Psychological constructs as local optima

David Moreau ✉ *and Kristina Wiebels*

Psychological constructs are necessary abstractions to operationalize otherwise intractable entities. However, the way constructs are defined and refined over time introduces notable bias into models of behaviour, which prevents effective knowledge building within and across subfields.

Many life outcomes, such as academic and professional success, lifespan, and relationship longevity, are predicted by working memory capacity — the ability to control and maintain task-relevant information in the service of complex cognition[1]. Because a construct like working memory capacity cannot be directly observed, psychologists rely on specific tests (working memory tasks) to measure it in a rigorous, scientific way.

In principle, new working memory tasks could be designed to assess working memory capacity in a range of contexts and environments. By tapping a diverse set of empirical instantiations (operationalizations), this process could enable richer, more valid assessments that better represent the variety and complexity of ecological situations drawing upon the construct. However, in practice the process of developing new working memory tasks is far less creative: instead of relying on a consensus definition of working memory capacity to seek original, novel operationalizations, new tasks are typically established via convergent validity (the extent to which the new measure is related to existing measures of the same construct). Consequently, new working memory tasks end up closely resembling previous ones.

The validation and refinement of other psychological constructs generally follows a similar process, in which convergent validity largely determines which tests are readily understood to probe the same constructs. This process creates a strong dependency between current and previous tests and constrains empirical exploration on the basis of initial operationalizations. Consequently, current constructs closely match those of a century ago, not only in their taxonomy but also in the paradigms and assessments used to measure them. Restricting exploration in this way can prevent uncovering the true delineation of a construct by leaving valuable operationalizations untapped.

An optimization problem

The process of defining and refining constructs in psychology can be considered an optimization problem. In computer science, success in solving optimization problems is determined by the initial starting point within the search space and the strategy used to explore the search space. When algorithms fail to adequately sample the space of all possible solutions, algorithmic searches may get stuck in local optima — apparently efficient, but in reality suboptimal, solutions — falling short of discovering true, global optima.

Similarly, the initial operationalizations of psychological constructs, together with the strategy deployed to refine them, influence our ability to discover the optimal partition of the human mind. Although starting points for the empirical exploration of psychological constructs were traditionally informed by careful observations and detailed introspection, most pre-date scientific advances that have profoundly shaped understanding of brain and mind. Initial operationalizations are therefore unlikely to have perfectly captured their respective constructs from the outset.

Suboptimal starting points are not necessarily problematic if search strategies include built-in mechanisms that encourage exploration. However, unless researchers deliberately wander off charted territory, constructs are, by design, bound to gravitate around their initial, imperfect operationalizations. In this scenario, solutions tend to fall into local optima closest to the starting points, rather than global optima. More research does not solve the problem: as new findings accumulate, researchers get further entrenched into the prevailing construct operationalization, making it increasingly difficult to redirect empirical investigations in new directions that could eventually lead to a genuine, global understanding.

The consequences of exploring too little are widespread and tangible. Despite decades of research, core disagreements remain about the precise boundaries between ubiquitous constructs such as executive function, cognitive control, attention and working memory. This lack of consensus in construct delineation also obscures similarities across research areas that have developed independently, with distinct terminology and paradigms referring to the same underlying ideas[2]. For example, self-regulation is often measured with tests of impulse control in personality psychology, but with executive function tasks in cognitive psychology[3].

School of Psychology and Centre for Brain Research, University of Auckland, Auckland, New Zealand.

✉*e-mail: d.moreau@auckland.ac.nz*

https://doi.org/10.1038/s44159-022-00042-2

Because it segregates related findings while conflating others that would be best understood separately, this overall lack of consistency in construct delineation prevents effective cumulative knowledge building within and across subfields.

A tale of contrasting validities

This view might seem at odds with more than a century of research demonstrating that general traits and abilities can be partitioned into distinct subcomponents, many of which are supported by unique neural signatures. For example, working memory capacity correlates strongly with fluid intelligence but remains dissociable from it[4] and is supported by a specific functional brain network[5]. Yet the rich converging evidence for reliable and dissociable constructs does not guarantee epistemic validity; that is, it does not imply that current constructs represent an optimal, or even a good, partition of human attributes.

Objections to current construct delineations remain even if we restrict our discussion to the confines of predictive validity (the extent to which a measure predicts scores on some criterion outcome). For example, to say that working memory capacity is a good predictor of academic performance tells us very little about what 'good' means. Arguably any measure with a cognitive component, administered in testing conditions that resemble school curricula, will tend to correlate positively with academic performance. Predictive performance is relative, yet the alternatives against which predictions derived from psychological constructs are compared are typically not made explicit.

