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ARTICLE AVAILABLE ONLINE
Twin Research and Human Genetics
Volume 15 ▌Number 1 ▌pp. 97–106

The Heritability and Genetic Correlates of Mobile Phone Use: A Twin Study of Consumer Behavior

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There has been almost no overlap between behavior genetics and consumer behavior research, despite each field's importance in understanding society. In particular, both have neglected to study genetic influences on consumer adoption and usage of new technologies — even technologies as important as the mobile phone, now used by 5.8 out of 7.0 billion people on earth. To start filling this gap, we analyzed self-reported mobile phone use, intelligence, and personality traits in two samples of Australian teenaged twins (mean ages 14.2 and 15.6 years), totaling 1,036 individuals. ACE modeling using Mx software showed substantial heritabilities for how often teens make voice calls (.60 and .34 in samples 1 and 2, respectively) and for how often they send text messages (.53 and .50). Shared family environment – including neighborhood, social class, parental education, and parental income (i.e., the generosity of calling plans that parents can afford for their teens) — had much weaker effects. Multivariate modeling based on cross-twin, cross-trait correlations showed negative genetic correlations between talking/texting frequency and intelligence (around –.17), and positive genetic correlations between talking/texting frequency and extraversion (about .20 to .40). Our results have implications for assessing the risks of mobile phone use such as radiofrequency field (RF) exposure and driving accidents, for studying adoption and use of other emerging technologies, for understanding the genetic architecture of the cognitive and personality traits that predict consumer behavior, and for challenging the common assumption that consumer behavior is shaped entirely by culture, media, and family environment.

■ **Keywords:** behavior genetics, twins, personality, intelligence, product usage, mobile phones, consumer research

For decades, twin and adoption studies have shown that genes have strong influences on many human behavioral traits, including intelligence, personality, and mental illness (Bouchard & Loehlin, 2001; Deary et al., 2006; Keller & Miller, 2006; Penke, Denison & Miller, 2007; Plomin et al., 2008). More recent research shows that genes also shape surprisingly varied traits such as political beliefs (Hatemi et al., 2010), religious values (Button, Stallings, Rhee, Corley, & Hewitt, 2011), economic risk seeking (Le, Miller, Slutske, & Martin, 2010), subjective happiness (Bartels et al., 2010), social network structure (Fowler, Dawes, & Christakis, 2009), and female orgasm rate (Zietsch, Miller, Bailey, & Martin, 2011). Moreover, the heritability of behavioral traits — the proportion of variance explained by genetic differences between people — tends to increase with age, such that genetic influences are actually stronger in adults than in children (Plomin et al., 2008). Genetic effects are proving so pervasive that the influence of behavior genetics has been expanding from psychology into political science, economics, sociology, and history (Bowles & Gintis, 2002; Clark & Hamilton, 2006; Fowler & Schreiber, 2008; Freese & Shostak, 2009).

However, consumer behavior research remains relatively untouched by the behavior genetics revolution. This is an odd state of affairs, because many of the same traits that consumer researchers have shown to influence consumer behavior — such as capacities for attention, sensory discrimination, learning, memory, imagery, and analytical decision making, as well as propensities for various emotions, moods, and values — are known to be heritable.

RECEIVED 01 December, 2011; ACCEPTED 04 December, 2011.

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Miller, G., Zhu,G., Wright, M.J., Hansell, N.K. & Martin, N.G. (2012). The heritability and genetic correlates of mobile phone use: A twin study of consumer behavior. *Twin Research and Human Genetics*, *15*, 1, 97–106. DOI 10.1375/twin.15.1.97

Moreover, some of the most important consumer demographic variables — education, income, wealth, and social class — show substantial heritability (Bjorklund, Lindahl, & Plug, 2006; Liu & Zeng, 2009), because they are largely predicted by general intelligence, which shows a heritability of about .80 in adults (Deary et al., 2006). Yet the world of twin research has had little overlap with the world of marketing departments in business schools, so genetic influences on consumer behavior have remained largely invisible (Miller, 2009).

One recent exception is Simonson and Sela (2011), who studied consumer judgment and choice in a sample of 110 monozygotic (MZ, or identical) twins and 70 dizgyotic (DZ, or fraternal) twins. They found significant heritability for 7 out of 23 product preferences surveyed (e.g., for dark chocolate, hybrid cars, and science fiction), and for 13 out of 39 items concerning consumer judgment and decision making (e.g., compromise options, loss aversion, near-future temporal discounting, and maximizing versus satisfying). Near the conclusion of their article, Simonson and Sela (2011) suggested that twin research might reveal the genetic predispositions that lead certain consumers to prefer a certain type of mobile phone, which leads nicely to our study.

Here, we extend behavior genetics methods to study consumer use of the world's dominant communication technology: the mobile phone. Out of 7.0 billion people on earth, about 5.8 billion use mobile phones as of 2011, compared to 1.8 billion current internet users and 1.2 billion landlines (Portio Research, 2011). Mobile users have increased seven-fold from 730 million in 2000, now with around 114 subscriptions per 100 people in the developed world, and around 70 per 100 in the developing world (International Telecommunications Union, 2011). China Mobile alone has over 620 million subscribers (China-Mobile-Ltd, 2010). Global mobile telecoms service revenue is now $1.3 trillion/year, and will reach $1.7 trillion/year by 2015, compared to $1.5 trillion for the auto industry and $600 billion for the pharmaceutical industry (Portio Research, 2009). In 2015, mobile subscriptions will number over 7 billion, such that nearly every human on earth will have access to a mobile phone (Portio Research, 2011). At that point, our species will be sending about 12 trillion text messages per year (Portio Research, 2011). Thus, mobile phones are arguably the most successful and ubiquitous consumer products ever developed. They play important roles not only in work, commerce, and economic growth, but also in social coordination, kinship, friendship, courtship, mating, marriage, and family life, with behavioral effects of interest in psychology, psychiatry, economics, political science, sociology, marketing, organizational behavior, and health care.

