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Fluid intelligence, memory span, and temperament difficulties predict academic performance of young adolescents

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Abstract

There are several candidate measures when asking which psychological construct significantly predicts academic performance. Hundreds of studies have addressed this issue by measuring intelligence, basic cognitive processes, or personality. However, the simultaneous consideration of a broad and varied array of measures is much less common. Here we consider several cognitive and personality measures concurrently to define latent factors representing six constructs of presumed interest: fluid intelligence, short-term memory, working memory, processing speed, controlled attention, and temperament difficulties. One hundred and thirty-five secondary school students were tested. Their academic performance was measured by average grades in the nine scholastic areas of their curriculum. The main finding shows that a latent factor defined by fluid intelligence and memory span along with a latent factor defined by impulsiveness, sensation seeking, and lack of fear account for an impressive figure of 60% of the variance in academic performance.

Keywords: Fluid intelligence; Short-term memory; Working memory; Processing speed; Controlled attention; Temperament; Academic performance

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1. Introduction

The prediction of academic performance has been an important research topic in psychological science for almost one century (Boekaerts, 1995; Furnham & Chamorro-Premuzic, 2004; Gagne & St Pere, 2002; Jensen, 1998; Lubinski, 2004; Petrides, Chamorro-Premuzic, Frederickson, & Furnham, 2005; Vigil-Colet & Morales-Vives, 2005). Various venerable psychological constructs have shown significant associations with academic performance, but perhaps psychometric intelligence can be nominated as the most frequently considered. Indeed, after a comprehensive review of the published literature, the seminal report by Neisser et al. (1996) concluded that psychometric intelligence is the best single predictor of academic performance (Kuncel, Hezlett, & Ones, 2001).

Nevertheless, personality variables can also play a role. Thus, for instance, Wolfe and Johnson (1995) measured 32 personality variables, finding that self-discipline predicts college grade point average. Recently, Duckworth and Seligman (2005) reported that self-discipline out did psychometric intelligence in predicting academic performance in adolescents. Specifically, their results indicated that self-discipline accounted for more than twice as much variance as intelligence in final grades.

Beyond intelligence and personality, constructs from the human information processing approach have been considered as predictors of academic performance also. Several studies have shown that measures of processing speed and working memory correlate significantly with academic performance (Daneman & Carpenter, 1980; Luo, Thompson, & Detterman, 2003). Gathercole, Pickering, Knight, and Stegmann (2004) found that achievement in the curriculum areas of mathematics and science is significantly related with working memory capacity. Interestingly, they distinguish between basic cognitive abilities and previous knowledge, stating that basic cognitive abilities are germane for learning situations such as those encountered in schools. Baddeley and Gathercole (1999) suggest that these basic mental processes could estimate future abilities to learn.

Luo, Thompson, and Detterman (2006) examined the criterion validity of processing speed and working memory, because both are related to psychometric intelligence (Ackerman, Beier, & Boyle, 2002, 2005; Colom, Abad, Rebollo, & Shih, 2005; Colom, Rebollo, Abad, & Shih, 2006; Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004; Fry & Hale, 1996; Salthouse, 1996). They measured academic performance also. Their results indicated that these basic cognitive processes along with crystallized intelligence account for about 60% of the variability in academic performance.

In summary, the majority of studies analyze the relationship between cognitive or personality measures and academic performance. With rare exceptions, these measures are treated in isolation. Therefore, contrary to most studies, here we consider several cognitive and personality measures concurrently, in order to define latent factors intended to represent several psychological constructs that are reasonable candidates to predict academic performance. These constructs are fluid intelligence, short-term memory, working memory, processing speed, controlled attention, and temperament difficulties. To our knowledge, there are no previously published studies testing the predictive validity, at the latent variable level, of such a broad array of constructs.

2. Method

2.1. Participants

One hundred and thirty-five secondary school randomly selected students took part in the study. There were 68 boys and 67 girls and their mean age was 13.42 (SD = .66). All of them were living in an urban setting. It should be noted that secondary school is compulsory in Spain, and, therefore, the results can be safely considered representative.

