Process Overlap Theory is a Milestone Achievement Among Intelligence Theories

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Commentary

Process Overlap Theory is a Milestone Achievement Among Intelligence Theories

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In their finely wrought first sentence, Kovacs and Conway (2019) offer a koan worthy of prolonged meditation. Their question of how there is "no such thing" as general intelligence (*g*) and yet psychometricians can be remarkably good at measuring it would be easy to dismiss if it were a cynical joke, but Kovacs and Conway advance the question respectfully and in good faith. Their efforts to wrestle with this paradox have paid off in the form of a productive explanation of general intelligence. Because debates about the theoretical status of *g* can turn ugly, it is refreshing to read an attempt to resolve the controversy that treats all parties with dignity.

Despite considerable variation in the particulars, there is a sense in which psychometric theories of intelligence have yielded a consistent set of answers for many decades. From the debut of factor analysis (Spearman, 1904) to the present, psychometric *g* appears in essentially every cognitive ability data set (Carroll, 1993; Jensen, 1998). Although Spearman hypothesized that group factors did not exist, they were observed almost as soon as researchers started looking for them (Burt, 1909). Not long after that, they began appearing even in data collected in Spearman's lab, and he devoted a chapter to describing group factors in his seminal work, *The Abilities of Man: Their Nature and Measurement* (Spearman, 1927). Although the labels differ, early multifactor models (Holzinger & Swineford, 1939; Thurstone, 1938) identified constructs that closely resemble those of current, widely, accepted psychometric models (Schneider & Flanagan, 2015). Whatever problems we may have in the psychometric study of intelligence, a shortage of replicable findings is not among them.

We have devoted much of our scholarship to tending and amending two grand psychometric theories whose source theorists have passed: *Gf-Gc* theory (Horn & Blankson, 2005; Horn & Cattell, 1966) and the Three Stratum Theory of Cognitive Abilities (Carroll, 1993). These theories have only minor differences with respect to the narrow and broad abilities of intelligence, but they differ on the theoretical status of *g*. Carroll believed that the evidence for psychological *g* is overwhelming and Horn and Cattell were equally convinced that psychometric *g* does not represent a true psychological construct.

The Cattell-Horn-Carroll (CHC) theory of cognitive abilities (McGrew, 1997, 2005, 2009; Schneider & McGrew, 2012, 2018)

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does not replace *Gf-Gc* theory or the Three-Stratum Theory.[1] It is more like a superordinate category in the same way that "Christianity" describes a group of highly similar religious traditions that in places may have sharp theological differences. CHC theory is an ecumenical space in which scholars can contribute to the growing knowledge and understanding of the broad and narrow abilities of intelligence without fighting endlessly about *g*. Personally, we both suspect that psychometric *g* is not an ability in the same sense as the other abilities in CHC theory, but we are openminded to the possibility that Carroll and others are right about the psychological reality and importance of *g*. Officially, CHC theory will remain neutral about the status of *g* until the evidence one way or the other becomes convincing not only to us but to most scholars in the field. For this reason, we have followed the introduction of POT and its reception by other scholars with keen interest.

Additional Causes of the Positive Manifold

We appreciate that POT is an explicitly incomplete explanation of the general factor intelligence—Kovacs and Conway (2016a) assume that cognitive tests correlate for additional reasons beyond process overlap such as mutualism (Maas et al., 2006) and individual differences in white-matter integrity. Like Kovacs and Conway, we are skeptical that mutualism is a complete explanation of the positive manifold but believe it to be a plausible partial cause of it. We believe that there are many additional explanations of the positive manifold that do not necessarily involve psychological *g*—see Barbey (2018) for a description of relevant explanations of the positive manifold such as lateral prefrontal cortex theory, multiple demand theory, and network neuroscience theory. Additionally, all the fuss regarding the positive manifold representing *g* may be overstated. Stankov (2017) accepts the notion of *g*, but suggests that when other less known tentatively identified broad abilities (e.g., *Gk* = kinesthetic abilities; *Gh* = tactile abilities; *Go* = olfactory abilities) are added to structural models, the prominence or importance of *g* decreases—it becomes a "diminutive general."

In their simulation study, Kovacs and Conway (2019) created a large matrix of domain-general and domain-specific processes, each statistically independent of the other. We understand why the processes were assumed to be mutually independent in a demonstration of how process overlap can produce a positive manifold. To explain the positive manifold with correlated variables is to beg the question. However, the assumption that individual differences in basic psychological processes are uncorrelated seems unlikely. If they were uncorrelated, it would mean that they were not influenced by any "common causes" such as disease, injury, malnutrition, genetic variants, or societal practices that influence many aspects of brain functioning simultaneously.