Despite its economic and social importance, mobile phone use is understudied in both consumer behavior research and behavior genetics research. A literature search for 'mobile phone' and related keywords across all journals for the period 1990–2011 yielded about 3,600 papers, mostly technology oriented, but also including prominent *Nature* papers quantifying mobile phone use patterns to track human mobility patterns (Gonzalez et al., 2008) and the evolution of social groups (Palla, Barabasi, & Tamas, 2007). By contrast, mobile phone searches through the consumer behavior and consumer psychology fields yielded only about 10 papers, and the behavior genetics field yielded zero.

In an attempt to advance research on both the heritability of consumer behavior traits and consumer research on mobile phone use, this paper uses two (partially overlapping) samples of Australian teenaged twins to study the heritability and genetic correlates of mobile phone use. We focus on mobile phones rather than other products simply to give an example of how behavior genetics can be applied to help understand consumer behavior, and because mobile phones are the most successful products in history. We do not expect there to be any special genetic variants or neurogenetic pathways that influence mobile phone use and that do not influence use of other goods or services. We do not claim that genetic studies on mobile phone use are uniquely interesting at a theoretical level. But we do think it is useful to see whether there are genetic influences on consumer behavior, starting with one exemplar product, because genetic influences have been so neglected in consumer behavior research.

Skeptics unfamiliar with behavior genetics might object: How could genes influence mobile phone use, given the impossibility of evolutionary adaptation to a communications technology that has existed for only one human generation? There is a crucial distinction here between species-typical, complex genetic adaptations (which cannot arise overnight) versus genetic variants that influence individual differences (which could immediately influence responses to new technology) (Bouchard & Loehlin, 2001; Keller & Miller, 2006). Previous behavior genetics studies have already found genetic influences on how often people use other evolutionarily novel technologies, including viewing television (Plomin, Corley, Defries, & Fulker, 1990; Rowe & Herstand, 1986; Sherry, 2001) and reading books (Friend et al., 2009; Harlaar et al., 2007; Martin et al., 2009) — just as pharmacogenomics studies have found substantial genetic influences on people's responsiveness to recently discovered psychiatric drugs for depression and schizophrenia (Daly, 2010). Also, personality traits known to be heritable influence usage patterns for every communication medium analyzed so far, including television, movies, music, art, books, email, online gaming, social networking sites, and chat rooms (Anolli et al., 2005; Chamorro-Premuzic et al., 2009; Finn, 1997; Hertel et al., 2008; Jeng & Teng, 2008; Kingston et al., 2009; Kraaykamp & van Eijck, 2005; Krcmar & Kean, 2005; Landers & Lounsbury, 2006; McManus & Furnham, 2006; Persegani et al., 2002; Ross et al., 2009; Sherry, 2001; Shim & Paul, 2007). Many of these heritable personality traits — especially extraversion, impulsivity, and neuroticism — also influence normal and addictive use of mobile phones (Arns, Van Luijtelaar, Sumich, Hamilton, & Gordon, 2007; Butt & Phillips, 2008; Ehrenberg et al., 2008). Thus, there are clear pathways for genes to influence personality and cognitive traits that could influence mobile phone use and yield positive heritabilities and interesting genetic correlates of mobile phone use.

Materials and Methods

Samples

Teenaged twins were recruited from schools in Brisbane, Australia, and surrounding areas, in the context of studies on melanoma risk factors (see Zhu et al., 2007, for details) and on biological markers of cognitive abilities (see Wright and Martin, 2004 for details). Sample 1 (the melanoma risk study) included 548 participants from 274 families, including 88 MZ and 185 DZ twin pairs, mostly aged 14 years. Sample 2 (the cognitive markers study) included 723 participants from 323 families, including 112 MZ and 201 DZ twin pairs and 97 single twins or siblings of twins, mostly aged 16 years. There was some overlap between the samples because 235 individuals completed the questionnaires at both ages 14 years and 16 years, so the total sample size was 1,036, rather than 1,271, individuals. Mobile phone data were collected between 2005 and 2010, with 90% of the data collected from 2006 to 2009. Mobile phone use has been increasing rapidly among Australian teenagers from 2005 to the present, so the percentage of teens who did not use a phone (20% of Sample 1, 8% of Sample 2) would be lower today.

Written, informed consent was obtained from all participants and their parents, and ethics approval was obtained from the Human Research Ethics Committee at the Queensland Institute of Medical Research. Zygosity (whether the twins were identical or fraternal) was determined by using a commercial kit (AmpFlSTR Profiler Plus Amplification Kit, ABI) and crosschecking with blood group and other phenotypic data, yielding an estimated probability of correct zygosity assignment of greater than 99.99% (Nyholt, 2006).

Questionnaire

Participants answered five questions about mobile phone use: (1) Do you use a mobile phone? (forced-choice response: *yes/no*); (2) How often do you speak on a mobile phone? (tick 1 of 10 possible responses: *never, about once a month, 2–4 times per month, 2-4 times per week, 5–7 times per week, 2–3 times per day, 4–10 times per day, 10–20 times per day, 20–30 times per day,* or *more than 30 times per day*); (3) On average how many minutes per day do you speak on a mobile phone? (response written in: average minutes per day); (4) How often do you use SMS/text messaging on a mobile phone? (tick 1 of 10 possible responses, the same as for Item 2); (5) On average how many times per day do you use a mobile phone for SMS/text messaging? (response written in: average times per day).

Mothers of twins completed a demographic questionnaire including ethnic ancestry for all eight of the twins' great grandparents. All of Sample 1 also completed the Junior Eysenck Personality Questionnaire (Eysenck and Eysenck, 1975), which yields scores for extraversion and neuroticism, but only 30% (216 of 723) of Sample 2 did so. The remaining 70% of Sample 2 participants (507 of 723) completed the NEO personality questionnaire (NEO-PI-R or NEO-FFI; Costa and McRae, 1992), which yields scores for openness, conscientiousness, agreeableness, neuroticism, and extraversion. To avoid scale differences between the instruments, subsamples were separately normalized to the same mean and variance. Almost all (722 of 723) of the Sample 2 participants, but none of the Sample 1 participants, completed a measure of intelligence, the Multidimensional Aptitude Battery (Jackson, 1998), which yields 10 subtest scores and scores for verbal, performance, and full-scale IQ scores.

