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Fluid intelligence and working memory capacity: Is the time for working on intelligence problems relevant for explaining their large relationship?

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ABSTRACT

A recent report has shown that the relationship, at the latent variable level, between fluid ability and working memory capacity is affected by the time allowed for completing problems requiring the former (Chuderski, 2013): the greater the time, the lower the relationship. The underlying argument is that untimed administration of fluid ability problems compensates working memory capacity limitations. The present report analyzes a group of three hundred and two participants that completed a set of three fluid tests and six working memory tasks. Latent variable analyses revealed consistent correlations (weighted average $r = .86$) between fluid ability and working memory capacity irrespective of administration times. Furthermore, the lowest difference in fluid ability between individuals with high and low working memory capacity was observed for the highly speeded condition. Their difference was greater when increased time was allowed for completing the fluid problems. Therefore, the relationship between fluid ability and working memory capacity appeals to underlying general common mechanisms unrelated with time constraints. Here we suggest that the reliability by which the relevant information can be preserved in the short-term for successful on-line processing seems a likely candidate.

1. Introduction

Fluid ability (Gf) and working memory capacity (WMC) are strongly related at the construct level. It is important to underscore that constructs and measures are not the same thing. Constructs are estimated using measures, but the latter are not the former (Jensen, 1998). From this perspective, only latent-variable analyses can provide valuable results for uncovering the most likely relationship between Gf and WMC. There are studies supporting their almost isomorphic nature, but there is not unanimity (Ackerman, Beier, & Boyle, 2005, but see the re-analysis by Oberauer, Schulze, Wilhelm, & Süb, 2005). We have underscored elsewhere that constructs must be sampled appropriately, meaning that several varied measures are required for tapping the same latent factor (Martínez et al., 2011). When this is done, results do support the quasi-isomorphic nature of Gf and WMC (Colom, Abad, Rebollo, & Shih, 2005; Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004; Kyllonen & Christal, 1990; Oberauer, Süß, Wilhelm, & Sander, 2007; Oberauer, Süß, Wilhelm, & Wittman, 2008).

Recently, Chuderski (2013) has published a thought-provoking report suggesting that the large correlation between Gf and WMC can be explained by time-constraints when completing fluid problems. This study supported their isomorphism when highly speeded Gf tests were administered. Increasing the time for solving the fluid problems substantially degrades the relationship between Gf and WMC (changing from 1.0 in highly speeded Gf tests to .62 for virtually untimed Gf tests). It is suggested that fluid reasoning is iterative on untimed intelligence testing. In this regard, low working memory individuals are thought to compensate their capacity limitations in unspeeded conditions. Hence the lower correlation observed between fluid ability and working memory capacity when the former was measured without severe time restrictions. However, if the argument is likely, then low working memory individuals must show fluid scores closer to high working memory individuals with increased administration times. This issue will be tested in the present study.

In short, here we firstly analyze the correlation, at the latent variable level, between Gf and WMC using a diverse set of measures. We will measure WMC by six verbal, numerical, and spatial tasks, whereas Gf will be measured by three standardized tests.

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The Raven Advanced Progressive Matrices Test (RAPM) will be administered under three timed conditions (20, 30, and 40 min) whereas the remaining fluid measures will be administered following recommendations of the tests' manuals (see below). Following Chuderski's report, we predict that the relationship between Gf and WMC must decline monotonically from the 20 min condition. Secondly, we tests if high and low working memory capacity individuals show reduced differences at increased administration times of fluid ability problems. Again, following Chuderski's rational we predict that the largest difference between these individuals varying in their working memory capacity must be observed in highly speeded conditions.

2. Methods

2.1. Participants

Three hundred and two university students participated in this study to fulfill a course requirement. Seventy-seven percent were females and the mean age was 19 years (SD = 3.6). Participants were randomly assigned to three administration conditions regarding the RAPM. Ninety-three were submitted to the 20 min condition (high-speed), 99 to the 30 min condition (moderate speed), and one hundred and ten to the 40 min condition (low speed).

2.2. Measures

Fluid ability was measured by the RAPM (Raven, Raven, & Court, 2004), the reasoning tests from the Differential Aptitude Test Battery (DAT-AR) (Bennett, Seashore, & Wesman, 1990), and the dominoes test (D-48) (Pichot, 1961). Verbal working memory was measured by the ABCD and Alphabet tasks. Both tasks were modeled after Kyllonen and Christal (1990). The mental counters and computation span tasks measured numerical working memory. The counter task was modeled after Larson and Sacuzzo (1989). The computation span task was modeled after Ackerman, Beier, and Boyle (2002). Finally, spatial working memory was measured by the dot matrix and letter rotation tasks. Both tasks were modeled after Miyake, Friedman, Rettinger, Shah, and Hegarty (2001). A detailed description can be found in Appendix 1.

