the problem, theoretical resources that we can use to attack it, and the possibility for future collaboration" (62).

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Review of Gualtiero Piccinini's *Neurocognitive Mechanisms: Explaining Biological Cognition*

Gualtiero Piccinini, *Neurocognitive Mechanisms: Explaining Biological Cognition*. Oxford: Oxford University Press (2020), 416 pp. $115.00 (hardcover).

It is common for philosophers of neuroscience to be deeply engaged with the relevant experimental literature. This may be why the last couple of decades have seen an increase in philosophers of neuroscience obtaining formal training in neuroscience concurrently with philosophy or coming to philosophy from a previous life as a neuroscientist. By the turn of the twenty-first century, scientific practice came to inform and inspire the new mechanist movement. Philosophers of neuroscience interested in cognition often find themselves attempting to integrate work on experimentation and mechanisms with research in the cognitive sciences and psychology that commonly centers on computational understandings of cognition. It is within this background that Gualtiero Piccinini's latest book is situated.

Piccinini's general aim in his book is to defend a "computational theory of cognition" (CTC) and extend many claims he previously made about the nature of computation (Piccinini 2015) to cognitive neuroscience research. More precisely, it defends the thesis that "*biological cognitive capacities are constitutively explained by multilevel neurocognitive mechanisms, which perform neural computations over neural representations*" (1; emphasis original). Piccinini's writing is excellent: it is clear and straightforward, and the argumentation is often incisive. The book is nicely organized with effective chapter transitions that provide helpful "here's where we're at" summaries.

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The material is broad in scope, including history (e.g., early computational models of neurons), metaphysics (e.g., realization), philosophy of science (e.g., mechanistic explanation), and philosophy of mind (e.g., representations). This is a must-read book for philosophers interested in issues of explanation and accounts of the mind and for cognitive and neural scientists interested in learning more about interpretations of the deeper theoretical commitments of their empirical work.

Piccinini's focus is cognitive phenomena, particularly those of "earthly organisms" with a "specialized control organ," namely, nervous systems with brains (2). As such, he asserts that the sciences of cognition are committed to explanations in terms of neurocomputational processes, specifically, those neural phenomena of a computational nature that are "grounded in mechanistic, functionalist, egalitarian ontology" (1). Piccinini builds his case over the course of fourteen chapters (and an introduction) that can be viewed as falling into four parts: metaphysics, computation, multilevel mechanistic explanatory integration, and consequences and challenges.

Part 1, chapter 1 sets the metaphysical foundation for later proposals by offering an "egalitarian ontology," in which all levels exist equally and none are prior to, fundamental to, or ground the others (36). Although there may be phenomena reasonably understood as "higher level," such as cognitive capacities like reasoning, such levels are to be viewed as invariant aspects of their lower-level constituents, such as neurons. Chapter 2 focuses on metaphysics of realization. Ontological egalitarianism is offered as a way to deal with typical challenges raised against the special sciences (e.g., those involving reductionism and autonomy). As is argued, an egalitarian ontology that does not privilege levels of investigation is the required metaphysics for multilevel mechanistic explanation, which is most relevant to cognition. Chapter 3 moves to the ontology of living organisms. What separates biological from nonbiological phenomena is that their functional mechanisms serve teleological functions, such as a heart's function being to circulate an organism's blood. Chapter 4 pulls together the previous chapters to make the claim that a mechanism's functional organization must be understood as the basis for what its mechanisms do (91), which underlies an account of biological minds in terms of mechanistic functionalism.

Part 2 is about understanding cognition in computational terms. Chapter 5 is a historical discussion of Warren McCulloch and Walter Pitts's foundational modeling work. Piccinini claims that their contribution was not so much to traditional neural network and connectionist research as it was to functional mechanistic understanding of cognition as computation and information processing. Chapter 6 discusses the kind of computation relevant to biological cognition, namely, the kind of physical computation defended in Piccinini's (2015) previous book. The conclusion is that biological cognition is a mechanistic kind of computation.

