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Can fluid intelligence be reduced to 'simple' short-term storage?

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ABSTRACT

Much is written regarding the associations between human intelligence and cognition. However, it is unusual to find comprehensive studies. Here twenty four measures tapping eight cognitive abilities and skills are considered for assessing a sample of one hundred and eighty five young adults. The simultaneous relationships among fluid, crystallized, and spatial intelligence, along with short-term memory, working memory capacity, executive updating, attention, and processing speed are analyzed using a latent-variable approach. The key findings show that (a) short-term storage, working memory, and updating are hardly distinguishable, and (b) fluid intelligence is near-perfectly correlated with these three cognitive functions. It is concluded that this nuclear intelligence component can be largely identified with basic and general short-term storage processes, namely, encoding, maintenance, and retrieval.

1. Introduction

Since the very beginning of the scientific study of human behavior two main disciplines were identified. The experimental approach is based on the manipulation of independent variables to find out its effect over a previously specified dependent variable, whereas the correlation approach analyzes patterns of co-variation among diverse psychological measures. The still widespread separation of the experimental and correlation approaches slows down progress in the scientific study of human behavior, as noted by several researchers across the years (Cronbach, 1957, 1975; Eysenck, 1967; Terman, 1924; Underwood, 1975).

Perhaps human intelligence is the psychological factor most frequently analyzed at the intersection between the two disciplines of scientific psychology (Wilhelm & Engle, 2005). Because of its relevance for predicting everyday life behaviors, such as scholastic achievement, work performance, health, longevity, or crime (Deary & Der, 2005; Neisser et al., 1996) researchers have asked about the causes underlying the documented intelligence differences at the population level.

In the second part of the XX century hundreds of empirical studies exploring the relationships between intelligence differences, as assessed by standardized tests, and performance differences on a range of cognitive tasks, were published (Deary, 2000; Hunt, 2011; Jensen, 1998, 2006; Lohman, 2000). Perhaps the main conclusion that might be derived from these research efforts is that some cognitive functions are much more relevant than others for understanding intelligence differences.

Some theories underline processing speed (Jensen, 2006), while other models appeal to attention scope (Cowan, 2005), dual mechanisms for information maintenance and retrieval (Unsworth, Redick, Heitz, Broadway, & Engle, 2009), or simple short-term storage (Colom, Abad, Quiroga, Shih, & Flores-Mendoza, 2008; Colom, Rebollo, Abad, & Shih, 2006). Unfortunately, the debate is still open because, as noted by Unsworth and Engle (2007) or Unsworth et al. (2009) there are several

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issues not properly addressed in most of the published studies: (a) limited range of tasks for measuring the constructs of interest, (b) arguable scores derived from these tasks, (c) analyses of raw correlations instead of latent factors, and (d) use of small and improperly recruited samples.

Here an effort is made for overcoming many of these limitations. Following required guidelines for latent variable analyses (Ackerman, Beier, & Boyle, 2005; Johnson & Bouchard, 2005) a total of eight psychological constructs, both from the correlation and experimental approaches, are tapped by three diverse measures each. The constructs from the correlation approach were fluid, crystallized, and spatial intelligence, whereas the constructs from the experimental approach were short-term memory, working memory capacity, executive updating, attention, and processing speed.

The main interest focuses on the constructs, not on specific measures. Note that these measures tap the constructs as comprehensively as possible. A large sample comprising one hundred and eighty five young adults is assessed by this set of measures. Taking into account our own previous findings (Colom, Abad, Rebollo, & Shih, 2005; Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004; Colom & Shih, 2004; Colom et al., 2006; Colom et al., 2008) along with diverse results from other research laboratories (Beier & Ackerman, 2004; Hornung, Brunner, Reuter, & Martin, 2011; Krumm et al., 2009; Unsworth & Engle, 2007) it is predicted that memory span will be highly related to fluid intelligence. By using the term 'memory span' we are also predicting that short-term memory, working memory capacity, and executive updating will be hardly distinguishable (Colom et al., 2008; Unsworth & Engle, 2007). Importantly, these predictions will be tested concurrently against several potential candidates.

2. Method

2.1. Participants

One hundred and eighty five university Psychology undergraduates took part in the study (eighty percent were females). Their mean age was 19.7 (SD = 2.0). They participated to fulfill a course requirement and written informed consent was obtained.

2.2. Constructs of interest

Fluid-abstract intelligence (Gf) assesses the complexity level that subjects can reach in situations at which previous knowledge is irrelevant, whereas crystallized-verbal intelligence (Gc) relies in the ability to face academic types of skills and knowledge, such reading or math (Cattell, 1971). Spatial intelligence (Gv) implicates the construction, temporary retention, and manipulation of mental images (Lohman, 2000). Short-term memory (STM) involves the encoding, temporary retention, and retrieval of relevant information for later recall, whereas working memory (WMC) captures the ability for temporarily store varied amounts of information while facing a concurrent processing requirement (Colom et al., 2006). Executive control implicates the ability for active regulation of mental processes. Inhibition, shifting, and updating are key components of this type of control. Because updating appears to be the only executive basic function genuinely related to intelligence (Friedman et al., 2006) only this component is considered here. Attention is a broad cognitive function for focusing available mental resources (Baddeley, 2002). Here we consider the control of automatic responses (inhibition). Finally, processing speed is usually measured by reaction time tasks with low knowledge requirements (Sheppard & Vernon, 2008) so relatively simple verification tasks are administered in the present study.

A detailed description of specific measures tapping these constructs can be found in the Appendix A.

2.3. Procedure

Testing took place in five sessions — approx. 1 h each. The intelligence tests and cognitive tasks were collectively administered in groups of no more than 20 participants for a total of 5 h approximately. The first and second sessions were dedicated to intelligence testing, whereas the third, fourth and fifth sessions were dedicated to the cognitive tasks.

3. Results

The raw correlations, descriptive statistics, and reliability indices (internal consistency) are reported in Table 1. Note that for the timed measures (attention and processing speed) achieved accuracy levels were, as desired, very high, with values ranging from a minimum of 80% to a maximum of 95%.

Several confirmatory factor analyses (CFA) were computed using AMOS 5.0 (Arbuckle, 2003). The models were assessed by the next fit indices. The CMIN/DF (Chi Square/Degrees of Freedom) ratio is first considered given that it is usually taken as a rule of thumb (Jöreskog, 1993). Values showing a good fit must be around 2.0. Second, the RMSEA index is sensitive to misspecification of the model. Values between 0 and .05 indicate very good fit, values between .05 and .08 indicate reasonable fit, and values greater than .10 indicate poor fit (Ackerman, Beier, & Boyle, 2002; Byrne, 1998). Note that theoretical cleanness is preferred over excellent fit indices obtained after the arguable post hoc addressing of modification indices without conceptual value.

Firstly, the measurement model for the intelligence constructs was tested. Fig. 1 shows the results. Fit indices were appropriate: $\chi^2 = 54.4$, DF = 24, χ^2/DF = 2.3, RMSEA = .08. As expected, Gf, Gc, and Gv were highly related with values ranging from .72 to .86.

Secondly, the measurement model for the cognitive constructs was tested. Fit indices were appropriate: $\chi^2 = 155.7$, DF = 80, χ^2/DF = 1.9, RMSEA = .07. Fig. 2 displays the results. Memory span constructs (short-term memory, working memory, and updating) are very highly related, as well as attention and processing speed. Importantly, the correlation among memory span factors can be fixed to 1 without a significant change of fit ($\Delta\chi^2_{(3)} = 8.17$;