2.3. Procedure

Participants completed the intelligence measures in two separate testing sessions in groups of no more than 25 individuals. The first session was devoted to the RAPM, whereas the second session included the DAT-AR and the D-48. The cognitive tasks were also completed in two sessions. In the first session the ABCD, the computation span, and the letter rotation task were administered. In the second session the remaining WM tasks were completed.

3. Results

Table 1 shows the descriptive statistics for the nine measures and the three RAPM groups. Results were largely similar regardless of the group, except for the RAPM. In this latter instance, increased administration time produced higher mean scores and these were the computed effect sizes: *d* (20 min group vs. 30 min group) = .39, *d* (30 min group vs. 40 min group) = .58, *d* (20 min group vs. 40 min group) = 1.01. Therefore, the 30 min group obtained an advantage equivalent to 6 IQ points over the 20 min group, the 40 min group obtained an advantage equivalent to 9 IQ points over the 30 min group, and the 40 min group obtained an advantage equivalent to 15 IQ points over the 20 min group. Skewness and kurtosis values were within the normal range. Reliabilities were also appropriate. Note that the reliability for the RAPM was almost identical for the three administration times (.77 for 20 min, .76 for 30 min, and .75 for 40 min).

Table 2 depicts the correlation matrix among the administered measures, again by RAPM group. Importantly, the correlation between the RAPM and the remaining two fluid measures were largely similar. This suggests that administration times do not change the nature of what is measured by the RAPM.

Afterwards, we defined the general latent-variable model including all the fluid ability and working memory capacity measures. The AMOS program (Arbuckle, 2006) was used for the computations (using maximum-likelihood estimation) testing the similarity among results for the three RAPM groups. Multivariate normality was confirmed using the Bollen-Stine Bootstrap method ($p = .164$). Model fitting was assessed using the Mean Square Error of Approximation (RMSEA) (Steiger, 1990), the χ^2/df ratio, the Tucker Lewis index (TLI) (Hu & Bentler, 1999), and the Comparative Fit Index (CFI) (Bentler, 1990). A χ^2/df ratio < 3.00, RMSEA values < .05, as well as TLI and CFI values > .95, are indicative of proper fit.

Figure 1 depicts the latent results for the three RAPM groups. The remarkable general finding is that there were large and consistent correlations between fluid ability (Gf) and working memory capacity (WMC) across groups. For the 20 min group the correlation was .89 (confidence interval = .84, .92), for the 30 min group

Table 1
Descriptive statistics for the three groups (20, 30, and 40 min).

	RAPM	DAT-AR	D48	ABCD	Alphabet	CompSpan	MentCount	LetterR	DotMatrix
20 min (*N* = 93)									
Mean	20.2	26.2	32.3	9.2	62.3	42.3	46.3	42.6	81.6
SD	4.4	6.3	6.5	3.9	15.6	9.3	8.7	9.7	9.9
Skew	−.05	−.51	−1.4	−.66	−.60	−.97	−1.3	.09	−.73
Kurt	−.26	.16	2.8	−.61	.50	.34	2.1	−.18	2.3
30 min (*N* = 99)									
Mean	22.0	25.7	31.4	9.4	59.2	42.5	46.1	40.9	80.0
SD	4.8	6.6	6.1	3.8	14.4	9.9	8.7	10.1	8.6
Skew	−.59	−.40	−.57	−.61	−.31	−1.4	−1.6	.32	.01
Kurt	.62	.34	.28	−.60	.35	2.0	3.6	−.44	−.49
40 min (*N* = 110)									
Mean	24.7	25.7	33.0	9.5	62.7	43.1	46.4	43.3	80.7
SD	4.5	6.2	6.2	3.7	13.7	8.4	7.1	9.9	9.1
Skew	−.29	−.07	−1.2	−.71	−.46	−1.1	−.68	.24	−.50
Kurt	.03	−.41	2.8	−.48	.73	1.5	.15	−.40	.86
Reliability	.77/.76/.75	.83	.85	.85	.78	.84	.79	.79	.83