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# Moderators of learning and performance trajectories in microworld simulations: Too soon to give up on intellect!?

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ABSTRACT

The burgeoning increase in the importance given to non-cognitive factors in complex decisions making, has led to calls to question intelligence as the primary explanatory model of success. Features of a business microworld simulation were experimentally manipulated to investigate the incremental value of 20 cognitive and non-cognitive predictors of learning and performance trajectories. Using a combined experimental-differential paradigm and mixed-level modelling, it was predicted that of these, facilitating personality traits (e.g., openness and extraversion), growth/motivational mindsets (e.g., learning goals, need for cognition, and beliefs of malleability), and tentatively, emotion-regulation (e.g., managing and facilitating emotions) would moderate the impact of microworld complexity and experience on performance. Results from 142 experienced business managers replicate the pervasive importance of general and domain-specific reasoning. Contrary to expectations, of the 16 non-cognitive factors investigated, only three mindset variables showed incremental value, and only performance-goal orientations moderated effects above reasoning. These findings give prima facie reason to question the purported importance of conative factors, over and above intellect. However, rather than discount non-cognitive factors entirely, our analyses suggest that with refinement, microworlds and mixed-level modelling may well-support the experimental methods needed to understand moderators of real-world problem solving.

## 1. Introduction

Success in cognitively demanding activities is determined by a multiplicity of factors. Cognitive abilities, such as working-memory and general reasoning capacity, have been demonstrated time and time again as consistent and dominant predictors of work and formal educational outcomes (Gottfredson, 1997; Sternberg & Grigorenko, 2002). Although the role for "non-cognitive" factors in training is rarely disputed (Barrick, Mount, & Judge, 2001), they have historically been considered secondary to intellect. However, this has begun to change, particularly over the last two decades (Scherbaum, Goldstein, Yusko, Ryan, & Hanges, 2012). In a review of the work-based training literature of the late 20th century, Colquitt, LePine, and Noe (2000) concluded that traditional cognitive abilities approaches to "trainability [are] insufficient, given the strong effects of motivational variables over and above cognitive ability" (p. 702). Sitzmann and Ely's (2011) meta-analysis of self-regulated learning in work-related training reported that taken together, "… self-regulatory processes collectively account for more variability in learning than the strongest independent predictor: cognitive ability" (p. 435) – 17% of the variance in learning was accounted for by goals, persistence, effort, and self-efficacy, after controlling for cognitive ability.

Other claims of the importance of non-cognitive factors are more controversial. Concepts such as self-control have been proposed to outdo intelligence in predicting success (Duckworth & Seligman, 2005, 2017). Grit, a related concept defined as perseverance and consistency of passion for long-term goals, has also been proposed as a broad incremental success indicator over and above measures of intellect. Duckworth, Peterson, Matthews, and Kelly (2007, p. 1099) speculated that "grit, like IQ, is of ubiquitous importance in all endeavors in which success requires months or even years of sustained effort and interest". While there is controversy over whether both aspects of grit, i.e., perseverance and consistency of passion, are associated with performance, and whether they are distinct from well-established constructs such as conscientiousness and dispositions toward engaging in deliberate practice (Credé, Tynan, & Harms, 2017), it remains the case that the historical dominance of intellect as the most important, general predictor of success is being questioned. Even within more traditional

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cognitive domains, there are moves to incorporate a broader range of conative dispositions when accounting for success. Notably, Dörner and Funke (2017) proposed a revised definition of complex problem solving as "not only a cognitive process but … also an emotional one strongly dependent on motivation … [and other] self-regulated psychological processes" (p. 6).

The current research sought to investigate the role of conative dispositions in complex learning and decision-making through a frame of self-regulation (Bandura, 1997; Birney, Beckmann, Beckmann, & Double, 2017; Güss, Burger, & Dörner, 2017; Metcalfe, 1993; Mitchum, Kelley, & Fox, 2016; Stankov, 1999; Stankov & Lee, 2017; Zimmerman, 2002). Based on our review of the literature, it is our contention that under the right conditions, the importance of conative dispositions in the application of cognitive resources to learning, decision making and problem-solving should be observable, if they exist, over and above cognitive abilities. We argue, as have others (Cronbach, 1957), that the traditional approach to studying correlates of problem solving that almost exclusively relies on between-subjects designs, is limited in its capability to serve as the foundation for understanding dynamic decision making. Accordingly, we adopt experimental methods to investigate individual differences (and vice versa) using a business microworld simulation as the basis of our experimental design. Our study is based on a sample of experienced mid-level senior managers who are engaged in training that is structured and framed with learning objectives relevant to their work. This combination provides an effective methodological paradigm for investigating real-world learning and performance (J. F. Beckmann & Goode, 2017; Goode & Beckmann, 2010), while allowing for experimental manipulations that are necessary to identify the moderating effects of other variables.

In the following sections, we briefly review the nature of microworld simulations and describe the one used in the current study. We then go on to reflect on the relationship between our task and typical complex problem solving activities, and introduce four clusters of individual differences variables the extant literature would predict to play a role in determining performance and learning trajectories –*Personality*, *Growth Mindsets*, *Emotional Intelligence,* and of course, *Reasoning*.