Statistical Methods

Mobile phone use was treated as a binary categorical variable, but all other variables were treated as continuous because they were approximately normally distributed. All analyses were conducted using full information maximum likelihood estimation (FIML) within the Mx program, the most widely used behavior genetics modeling software (Neale et al, 1999). Standard structural equation modeling (SEM) methods were used for univariate and multivariate (Cholesky decomposition) analyses (Neale & Cardon, 1992). Behavior genetic modeling using the classical twin design depends on the equal environments assumption (that identical and fraternal twins experience equally correlated environments), but this assumption is typically valid (Bouchard & McGue, 2003; Derks, Dolan, & Boomsma, 2006). Univariate genetic analysis yields heritability estimates for each trait, which express the proportion of variance in the trait that is explained by genetic differences between individuals. Multivariate genetic analysis yields estimates of genetic correlations between traits, which express how much genetic overlap there is between traits, or what proportion of the genetic variants (quantitative trait loci [QTLs] and/or copy number variants [CNVs]) that influence one trait also influence the other trait (Kelly, 2009). Genetic correlations are very important in evolutionary biology for understanding genomic architecture (the so-called G matrix of additive genetic variances and covariances among traits), for understanding synergies and tradeoffs between traits, and for predicting 'evolvability' in response to natural or artificial selection (Arnold, Burger, Hohenlohe, Ajie, & Jones, 2008). In psychology, high genetic correlations between behavioral traits suggest that they tap the same sources of genetic variance, and probably similar neurophysiological, cognitive, and affective processes (e.g. Loehlin, 2011).

Results

Demographics

For Sample 1 ($N = 548$), 49.6% were female, and the mean age was 14.24 years ($SD = .43$, range 14–15 years). For Sample 2 ($N = 723$), 55.3% were female, and the mean age was 16.56 years ($SD = .88$, range 14–21 years). Self-reported ancestry information was available for more than 99% of families. The sample was almost entirely Caucasian in origin, predominantly Anglo-Celtic, with less than 1% reporting complete non-European ancestry and a further 8% reporting partial non-European ancestry. Sample 2 had a mean IQ of 112.0 ($SD = 12.8$, range 79–153); IQ data were not available for Sample 1.

TABLE 1A

Talk Frequency: How Often Participants Use Mobile Phones to Make Voice Calls

Frequencies	Call frequency (%)			
	Sample 1		Sample 2	
Never use mobile	108	(19.7)	55	(7.6)
Rare	16	(2.9)	12	(1.6)
Once a month	78	(14.2)	64	(8.8)
2–4 times/month	111	(20.2)	113	(15.6)
2–4 times/week	136	(24.8)	199	(27.5)
5–7 times/week	63	(11.4)	121	(16.7)
2–3 times/day	24	(4.3)	103	(14.2)
4–10 times/day	8	(1.4)	43	(5.9)
> 10 times/day	4	(0.7)	13	(1.7)
Total	548	(100)	723	(100)

TABLE 1B

Text Frequency: How Often Participants Use Mobile Phones to Send SMS or Text Messages

Frequencies	SMS or Text Frequency (%)			
	Sample 1		Sample 2	
Never use mobile	108	(19.7)	55	(7.6)
Rare	21	(3.8)	7	(0.9)
Once a month	20	(3.6)	14	(1.9)
2–4 times/month	43	(7.8)	53	(7.3)
2–4 times/week	57	(10.4)	63	(8.7)
5–7 times/week	88	(16.0)	113	(15.6)
2–3 times/day	75	(13.6)	123	(17.0)
4–10 times/day	69	(12.5)	137	(18.9)
10–20 times/day	41	(7.4)	86	(11.8)
20–30 times/day	15	(2.7)	33	(4.5)
> 30 times/day	11	(2.0)	39	(5.3)
Total	548	(100)	723	(100)

Patterns of Mobile Phone Use

Mobile phones were used by 80.3% of Sample 1 and 92.4% of Sample 2. This is consistent with another study showing that 94% of Australian adolescents use mobile phones (Inyang et al., 2010). Nonusers were coded as zero for all phone use variables in the following analyses.

Tables 1a and 1b show the frequencies of calls made and texts sent, respectively. Modal call frequency was 2–4 times per week, with only 16% calling more than once a day, and 34% calling less than once a week. Modal text message frequency was 5–7 times per week, with only 27% texting more than once a day, and 14% texting less than once a week. Thus, texting was more popular than calling. Both measures of phone use frequency showed high positive skew, with many light users but a few heavy users.

Univariate Twin Correlations and Heritabilities

Of the personality traits measured in these samples by the Junior Eysenck Personality Questionnaire, the NEO-PI-R, and the NEO-FFI, only extraversion showed significant correlations with mobile phone use — which is not surprising, given that social outgoingness should predict communication frequency. Thus, we did not further analyze the other personality traits, but focused on extraversion.

For genetic analyses, first we separately analyzed univariate heritabilities for each trait of interest; later, we looked at multivariate relations such as genetic correlations among traits. Table 2 shows correlations within MZ pairs and DZ pairs in samples 1 and 2 for six key traits: whether a mobile phone is used, frequency of talking on the phone, frequency of SMS/texting on the phone, extraversion, and intelligence. The MZ correlations are higher than the DZ correlations for all traits in both samples (although the 95% confidence intervals overlap for some traits), which suggests genetic influence on each trait.

Table 2 also shows ACE model parameters derived from the MZ and DZ correlations using Mx software, each expressed as a percentage of total variance. The A parameters represent the influence of additive genetic variance on each trait, corresponding to narrow-sense heritabilities; the C parameters represent the influence of common (shared family) environment; the E parameters represent residual variation, including the influence of measurement error and nonshared (individual-specific) environmental factors.

