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g as bridge model

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Abstract: g*—a statistical factor capturing strong intercorrelations between individuals' scores on different IQ tests—is of theoretical interest despite being a low-fidelity model of both folk psychological intelligence and its cognitive/neural underpinnings.* g *idealizes away from those aspects of cognitive/neural mechanisms that are not explanatory of the relevant variety of folk psychological intelligence, and idealizes away from those aspects of folk psychological intelligence that are not generated by the relevant cognitive/neural substrate. In this manner,* g *constitutes a high-fidelity bridge model of the relationship between its two targets, and thereby helps demystify the relationship between folk and scientific psychology.*

1. Introduction

Psychometric *g* is a statistical factor that captures the remarkably strong positive intercorrelations between all of any given individual's scores on different IQ tests and subtests. There are many varieties of IQ subtest, probing verbal ability, analogical reasoning, mathematical ability, pattern-matching ability, and so on. The first great finding of the IQ-testing tradition is that subjects who do better than most people on any given one of these subtests are also likely to do better than most people on any of the others (Mackintosh 2011). *g* is thus commonly considered a statistical distillation of what all IQ subtests measure in common. The second great finding of the IQ-testing tradition is that *g* is predictively fecund—among psychological constructs, only conscientiousness competes with *g* as a predictor of educational attainment, job complexity, socioeconomic status, and other prominent measures of success in life (Gottfredson 1997). Nevertheless, experts are divided about its theoretical interest.

Some skeptics deny that *g* measures anything more theoretically interesting than the ability to do well on IQ tests, but most intelligence researchers assume that *g* is a very good model (if not a direct measure) of something of theoretical interest. (Researchers variously refer to the phenomenon modelled by *g* as 'general intelligence', 'the positive manifold', or just 'the *g*-factor'.) Non-skeptics tend to emphasize one or the other of two target systems purportedly modeled by *g*. According to some intelligence researchers, *g* is a model of folk psychological intelligence—the personal-level capacity that ordinary folks are talking about when they call somebody smart. According to others, *g* is a model of the cognitive or neural substrates of that capacity.

I'll argue that *g* is of theoretical interest despite being a low-fidelity model of each of these targets. I'll begin by assuming that *g* isn't a very good measure of folk psychological intelligence. I'll then argue that it isn't a very good measure of what's going on in the brains or cognitive systems of (un)intelligent people, either. I'll go on to argue that *g* is nevertheless explanatorily important insofar as it idealizes away from those aspects of the relevant neural/cognitive substrates that aren't explanatory of the relevant variety folk psychological intelligence, and idealizes away from those aspects of the relevant variety of folk psychological intelligence that aren't generated by the relevant neural/cognitive substrates. In that manner, *g* constitutes a high-fidelity 'bridge model' of the relationship between its two distinct targets, and thereby helps demystify the relationship between folk psychology and scientific psychology.

2. *g* isn't a very good measure of folk psychological intelligence

Elsewhere (Curry forthcoming), I have argued for an interpretivist account of folk psychological intelligence inspired by Ryle's (1945) analysis of intelligence-talk and Dennett's (1991) notion of real patterns detected from the intentional stance. On my account, to be intelligent (in the sense invoked in folk psychological practices) is to be comparatively good at solving intellectual problems that an interpreter deems worth solving. In short: you're intelligent if you behave (in ways that folks deem smart) more successfully than other people, and you're unintelligent if you behave (in ways that folk deem smart) less successfully than other people. Since the extant empirical evidence indicates that different lay interpreters, both between and within cultures, deem different intellectual problems worth solving (and, indeed, deem different problems to count as *intellectual* problems), it follows from my definition that what it is to be intelligent varies alongside the lay interpreters in question.

