, information, and convenience, and an illusion of support through a multitude of "smart recommendations." The smart options provide individuals with simplified overviews and intelligent choices in an increasingly complex and chaotic world. Algorithms tell you what products you might like or where you might want to travel or whom you might want to meet, based on what you and your social network prefers. So why waste a lot of time looking for something when algorithms can do the job instead? This is an irresistible opportunity to live in a world where everything is arranged for your convenience. We are already getting so used to the comforts of "smart recommendations" that we don't stop using them, even if we don't like the hidden surveillance. Although people don't like being tracked and would prefer more privacy protection, they continue to use Google and Facebook (Zuboff, 2019).

Another basic characteristic with instrumentarian intelligence is its lack of transparency. It does not and cannot explain how the behavioral surplus will be used because hidden data are much more accurate. Human behavioral data are most valuable when they are unobtrusive, being outside of human awareness (Zuboff, 2019).

According to Zuboff (2019), instrumentarian intelligence is the unthinkable realization of Skinner's vision of a perfect totalitarian society. In his book *Beyond Freedom & Dignity*, (1971), Skinner prescribed a future based on behavioral control and a society built upon behavioral modification across entire human populations. By abandoning the illusion of individual freedom, one could, with the help of behavioral techniques, design a society built on collective values aimed at the greater good.

The main difference today is that the largest driver of behavioral modification is peer behavior. The millions of online social networks and interactions are assumed to reveal the true patterns of causality, enabling us to "engineer" even better social systems. Autonomous choice has been transformed into reinforcement, and action into conditioned response. "Social network incentives" is the new version of "reinforcement." Instead of focusing on individual behavioral change, it is more powerful to focus on changing the connections between people (Zuboff, 2019).

It is the behavioral patterns in groups and networks that can predict behavior more precisely than ever before. This is the new human superorganism, a swarm controlled through algorithms. Social pressure is an efficient means of behavioral modification, and is the mechanism that can ensure that all parts work in harmony toward collective aims. It makes it possible to transform machine learning into a hive mind where each element operates in harmony with every other element. This is a networked system moving seamlessly toward unity, where everyone share the same understanding, aiming to achieve the same outcomes in the most efficient way (Zuboff, 2019).

The assumption is that one can objectively determine what is correct through a mathematical, predictive science. These data can provide insight into who we really are, as more and more behavioral actions are digitized. The continuous streams of data about human behavior are powerful predictors of future behavior. They can be used to develop superior incentive design that eliminates chaos, conflict, and abnormality in favor of predictability and automatic regularity. It bears the promise of replacing fallible politics with a superior instrumentarian governance. Democracy creates friction that threatens the rational efficiency of the community as a single, high-functioning "superorganism." Political action is highly inefficient compared with the scientific schedules of reinforcement that aim for the greater good (Zuboff, 2019).

This neobehavioristic Skinnerian society, which once received so much criticism, is now here. The interest has shifted from using automated machine processes to map individuals' behavior to using machine processes to shape behavior according to the interests of surveillance capitalists. To governments, surveillance capitalism offers omniscience, control, and certainty. Government becomes convenient because "objective" algorithms can make decisions. Behavioral modification is placed at the heart of this system, administered by a specialist class that can implement the greater good for all (Zuboff, 2019).

This type of intelligence is now moving into the political domain, with the Chinese government being the first country to implement a nationwide reputation system. The private sector and local authorities have already used reputation systems for some years, but the new system represents a major shift from a "reputation society" to the rise of a "reputation state."

The comprehensive and mandatory Social Credit System (SCS) is the first digital nationwide scoring system in the world, which rates the behavior of citizens, companies, and other entities. The reputation scores combine both government information and personal reputation scores that have already been developed by private businesses (e.g., Sesame credit). The aim is to utilize the enormous amount of digital personal data in a system that can "improve" citizens' behavior and "build sincerity" in economic, social, and political life (Dai, 2018). In this reputation state, advanced digital technology and powerful algorithms are at the core of a new and superior governing model. Every Chinese citizen is to have a file compiling data from public and private sources. All citizens receive a "grade" that builds on many different behaviors, and this grade will automatically change as the individual improves or worsens their behaviors. When citizens become aware of the importance of having a good reputational score, the idea is that they will constantly seek to gain rewards or avoid punishments for "the greater good of the Chinese society." The pilot programs in many different cities in China have already shown that behavioral modification at a macro level is possible. However, instrumentarian intelligence is now taken to new extremes, as the whole nation is included in a huge social experiment, which aims to be the foundation of its future society (Zuboff, 2019).