Heritabilities were substantial for five of the six measures of mobile phone use. The heritability of using a mobile phone at all was about 50% for Sample 1 (in which 80.3% were users), but dropped to a nonsignificant level for Sample 2 (in which 92.4% were users; probably driving a restriction-of-variance effect). Heritability of talk frequency (how often the mobile phone was used to make voice calls) was 60% in Sample 1 and 34% in Sample 2. Heritability of text frequency (how often the mobile phone was used to send SMS/text messages) was 53% in

https://doi.org/10.1375/twin.15.1.97 Published online by Cambridge University Press

TABLE 2

Twin Correlations and ACE Parameters From Best Fitted Model

Measures	Sample	Twin correlations (95% CI)*		Best fitted model		
		MZ	DZ	A	C	E
Mobile phone used	1	0.74 (0.64–0.81)	0.49 (0.38–0.59)	49.6	24.2	26.2
	2	0.11 –0.06–0.27)	0.29 (0.17–0.41)	-	22.6	77.4
Talk frequency	1	0.71 (0.59–0.79)	0.41 (0.29–0.52)	59.8	11.2	29
	2	0.55 (0.42–0.66)	0.39 (0.26–0.49)	33.7	21.7	44.6
Text frequency	1	0.72 (0.61–0.79)	0.45 (0.34–0.55)	53.1	18.8	28.2
	2	0.55 (0.43–0.65)	0.30 (0.17–0.42)	50.4	4.9	44.7
Extraversion	1	0.59 (0.44–0.69)	0.16 (0.02–0.29)	53.8	-	46.2
	2	0.47 (0.32–0.58)	0.15 (0.01–0.27)	42.9	-	57.2
Intelligence	2	0.86 (0.81–0.89)	0.54 (0.43–0.62)	63.9	21.9	14.2

Note: * MZ/DZ pairs in samples 1 and 2 were 88/185 and 112/201, respectively

Sample 1 and 50% in Sample 2. The effect of common (shared family) environment was low for all measures of mobile phone use, ranging from 5% for text frequency in Sample 2 to 24% for mobile phone used in Sample 1. Generally, shared family environment had a larger effect on whether teens used a mobile phone at all (probably because parents got phones for either both twins or neither twin) than on how often teens used their phones once they had them.

Heritabilities were substantial for the other two traits as well. Heritability of extraversion was 54% in Sample 1 and 43% in Sample 2, with zero effect of shared family environment. Heritability of intelligence was 64% in Sample 2, with some apparent influence (22%) from shared family environment (intelligence data were not available for Sample 1). Note that this apparent influence of shared family environment on intelligence may have actually reflected additive genetic variance due to assortative mating for intelligence among the parents of these twins (see Baker, Treloar, Reynolds, Heath, & Martin, 1996).

Phenotypic and Genetic Correlations Among Traits

Phenotypes are the observable bodily or behavioral characteristics of an orgasm, so phenotypic correlations are simply the raw correlations between traits. The phenotypic (Spearman's) correlations among key traits are shown in Table 3, for Sample 1 above the diagonal and for Sample 2 below the diagonal. In both samples, there were substantial phenotypic correlations among all three measures of mobile phone use, ranging from .46 to .70. In both samples, there were slight positive correlations between most measures of mobile phone use and extraversion. Intelligence (available only for Sample 2) shows slight negative correlations with all three measures of mobile phone use. Correlations between extraversion and intelligence were negligible in both samples.

Genetic correlations among key traits are shown in Table 4, for Sample 1 above the diagonal and for Sample 2 below the diagonal. These were calculated in Mx, based on the usual cross-twin, cross-trait correlations. The genetic correlations showed much the same pattern as the phenotypic correlations. In both samples, there were substantial genetic correlations among all three measures of mobile phone use, ranging from .43 to .95. Extraversion showed mild genetic correlations with talk and text frequencies in Sample 1 (.20 and .23, respectively), and showed moderate genetic correlations with talk and text frequencies in Sample 2 (.40 and .33). Intelligence (in Sample 2) showed slight negative genetic correlations of –.17 with both talk frequency and text frequency. Genetic correlations between extraversion and intelligence were negligible.

Discussion

This article has two key results, two key limitations, and several implications. The first key result is that mobile phone use showed moderate heritabilities for five out of six measures: talk and text frequency in both samples; and whether a mobile phone was used at all in Sample 1, in which there was more variance. Estimates of A (additive genetic variance) for these measures ranged from 34% to 60% and, in each case, estimates of C (shared family environment) were much lower, ranging from 5% to 24%. The sixth measure, whether a mobile phone was used at all in Sample 2, showed negligible heritability, but this may have reflected the fact that over 92% of Sample 2 used a mobile phone, so there was not much variance for genes to explain — as suggested by the rather high (77%) estimate of E (residual variance) for this measure. Also, the heritabilities that we found for extraversion (54% in Sample 1, 43% in Sample 2) and for intelligence (64% in Sample 2) are consistent with other twin studies (Bouchard & Loehlin, 2001; Deary, Spinath, & Bates, 2006; Plomin, Defries, McClearn, & McGuffin, 2008).

The clear implication of these heritability results is that genes matter more than family environments in predicting how often people use their mobile phones to talk and text. Shared family environment, including neighborhood, local schools, social class, family housing, parental education, and parental income had only a small effect on

TABLE 3

Phenotypic (Spearman's) Correlations Between Variables in Samples 1[a] and 2[b]

Measures	Phone	TalkF	TextF	Ext	IQ
Mobile phone used	1	.702**	.695**	.067	—
Talk frequency	.467**	1	.666**	.084*	—
Text frequency	.464**	.553**	1	.121**	—
Extraversion	.114**	.212**	.226**	1	—
Intelligence	−.105**	−.110**	−.174**	−.010	1

Note:[a] above the diagonal, N = 548 individuals. [b] below the diagonal, N = 723 individuals
*$p < .05$, **$p < .01$.

whether teens used a mobile phone at all, and even less effect on how often teens use their phones to talk and text. This is an important point, because it automatically eliminates many potential confounds. For example, richer parents may buy their teenage children more generous mobile phone plans with more talk minutes and texts per month, but that wealth effect cannot explain the genetic results here, because parental wealth is a shared family environment effect already taken into account by the behavior genetic modeling.

The second key result is that there are phenotypic and genetic correlations — modest, but theoretically important — between mobile phone use and other traits such as extraversion and intelligence. It is not surprising that teens talk and text somewhat more often if they are more extraverted (outgoing, sociable, talkative, active), and the extraversion effect on mobile phone use has been found in another study of Australian adolescents (Inyang et al., 2010). It may be more surprising that there are modest negative correlations, both phenotypic and genetic, between intelligence and mobile phone use. This means that some of the same genetic variants that increase general intelligence also tend to decrease mobile phone usage. At the psychological level, perhaps more intelligent teens have less interest in the typical content of talking and texting among their peers: sexual gossip and pop culture. Or perhaps higher verbal fluency means that teens with higher intelligence can express any given thought more efficiently, requiring less talk and fewer texts.

