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Why does working memory capacity predict RAPM performance? A possible role of distraction

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ABSTRACT

Current theories concerning individual differences in working memory capacity (WMC) suggest that WMC reflects the ability to control the focus of attention and resist interference and distraction. The current set of experiments tested whether susceptibility to distraction is partially responsible for the established relationship between performance on complex span tasks and the Raven's Advanced Progressive Matrices (RAPM). This hypothesis was examined by manipulating the level of distraction among the incorrect responses contained in RAPM problems, by varying whether the response bank included the most commonly selected incorrect response. When entered hierarchically into a regression predicting a composite score on span tasks, items with highly distracting incorrect answers significantly improved the predictive power of a model predicting an individual's WMC, compared to the model containing only items with less distracting incorrect responses. Additional analyses were performed examining the types of errors that were made. A second experiment used eye-tracking to demonstrate that these effects seem to be rooted in differences in susceptibility to distraction as well as strategy differences between high and low WMC individuals. Results are discussed in terms of current theories about the role of attentional control in performance on general fluid intelligence tasks.

1. Introduction

Since the earliest days of psychology, one recurring topic has been the measurement of intelligence. The idea that there may be stable differences between individuals in their general abilities that allow some to learn faster and more easily than others, particularly in educational settings, is indeed an intriguing concept. As such, a considerable amount of individual differences research has focused on the study of intelligence, with one interesting finding being the correlation in performance on tests of working memory capacity (WMC) and general fluid intelligence (gF; Kane et al., 2004). In particular, the Raven's Advanced Progressive Matrices (RAPM, Raven, Raven, & Court, 1998) has been used to investigate the WMC–gF relationship in numerous experiments and has consistently been shown to correlate with performance on complex span tasks at around .30 (Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Kane et al., 2004; Unsworth & Engle, 2005; Wiley & Jarosz, 2012; Wiley, Jarosz, Cushen, & Colflesh, 2011). While this correlation has been reliably demonstrated, there are still many questions about it that are unanswered. In particular, what is it about tests of WMC that predicts performance on the RAPM?

In practice, WMC is usually measured by complex span tasks that assess the ability to hold multiple objects in memory while performing a concurrent processing task. As shown in the left side of Fig. 1, the operation span (Ospan) task involves remembering lists of words while simultaneously verifying math equations. Ospan presents processing and memory components in each item, followed by a test for the memory components at the end of the set of items. In contrast, the

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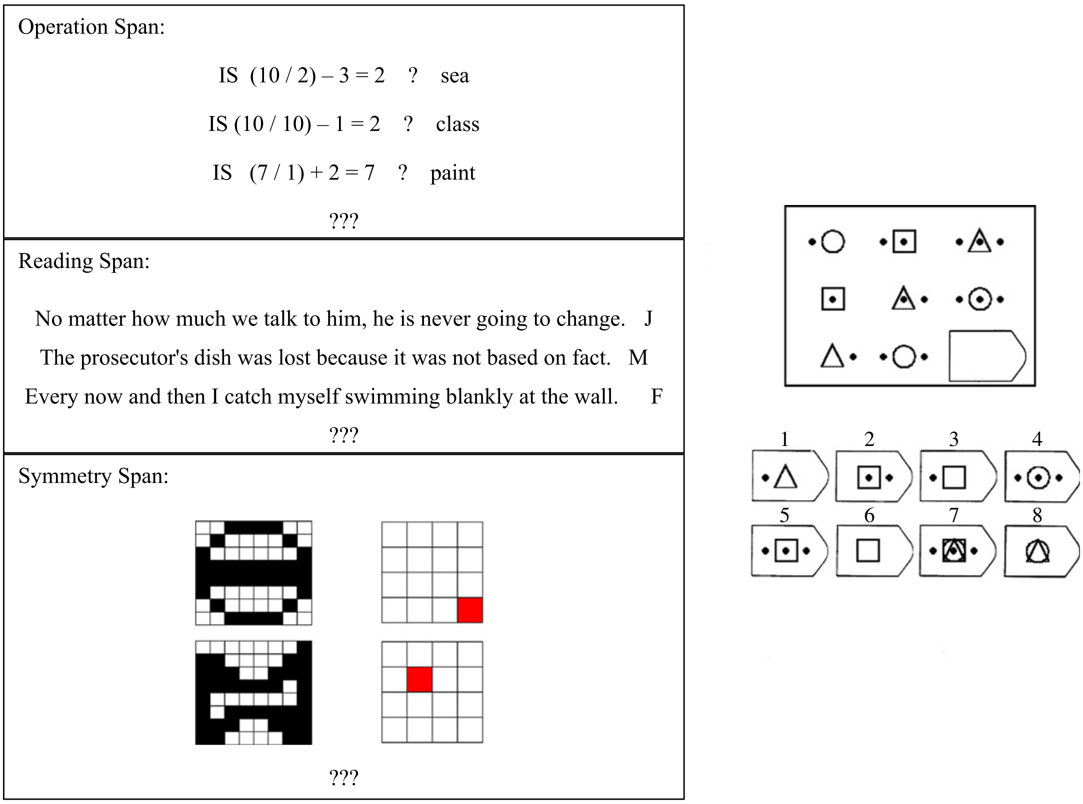