From a political perspective, SCS aims to tackle many of the country's governmental problems, such as fraud, corruption, and difficulties in enforcing court judgments (Dai, 2018). In the Chinese society today, there is a lack of honesty and trust among the population, which is illustrated by numerous reports about food poisonings, chemical spills, financial fraud, and academic dishonesty. According to one survey, "moral decline" was regarded as the largest problem in China in 2017, mentioned by 47 percent of respondents. In comparison, only 15 percent of respondents from other countries mentioned the same issue (Engelmann, Chen, Fischer, Kao, & Grossklags, 2019).

Furthermore, SCS is expected to boost the domestic economy because it will give millions of Chinese citizens without a financial history access to credit in the domestic market. In China, 225 million citizens have no bank account. Citizens can also use SCS to apply for loans based on trustworthiness scores, without having to prove their financial creditworthiness (Engelmann et al., 2019). The long-term goal is to avoid societal instability and cope with the social distrust (Zuboff, 2019). In the private sector, these scoring systems have already boosted the circular economy by introducing new ways that people can trust people they don't know ("The rise of the second-hand market in China boosts the circular economy," 2020).

In line with instrumentarian intelligence, the reputation score and the rating system covers a diverse range of behaviors which are not fully disclosed, but we know it includes a mix of online and offline actions on where you go, what you buy, and who you know. Some of the behavioral indicators are timely payment of invoices, contractual commitment, legal standing, and the degree of money gambling. One must also be careful about criticizing the government (Nspirement-Staff, 2020).

Just recently, SCS has raised controversy because a college rejected a student with a good social credit score because his father was on the blacklist of the system. This incident revealed that the calculations are not only built on individual behavior, but on an evaluation of your social network. The Chinese people are now becoming more concerned that SCS will turn into a feudal system where you are bound by the actions of others (Nspirement-Staff, 2020). It shows the huge challenge of designing a one-dimensional system that everyone accepts and perceive as fair.

Zuboff (2019) claims that the Chinese reputation system can best be understood as the culmination of instrumentarian intelligence, with an authoritarian taking control over both public and private data. The Chinese leaders have in effect defined what is "good" and "bad" behavior across a variety of financial and social activities, and ratings are automatically aggregated based on citizens' behavior. The ingenious strategy in instrumentarian intelligence is that it motivates the social network to improve and influence each other in establishing the correct norms of behavior. If you are a Chinese citizen and want to get a better score, you either have to avoid contact with "bad" friends or try to make your friends behave better according to government policy. Thus, learning "good" behavior can be accelerated when it is shaped by a stronger form of social pressure, creating herding effects that make everyone adhere to the system rules (Zuboff, 2019).

This is neobehaviorism implemented in a totalitarian state. The state takes the role of being an authoritarian teacher, with the communist ideology as the curriculum. The algorithms are designed to achieve guaranteed social outcomes by providing different rewards and punishments through a schedule of reinforcements. "Good" behavior can result in material rewards and reputational gain, while "bad" behavior can lead to loss of material resources and reputation. The algorithms are described as the "fair eye" that constantly looks after its citizens (Zuboff, 2019).

