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Relations between running memory and fluid intelligence☆

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ABSTRACT

A total of 1734 adults performed two running memory tasks and a battery of cognitive tests representing four cognitive abilities. Simultaneous analyses were used to identify unique relations of each cognitive ability, including fluid intelligence, on the running memory measures. The large sample size allowed powerful analyses of the relations at the level of individual trials, separate list lengths, and different serial positions. The results indicated that the relations of running memory performance with cognitive abilities were remarkably constant from the first to the last trial, across different list lengths, and on successive input positions. It is proposed that an important aspect of fluid intelligence is the ability to cope with novelty and complexity, and that running memory tasks may merely be one of many ways in which those processes can be operationalized.

1. Introduction

A great deal of research has investigated relations between working memory (WM) and fluid intelligence (Gf), and meta-analysis estimates of the relations have ranged from about .4 to .8 (Ackerman, Beier, & Boyle, 2005; Kane, Hambrick, & Conway, 2005; Oberaurer, Schulze, Wilhelm, & Sus, 2005). These correlations indicate that people who are more successful at performing WM tasks are also better at Gf tests, but there is still little consensus with respect to what is responsible for the relations, or even the direction of the relations.[1]

The rationale for the current study was that it may be possible to gain insight into the reasons for the WM–Gf association by examining the relations at the level of individual items. That is, when the sample is sufficiently large, correlations can be decomposed to examine WM–Gf relations across items at different levels of difficulty, or across successive trials representing different amounts of experience on the task.

An early example of this approach was reported by Salthouse (1993a) in which relations of a composite WM measure, based on two complex span tasks, were examined across successive items in a prototypical Gf task, the Raven's Progressive Matrices test. Although some theoretical perspectives (e.g., Carpenter, Just, & Shell, 1990) would have predicted stronger WM relations on more difficult items, the WM–Gf correlations were nearly the same across problems varying in the number of relations among elements. Furthermore, the pattern of nearly constant relations of WM across Raven's items with different numbers of relational rules was later replicated by Unsworth and Engle (2005) and Wiley, Jarosz, Cushen, and Colflesh (2011).

The WM–Gf relation was recently examined at the level of individual items in complex span WM tasks by Salthouse and Pink (2008). The major finding in that study was that the relations with cognitive abilities, especially Gf, were nearly constant across different set sizes in the span tasks and across successive trials. The authors concluded that “The small variation in the Gf–WM relations across set sizes suggest that the amount of required simultaneous storage and processing is not critical to the existence, or even much of the magnitude, of the relations between these tasks and other cognitive abilities. The finding that the initial trial in the WM tasks is nearly as informative as later trials with respect to individual differences in Gf also suggests that the relationship of WM variables with

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[1] The ambiguity with respect to the direction of the relation is evident in the following quotation: “A person's ability to reason with novel information can be largely attributed to WM capacity, *and vice versa*.” (Shipstead, Redick, & Engle, 2012). (Italics added).

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Gf apparently does not depend on processes that extend over successive trials, such as within-task learning or the accumulation of proactive interference (p. 369–370)."

These earlier studies indicate that relations at the level of individual items can be very informative in establishing boundary conditions for the WM–Gf relations. However, all of the prior studies assessed WM with complex span tasks, and a primary purpose of the current study was to investigate cognitive ability relations in running memory WM tasks. The tasks in this project were similar to the running memory task introduced by Pollack, Johnson, and Knaff (1959), and can be considered to assess WM because the participant is required to report only the most recent items in a list of unpredictable length, and thus he or she must repeatedly update the status of continuously changing information.

The running memory tasks in the current study involved the presentation of 4 to 12 items, with the participant instructed to report the last four items in the order in which they were presented. Parallel versions of the tasks with verbal (letters) and spatial (dot locations) stimuli were administered to examine the generalizability of the WM–Gf relations with material (spatial information) that may be less amenable to verbal rehearsal than the alphanumeric material often used in running memory tasks. With both types of material, longer lists were expected to be more difficult because more updating of the most recent four items was presumably required. Level of difficulty might also be expected to vary across different input positions if there was a recency benefit for the last input positions.