As Sternberg and Grigorenko (2004) and their collaborators in cross-cultural psychology have extensively documented, *g* tracks some—but not all—of the varieties of intelligence that have emerged in relation to folk psychological practices around the globe. In particular, *g* is plausibly a decent model of a variety of intelligence that became extremely salient in the folk psychological discourses of some WEIRD—Western, Educated, Industrialized, Rich, Democratic (Henrich et al. 2010)—contexts in the 20th century, but which is much less salient in other cultural contexts. However, skeptical philosophers and psychologists have provided serious reasons to doubt that *g* is a *very* good measure even of the varieties of folk psychological intelligence that have emerged, alongside IQ testing itself, within WEIRD contexts (Block & Dworkin 1974). So I'll henceforth assume that *g* isn't a very good measure of what folks are talking about when they talk about intelligence in everyday life: it doesn't straightforwardly measure intelligence as conceptualized in WEIRD, IQ-test-influenced settings, and it flat-out fails to measure intelligence as conceptualized in many other settings. Nevertheless, my account of folk psychological intelligence leaves open the possibility that *g* is a great measure of the neural or cognitive underpinnings of what folks are talking about when they talk about intelligence.

3. *g* isn't a very good measure of cognitive or neural functioning

Several prominent psychologists and cognitive neuroscientists are increasingly optimistic about unearthing a particular neural or cognitive mechanism (or set of mechanisms) that is fully responsible for the comparatively superior (or inferior) capacity measured by *g*, and thereby discovering intelligence squarely in the brain or cognitive system. I think their optimism about reduction is misplaced. To substantiate my pessimism, let's go through a few prominent recent attempts to reduce intelligence to its neural or cognitive substrates.

3.1. Neural correlates

Jensen (2006: *ix*), in a refinement of Spearman's original speculation that *g* measured a kind of "mental energy", influentially interpreted *g* as an indirect "measurement of cognitive speed" which could be more directly measured via reaction time paradigms which correlate strongly with *g*. Because of this correlation, Jensen was convinced that "intelligence is the periodicity of neural oscillation in the action potentials of the brain and central nervous system" (2011: 173). In other words, intelligence is nothing more and nothing less than the frequency of brainwaves, and IQ testing provides a good (if indirect) measure of this physical feature of the brain. Jensen's simple reductionist theory of intelligence hasn't held up in the light of PET and fMRI research in cognitive neuroscience. For one thing, cognitive neuroscientists have demonstrated that a higher frequency of brainwaves isn't actually straightforwardly correlated with greater neural processing power; nor is any other particular pattern in the frequency of brainwaves (Haier 2017). It turns out that, despite Jensen's best efforts, Spearman's notion of mental energy has no neural referent. Nevertheless, more empirically adequate neurological theories of intelligence have risen in Jensen's theory's stead.

The best developed among them—Jung and Haier's Parieto-Frontal Integration Theory—goes a long way towards identifying the neural correlates of the cognitive processes recruited when people take IQ tests. There is surely something to Jung and Haier's suggestion that the efficient integrated operation of a parieto-frontal sense-remember-judge-act network underlies the variety of intelligence purportedly measured by *g*. (It plausibly partially underlies many other varieties of folk psychological intelligence as well.) But Jung and Haier have no proposal as to the cause of this efficiency, which could theoretically stem from a wide variety of sources, only some of which could be plausibly construed as the incarnation of intelligence in the brain. (More on alternative sources of efficiency anon.) Indeed, in responding to critics, Jung and Haier back off of the claim to have provided a reductionist theory of the positive manifold modelled by *g*, and instead insist only that "in our view, it is still too early to rule out a neural basis for a general factor of intelligence independent of a neural basis for specific cognitive abilities" (2007: 176). In other words, Jung and Haier insist that it is possible that the parieto-frontal efficiency which underlies successful IQ test-taking is generated by intelligence qua mechanism in the brain. They claim to have located that mechanism in a reasonably delimited parieto-frontal network. But, in the end, they make no claim to have identified the mechanism itself.

Localization isn't nearly enough to ground reduction. If researchers hope to reduce intelligence to a neural—or, failing that, cognitive—state or process, then they'll have to identify a candidate mechanism that produces that state or carries out that process. To be fair, some researchers have done just that. The most plausible candidate mechanism currently on offer is working memory capacity.