Furthermore, the Chinese government has begun issuing behavioral information about the system on several platforms like the official SCS national website "Credit China" and its equivalent municipal outlet "Credit China (Beijing)." In one study, researchers examined 200,000 behavioral records and 1,000 reports on citizens' behaviors on these official sites. To some degree, the SCS is dependent on the citizens being able to distinguish between behaviors that result in reward and those that lead to sanction. Still, there is very little specific explanation of what characterizes "good" redlisted behavior. In general, the positive case stories on the website illustrate activities that intend to be "genuinely" moral, with no descriptions of material rewards. Instead, citizens gain reputation by being awarded symbolic honorary titles such as fulfilling legal obligations (Class A Taxpayer), performing professional (Taxi Star) or volunteering (Five-Star Volunteer) duties.

However, there is no explanation of the criteria that determine how an individual or a company can be awarded a symbolic title. The concealment of this information is in keeping with core principles in instrumentarian intelligence. If this information is published openly, positive norms may be turned into market transactions and weaken the intrinsic motivation. For instance, if one gets a higher score for being honest, individuals may do this to get a reward and not because it is good moral behavior. As with all behavioristic engineering designs, they can easily end up turning everyone into extrinsically motivated citizens. If there is very specific information on how to get on the redlist, people will become more focused on getting the prizes, which is a problem when there also are a limited number of prizes available (e.g., a first-class train ticket) (Engelmann et al., 2019).

In general, there is more information about the “bad” blacklisted behavior compared with the “good” redlisted behavior on the website. Blacklisted behaviors often refer to failure to pay back debt or informational misconduct (Engelmann et al., 2019). This list is not a new part of the system. The government has already reported thousands of defaulters that have missed executive positions at enterprises because of their debts or defiance of a court order. People on the list can be prevented from buying airplane tickets, bullet train, or first- or business-class rail tickets; selling, buying, or building a house; or enrolling their children in expensive fee-paying schools. There are also restrictions on receiving honors and titles. If the defaulter is a company, it may not be able to issue shares, accept foreign investment, or work on government projects (Zuboff, 2019). In addition, Blacklists are used for public shaming in an attempt to motivate people to avoid ending up on the list (Engelmann et al., 2019). Public authorities even display photos and names of debtors in cinemas before people begin watching a movie (Zhang, 2020).

However, there is no specific information about the scoring mechanism behind blacklisted behavior (Engelmann et al., 2019). One new development with SCS is that it appears that just having a low score without being on the blacklist may have negative consequences. It can be more difficult to get bank loans, and your internet speed can be reduced. People also bring their personal ratings into every corner of their social life, as dating sites now allow users to publish their individual reputation score. People with lower scores risk being rejected by suitors (Nspirement-Staff, 2020). When the reputation score becomes part of social life, it becomes a part of one’s identity. This amplifies the importance of the scoring system, as it merges online and offline behaviors into one single score for a human life.

The social comparison in the ranking system make people “measurable” and “quantifiable” in a way we have never seen before. When all people are positioned along a one-dimensional scalar measure, it makes it easy to assess who are more or less valuable than others. The simplicity of the score also makes it convenient and highly attractive to use. The fact that individuals have voluntarily started showing their score in dating apps illustrate how such systems rapidly become “normalized” and invade new social domains independent of the government original intentions.

The rating system may create new social hierarchies. If the government rewards some individuals and penalizes others, it is likely that individuals will begin to do the same in social relationships, according to their reputation score. Individuals can easily compare themselves with others and assess their current performance in the system. While governments can exert a powerful control over people through surveillance technology, it is even more powerful when individuals begin to voluntary self-monitor and control their behavior accordingly.

From one perspective, this is a gamification of life itself; individuals will constantly be searching for new opportunities to acquire points and move towards the top of the leaderboard. However, instrumentarian intelligence cannot fully disclose its reward mechanisms. One study of the Sesame credit system in China indicates that the lack of understanding of what factors influence credit scores is likely to become a stressful experience for many individuals (McDonald & Dan, 2020). Those who have a low score may discover that the credit system is designed to thrust their scores into an unavoidable downward spiral. When your score drops, you tell your friends, who, fearful of being negatively influenced by your score, quietly drop you as a contact. The algorithm notices that you have lost some of your "high-achiever" friends, and your score continues downwards (Zuboff, 2019).