Many prior studies investigated WM–Gf relations with simple correlations, often involving a single Gf measure. However, there are at least two limitations of this approach. First, single variables seldom exclusively or exhaustively correspond to specific theoretical constructs because not only do they likely include influences from other theoretical constructs, test-specific factors and measurement error, but they typically only reflect a portion of the relevant construct. And second, when a single predictor construct is considered in the analyses all of the shared relations are attributed to that construct, whereas unique contributions of the construct can be determined if multiple constructs are included in the same analysis.

An analytical procedure termed contextual analysis (Salthouse, Pink, & Tucker-Drob, 2008) addresses these concerns by representing each cognitive ability as a latent construct defined by the variance common to between three and four observed variables, and examining relations of several cognitive abilities to the target variable within a single analysis. The contextual analysis model is illustrated in Fig. 1, with observed variables represented as rectangles and latent variables represented as circles. Note that four cognitive abilities, each represented as latent constructs, are simultaneous predictors of the target variable. The relations of greatest interest in this project are the paths indicated by the dotted lines because they indicate the unique influences of the cognitive abilities on the target variable after controlling influences associated with age and the other abilities. Because

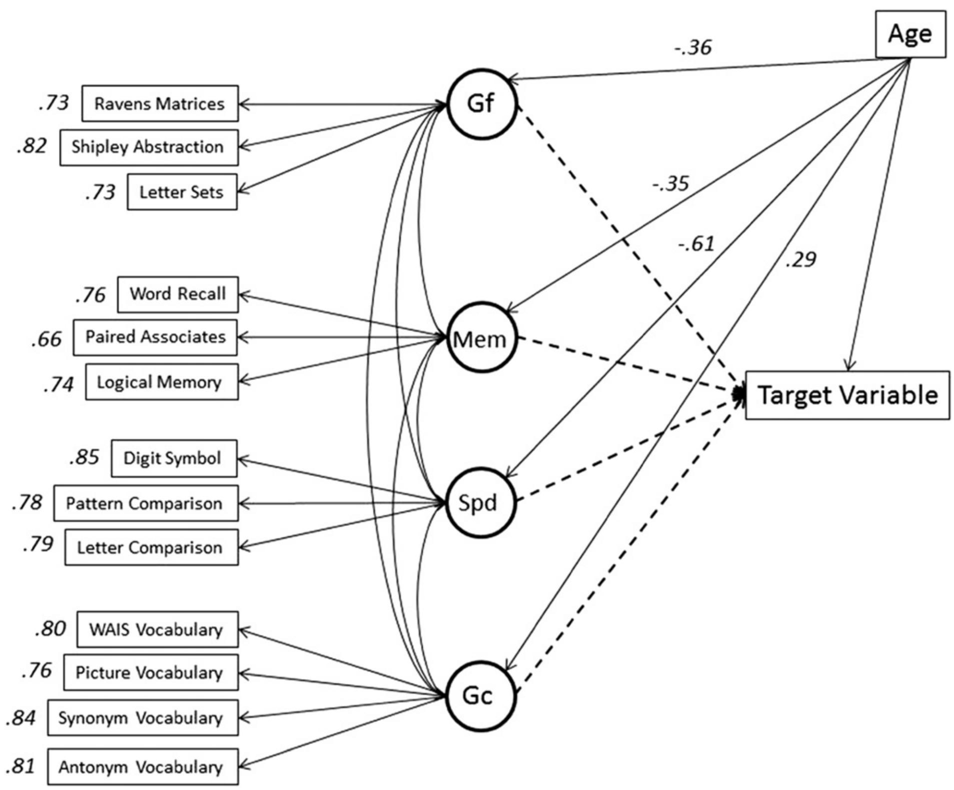

Fig. 1. Contextual analysis model used in the analyses of the relations of cognitive abilities to running memory variables. The numbers in the arrows from age are standardized coefficients, and the numbers to the left of the variable names are the standardized loadings of the variables on the cognitive ability constructs.