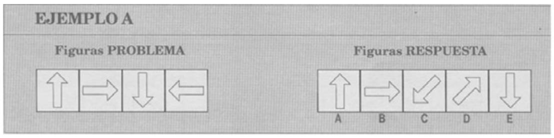
2.2. Measures and procedures

Fluid intelligence (Gf) is defined as "an expression of the level of complexity of relationships which an individual can perceive and act upon when he does not have recourse to answers to such complex issues already stored in memory" (Cattell, 1971, p. 99). This construct is measured by tests that have little cultural content (abstract tests like the Progressive Matrices Test or verbal tests that depend on figuring out the relationships between certain words when the meanings of all the words themselves are highly familiar). The abstract reasoning subtests from the Differential Aptitude Test, DAT-5 (Bennett, Seashore, & Wesman, 1990) and the inductive reasoning subtests from the Primary Mental Abilities, PMA (Thurstone, 1938) were administered (Fig. 1).

Short-term memory (STM) is defined by tasks that "can be performed with relative removal of attention from the representation of the list items" (Engle, Tuholski, Laughlin, & Conway, 1999, p. 314). Thus, STM was measured by tasks requiring the temporary maintenance of quantitative or spatial items for later recall: forward digit span (FDSPAN) and Corsi Block (Colom et al., 2005). In FDSPAN, single digits were randomly presented at the rate of one digit per second. Set size ranged from three to nine items (7 levels × 3 trials each = 21 trials total). Corsi Block comprised nine boxes with three different configurations that changed on each trial. One box at a time turned orange for 650 ms each and the order in which they were tapped must be remembered. The sequences increased from 3 to 9 taps (7 levels × 3 trials each = 21 trials total). The score was the number of trials (for FDSPAN) or taps (for Corsi) reproduced appropriately. Whereas FDSPAN required the reproduction of the entire sequence, Corsi did not (appropriately located single taps are computed irrespective of the entire sequence).

Working memory (WM) is characterized by dual tasks "in that attention must be shifted back and forth between the representation of the list items and the so-called processing component of the task" (Engle et al., 1999, p. 314). Miyake, Friedman, Rettinger, Shah, and Hegarty (2001) state: "to follow the convention in the field, we refer to simple storage-oriented span tasks with no explicit concurrent processing as short-term memory (STM) span tasks and to complex span tasks that involve not only a storage requirement but also an explicit concurrent processing requirement as WM span tasks. According to this classification, traditional verbal span measures such digit and word spans are considered STM span tasks, whereas more complex span measures such as reading or operation spans are considered WM span tasks" (p. 622). Therefore, WM was measured by computation span and dot matrix, both including a verification task and a recall task. In the firs task, 6 s were allowed to see the math equation and the displayed solution, regardless of its accuracy, must be remembered. After the final equation of the trial was displayed, the solutions from the equations must be reproduced in their correct serial order. Trials ranged from three to seven equation/solutions (5 levels × 3 trials each = 15 trials total). Dot matrix requires the participant to verify a matrix equation and then to retain temporarily a dot location displayed in a 5 × 5 grid. The matrix equation requires adding or subtracting simple line drawings and is presented for a maximum of 4.5 s. Once the response is delivered, the computer displayed the grid for 1.5 s. After a given sequence of equation-grid pairs, the grid spaces that contained dots must be recalled. The trials increased progressively in size from two to five equations and

Abstract Reasoning Sub-Tests from the DAT-5



Inductive Reasoning Sub-Test from the PMA

a m b c m d e f m g h i j   h i j k l m

Forward Digit Span (FDSPAN)

9 3 8 5 7 >>>>>> ANSWER SCREEN__________

Corsi Block

Computation Span

(2+2) + 2 = 5 >>>>> (3+2) – 4 = 1

Dot Matrix

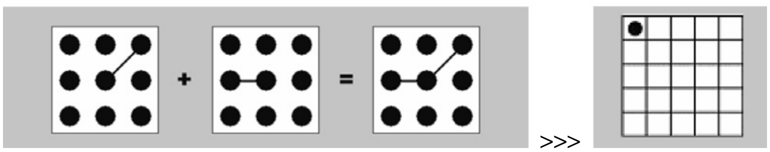
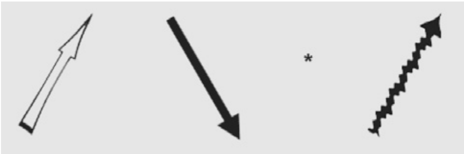


Fig. 1. Examples of the administered tests and tasks.