Furthermore, the story about the rejected Chinese student raises the question to what degree our own history should follow us or haunt us. Although digital traces of most of our daily lives are stored, does this imply that all these data should be used? The SCS makes it more difficult to leave our personal histories behind. We would likely become overly cautious, with a constant worry about doing things wrong that cannot be forgotten. Since the logic behind the ranking is a secret, citizens are left to guess how they can improve their scores, by taking actions such as getting rid of friends with low scores, or try to find high-scoring individuals who can boost one's own rank (Zuboff, 2019).

Will people protest? One must remember that China is not a democracy, and has a long history of citizen surveillance. The "dang'an" is a wide-ranging personal dossier which includes hundreds of millions of Chinese citizens. It records the most intimate details of life, and is updated by teachers, Communist Party officials, and employers. Citizens have no rights to see its contents, and it has been used to surveil people for a long time (Zuboff, 2019). Nor is there a clear distinction between a private and a public sphere in Chinese society. The public interest is very important in Chinese civil law, with private information only being protected from disclosure when it refers to information that is irrelevant to the public interest (Engelmann et al., 2019).

The Chinese instrumentarian intelligence envisions a grandiose reputation state built on communist ideology, with the algorithms in the SCS being the core engine that constantly produces and updates "character" scores. This is a brave new world where the correct outcomes are known in advance and can be guaranteed through behavioral modification. Still, it remains to be seen if the Chinese people will let the machine hive become the model in which all citizens march in the same direction based on the same understanding of what matters most (Zuboff, 2019).

15.3 Civic Intelligence

Early in the fifteenth century, a small and exclusive elite owned books. This situation changed dramatically with the invention of the printing press. Later in the same century, new print shops were popping up all over Europe at an unprecedented scale. These print shops became a meeting place for a diverse group of skilled workers. Each area of expertise required specific skill sets not shared with other professions. New occupational groups were required to do this new type of collective work, such as scholars, editors, translators, correctors, type designers, etchers, print dealers, engineers, carvers, and artists. Professional groups that previously had worked on books separately from each other, like illuminators, goldsmiths, university professors, clerks, monks, and preachers, were now brought together. Close contact between astronomers and engravers, physicians and painters, encouraged new ways of coordinating the work of brain, eyes, and hands. In those places where the workshop prospered, it became the most important cultural center, attracting local literati and celebrated foreigners; providing both a cross-cultural meeting place and "international house" for the expanding cosmopolitan book learning. The demand for vernacular scriptures and service books brought "communities of strangers" together, such as various religious groups on foreign soil who began to communicate with printers. Wealthy people also helped support this collective knowledge development and financed the expensive large Latin volumes that were used by late medieval faculties of theology, law, and merchants. As Eisenstein writes: "The print shop bridged many worlds and gave promise of a new and brighter future" (Eisenstein, 1980: 55–56, 446–448) (Figure 15.1).

A few decades into the internet revolution, we now have at our hands an even more powerful tool for cosmopolitan digital learning, but we are still

Figure 15.1 Printer's workshop in Antwerp, sixteenth century. Fourth plate from a print series entitled Nova Reperta (New Inventions of Modern Times) consisting of a title page and 19 plates, engraved by Jan Collaert I (ca. 1530–1581), after Jan van der Straet, called Stradanus, and published by Philips Galle around 1600. Illustration of men working at the book mill in Antwerp, Belgium. In the background, a man prepares paper for printing in the press depicted on the right. In a screw press such as that shown, each sheet had to be laid on the type, moved into the press, and pressure applied using the screw. In the center of the foreground, a young boy lays out the newly printed paper for proofreading. On the left, workers set type to be printed. Credit Harris Brisbane Dick Fund, 1934. The Metropolitan Museum of Art, CC0 1.0 Universal Public Domain Dedication

far from having created anything that resembles these magnificent local "international houses" in our new global online setting. However, the stories from the virtual teams in online innovation contests describe meeting places that illustrate the seeds of a prosperous culture of creativity that brings strangers together. Wikipedia also stands out as a exemplary example of what is possible, in the increasingly polluted, commercialized, and corrupt ocean of information most people are struggling to cope with. There are interesting new experiments with participatory democracy, but the general trend is that democracies are struggling, and the Internet has not helped the case. Pointing to machine intelligence as the savior is tempting, but there is an increasing concern that both a "smart society" or a reputation state represent ideals far removed from the kind of society we really want.