One main limitation of the study is that these results concern predictors of mobile phone use within a population that is very homogenous with respect to nationality (Australian), language (English), ethnicity (almost all of Anglo-Celtic origin), and age (mostly aged 14–18 years). However, the sample included participants of both sexes from a wide range of social classes, with a wide range of extraversion and intelligence. Although mobile phone use within societies is not much influenced by shared family environment, mobile phone use across societies is heavily influenced by technological factors (invention and improvements in mobile technology) and economic factors (mobile phone cost relative to average income). There is a good analogy here to human height, which is highly heritable within populations, but can increase dramatically over historical time with improved nutrition and medical care (Silventoinen, 2003). These findings need replicating in larger, genetically informative samples, especially in other age groups, ethnicities, and countries. In regions such as Scandinavia, where virtually everyone has a mobile phone, genetic influences may not predict mobile phone ownership, but might predict frequencies of calls and texts even more strongly because there will be less restriction of range among mobile users in their heritable traits such as intelligence, personality, education, occupational status, wealth, etc.

A second limitation concerns the limited accuracy of self-reports of mobile phone use. Estimates for E (residual variance) in talking and texting frequencies were modest to moderate, ranging from 28% to 45%. This residual variance is likely to reflect substantial error variance in the self-report measures concerning frequencies of talking and texting. Previous studies show that recall accuracy for mobile phone use is only moderate, in both adolescents (Inyang, Benke, Morrissey, McKenzie, & Abramson, 2009) and adults (Timotijevic et al., 2009 Vrijheid et al., 2006; Vrijheid et al., 2009), with substantial random error and typically about 20% underestimation of call number and 40% overestimation of call duration. Thus, the observed heritabilities and genetic correlations estimated from these self-report data are probably lower than the true values.

This study has implications for several domains of consumer research. One domain concerns product liability and the health risks of mobile phone use. Without understanding the heritability, phenotypic correlates, and genetic correlates of mobile phone use, it is very hard to draw firm conclusions from epidemiological studies of alleged mobile phone health risks. Many studies have assessed possible health problems associated with radiofrequency field (RF) exposure generated by mobile phone antennae, including possible brain tumors and genetic damage (Ahlbom et al., 2004; Khurana et al., 2009; Hardell et al., 2008; Valentini et al., 2007; Vijayalaxmi, & Prihoda, 2008) others have focused on the increased risk of car accidents while dual tasking with driving and mobile phone use (Caird, Willness, Steel, & Scialfa, 2008;

TABLE 4

Genetic Correlations Between Variables in Samples 1a and 2b

Measures	Phone	TalkF	TextF	Ext	IQ
Mobile phone used	1	.82	.82	.25	—
Talk frequency	.43	1	.86	.20	—
Text frequency	.95	.66	1	.23	—
Extraversion	.07	.40	.33	1	—
Intelligence	−.15	−.17	−.17	.06	1

Note: a above the diagonal, based on 88 MZ and 185 DZ twin pairs. b below the diagonal, based on 112 MZ and 201 DZ twin pairs.

https://doi.org/10.1375/twin.15.1.97 Published online by Cambridge University Press

Horrey & Wickens, 2006; Redelmeier & Tibshirani, 1997; Strayer et al., 2006). However, consider the implications of the small, but significant, negative correlations we found between mobile phone use and intelligence. Higher intelligence is associated with greater longevity and better health in many ways (Arden, Gottfredson, & Miller, 2009; Batty, Deary, & Gottfredson, 2007). Because more intelligent, healthier people apparently use mobile phones less often, epidemiological studies could find apparent correlations between health problems and mobile phone use that are really driven by underlying associations between intelligence and health, and between intelligence and lower mobile phone use. Neglecting the phenotypic and genetic correlations of mobile phone use could lead to overestimating the dangers of RF exposure. Also, given that more intelligent people have fewer driving accidents (Whitley et al. 2010), apparent population-level correlations between mobile phone use and accident risk may partly reflect the role of intelligence in both, leading to overestimates of the driving risks from mobile phones; however, this possibility does not detract from the many experimental studies in driving simulators that show increased accident risk from phone use (Caird et al., 2008; Horrey & Wickens 2006). Future studies of RF exposure and driving risks associated with mobile phone use should also measure phone users' other health-relevant behavioral traits, including intelligence and other personality traits, ideally in genetically informative samples including twins and their families.

More data on the genetic bases of mobile phone use would also be useful in other research domains. Data on mobile phone use patterns have already been used to analyze individual mobility patterns (Gonzalez, Hidalgo, & Barabasi, 2008), social networks (Lambiotte et al., 2008; Onnela et al., 2007), and the dynamics of group formation (Palla et al., 2007), and for telephone surveys (Lavrakas, Shuttles, Steeh, & Fienberg, 2007). Studies that are genetically informative would allow stronger inferences from mobile phone studies in many such areas. A better understanding of the phenotypic and genetic correlates of mobile phone use would also be useful in the telecoms industry, including consumer behavior research on handset design, user interface design, smartphone 'app' usability, marketing, and advertising. More generally, the cognitive and personality traits that influence mobile phone use might also influence adoption and use of other new technologies, new products, and new brands, giving consumer researchers better insight into the nature of 'early adopters', the diffusion of innovations, and other issues. Further twin studies in consumer psychology may challenge the conventional wisdom that parental socialization and family environment is crucial in the development of young consumers' knowledge, skills, and preferences.