3.2. Working memory

Cognitive scientists use the term 'working memory' to refer to "a domain-general resource that enables representations to be actively sustained, rehearsed, and manipulated for purposes of reasoning and problem solving" (Carruthers 2014: 12). When you rehearse a phone number in your head while looking for a piece of paper to scribble it down on, you're using your working memory. Working memory *capacity* is a common measure both of how much information can be maintained in working memory and of how well that information can be processed. Research on working memory capacity has increasingly shown that it is a critical component in much—perhaps even most—complex cognition. As such, researchers have become increasingly interested in the hypothesis that intelligence can be explained largely in terms of—perhaps even be reduced to—working memory capacity.

This hypothesis makes some intuitive sense: solving puzzles almost always involves actively sustaining and manipulating information. And, at first glance, the evidence in favor of reducing intelligence to working memory capacity is impressive. When you give somebody both an IQ test and a test of working memory capacity, the two resulting scores correlate positively. In particular, working memory capacity and 'fluid *g*'–the factor capturing how well people do on IQ tests that are designed to focus on pure reasoning abilities, as opposed to reasoning that makes use of what the reasoner knows—tend to have a correlation somewhere between .6 and .8 (Carruthers 2014); that is a very strong correlation (indeed, that range is only slightly lower than the range of correlations that made *g* such an important finding in the first place). Moreover, much of the parieto-frontal network that Jung and Haier identify as the neural correlate of *g* has also been shown to be active in working memory (Deary et al. 2010).

Finally, there is some evidence that increases in working memory capacity yield increases in fluid *g* (Jaušovec & Jaušovec 2012).

On the other hand, there is also evidence that cuts against reduction. Working memory capacity, while quite domain-general, is nevertheless more domain-specific than fluid *g*: it correlates more with tests of verbal ability than with tests of spatial ability, for instance. And working memory's contribution to performance on tests of fluid *g* seems to be independent of the respective contributions of associative learning and information processing speed (Mackintosh 2011: 154–155). So there is good reason to doubt that working memory is the sole cognitive underpinning of fluid *g*. Moreover, there is some good reason to doubt that working memory is a cognitive underpinning of intelligence at all: some of the researchers responsible for discovering the correlations between fluid *g* and working memory capacity have argued that the two are explanatorily distinct phenomena that are nevertheless strongly correlated because they share a common underpinning (Shipstead & Engle 2018). But for my purposes we can set these complex questions about the weight and interpretation of the extant evidence aside. My argument against the reduction of intelligence to working memory capacity is at once more abstract and more straightforward: my argument rests on the premise that reduction would add nothing to—and indeed subtract something from—our understanding. In particular, reduction would hinder our understanding of intelligence while adding nothing to our understanding of how cognitive systems work.

With regard to the latter: working memory capacity is already a reasonably well-defined construct that measures the operations of a central and reasonably well-delimited (albeit complex and distributed) cognitive subsystem, and thereby plays a clear explanatory role in cognitive science. Stipulating that this construct is a measure of intelligence—without making any concrete suggestions for how that stipulation should change our understanding of working memory or the functioning of cognitive systems more generally—does nothing to enhance its explanatory power. Thus, reduction is justified in this case only if it sheds light on the phenomenon being reduced.

But reduction to working memory capacity can only obfuscate intelligence. Even granting that IQ tests measure intelligence well, any attempted reduction of intelligence to working memory capacity will hinder our understanding of intelligence in at least two respects.

First, working memory capacity is super highly correlated, not with *g*, but only with one of its component factors, fluid *g*, which is derived from minority subset of IQ tests. Most IQ tests also measure other component factors, including most prominently 'crystallized *g*': the factor capturing how well people do on IQ tests that are designed to focus on reasoning that makes use of what the reasoner knows. The calling card of plain old undifferentiated *g* is that there are strong intercorrelations between how well people do on *all* IQ tests—including relatively pure tests of fluid *g*, relatively pure tests of crystallized *g*, and a wide range of hybrids. By my lights, the heterogeneous nature of the positive manifold should be telling when it comes to constructing a theory of intelligence: the fact that both fluid *g* and crystallized *g* are statistical components of undifferentiated *g* intriguingly mirrors the fact that folk psychological conceptions of intelligence across cultures tend to invoke both fluid reasoning and the use of crystalized knowledge (Sternberg & Grigorenko 2004). Meanwhile, the correlation of crystallized intelligence and working memory capacity, like the correlation of undifferentiated *g* and working memory capacity, is somewhere between .3 and .6 (Mackintosh 2011)—the two are clearly importantly related, but it is equally clear that a direct reduction of one to the other won't be in the offing.