Focusing on predictive validity can also hinder efforts to understand constructs because measures based on more accurate operationalizations (that is, measures that better capture the 'true' construct) might have lower predictive validity than measures based on less accurate operationalizations, and therefore get discarded[6]. The same problem holds when comparing constructs with one another; for example, a fuzzy construct such as executive function might be more predictive of a given outcome than a more narrowly defined construct such as cognitive control not because it is a more valid predictor, but simply because it encompasses a broader range of cognitive abilities. Thus, predictive validity cannot serve as a substitute, or even a proxy, for epistemic validity.

Breaking free from local optima

Because it primarily reflects the historical hazards of construct refinement, the approach currently favoured in psychology almost certainly lacks epistemic validity. In this context, effective solutions cannot stem from higher predictive accuracy or fancier statistical models; rather, they require a fundamental epistemological shift in how psychologists study the mind.

In computer science, typical solutions to escape local optima are based on re-initializing starting values and deliberately nudging exploration towards new areas of the sample space. Similar approaches could be valuable to psychology; for example, it has been argued that psychological constructs need to be fundamentally redefined on the basis of recent advances in neuroscience[7]. This could be achieved via data-driven techniques to either infer mental structure from functional brain parcellation[8] or test existing construct delineations against neuroimaging data[9].

Attempts to refine psychological constructs as currently defined could also be valuable. Because this approach centres on the strategies used to guide empirical exploration, rather than on redefining the constructs themselves, it promotes continuity with past literature. One particularly promising avenue is systematically manipulating construct operationalizations to probe their influence on task performance. In the context of working memory, efforts to diversify operationalizations by varying stimuli and experimental parameters could be further extended to more complex environments with greater ecological validity. Direct manipulation of task parameters can help researchers understand when current operationalizations break apart and why, thus providing important insight about the hypothesized boundaries between constructs.

Researchers can also exploit environmental factors to assess the psychometric structure linking constructs to one another. For example, recent evidence has demonstrated the potential of lesion studies to arbitrate between competing structural models of cognitive ability[10]. Similarly, studying the impact of interventions on constructs and their dynamics — in particular, which constructs tend to covary over the course of an intervention and which do not — can shed light on the architecture of human traits and abilities. Leveraging the dynamics of cognitive performance elicited by environmental factors can help to generate focused and falsifiable predictions about constructs that can adjudicate between competing theories.

Encouraging ourselves to venture off the beaten path by reassessing current definitions of psychological constructs and exploring their boundaries can facilitate tangible progress in the field while ensuring that empirical investigations remain well grounded and trustworthy.

1. Barrett, L. F., Tugade, M. M. & Engle, R. W. Individual differences in working memory capacity and dual-process theories of the mind. *Psychol. Bull.* **130**, 553–573 (2004).
2. Moreau, D. How malleable are cognitive abilities? A critical perspective on popular brief interventions. *Am. Psychol.* https://doi.org/10.1037/amp0000872 (2021).
3. Enkavi, A. Z. et al. Large-scale analysis of test-retest reliabilities of self-regulation measures. *Proc. Natl Acad. Sci. USA* **116**, 5472–5477 (2019).
4. Conway, A. R. A., Kane, M. J. & Engle, R. W. Working memory capacity and its relation to general intelligence. *Trends Cogn. Sci.* **7**, 547–552 (2003).
5. Gray, J. R., Chabris, C. F. & Braver, T. S. Neural mechanisms of general fluid intelligence. *Nat. Neurosci.* **6**, 316–322 (2003).
6. Shmueli, G. To explain or to predict? *Stat. Sci.* **25**, 289–310 (2010).
7. Poldrack, R. A. & Yarkoni, T. From brain maps to cognitive ontologies: informatics and the search for mental structure. *Annu. Rev. Psychol.* **67**, 587–612 (2016).
8. Smith, S. M. et al. Correspondence of the brain's functional architecture during activation and rest. *Proc. Natl Acad. Sci. USA* **106**, 13040–13045 (2009).
9. Poldrack, R. A. et al. Discovering relations between mind, brain, and mental disorders using topic mapping. *PLoS Comput. Biol.* **8**, e1002707 (2012).
10. Protzko, J. & Colom, R. Testing the structure of human cognitive ability using evidence obtained from the impact of brain lesions over abilities. *Intelligence* **89**, 101581 (2021).

Competing interests
The authors declare no competing interests.