We assume that cognitive processes can be influenced simultaneously via mechanisms that have nothing to do with psychological *g*, even if psychological *g* exists. For example, lead exposure has wide-ranging effects on the entire body, including the brain, particularly during early development (Caito & Aschner, 2017). It is likely that it simultaneously degrades all cognitive functions, even if some functions are more fragile than others. Individual differences in lead exposure alone could produce a positive manifold, albeit a weak one. The cumulative effect of many general neurotoxins would produce a somewhat stronger positive manifold. The general factor that would emerge in a factor analysis of abilities correlated solely because of individual differences in exposure to general toxins would be quite real, but such a factor would not represent an ability.

Trisomy 21, the cause of Down Syndrome, disrupts the function of essentially all neurons (Patterson, 2009; Roubertoux & Kerdelhué, 2006). Thus, even if all cognitive abilities were otherwise uncorrelated, the presence of Trisomy 21 in some members of the population would give rise to a small positive manifold. Likewise, any genetic variant or chromosomal abnormality that affects the function of most or all neurons would produce a positive manifold, even if none of them act on an ability we would call psychological *g*.

It is well documented that people with high cognitive abilities tend to have higher socioeconomic status (Gottfredson, 1997). It is also likely that economic inequality makes the positive manifold larger than it would otherwise be. If higher-status individuals are able to gain access to better health care, eat healthier food, live in areas with lower levels of environmental toxins, and send their children to schools that provide systematically better education on multiple dimensions, then it is seems likely that otherwise uncorrelated cognitive functions would become positively correlated.

If individual differences in cognitive processes are somewhat correlated due to common causes, mutualism, or other reasons, then the degree of process overlap need not be as high as Kovacs and Conway (2019) posit in their simulation study to produce a positive manifold as strong as observed in empirical studies.

Additional Causes of Ability Differentiation

Process overlap theory gives us a plausible mechanism by which ability differentiation occurs in the form of executive function bottlenecking. We suspect that there are additional mechanisms. We suspect that there are far more variables that interfere with all cognitive processes than there are variables than improve upon the normal functioning of all cognitive processes. Our suspicion rests on the assumption that we can with a single action much more easily destroy a complex system than improve every component of it at once. If we want to improve the quality of an automobile—including the seats, the stereo system, the brakes, the horsepower, the fuel efficiency, and the windshield wipers—we will need to make many small improvements to each component separately. If we want to ruin every part of the car, we merely need to bury it in a sandpile, drive it into a lake, drop it off a cliff, smash it in a car crusher, or lend it to unsupervised teenagers.

[1] The CHC model presented in Figure 1 in Kovacs and Conway (2019) references an older version of CHC theory. The most important recent changes at the broad ability level are (a) the change of *Gsm* to *Gwm* (short-term working memory) and (b) the splitting of *Glr* into two broad abilities, *Gl* = Learning Efficiency; *Gr* = Retrieval Fluency (Schneider & McGrew, 2018).

In like manner, to disrupt brain functioning globally is a simpler task compared to improving the entire brain at once. If the positive manifold is partly explained by variables with global influence on brain functioning and if variables with global influence on brain functioning are disproportionately harmful, then test performances will correlate more strongly among people with low ability. In contrast, people with high ability would likely have experienced fewer large global negative influences and had more small local positive influences on cognitive processes. Thus, their test performances would be predicted to have weaker correlations. Thus far, the literature on genetic influences on cognitive ability are consistent with our hunch. Most known genetic effects on cognitive ability that are global and large are negative (e.g., PKU). Thus far, there are no known single gene variants that produce large global positive effects on cognitive ability (Hill et al., 2018).

Concerns about POT-Structural

If the statement that *g* is a formative variable merely means that it is the result of overlapping processes and has no causal role in creating the positive manifold, then we have no objection to the statement. However, Figure 3 in Kovacs and Conway (2019) implies that *g* is the sum of all the CHC broad ability factors. Because the broad abilities are highly correlated, the sum would mostly consist of shared variance. However, it would also consist of variance specific to each broad factor. If so, it would seem that formative *g* is not purely general but a mix of overlapping and non-overlapping abilities.