In describing the collective knowledge advancement that emerged after the invention of the printing press, Lewis Mumford (1970) praised medieval "polytechnics" because it absorbed many important changes without losing the inventions and skills derived from earlier cultures. In the sixteenth century, polytechnics was still developing, as the exploration of the world brought both natural resources and technical processes back to Europe. For the first time in history, the art and polytechnics of the world began to learn from each other, to increase their practical effectiveness and symbolic expression. The power in polytechnics is that skills, esthetic judgements, and symbolic understandings are diffused throughout the whole community; they are not restricted to one specific group or occupation. Nor can they be reduced to a single, standardized uniform system, under centralized control (Mumford, 1970: 140–143).

In stark contrast, Mumford identifies "monotechnics", a new and powerful technological system that emerged at the same time. Inspired by political and military domination, monotechnics was built around mechanization and automation, with the goal of reaching out as far as possible; make everything faster and more efficient. Pride was to become associated with the many new technological achievements in mechanization and machine-made products, seen as major progress compared with the primitive agricultural and handcraft cultures of the past (Mumford, 1970: 142–143, 155).

However, it is often not recognized that during the long transitional period from handicraft to complete mechanization, the crafts also multiplied and became more differentiated, contributing to societal innovation processes. For instance, there was a huge diversity of different types of small-scale mechanization in power-driven mills. While there were approximately 90 crafts in 1568, this number had even increased to 250 crafts two centuries later. Nevertheless, by the end of the nineteenth century, most of the crafts had disappeared (Mumford, 1970: 142–143).

It was monotechnics, based upon scientific intelligence and quantitative production, that replaced polytechnics with its emphasis on economic expansion, material repletion, and military superiority. The change from traditional polytechnics into a uniform, all-embracing monotechnics also marked a shift from a limited goods economy, based on a diversity of natural functions and vital human needs, to a power economy, concentrated around the use of money. Human autonomy and diversity was sacrificed for a system of centralized control built around automation, speed, quantity, and control (Mumford, 1970: 153–157, 165).

Is history repeating itself? Surveillance capitalism and instrumentarian intelligence can be regarded as the monotechnics of our time. Big data is available at an unprecedented scale, and we humans are using it at the utmost of our capabilities. The gigantic revenues and the powerful capabilities are far too tempting to resist.

On one hand, both the Internet and the digitization of information have led to human collective problem solving evolving into various new and more complex forms. Both the current pandemic and climate change show that it is vital that we learn how to organize our societies in ways that enable us to cope with the challenges of our time. On the other hand, because societies have become so complex, decisions need to be increasingly made by algorithms. As instrumentarian intelligence aims to become the dominant force, it is even more urgent to identify the areas where human collective problem solving should still be at the forefront. In the fight for what an intelligent society should be, the notion of civic intelligence (Schuler, De Liddo, Smith, & De Cindio, 2018) can perhaps encompass many of the promising examples of CI in this book.

John Dewey once claimed that a democracy was not just about institutions and elections – the citizens also had to embrace diversity and discussion by adopting a scientific attitude with respect to the practical affairs in civil society. If the people themselves become dogmatic, and regard diversity as a threat, insisting that social arrangements should follow tradition, there will be no development, only conformity. Within his perspective, civic intelligence required people to speak freely, be allowed to criticize the system, and be open to listening to others (Anderson, 2006). In polytechnics, it is the needs, aptitudes, and interests of living organisms that are important (Mumford, 1970: 155).

In comparison with instrumentarian intelligence, civic intelligence highlights a use of technology controlled by the community and its citizens. In this sense, the "civic dimension" in CI is a critical alternative to the dehumanizing aspects of instrumentarian intelligence, which objectifies humans and reduces them to behavioral surplus. Building on the analysis in the book, I provide a tentative overview of how civic intelligence is different from instrumentarian intelligence (Table 15.1).