Part 3 is the book's core. Chapter 7 describes the multilevel mechanistic explanatory integration needed to explain biological cognition in neurocomputational terms. Discussions include causation in explanations of mechanisms and attempts to defend mechanistic accounts from various critiques (e.g., the requirement of maximal detail). Chapter 8 is about cognitive neuroscience and claims that it "has emerged as the mainstream approach to cognition" (182). Piccinini begins the chapter with an interpretation of the history of cognitive science. He claims that cognitive science had/has a division of labor based on a "two level" (182)

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view of the science of cognition: one investigates the functional/cognitive level (e.g., psychology) and the other the implementation/mechanistic level (e.g., neuroscience). Following from his commitments to ontological egalitarianism, Piccinini claims that the two-level approach was/is wrong and that cognition is properly studied via multilevel neurocognitive mechanisms. The discussion concludes with the claim that if cognition is to be explained in terms of multiple levels, mechanisms, computations, and representations, then cognitive neuroscience is the discipline that already does that. Chapter 9 is the most important chapter of the book. Here CTC is presented and defended as the correct theory of cognition for two primary reasons (207): first, neural spike trains are the vehicles that are functionally significant, medium-independent functional mechanisms that underlie cognitive capacities, and second, neural vehicles integrate information in a rule-governed way that demonstrates that neurocognitive processes are computations. These reasons lead Piccinini to conclude that "the Computational Theory of Cognition is here to stay" and that "everyone is (or should be) a computational neuroscientist, at least in the general sense of embracing neural computation" (243).

The final part discusses issues resulting from the claims previously laid out. Chapter 10 argues that cognition qua computation is not defined in terms of the Church–Turing thesis. Chapter 11 raises two common objections to CTC: first, that computation is insufficient to explain all cognition, and second, that neural processes are in at least some ways incompatible with a computational view. Piccinini argues why these two objections are wrong, as well as addressing other nuisances that CTC commonly faces, such as its compatibility or incompatibility with situated approaches to cognition. Chapter 12 presents an overview of some empirical work intended to support the idea that neurocomputations involve neural representations. Chapter 13 argues that neural computation is neither digital nor analog but is a "sui generis" form of computation specific to nervous systems. The book concludes with chapter 14 and a discussion of the computational theory of mind as a theory of cognition and consciousness, and then with a fifteen-point summary of the book's main points.

Though strong in many ways, this book suffers from some weaknesses. One is Piccinini's presentation of the history and current standing of noncognitive neuroscience approaches to cognition; for example, "to a large extent, cognitive science has already turned into cognitive neuroscience" (3) and "cognitive science as traditionally conceived is on its way out and is being replaced by cognitive neuroscience" (192). Where is the evidence for such claims? Scientometrics articles related to this topic do not support Piccinini's claim (see also Dale 2021). For instance, Núñez and colleagues (2019) utilized various quantitative measures (e.g., citation count) to assess the status of various fields in cognitive science. They found that "the field has been largely subsumed by (cognitive) psychology" (782) and that there is "a weak presence of neuroscience" (787).

Another weakness concerns evidence for the claim that cognitive neuroscience illustrates the integrationist mechanistic framework (183). Piccinini provides some examples (e.g., section 8.6) intended to demonstrate that cognitive neuroscience integrates features from other disciplines, such as "experimental protocols from cognitive psychology into neuroscience experiments" (183). Still, even if methods from other disciplines are utilized by some cognitive neuroscientists, it does not follow that cognitive neuroscience *as a field* utilizes those methods (e.g., as part of cognitive neuroscience graduate school training). In addition, piecemeal examples of methods do not support Piccinini's overarching claim that cognitive neuroscience provides multilevel mechanistic explanatory integration of the kind much of the book aims to defend. It is not clear that any examples are provided of a cognitive phenomenon explained in an integrated multilevel mechanistic way.

A third weakness is the treatment of nonneurocomputational mechanistic approaches to cognition. Granted, no single book can be expected to address all the relevant material in the sciences of cognition. Still, for those sympathetic to nonneurocomputational mechanistic approaches like dynamicism and radical embodiment, the engagement is wanting. The primary reason is that such alternatives are too quickly dismissed, for example, "this argument [i.e., dynamical hypothesis] presupposes that there is a contrast between dynamical systems and computational ones. There is no such contrast!" (249). Because Piccinini is so well versed in a variety of literatures, additional engagement with alternatives could have made for a fiery debate or possibly even converted some to his position. With all that said, none of these weaknesses deter from the fact that Piccinini has provided us with one of the most engaging (and provocative) works in contemporary philosophy of neuroscience.

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Review of Nancy Cartwright's *A Philosopher Looks at Science*

Nancy Cartwright, *A Philosopher Looks at Science*. Cambridge: Cambridge University Press (2022), 210 pp. $12.95 (paperback).

Nancy Cartwright's latest book,[1] *A Philosopher Looks at Science*, comprises a short introduction, three numbered chapters, and a short conclusion. The introduction focuses on three claims that Cartwright will challenge:

[1] Cartwright has written numerous books, and it's entirely possible that she will have published another one by the time this review appears.

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