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Memory span and general intelligence: A latent-variable approach

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Abstract

There are several studies showing that working memory and intelligence are strongly related. However, working memory tasks require simultaneous processing and storage, so the causes of their relationship with intelligence are currently a matter of discussion. The present study examined the simultaneous relationships among short-term memory (STM), working memory (WM), and general intelligence (*g*). Two hundred and eight participants performed six verbal, quantitative, and spatial STM tasks, six verbal, quantitative, and spatial WM tasks, and eight tests measuring fluid, crystallized, spatial, and quantitative intelligence. Especial care is taken to avoid misrepresenting the relations among the constructs being studied because of specific task variance. Structural equation modelling (SEM) results revealed that (a) WM and *g* are (almost) isomorphic constructs, (b) the isomorphism vanishes when the storage component of WM is partialed out, and (c) STM *and* WM (with its storage component partialed out) predict *g*.

Keywords: Memory span tasks; Short-term memory; Working memory; General intelligence; Structural equation modelling

Working memory (WM) tasks are strongly related to *g* (Ackerman, Beier, & Boyle, 2002; Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004; Colom & Shih, 2004; Süβ, Oberauer, Wittman, Wilhelm, & Schulze, 2002), reasoning ability (Kyllonen & Christal, 1990), fluid intelligence (Colom, Flores-Mendoza, & Rebollo, 2003; Engle, Tuholski, Laughlin, & Conway, 1999; Kane et al., 2004), spatial ability (Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001), and reading comprehension (Daneman & Merikle, 1996).

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Indeed, several studies suggest that WM and intelligence are indistinguishable (isomorphic) constructs. Kyllonen and Christal (1990) found structural coefficients of .80 through .88 between WM and reasoning ability. Colom et al. (2003) found a correlation of .70 between a composite measure of WM and measures of fluid intelligence. Ackerman et al. (2002) found a structural coefficient of .70 between WM and *g*. In three separate studies, Colom et al. (2004) found a mean structural coefficient of .96 between general intelligence (*g*) and WM. Finally, Colom and Shih (2004) reported a structural coefficient of .86 between *g* and WM.

However, Ackerman, Beier, and Boyle (2005) conducted a meta-analysis examining the relationship between WM and *g*, as well as between STM and *g*. This study was based on a literature search ranging between 1872 and 2002. The meta-analytically derived correlation between cognitive ability and WM was .36, whereas the meta-analytically derived correlation between STM and cognitive ability was .28. Further, after a SEM analysis, the correlation found between STM and *g* was .49, whereas the correlation between WM and *g* was .50, which suggested that STM and WM were equally related to *g*.

Nevertheless, there are some studies claiming that WM is a much better predictor than STM. These studies consider the simultaneous estimation of relationships between the three constructs of interest, as opposed to examining WM and intelligence, or STM and intelligence, in separate analyses. Engle et al. (1999) and Conway, Cowan, Bunting, Therriault and Minkoff (2002) reported that when those relations are estimated simultaneously, the correlation between WM and intelligence is large and significant, whereas the correlation between STM and intelligence is negligible.

However, Ackerman et al. (2005) indicate that these studies are relatively limited in their assessment of the constructs of interest. For example, only two tests were used as indicators of intelligence. Furthermore, the indicators for WM and STM were also limited (Beier & Ackerman, 2004). This would be seen with some reservations, because the relations among the constructs being studied could be misrepresented. A better approach for sampling the construct space would be to include heterogeneous tasks to control for the effect of unwanted variance. Although the results of these previous studies are suggestive, they may not constitute the best evidence for examining the relations among the constructs of interest (Beier & Ackerman, 2004).

Recently, Kane et al. (2004) take a latent variable approach that resembles the study to be reported in the present article. Several measures of verbal and visuo-spatial WM and STM span were employed, as well as several diverse cognitive ability measures. Four main results can be highlighted. First, the correlation among WM and STM latent factors across content domains ranged from .63 to .89. Although those researchers did not report the results of a model where STM and WM were represented as two correlated higher order factors, we did this analysis after their correlation matrix and the resulting correlation was almost perfect ($r = .99$). Second, STM was found more domain-specific than WM. The correlation between STM-Verbal and STM-Spatial was .63, whereas the correlation between WM-Verbal and WM-Spatial was .83. Testing the structure of WM, those researchers found that a single factor model did not provide a good fit to the data, whereas a two-factor model distinguishing WM-V and WM-S did. Nevertheless, they treated WM as a unitary latent factor, while they preferred to treat the STM construct distinguishing verbal and spatial short-term storage. Third, the general structural model relating STM, WM and reasoning suffered from the well-known multicollinearity problem. Nevertheless, the primary interest was to test for the relation between what is shared among WM tasks and what is shared among reasoning tasks. WM span tasks were thought to be multiple determined by both domain-general executive attention processes and domain-specific coding and storage (STM) processes. Therefore, Kane