Multivariate genetic studies could also bring some order and simplicity to individual differences research in consumer psychology, which has been bedeviled by a runaway proliferation of constructs such as 'need for cognition', 'need for uniqueness', 'integrative complexity', 'regulatory focus', 'affect intensity', etc. These old individual-differences constructs have almost never demonstrated convergent or discriminant validity compared to general intelligence and the Big Five personality traits, and most should have died long ago. Yet they continue to stumble around the research landscape like zombies, and have already overrun most corporate marketing departments. The 'central six' traits (the Big Five plus intelligence) seem more viable in several ways: they are relatively independent, substantially heritable, stable across life, universal across cultures, evolutionarily ancient, and found in other primate species; they also predict behavior across a wide range of domains, and subsume most other individual-differences constructs (Freeman & Gosling, 2010; Lubinski, 2004; Miller, 2009; Ozer & Benet-Martinez, 2006). There may be other traits that seem to account for some of the variance in adoption and use of mobile phones and other new technologies. However, they should be measured alongside the central six traits in a genetically informative twin study to see whether they are genetically correlated with any of the central six, and whether they actually add any predictive power beyond the central six in accounting for technology adoption and use. For example, if 'integrative complexity' shows a high genetic correlation with general intelligence, there is no need to retain it as a distinct construct; likewise, if 'need for uniqueness' boils down genetically to openness plus a bit of extraversion. Genetic correlations could help separate the real value-added constructs in consumer research from the zombie constructs that survive only through historical momentum, through unfamiliarity with the central six, and through the incentives to attach one's name to a new construct to obtain tenure in a business school's marketing department (in which most consumer behavior research occurs).

Finally, we emphasize that genetic influences on how often people use a particular technology do not imply an evolutionary history of genetic adaptation to the technology. The explanatory power of behavioral genetics is not restricted to evolutionarily ancient forms of behavior. This study points the way to multivariate genetic analyses of psychological traits and use of other emerging technologies such as 4G smartphones, smart drugs, personalized DNA sequencing, 3-D printing, electronic glasses, eco-cities, and space tourism. Ancient genetic variants can have dramatic effects on how humans use futuristic goods and services — and consumer behavior research has the behavior genetics tools to study such exciting effects.

Acknowledgments

The authors thank the twins for participating, Ann Eldridge and Marlene Grace for data collection, Anjali Henders for coordination, and Harry Beeby, David Smyth, and Daniel Park for IT support. Funding was provided by the Australian Research Council (A7960034, A79906588, A79801419, DP0212016, DP0343921) and the Australian National Health and Medical Research Council (552485). The funding sources had no involvement in study design, in the collection, analysis, or interpretation of data, in the writing of this paper, or in the decision to submit this paper for publication.

References

Ahlbom, A., Green, A., Kheifets, L., Savitz, D., & Swerdlow, A. (2004). Epidemiology of health effects of radiofrequency exposure. *Environmental Health Perspectives, 112*, 1741–1754.

Anolli, L., Villani, D., & Riva, G. (2005). Personality of people using Chat: An on-line research. Cyberpsychology and Behavior, 8, 89–95.

Arden, R., Gottfredson, L. S., & Miller, G. F. (2009). Does a fitness factor contribute to the association between intelligence and health outcomes? Evidence from Medical Abnormality Counts among 3654 US Veterans. *Intelligence, 37,* 581–591.

Arnold, S. J., Burger, R., Hohenlohe, P. A., Ajie, B. C., & Jones, A. G. (2008). Understanding the evolution and stability of the G-matrix. *Evolution, 62,* 2451–2461.

Arns, M., Van Luijtelaar, G., Sumich, A., Hamilton, R., & Gordon, E. (2007). Electroencephalographic, personality, and executive function measures associated with frequent mobile phone use. *International Journal of Neuroscience, 117,* 1341–1360.

Baker, L. A., Treloar, S. A., Reynolds, C. A., Heath, A. C., & Martin, N. G. (1996). Genetics of educational attainment in Australian twins: Sex differences and secular changes. *Behavior Genetics*, *26,* 89–102.

Bartels, M., Saviouk, V., de Moor, M. H. M., Willemsen, G., van Beijsterveldt, T. C. E. M., Hottenga, J. J., de Geus, E. J. C., & Boomsma, D. I. (2010). Heritability and genome-wide linkage scan of subjective happiness. *Twin Research and Human Genetics, 13*, 135–142.

Batty, G. D., Deary, I. J., & Gottfredson, L. S. (2007). Premorbid (early life) IQ and later mortality risk: Systematic review. *Annals of Epidemiology, 17,* 278–288.

Björklund, A., Lindahl, M., & Plug, E. (2006). The origins of intergenerational associations: Lessons from Swedish adoption data. *Quarterly Journal of Economics, 121*, 999–1028.

Bouchard, T. J., & McGue, M. (2003). Genetic and environmental influences on human psychological differences. *Journal of Neurobiology, 54*, 4–45.

Bouchard, T. J., & Loehlin, J. C. (2001). Genes, evolution, and personality. *Behavior Genetics, 31,* 243–273.

Bowles, S., & Gintis, H. (2002). The inheritance of inequality. *Journal of Economic Perspectives, 16*, 3–30.

Butt, S., & Phillips, J. G. (2008). Personality and self reported mobile phone use. *Computers in Human Behavior, 24*, 346–360.

Button, T. M. M., Stallings, M. C., Rhee, S. H., Corley, R. P., & Hewitt, J. K. (2011). The etiology of stability and change in religious values and religious attendance. *Behavior Genetics, 41,* 201–210.

Caird, J. K., Willness, C. R., Steel, P., & Scialfa, C. (2008). A meta-analysis of the effects of cell phones on driver performance. *Accident Analysis and Prevention, 40,* 1282–1293.

Chamorro-Premuzic, T., Reimers, S., Hsu, A., et al. (2009). Who are thou? Personality predictors of artistic preferences in a large UK sample: The importance of openness. *British Journal of Psychology, 100*, 501–516.

China Mobile (2011). *Operation Data: Customer Numbers.* Retrieved from http://www.chinamobileltd.com/ir.php?menu=11

Clark, G., & Hamilton, G. (2006). Survival of the richest: The Malthusian mechanism in pre-industrial England. *Journal of Economic History, 66*, 707–736.

Costa, P. T., & McCrae, R. R. (1992). *Professional manual: Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor-Inventory (NEO-FFI).* Odessa, FL: Psychological Assessment Resources.

Daly, A. K. (2010). Genome-wide association studies in pharmacogenomics. *Nature Reviews Genetics, 11*, 241–246.

Deary, I. J., Spinath, F. M., & Bates, T. C. (2006). Genetics of intelligence. *European Journal of Human Genetics, 14*, 690–700.

Derks, E. M., Dolan, C. V., & Boomsma, D. I. (2006). A test of the equal environments assumption (EEA) in multivariate twin studies. *Twin Research and Human Genetics, 9*, 403–411.