More importantly, it is not clear that formative *g* is of any importance in POT. A formative variable like socioeconomic status is useful to specify if we can assume that the benefits of high status can be obtained by a variety of means (e.g., earning more money, becoming more educated, or attaining positions of authority in important organizations) and that a lower value on one indicator of status can be compensated for by a high value on another indicator. A less-educated but wealthy entrepreneur and a well-educated professional with a modest income may have different flavors of status, but they likely enjoy many of the same benefits that come from being an esteemed member of a community. We are curious if people with the same level of formative *g* are predicted to enjoy similar advantages even if the ingredients of formative *g* are quite different. If so, formative *g* is worth keeping. If not, there is no reason to clutter our theories with it other than as a historical footnote.

Broad Abilities Are as Mysterious as Psychometric g

We agree with Kovacs and Conway (2019) that constructs with a realist ontology and reflective measurement are the proper focus of intervention and theoretical investigation. They suggest that CHC broad factors may serve in this role. Broad factors consist of several narrow ability constructs. For example, *Gv* (visual-spatial processing) consists of narrow abilities such as the ability to rotate mental images quickly, visualize missing pieces of a partial image, estimating line lengths, and many other abilities. Unfortunately, there are so many narrow abilities that it is impractical to measure them with fidelity in any one individual. Thus, we agree with Kovacs and Conway that CHC broad ability constructs are the proper focus for practitioners when they interpret cognitive ability profiles. Even so, we are not sure if broad abilities reflect abilities with realist ontology or if they are higher-order abstractions like psychometric *g*.

For now, POT has no explanation for the clustering of narrow abilities within broad constructs. Frankly, neither does CHC theory. We agree with Kovacs and Conway (2016b) that mutualism may be an especially important explanation of the clustering of basic processes into specific ability clusters. Cattell (1987) speculated that some broad factors reflect individual differences in the functioning of primary and association cortex regions for different sensory modalities. Some clustering of narrow abilities may occur simply because specific brain functions are largely determined by regions of the brain that are in close physical proximity. For example, a small lesion in the parietal lobe may interfere with several visual-spatial narrow abilities at the same time. Another mechanism that causes certain narrow abilities to form broad ability clusters is that they use the same sets of neurotransmitters and that individual differences in the functioning of a specific neurotransmitter may affect specific sets of cognitive processes but not others. For example, enhancements in acetylcholine signaling may improve visual-spatial functions (Gratton et al., 2017).

POT Need Not Die If Psychological g Is Proven to Exist

Suppose that in the coming years that we find convincing evidence that a psychological attribute consistent with *g* theory exists. For example, Geary (2018) has presented an intriguing hypothesis, which would be consistent with Spearman's concept of a general mental energy, that efficiency of mitochondrial functioning at the level of individual cells may give rise to some psychological construct we could call *g*. Imagine that people really do use their general intelligence directly and actively to answer vocabulary tests, digit span tests, and mental rotation speed tests. Is it then possible to imagine that process overlap does not explain the positive manifold at all? We find it hard to believe that POT would be disproven entirely. There is a large but finite number of cognitive processes, and there are no pure measures of any of them. All tests are influenced by a mix of cognitive processes, and process overlap will account for at least some portion of their correlations.

The Future of POT

We find POT to be enormously appealing and will pay close attention to its development. We hope that greater clarity is forthcoming about exactly which processes are most important in determining intelligent performance in tests and in daily decisions.

POT has successfully caused us to reconsider many aspects of CHC theory. We have always been clear that abilities discovered by factor analysis do not necessarily describe processes operating within individuals. Thinking carefully about POT has made it clear that we need to articulate this point more clearly and forcefully when we describe CHC constructs.

Inspired by the POT item response model, we have started to wonder if we can define the boundaries between narrow abilities in CHC theory as ensembles of basic processes that necessarily overlap no matter how they are measured and determine success in a multiplicative manner. We hope that pondering the implications of POT will suggest new research questions and important refinements to CHC theory.

Author Contributions

Kevin S. McGrew and W. Joel Schneider, in their long-time collaboration, have co-developed a set of ideas about the nature of the general factor of intelligence from which they drew to write this commentary. Dr. Schneider wrote the initial draft, and Dr. McGrew edited it and added several key ideas.

Conflict of interest

Dr. W. Joel Schneider has no financial conflicts of interest to disclose. Dr. Kevin McGrew is a coauthor of the Woodcock-Johnson IV battery and discloses that he has a financial interest in the WJ IV.

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