Quantitative Processing Speed

1 2 * 4

Spatial Processing Speed



Quantitative Controlled Attention

848 >>> 343 >>> 737 >>> 454

Spatial Controlled Attention

< +

> +

+ >

+ <

Sensation Seeking

Choose one: (A) Attending a concert of classical music, (B) Falling down from a bridge using an elastic rope.

Impulsiveness

Choose one: (A) If you have a free weekend to travel, you plan the possible route carefully; (B) Begin something before ending some other.

Lack of Fear

Choose one: (A) Walking through an empty and dark street at night where robbery have taken place previously; (B) Spending all night long with a relative that you don't like.

Fig. 1 (*continued*)

dots (4 levels × 3 trials = 12 trials total). In both tasks, the number of single hits in the verification and remembering tasks were obtained as the participant's score.

Processing speed (PS) was measured by simple short-term recognition speed tasks. In the quantitative version, single digits (defining a memory set that can comprise two, three, or four digits) are sequentially displayed for 650 ms each. After the last displayed digit, a fixation point appears for 500 ms and, finally, the probe digit appears in order to decide if it can be divided by one of the digits presented within the memory set. The trials ranged from two to four digits (3 levels × 10 trials each = 30 trials total). In the spatial version, several arrows (defining a memory set that can comprise two, three, or four arrows) are sequentially displayed for 800 ms each. The arrows can be displayed in one of seven orientations. After the last arrow is displayed, a fixation point appears for 500 ms and, finally, the probe arrow appears in order to decide if it has the same orientation of one of the arrows presented within the memory set. The arrows had distinguishable shapes in order to guarantee that their orientation is both memorized and evaluated. The trials ranged from two to four arrows (3 levels × 10 trials each = 30 trials total). In both tasks, half of the trials requested a positive answer and the score was the mean RT for the correct answers.

Controlled attention (CA) can be defined as the ability to maintain representations in a highly active state in the presence of interference (Engle et al., 1999). Kane and Engle's (2002) review nominates as measures of CA the flanker task, the antisaccade task, or the Stroop task, among others. Thus, we measured this construct by means of quantitative and spatial versions of the flanker task (Eriksen & Eriksen, 1974). The quantitative task requires deciding if the digit presented in the center of a set of three digits is odd or even. The target digit (e.g. odd) can be surrounded by compatible (e.g. odd) or incompatible (e.g. even) digits. The spatial task requires deciding if an arrow (horizontally depicted) points to the left or to the right of a fixation point. The target arrow pointing to a given direction (e.g. to the left) can be presented at the left (e.g. compatible) or at the right (e.g. incompatible) of the fixation point. In both tasks, there were a total of 32 practice trials and 80 experimental trials. Half of the trials were compatible and they were randomly presented across the entire session. The mean reaction time for the incompatible trials was the dependent measure.

Temperament difficulties (TD) were measured by the "CANTOBLANCO's Test of Temperament Difficulties" (EDTC-R), designed after the theory proposed by Lykken (1995). Note that we did not measure a broad variety of personality dimensions. This test comprises three sub-scales measuring sensation seeking, impulsiveness, and lack of fear (Herrero, Ordóñez, Salas, & Colom, 2002). In a study with 715 participants ranging in age from 15 to 88 yrs. (318 females and 397 males) the sensation seeking sub-scale correlated .73 ($p < .01$) with the Zuckerman's Sensation Seeking Scale (Zuckerman, 1979), whereas the impulsiveness sub-scale correlated .72 ($p < .01$) with the Barratt' impulsiveness scale, BIS 10.0 (Barratt, 1985). The EDTC-R has been employed to discriminate between prison inmates and the general population (Herrero & Colom, 2006).

Finally, academic performance (AP) was measured by the students' grades in the nine scholastic areas of their curriculum: nature sciences, social sciences, Spanish, English, mathematics, music, technology, gymnastics, and modelling arts.