Ehrenberg, A., Juckes, S., White, K. M., et al. (2008). Personality and self-esteem as predictors of young people's technology use. *Cyberpsychology and Behavior, 11*, 739–741.

Eysenck, H. J., & Eysenck, S. B. G. (1975). *Manual for the Eysenck Personality Questionnaire (adult and junior).* San Diego, CA: Digits.

Finn, S. (1997). Origins of media exposure — Linking personality traits to TV, radio, print, and film use. *Communication Research, 24*, 507–529.

Fowler, J. H., Dawes, C. T., & Christakis, N. A. (2009). Model of genetic variation in human social networks. *Proceedings of the National Academy of Sciences of the USA*, *106*, 1720–1724.

Fowler, J. H., & Schreiber, D. (2008). Biology, politics, and the emerging science of human nature. *Science,* 332, 912–914.

Freeman, H. D., & Gosling, S. D. (2010). Personality in nonhuman primates: A review and evaluation of past research. *American Journal of Primatology, 72*, 653–671.

Freese, J., & Shostak, S. (2009). Genetics and social inquiry. *Annual Review of Sociology, 35*, 107–128.

Friend, A., DeFries, J. C., Olson, R. K., Pennington, B., Harlaar, N., Byrne, B., Samuelsson, S., Willcutt, E. G., Wadsworth, S. J., Corley, R., & Keenan, J. M. (2009). Heritability of high reading ability and its interaction with parental education. *Behavior Genetics, 39*, 427–436.

Gonzalez, M. C., Hidalgo, C. A., & Barabasi, A. L. (2008). Understanding individual human mobility patterns. *Nature, 453*, 779–782.

Hardell, L., Carlberg, M., Soderqvist, F., & Mild, K. H. (2008). Meta-analysis of long-term mobile phone use and the association with brain tumours. *International Journal of Oncology, 32*, 1097–1103.

Harlaar, N., Dale, P. S., & Plomin, R. (2007). From learning to read to reading to learn: Substantial and stable genetic influences. *Child Development, 78*, 116–131.

Hatemi, P. K., Hibbing, J. R., Medland, S. E., Keller, M. C., Alford, J. R., Smith, K. B., Martin, N. G., & Eaves, L. J. (2010). Not by twins alone: Using the extended family design to investigate genetic influence on political beliefs. *American Journal of Political Science, 54*, 798–814.

Hertel, G., Schroer, J., Batinic, B., et al. (2008). Do shy people prefer to send E-Mail? Personality effects on communication media preferences in threatening and non-threatening situations. *Social Psychology, 39*, 231–243.

Horrey, W. J., & Wickens, C. D. (2006). Examining the impact of cell phone conversations on driving using meta-analytic techniques. *Human Factors, 48*, 196–205.

International Telecommunications Union. (2011). *The world in 2010: Information and communication technology (ICT) facts and figures*. Retrieved from http://www.itu.int/ITU-D/ict/material/FactsFigures2010.pdf

Inyang, I., Benke, G., Dimitriadis, C., Simpson, P., McKenzie, R., & Abramson, M. (2010). Predictors of mobile telephone use and exposure analysis in Australian adolescents. *Journal of Paediatrics and Child Health, 46*, 226–233.

Inyang, I., Benke, G., Morrissey, J., McKenzie, R., & Abramson, M. (2009). How well do adolescents recall use of mobile telephones? Results of a validation study. *BMC Medical Research Methodology, 9*, 36.

Jackson, D. N. (1998). *Multidimensional Aptitude Battery II*. Port Huron, MI: Sigma Assessment Systems.

Jeng, S. P., & Teng, C. I. (2008). Personality and motivations for playing online games, *Social Behavior and Personality. 36*, 1053–1059.

Keller, M., & Miller, G. F. (2006). Which evolutionary genetic models best explain the persistence of common, harmful, heritable mental disorders? *Behavioral and Brain Sciences, 29*, 385–404.

Kelly, J. K. (2009). Connecting QTLs to the G-matrix of evolutionary quantitative genetics. *Evolution, 63*, 813–825.

Khurana, V. G., Teo, C., Kundi, M., Hardell, L., & Carlberg, M. (2009). Cell phones and brain tumors: A review including the long-term epidemiologic data. *Surgical Neurology, 72*, 205–214.

Kingston, D. A., Malamuth, N. M., Fedoroff, P., et al. (2009). The importance of individual differences in pornography use: Theoretical perspectives and implications for treating sexual offenders. *Journal of Sex Research, 46*, 216–232.

Kraaykamp, G., & van Eijck, K. (2005). Personality, media preferences, and cultural participation. *Personality and Individual Differences, 38*, 1675–1688.

Krcmar, M., & Kean, L. G. (2005). Uses and gratifications of media violence: Personality correlates of viewing and liking violent genres. *Media Psychology, 7*, 399–420.

Lambiotte, R., Blondel, V. D., de Kerchove, C., et al. (2008). Geographical dispersal of mobile communication networks. *Physica a-Statistical Mechanics and Its Applications, 387*, 5317–5325.

Landers, R. N., & Lounsbury, J. W. (2006). An investigation of Big Five and narrow personality traits in relation to Internet usage. *Computers in Human Behavior, 22*, 283–293.

Lavrakas, P. J., Shuttles, C. D., Steeh, C., & Fienberg, H. (2007). The state of surveying cell phone numbers in the United States — 2007 and beyond. *Public Opinion Quarterly, 71*, 840–854.

Le, A. T., Miller, P. W., Slutske, W. S., & Martin, N. G. (2010). Are attitudes towards economic risk heritable? Analyses using the Australian twin study of gambling. *Twin Research and Human Genetics, 13*, 330–339.

Loehlin, J. C. (2011). Genetic and environmental structure of personality: A cluster-analysis approach. *Personality and Individual Differences, 51*, 662–666.

Liu, H., & Zeng, J. (2009). Genetic ability and intergenerational earnings mobility. *Journal of Population Economics, 22*, 75–95.

Lubinski, D. (2004). Introduction to the special issue on cognitive abilities: 100 years after Spearman's 'general intelligence,' objectively determined and measured. *Journal of Personality and Social Psychology, 86*, 96–111.