Of course, it is possible that fluid *g* captures the essence of *g* (and, by extension, of folk psychological intelligence), and that crystallized *g* is more noise than signal. Indeed, the IQ tests with the highest *g*-loadings—that is, that correlate most strongly with *g* itself—tend to be tests of fluid intelligence (like Raven's Progressive Matrices). But there are problems even with reducing fluid *g* alone to working memory capacity. As Block and Dworkin (1974) have argued, there is a strong case to be made that fluid *g* measures personality, motivation, and temperament to a large degree—for example, it seems to measure ambition, patience, and test-wiseness as well as pure reasoning capacity—and these characteristics aren't plausibly reduced to working memory capacity. Indeed, my account of folk psychological intelligence suggests that these character traits measured by fluid *g* are rightly taken to be part and parcel of intelligence: intelligence is the capacity to solve intellectual problems comparatively well, and solving problems better than one's peers takes grit as well as wits (Dweck & Bempechat 1983).

Nevertheless, I recognize that there remains a reasonable case to be made that, by shedding inessential character traits, working memory capacity distills the essence of fluid *g*, which itself, by shedding crystallized knowledge, distills the essence of undifferentiated *g*. But even if this is the case, a second pitfall awaits the attempt to reduce fluid *g* to working memory capacity (and indeed any attempted reduction of a psychometric kind to the workings of a cognitive mechanism).

Even if working memory capacity is *the* essential cognitive underpinning of intelligence, *g* isn't a very good model thereof. That's because the *g*-factor is, by its very nature, *comparative*—

it is an inter- (rather than intra-) individual construct that measures how somebody does on IQ tests relative to other people in their age-cohort. It doesn't measure how smart somebody is on a ratio scale; it measures only how much better or worse they perform than the average IQ-test-taker. *g* thus can't directly measure an intrinsic characteristic of any individual's mind, whereas we already have reliable ways of measuring working memory within a single individual on a ratio scale. (To my mind, this is a salutary fact about *g*, since on my definition folk psychological intelligence is also constitutively comparative.) As Borsboom and colleagues (2009) have pointed out, absent a theory of how to bridge differential and cognitive psychology, "intelligence dimensions like the g-factor can't be understood on the basis of between-subject data as denoting mental ability qua within-subject attribute." Fluid *g* couldn't be comprehensibly reduced to working memory capacity absent a grand unifying theory of how constitutively comparative capacities relate to intrinsic cognitive mechanisms.

In contrast, it bears repeating that cognitive psychologists already have a decent theoretical understanding of the mechanics of working memory capacity in its own right, not to mention reliable instruments that measure it on a ratio scale. And theorists can give working memory capacity due emphasis as a cognitive underpinning of intelligence without making an attempt at reduction. If my argument holds water, then, in attempting reduction, nothing new is learned, some of the plausibly explanatorily salient dimensions—crystallized intelligence and, arguably, other characteristics—of both folk psychological intelligence and *g* are erased, and an important distinction—between the intrapersonality of the cognitive mechanism of working memory and the constitutive interpersonality of intelligence—is obscured. So long as there is a viable nonreductive account of intelligence on the table, reduction carries no explanatory benefits and falls into at least two significant explanatory pitfalls.