The notion of civic intelligence is centered on values like responsibility, diversity, transparency, autonomy, and empowerment. As the different examples in this book has shown, the core value in civic intelligence is diversity, including informational, multicultural, cognitive, biological, and

Table 15.1. *A comparison of civic intelligence and instrumentarian intelligence. Two competing models for an intelligent society*

	Civic intelligence	Instrumentarian intelligence
Technology	– Local technology and community solutions are best. Participatory design.	– Universal, standardized solutions are best. One size fits all ("Megamachine").
	– Open algorithms (e.g., open access, open source).	– Hidden algorithms.
	– Decentralized control.	– Centralized control.
Learning	– Deliberation.	– Social learning through herding and social pressure.
	– Peer learning.	– Surveillance leads to stronger self-monitoring of individual behavior.
Governing model	– Many citizens govern.	– A few persons govern who know what the best values are (ideology-driven).
	– Process: Mass deliberation or mass voting.	– Process: Maximizing collection of personal information in both online and offline settings.
	– The best society is developed through inclusive deliberation (Example: Ostbelgien and Ireland).	– The best society requires a reputation state (e.g., China).
	– Slow implementation. The process is part of the goal.	– Time-efficient implementation. Achieve goal as quickly and accurate as possible.
Who owns the knowledge?	– The people (e.g., knowledge commons, open access).	The state or big commercial tech companies.
Theoretical perspective on humans	– Unique individuals. – Theories of diversity. – Humanism.	– Calculable individuals. – Behaviorism. – Totalitarianism.
CI vs. machine intelligence	– Human-to-human intelligence supported by machine intelligence.	– Machine intelligence (algorithms) supported by human-to-human intelligence.

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Table 15.1. (*cont.*)

	Civic intelligence	Instrumentarian intelligence
Transparency	– High.	– Low (algorithms must be hidden to be most effective).
Evaluation	– Continuous metadiscourses at all levels in society.	– Continuous statistical feedback built on automated algorithms.
	– Critical discourse (independent journalism).	– Critical discourse is minimized because it disturbs algorithmic accuracy (state-controlled journalism, censorship).
Individuality	– Autonomy (freedom to choose).	– Constrained autonomy.
	– Empowerment.	– Smart recommendations that restrict choices to a few options defined by the system.
Values	– Values develop through shared understanding.	– Important values can be predefined.
	– Responsibility, solidarity.	– Safety and trust.
	– Diversity (cultural, cognitive, informational).	– Conformism and rule compliance. Diversity threatens societal stability.
	– Deviations and errors are valuable.	– Errors threaten perfection and should be eliminated or avoided.
Motivation	– Cooperation and community participation (intrinsic motivation).	– Competition and improvement of personal reputation score (extrinsic motivation).

participatory. Anything that threatens this diversity, like conformism or herding, will weaken the potential of CI in a society. What is perhaps a paradox, is that both civic intelligence and instrumentarian intelligence seek informational diversity, but in radically different ways. Instrumentarian intelligence hides its presence to produce the best predictions, while CI attempts to maximize transparency in areas such as open science and open democracy.

The fight for civic intelligence will also be about the control of our collective memory. An enormous number of human knowledge products are being published openly today. People publish text, images, and videos, which others can locate at any point in time. Between these huge numbers of both content producers and consumers, there are relatively few search engines and social media platforms, which operate as the switchboards to decide what content should be given attention (Halavais, 2018: 120). For example, the debates around the value and legitimacy of YouTube have raised questions regarding who gets to speak, who gets the attention; what compensations or rewards are given for the work; and how trustworthy are the various forms of expertise and authority (Burgess & Green, 2018: 19). Today, only a few winners receive the majority of the attention on the Internet, and social groups that are already powerful tend to amplify their position.