McManus, I. C., & Furnham, A. (2006). Aesthetics activities and aesthetic attitudes: Influences on education, background and personality on interest and involvement in the arts. *British Journal of Psychology, 97*, 555–587.

Martin, N. W., Hansell, N. K., Wainwright, M. A., Shekar, S. N., Medland, S. E., Bates, T. C., Burt, J. S., Martin, N. G., & Wright, M. J. (2009). Genetic covariation between the author recognition test and reading and verbal abilities: What can we learn from the analysis of high performance? *Behavior Genetics, 39*, 417–426.

Miller, G. F. (2009). *Spent: Sex, evolution, and consumer behavior.* New York: Viking.

Neale, M. C., Boker, S. M., Xie, G., & Maes, H. E. (1999). *Mx: Statistical modeling* (5th ed.). Richmond, VA: Department of Psychiatry, Virginia Commonwealth University.

Neale, M. C., & Cardon, L. R. (1992). *Methodology for genetic studies of twins and families*. Dordrecht, Netherlands: Kluwer Academic Publishers.

Nyholt, D. R. (2006). On the probability of dizygotic twins being concordant for two alleles at multiple polymorphic loci. *Twin Research and Human Genetics, 9*, 194–197.

Onnela, J. P., Saramaki, J., Hyvonen, J., et al. (2007). Structure and tie strengths in mobile communication networks. *Proceedings of the National Academy of Sciences of the United States of America, 104*, 7332–7336.

Ozer, D. J., & Benet-Martinez, V. (2006). Personality and the prediction of consequential outcomes. *Annual Review of Psychology, 57*, 401–421.

Palla, G., Barabasi, A. L., & Tamas, V. (2007). Quantifying social group evolution. *Nature,* 446, 664–667.

Penke, L., Denissen, J. P., & Miller, G. F. (2007). The evolutionary genetics of personality. *European Journal of Personality, 21,* 549–587.

Persegani, C., Russo, P., Carucci, C., et al. (2002). Television viewing and personality structure in children. *Personality and Individual Differences, 32*, 977–990.

Plomin, R., Corley, R., Defries, J. C., & Fulker, D. W. (1990). Individual differences in television viewing in early childhood: Nature as well as nurture. *Psychological Science, 1,* 371–377.

Plomin, R., Defries, J. C., McClearn, G. E., & McGuffin, P. (2008). *Behavioral Genetics* (5th ed.). New York: Worth Publishers.

Portio Research (2011). *Mobile factbook 2011.* Retrieved from http://www.portioresearch.com/Portio%20Research%20Ltd%20Mobile%20Factbook%202011.pdf

Redelmeier, D. A., & Tibshirani, R. J. (1997). Association between cellular-telephone calls and motor vehicle collisions. *New England Journal of Medicine, 336*, 453-458.

Ross, C., Orr, E. S., Sisic, M., Arseneault, J. M., Simmering, M. G., & Orr, R. R. (2009). Personality and motivations associated with Facebook use. *Computers in Human Behavior, 25*, 578–586.

Rowe, D. C., & Herstand, S. E. (1986). Familial influences on television viewing and aggression: A sibling study. *Aggressive Behavior, 12*, 111-120.

Sherry, J. L. (2001). Toward an etiology of media use motivations: The role of temperament in media use. *Communication Monographs, 68,* 274–288.

Shim, J. W., & Bryant, P. (2007). Effects of personality types on the use of television genre. *Journal of Broadcasting & Electronic Media, 51*, 287–304.

Silventoinen, K. (2003). Determinants of variation in adult body height. *Journal of Biosocial Science, 35,* 263–285.

Simonson, I., & Sela, A. (2011). On the heritability of consumer decision making: An exploratory approach for studying genetic effects on judgment and choice. *Journal of Consumer Research, 37*, 951–966.

Strayer, D. L., Drews, F. A., & Crouch, D. J. (2006). A comparison of the cell phone driver and the drunk driver. *Human Factors, 48*, 381–391.

Timotijevic, L., Barnett, J., Shepherd, R., & Senior, V. (2009). Factors influencing self-report of mobile phone use: The role of response prompt, time reference and mobile phone use in recall. *Applied Cognitive Psychology, 23*, 664-683.

Vijayalaxmi, & Prihoda, T. J. (2008). Genetic damage in mammalian somatic cells exposed to radiofrequency radiation: A meta-analysis of data from 63 publications (1990–2005). *Radiation Research, 169,* 561–574.

Valentini, E., Curcio, G., Moroni, F., et al. (2007). Neurophysiological effects of mobile phone electromagnetic fields on humans: *A comprehensive review. Bioelectromagnetics, 28*, 415–432.

Vrijheid, M., Cardis, E., Armstrong, B. K., et al. (2006). Validation of short term recall of mobile phone use for the Interphone study. *Occupational and Environmental Medicine, 63*, 237–243.

Vrijheid, M., Armstrong, B. K., Bedard, D., Brown, J., Deltour, I., Iavarone, I., Krewski, D., Lagorio, S., Moore, S., Richardson, L., Giles, G. G., McBride, M., Parent, M. E., Siemiatycki, J., & Cardis, E. (2009). Recall bias in the assessment of exposure to mobile phones. *Journal of Exposure Science and Environmental Epidemiology, 19,* 369–381.

Whitley, E., Batty, G. D., Gale, C. R., Deary, I. J., Tynelius, P., & Rasmussen, F. (2010). Intelligence in early adulthood and subsequent risk of unintentional injury over two decades: A cohort study of 1,109,475 Swedish men. *Journal of Epidemiology and Community Health, 64*, 419–425.

Wright, M. J., & Martin, N. G. (2004). Brisbane adolescent twin study: Outline of study methods and research projects. *Australian Journal of Psychology, 56,* 65–78.

Zhu, G., Montgomery, G. W., James, M. R., Trent, J. T., Hayward, N. K., Martin, N. G., & Duffy, D. D. (2007). A genome-wide scan for naevus count: Linkage to CDKN2A and to other chromosomal regions. *European Journal of Human Genetics, 15,* 94–102.

Zietsch, B. P., Miller, G. F., Bailey, J. M., & Martin, N. G. (2011). Female orgasm rates are largely independent of other traits: Implications for function and dysfunction. *Journal of Sexual Medicine, 8,* 2305–2316.