Therefore, there were a total of 22 measures. These measures were used to define seven latent factors for fluid intelligence, short-term memory, working memory, processing speed, controlled attention, temperament difficulties, and academic performance, respectively. Importantly, the latent variable approach allows more definitive conclusions regarding the constructs of interest than do simple correlation approaches. Latent-variable procedures (a) statistically remove the error

Table 1
Descriptive statistics, zero-order correlation matrix, an reliability indices

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1. DAT-AR		.62	.36	.54	.34	.45	−.19	−.26	−.30	−.35	.21	.09	.21	.19	.12	.19	.10	.19	.17	.39	.22	.21
2. PMA-R			.39	.52	.42	.29	−.27	−.21	−.26	−.21	.10	.04	.10	.30	.28	.31	.26	.35	.32	.49	.39	.35
3. FDSPAN				.38	.42	.29	.03	.04	−.25	−.24	.00	−.07	−.00	.37	.31	.28	.19	.34	.39	.32	.33	.26
4. Corsi block					.40	.30	−.06	−.21	−.27	−.39	.12	−.03	.11	.33	.29	.28	.21	.30	.30	.44	.34	.32
5. Computation span						.31	−.19	−.16	−.25	−.10	.01	.01	.05	.28	.20	.28	.23	.30	.30	.34	.25	.27
6. Dot matrix							−.13	−.18	−.28	−.17	−.11	−.07	.02	.11	.06	.03	.14	.15	.13	.25	.13	.10
7. Quantitative speed								.48	.38	.21	−.23	−.19	−.09	−.05	−.04	−.05	−.10	−.05	−.11	−.12	−.10	−.11
8. Spatial speed									.32	.19	−.18	−.02	−.06	−.07	−.02	−.03	−.09	−.07	−.09	−.17	−.10	−.06
9. Quantitative attention										.42	−.10	−.03	.01	−.14	−.09	−.14	−.12	−.13	−.17	−.12	−.13	−.10
10. Spatial attention											−.22	−.10	−.12	−.19	−.14	−.12	−.01	−.12	−.21	−.26	−.12	−.12
11. Sensation seeking												.48	.39	−.18	−.28	−.20	−.40	−.32	−.24	−.11	−.33	−.29
12. Lack of fear													.47	−.30	−.29	−.26	−.31	−.31	−.29	−.26	−.33	−.30
13. Impulsiveness														−.22	−.26	−.18	−.24	−.20	−.23	−.13	−.28	−.23
14. Nature sciences															.82	.63	.69	.80	.76	.76	.78	.80
15. Social sciences																.70	.76	.83	.77	.73	.79	.84
16. Gymnastics																	.69	.62	.62	.59	.61	.69
17. Modelling arts																		.76	.66	.60	.71	.73
18. Spanish																			.80	.78	.85	.82
19. English																				.76	.75	.78
20. Mathematics																					.75	.76
21. Music																						.84
22. Technology																						
Mean	19.4	15.5	8.6	62.1	3.3	22.8	2354	1328	925	665	5.2	4.5	5.6	5.1	5.7	6.9	5.4	5.2	5.8	5.8	4.8	5.6
SD	6.9	5.8	2.8	18.2	2.9	6.4	1114	482	305	187	3.6	3.1	3.0	2.2	2.4	1.8	2.1	2.3	2.2	2.4	1.9	2.1
Reliability	.79	.84	.87	.83	.91	.79	.91	.74	.95	.97	.81	.70	.81	–	–	–	–	–	–	–	–	–