Fig. 1. Top-left: An example of an operation span trial. Each line appears independently, with answers written upon the appearance of the three question marks. Middle-left: An example of a reading span trial. Each line appears independently, with answers written upon the appearance of the three question marks. Bottom-left: An example of a symmetry span trial. Each line appears independently, with answers written upon the appearance of the three question marks. Note that the symmetry judgment and the grid intended for memorization are not on the screen at the same time. Right: An example of an RAPM-like problem.

RAPM (Raven et al., 1998) was originally designed as a test of the ability to find meaning in complex stimuli. The RAPM has been found to load heavily on to measures of gF across numerous studies (e.g., Kane et al., 2004; Marshalek, Lohman, & Snow, 1983), and is considered a prototypical test of gF by the designers of the test (Raven et al., 1998). Each item consists of a 3×3 matrix of figures that change along both rows and columns according to certain rules, with the bottom right figure missing. The problem solver is instructed to look both along the rows and down the columns in order to select the figure that correctly completes the pattern from a bank of potential responses beneath the matrix. The right side of Fig. 1 depicts a RAPM-like problem where the correct answer is response option 5, which can be reached by following a progression rule along the rows (adding a dot to each consecutive figure) as well as a distribution of three rule (each shape appearing once in each row/column). In the RAPM, test items are arranged in terms of their normed difficulty, with the easiest problems presented first and the hardest problems presented last.

While WMC tasks and the RAPM share relatively few surface features, the relationship between the two has been repeatedly demonstrated, and has resulted in numerous suggestions about why they are related. One early idea suggested that it is the number of rules and goals that must be stored in memory that drives the relationship between the two (Carpenter, Just, & Shell, 1990; Mulholland, Pellegrino, & Glaser, 1980). That is, the rules governing the progression of figures in the RAPM item's matrix, and the goals of the problem solver, must be held in WMC while completing each item. This account suggests that as items become more difficult over the course of the RAPM and require more rules and goals to solve, the relationship between the RAPM and WMC should increase. This *capacity account* is in line with some of the current capacity theories of WMC, such as the time-based/resource sharing model of WMC (Barrouillet, Bernardin, & Camos, 2004). Essentially, a high WMC individual has more resources to store information while concurrently processing, and as such can better keep track of goals and rules in a given item as items become more difficult.

An additional approach is a *learning account* (Guthke & Stein, 1996; Verguts & De Boeck, 2002a, 2002b). Having demonstrated that repeated use of a set of rules in an RAPM-like task increases the likelihood of applying those rules to later items (Verguts & De Boeck, 2002b) and improves solution rates compared to sets of items requiring different rules to solve (Verguts & De Boeck, 2002a), Verguts and de Boeck suggested that WMC may relate to the ability to learn complex rule combinations. Unfortunately, Verguts and de Boeck either did not measure WMC in their experiments (Verguts & De Boeck, 2002b), or when they did, they failed to analyze the relation between WMC and performance on the interleaved vs. repeated blocks of rules (Verguts & De Boeck, 2002a). However, according to a learning account, high WMC should lead to an increased ability to learn rules, and