It has even been suggested that modern military conflict will become knowledge-centric: "about who knows, what, when, where, and why." Search engines are vital in this informational war, and those interested in telling what is true will be interested in shaping such systems (Halavais, 2018: 239). In the age of television and radio, it was easy for governments to control the dissemination of information to the population. With the Internet, information is no longer communicated through a few national official channels. However, governments which have traditionally controlled mass media have gradually also increased their control over search engines and strengthened censorship. One example is the Chinese authorities, who just recently decided to redesign their own search engine algorithms in Baidu to be more appropriate to the communist ideology. As one of the few countries in the world, they block Wikipedia too.

It is urgent that we to ask ourselves who should own our collective memory, which comprises the foundation of a healthy civic intelligence. Surveillance capitalism began when Google discovered that the data exhaust in online activities could be used to produce predictions of user behavior. This made it possible to control human knowledge in new ways and sell prediction products that are *about* individuals rather than *for* individuals. Knowing what you want to find before you know it yourself has been a long-term goal. The big tech companies' lack of respect for the privacy of the user has become a major concern (Zuboff, 2019).

We have yet to see the prosperous democratic culture that some hoped would emerge from Web 2.0. According to Mulgan (2018: 211), any kind of collective intelligence relies on a knowledge commons of some kind, even at the micro level. If we compare the stone tool teaching in Boxgrove

500,000 years ago and the sharing of online videos today, it is evident that they both build on a human desire to share knowledge. Open access to knowledge is at the core of CI and constitutes the basis for informed political and scientific debates.

Nor is the surveillance society inevitable. A search engine like DuckDuckGo does not reveal any personal information. Today, there is more interest in developing new open source search engines and peer-to-peer search engines. However, it is difficult to create a large-scale public index when Google dominates the market. There needs to be broad political support across countries in order to establish a "human knowledge project" (Halavais, 2018). The recent emphasis on open access policies in scientific research also illustrates that the knowledge commons is gaining a more prominent position in democratic societies.

Furthermore, what is essential in civic intelligence is that human-to-human intelligence is at the core of any system, although machine intelligence can still provide important support. Wikipedia has a number of bots that do simple work. In citizen science projects, computers have become better at doing image analysis, and they are now used in combination with human crowds (Sullivan et al., 2018). Another example is how the Foldit community involves gamers in the further improvement of the game technology. A coding language called Lua can create a sequence of moves called recipes, which can perform one specific type of folding in the game. Thousands of player strategies are not only shared between gamers in the community, but they are also taught to the computers through machine learning. Some of the puzzle moves are then automated to make the game easier to play (S. Cooper et al., 2010: 120–122). This example illustrates the potential in a hybrid human–computer optimization framework that involves a community in designing the technology. The quality of the collective work can be improved by maximizing a large number of diverse contributions.

Furthermore, the many new democratic experiments across the world points towards the revival of a civic intelligence that was once at the core of the democracy in ancient Athens. Participatory democratic designs are being invented that involve both mass voting and mass deliberation in countries like Belgium, Ireland, Iceland, Italy, Mongolia, and Taiwan. They highlight that anyone both can and should participate in governing society. These experiments challenge the way we think about human capability, when all citizens are regarded as competent as competent, not just a small political elite. The many examples in this book show that CI is nourished by people who are different from each other, with different

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interests and unique perspectives. If these individuals show empathy towards each other and engage in critical discourse about their own society in a systematic manner, civic intelligence is likely to emerge. This will not only require participation in local communities, but also a sense of cosmopolitanism through global participation in the online setting.

Moreover, it is important to design local democracies in order to make people proud, encourage them to get involved, and become responsible citizens. This is not an issue about individual competence or technological superiority, but about how we can combine different types of collective problem solving in optimal ways. In contrast, instrumentarian intelligence assumes that algorithms can outperform human decision-making, enabling both a more efficient and accurate problem solving that is better and more fair compared with human collectives.