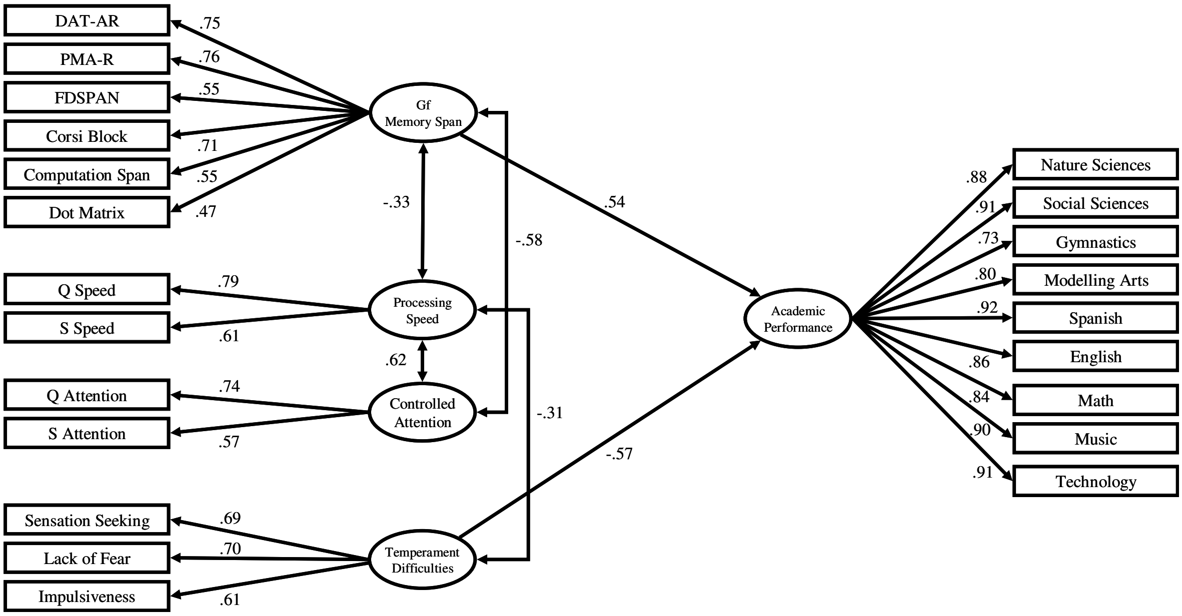


Fig. 2. Latent Model 3. DAT-AR = abstract reasoning subtest from the DAT-5; PMA-R = inductive reasoning subtests from the PMA; FDSPAN = forward digit span; Q Speed = quantitative processing speed; S Speed = spatial processing speed; Q attention = quantitative controlled attention; S attention = spatial controlled attention.

variance associated with the individual measures by considering only the variance shared among them all, (b) this shared variance represents the latent construct, and (c) increases statistical power (Byrne, 1998).

Psychometric tests (DAT-5-AR, PMA-R, and EDTC-R) were collectively administered in groups of no more than 20 participants, following instructions given by the test manuals. Computerized tests (STM, WM, PS, and CA) were also collectively administered but in smaller groups of no more than 10 participants. Academic grades were obtained from the school database.

3. Results

Table 1 shows the descriptive statistics for the 22 measures. The zero-order correlation matrix, as well as the reliability indices, are also shown.

The measures meet standard criteria for uni-variate normality with skew values less than 3 and kurtosis values less than 4 (Kline, 1998). Reliability indices (Cronbach's alpha) show appropriate values.

We used AMOS 5.0 to estimate latent variable models (Arbuckle, 2003). Several different indices of fit are proposed to argue the evaluation of fit provided by the chi-square statistic (Ackerman et al., 2002). This statistic quantifies whether there is a significant difference between the reproduced and observed covariance matrices. The χ^2/df index is considered as a rule of thumb, and values showing a good fit must be under 2.0. Use of the RMSEA (Root Mean Square Error of Approximation) is recommended, because it is sensitive to mis-specification of the model: values between 0 and .05 indicate very good fit, values up to .08 represent reasonable errors of approximation, and values greater than .10 indicate poor fit (Jöreskog, 1993).

By confirmatory factor analysis we define the measurement model (Model 1) comprising the seven freely correlated latent factors described above: fluid intelligence (Gf), short-term memory (STM), working memory (WM), processing speed (PS), controlled attention (CA), temperament difficulties (TD), and academic performance (AP). The fit of this model is appropriate: $\chi^2_{(189)} = 288.9$, $\chi^2/\text{df} = 1.53$, RMSEA = .063. Because the correlations among Gf, STM, and WM range between .86 and 1.0, we test a new (nested) model (Model 2) fixing these correlations to 1.0 and this results in a non-significant change of fit ($\Delta\chi^2_{(3)} = 3.4$; $p = .34$). The fit for Model 2 is also appropriate: $\chi^2_{(192)} = 292.32$, $\chi^2/\text{df} = 1.52$, RMSEA = .062. Consequently, the latent factors representing Gf, STM, and WM are collapsed into a single latent factor thought to represent "fluid intelligence–memory span capacity".