And there are several viable nonreductive accounts on the table. For instance, rather than measuring a cognitive mechanism itself, perhaps *g* measures an effect of the interactions of several mechanisms. As several researchers have argued, there is good reason to believe that the positive manifold is "an emergent property of anatomically distinct cognitive systems, each of which has its own capacity" (Hampshire et al. 2012: 1225). At its extreme, this approach leads to the conclusion that "*g* is 'not a thing' but instead is a summary statistic" and thus that "the search for the neural basis of *g* is meaningless" (Conway & Kovacs 2018: 59). If viable, this approach would avoid both pitfalls of reducing intelligence to working memory: it wouldn't exclude features of the positive manifold on an *ad hoc* basis, and it would have the flexibility to countenance the constitutively comparative nature of the positive manifold. (After all, some emergent properties—like the property being taller than somebody else—emerge only in the light of a relation that undergirds comparisons. The target of a summary statistic is a perfect candidate for just such a constitutively comparative emergent property.)

3.3. Mutualism

In that spirit, van der Maas and colleagues have vigorously argued that the intercorrelations between individuals' IQ test scores can be explained by reference to the dynamic interplay of specialized cognitive mechanisms.

Van der Maas et al. (2006) analogize *g* to the results of predator-prey dynamics in ecology. According to the Lottka-Volterra model (Weisberg 2013), high correlations between predator and prey populations needn't be caused by a single underlying factor (a shared food source, say) which bolsters both populations. Instead, the correlation can be caused—and in nature actually is often caused—by dynamic interactions between the two populations. The size of the prey population increases when the size of the predator population is small (because breeding outpaces being eaten), and decreases when the predator population is large (because being eaten outpaces breeding). At the same time, the predator population grows when the prey population is large (because eating causes breeding), and decreases when the prey population is small (because there isn't enough food to go around). These dynamics ensure that a strong correlation between the size of the populations emerges over time, without requiring any underlying factor to affect both populations.

Analogously, van der Maas and colleagues have demonstrated that high correlations between the performance of distinct cognitive mechanisms, which each undergird performance on some IQ subtest or other, needn't be caused by a particular underlying factor which fuels each performance. Instead, the correlations are plausibly caused by dynamic interactions between the distinct cognitive mechanisms. Research in cognitive psychology reveals that such dynamic relationships between cognitive processes exist. Short-term memory improves the development of cognitive strategies, and cognitive strategies improve the efficiency of short-term memory (Siegler & Alibali 2005). Language production and reasoning are similarly mutually beneficial: if you can think through it, then you can put it into words better, and if you can put it into words better, then that helps you think through it better (Fisher et al. 1994). And so on. These sorts of dynamic interactions between distinct cognitive mechanisms generate positive feedback loops, ensuring that strong correlations emerge over time between how well mechanisms function across the cognitive system.

g is an explanandum, not the explanans, of the mutualistic functioning of cognitive mechanisms. If theorists force *g* into the role of explanans, then they'll find that it is, at best, a low-fidelity model of that functioning: it idealizes away from all of the independently interesting, messy and complex mechanistic details. Van der Maas and colleagues (2014) go on to infer that *g* is of *theoretical* interest only as something to be explained; it is a *predictively* powerful construct, but it doesn't itself do any interesting explanatory work.

4. *g* as bridge model

I think this last inference is mistaken. On my view, *g* does interesting explanatory work, *not* as a model of mechanisms, but as a *bridge model* that illuminates the relationship between folk psychological intelligence and the functioning of cognitive systems.

On Weisberg's (2013) influential account, models are (concrete, mathematical, or computational) structures plus construals—scientists' interpretations of those structures as descriptions of target systems. Bridge models are structures that scientists construe as describing the relationship between two or more target systems. Bridge models are particularly useful as aids to explanations of the relationships between two different levels (or otherwise incommensurate varieties) of scientific explanation. Most explanatorily powerful models idealize away many irrelevant features of their target systems. In the case of bridge models, this means ignoring many (if not all) of the features of each of the target phenomena that aren't directly related to the other target phenomenon.