This tension between different types of intelligence is not new. Already in the middle of the twentieth century, Mumford criticized institutions in society because they did not fully serve human purposes. While civic life was diverse and multifaceted, institutions forced humans to participate in mechanical, power-focused hierarchies. Also at that time, Mumford feared that human life could end up being reduced to a mathematical order:

> *Of these vast transformations only an infinitesimal part is visible or can be reduced to any mathematical order. Form, color, odor, tactile sensations, emotions, appetites, feelings, images, dreams, words, symbolic abstractions – that plenitude of life which even the humblest being in some degree exhibits – cannot be resolved in any mathematical equation or converted into a geometric metaphor without eliminating a large part of the relevant experience.* (Mumford, 1970: 54)

If we are to listen to Mumford, the plenitude of life cannot be solved through the algorithms of a reputation state without eliminating important aspects of human experience. Both man and nature are open systems that even the strongest machine intelligence can only capture a tiny part of. Echoing our time, he warns against reducing law, customs, and moral codes to quantifiable indicators (Mumford, 1970: 191).

Still, this is exactly what instrumentarian intelligence and the reputation state does when it mathematizes human life. Both the surveillance capitalism and the Chinese social credit system (CSC) build on the belief that every aspect of human life can be calculated and managed. This is done by collecting enormous amounts of data from both the individual and the environment. It also brings forth increased use of surveillance cameras that aim to collect all types of micro behavior in the offline setting.

Furthermore, the new ranking systems represent powerful disciplinary techniques that normalize a life based on a reputation score. With the help of surveillance technology, the CSC is designed to constantly examine human behavior, leaving no place for refuge or alternative behavior. As the system colonizes all informal spheres of people's lives, it becomes an even more powerful tool that can shape people's lives. Because the formal and informal spheres fuse together into one reputation score, a low score will have devastating consequences on all areas of an individual's life. The system both individualizes performances by turning people into low and high achievers, while at the same time it standardizes group behavior according to a few prioritized dimensions. As citizen strive to improve their score, their lives will inevitably become more uniform when narrowed to the behavioral indicators that matter most.

If we follow Mumford, he claimed that it was impossible to make human complexity calculable. Still, this is exactly what instrumentarian intelligence envisions. What if Mumford got it wrong? At the most fundamental level, this is perhaps a question about what we think a human being actually is. If we look back to our origins, how we first became human, we might find some clue to help us better understand what a "human-centered" intelligent society could look like.

Just recently, archeologists made astonishing findings of *Homo sapiens* fossils in Morocco, at Jebel Irhoud. Until now, the common story about how we became humans was that we suddenly evolved from more primitive humans in East Africa around 200,000 years ago. From then on, we first spread out to the rest of Africa, and then we went on to conquer the rest of the world. However, the new findings call for a rewriting of the textbooks. What is sensational is that the fossils date back 300,000 years ago. There was not one Adam and one Eve, nor "a cradle of humanity" at some specific location in Africa – there were many. "If there was a Garden of Eden, it was all of Africa," says Professor Jean-Jacques Hublin, one of the leaders of the excavation in Morocco (Callaway, 2017; Ghosh, 2017). There was no superior center, rather a dispersal of *Sapiens* species at multiple places in Africa. The features in the fossils from Morocco and other *Sapiens*-like fossils from elsewhere in Africa reveal the diverse origins of our species. There was a multitude of primitive human species, each of whom looked different, with their own unique strengths and weaknesses. Three hundred thousand years ago, the Sahara was green and connected with the rest of Africa. Animals that roamed the East African savanna would also come to Jebel Irhoud, and *Sapiens* would follow them. They moved out of their safe havens and engaged with unknown others, living at different locations. And these humans, just as other animals, changed their appearance gradually over hundreds of thousands of years. It was this constant evolving mix of human contact and networks that formed *Sapiens* (Callaway, 2017; Ghosh, 2017).

We now know that there was no single superior group, just a continent full of diverse groups that eventually mixed together. Modern humans grew from this combination of many different human species. Today, we are in many ways facing the same challenge, but with much more urgency, to bring together diverse humans from different countries in solving the great challenges of our time, like climate change or pandemics. A society built on civic intelligence will need to embrace the diversity of all human resources, which still lies at the core of collective intelligence, as it has throughout our history. This is a new creation narrative for the next millennia.

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