Fig. 2 depicts Model 3, obtained by structural equation modelling (SEM). The fit of this model is appropriate: $\chi^2_{(199)} = 298.1$, $\chi^2/\text{df} = 1.5$, RMSEA = .061. There are several noteworthy points in Model 3. First, the correlation between Gf–Memory Span and TD is not statistically significant ($p = .19$). Second, the correlation between CA and TD is not statistically significant either ($p = .20$). Therefore, both correlations are dropped from the final model. Third, the regression weights from PS and CA to AP are not statistically significant ($p = .21$ and $p = .51$, respectively). Therefore, these weights are dropped from the final model. Fourth, the regression weight from Gf–Memory Span to AP is significant and high (.54). Fifth, the regression weight from TD to AP is also significant and large (−.57). Therefore, the latent factors for fluid intelligence–memory span and for temperament difficulties predict academic performance (62% of explained variance). Further, although Table 1 shows some significant zero-order correlations between their specific measures, the values obtained from Model 3 are orthogonal to one another and they have taken into account their respective correlations with processing speed and controlled attention.

4. Discussion

To our knowledge, this is the very first study considering the broad array of psychological constructs described above. Contrary to most studies (Petrides et al., 2005) here we considered cognitive and personality measures concurrently to tap the constructs of psychometric intelligence, short-term memory, working memory, processing speed, controlled attention, and temperament difficulties. These constructs were allowed to freely predict academic performance. This broad spectrum of measures was employed to define latent factors intended to represent the constructs of interest.

There are several points of interest that can be extracted from the reported results. First, basic cognitive abilities (defined by fluid intelligence, short-term memory, and working memory) and temperament difficulties (defined by sensation seeking, impulsiveness, and lack of fear) predict academic performance to a high degree. Together, these latent factors account for 62% of the variance in academic performance (60.8% corrected value).[1] This large predictive validity is

[1] $R^2_{\text{adjusted}} = R^2 - [p(1 - R^2)/(n - p - 1)]$.

orthogonal to processing speed and controlled attention. Note further that the predictive validity for fluid intelligence–memory span is independent of the predictive validity for temperament difficulties. Therefore, much is to be gained by measuring both cognitive and personality constructs.

This general finding is consistent with Duckworth and Seligman (2005), at least in part. These researchers found that self-discipline and psychometric intelligence predict academic performance. Actually, the correlation between intelligence and academic performance was estimated at .49, whereas the correlation between the latter and self-discipline was estimated at .67. Interestingly, their self-discipline scores comprised measures of impulsiveness, self-control, and delay of gratification, roughly comparable to sub-scales measuring temperament difficulties in the present study. Further, like the results reported here, their intelligence and self-discipline measures did not show a significant correlation. However, contrary to their findings, we have shown that cognitive and personality measures contribute approximately to the same degree to the prediction of academic performance. Perhaps the difference could be attributed to the use of latent variables instead of specific measures (Luo et al., 2006) but all we can say is that this would be addressed in the near future.

Second, the unification of fluid intelligence, short-term memory, and working memory measures into the same latent factor is in strong agreement with the proclaimed isomorphism between intelligence and memory span capacity (Colom et al., 2004, 2005; Engle, 2002).

Third, latent factors representing processing speed and controlled attention do not predict academic performance. Therefore, these cannot be considered genuine predictors of academic performance. Short-term recognition speed and the ability to resist interference appear to be irrelevant to account for individual differences in the broad array of considered scholastic areas of the adolescents' curriculum.

This finding is not consistent with Luo et al. (2006), who found that both processing speed and working memory correlate with academic performance measured by standardized tests. Nevertheless, processing speed showed a significantly smaller predictive validity than working memory: "processing speed may represent cognitive underpinnings encompassed by working memory, while working memory may pertain to additional mechanisms" (p. 110).