My positive proposal is that the same idealizations and abstractions that render *g* a low-fidelity model of both folk psychological intelligence and its cognitive underpinnings also render it a high-fidelity bridge model. By distilling the common core of IQ-test-taking-ability, *g* idealizes away all of the details of cognitive functioning except the fact that cognitive systems produce a positive manifold. At the same time, *g* also idealizes away the aspects (indeed, whole varieties) of folk psychological intelligence that aren't tracked by performance on IQ subtests. Nevertheless, under the proper respective construals, *g* serves as a low-fidelity model of each of these phenomena. In so doing, it doesn't allow researchers to get a very firm grasp on either the folk psychology or the cognitive psychology of intelligence. But, properly construed, it could allow theorists to get a firmer grasp on the relationship between these two varieties of psychological explanation. In Sellarsian jargon: *g*, construed as a bridge model, can help fuse the manifest and scientific images of intelligence into one synoptic vision.

As construed by van der Maas, *g* doesn't provide a mechanistic explanation, but it does capture the fact that cognitive mechanisms dynamically work together to form a general substrate for the constitutively comparative problem-solving capacities that constitute the relevant variety of folk psychological intelligence. Taken from the other direction, *g* is, at best, a low-fidelity model of folk psychological intelligence: it idealizes away from the multifarious cross-cultural differences between folks' conceptions of intelligence, and from many of the messy and complex details within conceptions. Nevertheless, *g* is a high-fidelity model of those aspects of folk psychological intelligence that are realized by the mutualistic network of cognitive mechanisms that subserves IQ-test-taking-ability. When properly construed as a bridge model, *g* thereby helps reveal why and how one variety of lay intelligence attribution is genuinely powerfully predictive (and in some senses explanatory) of human behavior. An idealization of the attributed suite of constitutively comparative problem-solving capacities maps onto a predictively fecund idealization of the dynamic interactions between cognitive mechanisms.

By the same token, treating *g* as a bridge model is explanatory of its own extremely high correlation with certain measures of success in life. *g* isn't a great measure of any particular aspect of cognitive functioning. Nor is it a great measure of any particular folk conception of intelligence. But it does help researchers zero in on those aspects of cognitive functioning—the relevant mechanisms and their interactions—that undergird core features of some culturally salient folk conceptions of intelligence. In other words, it is a great measure of the features of cognitive functioning that many people value when they value intelligence—and thus of the aspects of cognitive functioning that lead to certain kinds of success in a society partly structured by people's values.

Researchers make a mistake when they infer that *g* must be a great measure of cognitive functioning, since it is so predictive of success. On the contrary, we should expect *g* qua bridge model to correlate with success better than any great direct measure of cognitive functioning. After all, most folks (and their social institutions) don't care a wit about rewarding cognitive functioning per se—they care about rewarding those people whose cognitive functioning has put them in a position to accomplish valued goals. At the same time, we should also expect *g* qua bridge model to correlate with success better than any great direct measure of intelligence as it emerges in relation to any given folk conception, since it zeroes in on those aspects of folk psychological intelligence that are actually undergirded by more or less efficient and effective cognitive functioning.

I'll conclude by drawing a concrete philosophical lesson. Psychofunctionalists have often argued that belief attributions must literally describe cognitive functioning, since they are predictively fecund (Fodor 1987; Quilty-Dunn & Mandelbaum 2018). There is something to this thought: folk psychological beliefs must be undergirded by reliable patterns of cognitive functioning. Nevertheless, *g*, as bridge model, clearly highlights how intelligence attribution is predictively fecund without literally describing cognitive functioning. Likewise, the predictive fecundity of belief attribution at most shows that, if we were to construct the relevant bridge model, we'd find a relationship between some aspects of folk psychological belief and some cognitive underpinnings that are responsible for behaviors that can be predicted via belief attribution. It can't show that folk psychological belief is reducible to those cognitive underpinnings: intelligence attribution is similarly predictively powerful despite being irreducible. Of course, this doesn't show that psychofunctionalism about belief is false. Some reductions of folk psychological phenomena to cognitive phenomena are well-founded. But I have argued that, intrapersonally speaking, human cognitive architectures don't feature anything well-labeled 'intelligence'. It is still an open question, which won't be settled by appeals to the predictive power of folk psychology, whether they feature anything well-labeled 'beliefs'.

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