### 1.1. Microworld simulations

In business education and training, simulations are frequently used to allow trainees to explore, make mistakes and gain experiences in risk-free virtual environments that do not impose real costs on the trainee or the organization. The development of a simulation typically starts with an investigation and analysis of the structure of the real-world task with the goal of identifying core processes and procedures, which are then simulated in a virtual environment – the microworld. Microworlds can provide a more dynamic and intrinsically engaging training experience than commonly used case-study discussions (Wood, Beckmann, & Birney, 2009). They are often designed to accelerate learning of problem structure by collapsing long periods of history into short periods of simulation time (Funke, 1998).

Simulation variables can be classified into decision and outcome variables, as well as intervening mediating and moderating variables (Wood et al., 2009). *Decision variables* are those for which the problem solver or learner sets the values. *Output variables* form the feedback that is provided. The outputs are the consequences of the input decisions plus effects due to intervening relationships within the model. In practice, microworlds are likely to have multiple inputs, including some outside of the direct control of the learner. As in the real world, both the uncontrolled inputs and *mediator variables* may be unobserved, making it difficult to incorporate them into one's mental model of the problem structure. Mediators add to complexity if they entail delays between the inputs and the observed outputs (e.g., across multiple decision time-points). *Moderator variables* further add to the complexity by changing the relationship between decision and outputs variables under different circumstances (Brehmer & Dörner, 1993; Gonzalez, Thomas, & Vanyukov, 2005; Goodman, Wood, & Hendrickx, 2004; Sterman, 2000). For example, decision rules may change as a result of variations in task conditions, such as the differences in actions required when leading a team of motivated staff versus the actions needed to engage and lead a team of unmotivated staff (Goodman et al., 2004).

The microworld used in the current study was modelled on business stock management processes and decision making. The theoretical complexity of decisions was manipulated along two independent dimensions intrinsic to this problem, delays and outflow Delays occurred with regard to hiring and firing decisions (due to time needed to train new hires or due to notice periods when firing). Outflow of stock, over and above sales (e.g., through waste, defects, etc), was the other complexity variable manipulated. In all cases, the goal was to reach and maintain an ideal level of net inventory by taking into consideration staffing delays and stock outflow over a period of 30 simulated weeks via the management of the workforce (number of staff). The net inventory is thus managed solely via weekly staff hiring and firing decisions. Each weekly decision constitutes a "trial" within the microworld. A "run", consisting of 30 trials, constitutes the 30-week simulated period. That is, trials are nested within runs, and multiple runs (under different experimental conditions) are nested within participants. Performance was operationalised as a penalty score associated with the costs of a suboptimal level of inventory and staffing. Dynamic feedback is presented as a graph of the accumulating penalty score (see Supplementary Fig. 1 in Supplementary Material).

### 1.2. Microworlds and complex problem solving

Microworlds of the type we have just described, can be conceived generally to fall into the broad class of dynamic activities termed "Complex Problem Solving" or CPS tasks. Different researchers have designed CPS tasks for qualitatively different purposes, resulting in the term CPS taking on many different meanings (J. F. Beckmann, Birney, & Goode, 2017). CPS first emerged from a research tradition which considered it as a broad ability-related construct (or set of constructs) necessary for interacting successfully in a world that is more dynamic and inherently complex than what is traditionally assessed in standardized tests of cognitive abilities (Funke & Frensch, 2007; Greiff, Stadler, Sonnleitner, Wolff, & Martin, 2015). This dynamic nature is reflected in Dörner and Funke's (2017) (revised) definition of CPS ability, which emphasises "(a) self-regulation of processes, (b) creativity (as opposed to routine behavior), (c) a bricolage type of solution, and (d) the role of high-stakes challenges" (p. 6–7), in addition to cognitive ability. In practice, CPS tasks variously instantiate this definition to different extents.

Over time, like microworlds, CPS tasks have been presented as activities varying from high fidelity simulations with many input and output variables (approaching something akin to commercial flight simulators), to "*minimal complex systems*" which present the simplest possible interaction of variables (typically deterministic and linear) needed to assess a lower-bound CPS ability (e.g., for educational assessment purposes, such as PISA Funke, Fischer, & Holt, 2017; OECD, 2013). Inherent in the use of any task for assessment is a requirement for psychometric rigour (i.e., unidimensionality and validity). However, the higher-bounds of CPS competencies are thought to entail more than what is required to solve problems with a small number of linear equations. In fact, Dörner and Funke (2017) argue that an emphasis on psychometric qualities has led to a reduction in the psychological complexity of such tasks and concordantly, a reduction in their validity as assessments of "true" CPS ability.

High psychometric rigour may also, counter-intuitively, be antithetical to other objectives, for instance, when CPS tasks are used as dynamic multi-faceted training activities, or when the research objective is to decompose the multi-dimensional determinants of performance in dynamic settings. In these cases, validity contemplations