Fourth, the latent factor defined by the scholastic areas is very robust. Note that all areas show large weights on the academic performance latent factor, ranging from .73 to .92. This is consistent with the so-called "positive manifold principle" (Jensen, 1998). Teacher's ratings are highly consistent across content areas, and, therefore, it can be presumed that students' performance do not show large variations from one area to another. Nevertheless, the present findings should benefit from a replication with objective measures of academic performance (Schicke & Fagan, 1994).

Finally, fluid intelligence–memory span is significantly related with both processing speed and controlled attention (−.33 and −.58, respectively). The implication is that the predictive validity that must be attributed to fluid intelligence–memory span is largely genuine. The same is true for temperament difficulties: there is a −.31 correlation with processing speed, and, therefore, adolescents with a more difficult temperament (high sensation seeking, impulsiveness, and fearlessness scores) tend to show a faster speed of processing.

In summary, the present study is in strong agreement with the view that both cognitive abilities and personality are germane to predict individual differences in academic performance. Specifically, fluid intelligence, memory span, and temperament difficulties account for approx. 60% of the variance in the broad array of academic areas considered here. Future research will tell where the remaining 40% can be found, although one reasonable candidate might be crystallized intelligence. The comprehensive study by Luo et al. (2006) achieved the general conclusion that basic processes (processing speed and working memory) and crystallized intelligence account for 60% of the observed individual differences in academic performance. Fluid intelligence measures did not add to the latter beyond the measured basic processes. Therefore, perhaps a combination of fluid and crystallized intelligence along with memory span and temperament difficulties is necessary and sufficient to predict (almost perfectly) academic performance.

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References

Ackerman, P. L., Beier, M. E., & Boyle, M. O. (2002). Individual differences in working memory within a nomological network of cognitive and perceptual speed abilities. *Journal of Experimental Psychology: General, 131*, 567–589.

Ackerman, P. L., Beier, M. E., & Boyle, M. O. (2005). Working memory and intelligence: the same or different constructs? *Psychological Bulletin, 131*, 30–60.

Arbuckle, J. L. (2003). AMOS 5.0. Chicago: SmallWaters Corp.

Baddeley, A. D., & Gathercole, S. E. (1999). Individual differences in learning and memory. In P. L. Ackerman, P. C. Kyllonen, & R. D. Roberts (Eds.), *Learning and individual differences* (pp. 31–54). Washington, DC: APA.

Barratt, E. S. (1985). Impulsiveness subtraits: arousal and information processing. In J. T. Spence & C. E. Itard (Eds.), *Motivation, emotion and personality*. North Holland: Elsevier.

Bennett, G. K., Seashore, H. G., & Wesman, A. G. (1990). Differential aptitude test (fifth ed.). Madrid: TEA, S.A., 2000.

Boekaerts, M. (1995). The interface between intelligence and personality as determinants of classroom learning. In D. Saklofske & M. Zeidner (Eds.), *International handbook of personality and intelligence*. New York: Plenum.

Byrne, B. M. (1998). Structural equation modelling with LISREL, PRELIS, and SIMPLIS: basic concepts, applications, and programming. Mahwah, NJ: Erlbaum.

Cattell, R. B. (1971). Abilities: their structure, growth, and action. Boston: Houghton.

Colom, R., Abad, F., Rebollo, I., & Shih, P. C. (2005). Memory span and general intelligence: a latent-variable approach. *Intelligence, 33*, 623–642.

Colom, R., Rebollo, I., Abad, F. J., & Shih, P. C. (2006). Complex span tasks, simple span tasks, and cognitive abilities: a re-analysis of key studies. *Memory & Cognition, 34*, 158–171.

Colom, R., Rebollo, I., Palacios, A., Juan-Espinosa, M., & Kyllonen, P. (2004). Working memory is (almost) perfectly predicted by *g*. *Intelligence, 32*, 277–296.

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behaviour, 19*, 450–466.

Duckworth, A. L., & Seligman, M. E. P. (2005). Self-discipline outdoes IQ in predicting academic performance of adolescents. *Psychological Science, 16*, 939–944.

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science, 11*, 19–23.

Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. A. (1999). Working memory, short-term memory, and general fluid intelligence: a latent-variable approach. *Journal of Experimental Psychology: General, 128*, 309–331.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of target letter in a non-search task. *Perception and Psychophysics, 16*, 143–149.

Fry, A. G., & Hale, S. (1996). Processing speed, working memory, and fluid intelligence: evidence for a developmental cascade. *Psychological Science, 7*, 237–241.

Furnham, A., & Chamorro-Premuzic, T. (2004). Personality and intelligence as predictors of statistics examination grades. *Personality and Individual Differences, 37*, 943–955.

Gagne, F., & St Pere, F. (2002). When IQ is controlled, does motivation still predict achievement? *Intelligence, 30*, 71–100.

Gathercole, S. E., Pickering, S. J., Knight, C., & Stegmann, Z. (2004). Working memory skills and educational attainment: evidence from national curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology, 18*, 1–16.

Herrero, O., & Colom, R. (2006). Es verosimil la teoría de la delincuencia de David Lykken? [Is Lykken's criminal behaviour theory likely]. *Psicothema, 18*, 374–377.

Herrero, O., Ordóñez, F., Salas, A., & Colom, R. (2002). Adolescencia y comportamiento antisocial [Adolescent and antisocial behaviour]. *Psicothema, 14*, 340–343.

Jensen, A. R. (1998). The *g* factor. Westport, CT: Praeger.

Jöreskog, K. (1993). Testing structural equation models. In K. A. Bollen & J. S. Long (Eds.), *Testing structural equation models* (pp. 294–315). Newbury Park: Sage.

Kane, M., & Engle, R. (2002). The role of prefrontal cortex in WMC, executive attention, and general fluid intelligence: an individual-differences perspective. *Psychonomic Bulletin & Review, 9*, 637–671.

Kline, P. (1998). Principles and practice of structural equation modelling. New York: Guilford Press.

Kuncel, N. R., Hezlett, S. A., & Ones, D. S. (2001). A comprehensive meta-analysis of the predictive validity of the graduate record examinations: implications for graduate student selection and performance. *Psychological Bulletin, 127*, 162–181.

Lubinski, D. (2004). Introduction to the special section on cognitive abilities: 100 years after Spearman's (1904) 'General intelligence', objectively determined and measured. *Journal of Personality and Social Psychology, 86*, 96–111.

Luo, D., Thompson, L. A., & Detterman, D. K. (2003). The causal factor underlying the correlation between psychometric *g* and scholastic performance. *Intelligence, 31*, 67–83.

Luo, D., Thompson, L. A., & Detterman, D. K. (2006). The criterion validity of tasks of basic cognitive processes. *Intelligence, 34*, 79–120.

Lykken, D. (1995). The antisocial personalities. New York: LEA.

Miyake, A., Friedman, N. P., Rettinger, D. A., Shah, P., & Hegarty, M. (2001). How are viscospatial working memory, executive functioning, and spatial abilities related? a latent-variable analysis. *Journal of Experimental Psychology: General, 130*, 621–640.

Neisser, U., Boodoo, G., Bouchard, T., Boykin, A., Brody, N., Ceci, S., et al. (1996). Intelligence: knowns and unknowns. *American Psychologist, 51*, 77–101.

Petrides, K. V., Chamorro-Premuzic, T., Frederickson, N., & Furnham, A. (2005). Explaining individual differences in scholastic behaviour and achievement. *British Journal of Educational Psychology, 75*, 239–255.

Salthouse, T. A. (1996). The processing speed theory of adult age differences in cognition. *Psychological Review, 103*, 403–428.

Schicke, M., & Fagan, T. K. (1994). Contributions to self-concept and intelligence to the prediction of academic achievement among grade 4, 6, and 8 students. *Canadian Journal of School Psychology, 10*, 62–69.

Thurstone, L. (1938). *Primary mental abilities*. *Psychometric monographs 1*. Madrid: TEA.

Vigil-Colet, A., & Morales-Vives, F. (2005). How impulsivity is related to intelligence and academic achievement? *The Spanish Journal of Psychology, 8*, 199–204.

Wolfe, R. N., & Johnson, S. D. (1995). Personality as a predictor of college performance. *Educational and Psychological Measurement, 55*, 177–185.

Zuckerman, M. (1979). *Sensation seeking: beyond the optimal level of arousal*. Hillsdale: Erlbaum.