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Processing speed and intelligence as predictors of school achievement: Mediation or unique contribution?

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ABSTRACT

The relationships between processing speed, intelligence, and school achievement were analyzed on a sample of 184 Russian 16-year-old students. Two speeded tasks required the discrimination of simple geometrical shapes and the recognition of the presented meaningless figures. Raven's Advanced Progressive Matrices and the verbal subtests of Amthauer's Intelligence Structure Test were used as intelligence scales. The teacher-assigned grades in six school subjects that were aggregated into two scales represented real-life school achievement. Latent processing speed and intelligence as individual predictors each accounted for about 18% of the variability in scholastic performance. Taken together, they explained about 28% of the variance of school achievement. Although significantly correlated, each had a unique impact on school achievement; zero-constraining each of the two paths to school achievement resulted in a significantly worsened fit of a model. A mediation effect *processing speed → intelligence → school achievement* was bootstrapped to obtain an estimate of its statistical significance and was found to be non-distinguishable from zero. The results are inconsistent with the causal hypothesis that states that processing speed is a predictor of real-life scholastic performance because of the impact of processing speed on higher-order cognitive ability, which in turn underlies school achievement.

1. Introduction

Since intelligence tests were originally meant to determine children with potential difficulties in school education (Binet, 1905) and the first measurement of general intelligence included analysis of school examination scores (Spearman, 1904), the association between intelligence and scholastic performance is one of the best-established associations and is often referred to in the literature on cognitive ability. The relationship between intelligence scores and school performance that are commonly found in studies are moderate to strong (e.g., Bartels, Rietveld, Van Vaal, & Boomsma, 2002; Brody, 1992; Jencks, 1979; Jensen, 1998; Neisser et al., 1996). These results largely depend on the kind of indexes of school achievement that were examined and whether intelligence was analyzed at a manifest or a latent level. For instance, the observed magnitude of correlation with intelligence varies for different subjects and measures of performance. Achievement in mathematics and sciences tends to be better predicted by cognitive ability than achievement in the languages (e.g., Deary, Strand, Smith, & Fernandes, 2007; Krumm, Ziegler, & Buehner, 2008; Lu, Weber, Spinath, & Shi, 2011), with a portion of predicted variability in such subjects as arts being the lowest (e.g., Deary et al., 2007). Another issue is the measure of school achievement used in the analysis: achievement test scores are more highly correlated with intelligence than are teacher-assigned grades, probably because the latter tend to reflect, to some extent, not only real performance, but also some of the other characteristics of the child like effort or personal traits (e.g., see Jensen, 1998). On the side of cognitive ability, intelligence modeled

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at a latent level generally serves as a better predictor of scholastic performance than single test scores; test-specific variance adds much less to the explanation of the variability in school performance. In other words, the variance of school achievement that is predictable by intelligence scores is mostly accounted for by *g*, and not by the other factors that determine the scores on the different tests (Jensen, 1998).

At the same time, a large number of studies that were published in the last decades demonstrated that *g* could, in turn, be predicted by a number of basic cognitive processes. Processing speed and working memory are probably the best-established candidates to explain higher-order individual differences in cognitive ability (e.g., Colom, Abad, Quiroga, Shih, & Flores-Mendoza, 2008; Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Fry & Hale, 1996; Jensen, 1998; Kail & Salthouse, 1994). Correlations between single measures of processing speed and intelligence that are commonly reported in the literature are low to moderate; when measures of processing speed are based on response times from different speeded tasks, their correlations with intelligence approach those typically observed between psychometric tests (Grudnik & Kranzler, 2001; Jensen, 2006; Kranzler & Jensen, 1989; Sheppard & Vernon, 2008; Vernon, 1988).

Thus, the next logical step would be to relate these basic processes directly to scholastic achievement. However, studies addressing this problem are still relatively rare. Discussing this issue, Luo, Thompson, and Detterman (2003a) mentioned that the failure of early studies (e.g., Cattell & Farrand, 1890) to observe significant relationships between elementary cognitive processes and scholastic performance has influenced the field. Recent studies seem to come back to this problem; however, research interest has more often focused on the working memory construct as the explanatory factor for school achievement (e.g., Alloway, 2009; Krumm et al., 2008; Lu et al., 2011). The relationship between processing speed and scholastic performance remains much less explored, although processing speed was shown to be almost as a powerful predictor of school achievement as working memory is, in at least one study that analyzed two large datasets (Luo, Thompson, & Detterman, 2006).

A study on the relationship between processing speed and scholastic achievement in fact can address different questions. First, processing speed can be examined as a single predictor of school achievement. For example, Carlson and Jensen (1982) found that reaction time in a task designed in the Hick paradigm (Hick, 1952) and reading comprehension share about 30% of common variance. Very similar results were reported by Luo, Thompson, and Detterman (2003b). In their study, about 30% of the variance of scholastic performance was accounted for by the mental speed factor; the relationship between mental speed and school achievement was found to be invariant across different knowledge domains. Moreover, the latter study addressed another question, namely the etiology of these relationships. The covariance between mental speed and scholastic achievement was found to be mostly genetically mediated (similarly, other studies report that mental speed has a substantial genetic covariation with psychometric *g* (Baker, Vernon, & Ho, 1991; Rijsdijk, Vernon, & Boomsma, 1998) and intelligence has a mostly genetic covariation with school achievement (Kovas, Haworth, Dale, & Plomin, 2007; Petrill & Thompson, 1993; Thompson, Detterman, & Plomin, 1991; Wadsworth, DeFries, Fulker, & Plomin, 1995; Wainwright, Wright, Geffen, Luciano, & Martin, 2005)).

The next question that can be addressed is the question on the comparative strength of processing speed and intelligence as possible predictors of school achievement. Luo et al. (2006) formulated a very similar problem in terms of the criterion validity of tasks of basic cognitive processes. In the analyses of two datasets, which are the Woodcock-Johnson III Cognitive Abilities and Achievement Tests normative data and the Western Reserve Twin Project data (with a total of more than 5500 participants), the authors observed zero-order correlations between latent processing speed and achievement factors, which are similar or even higher than the correlations between conventional cognitive ability and achievement factors. In their earlier study, the same authors reported very similar results of almost equal zero-order shared variance between processing speed and scholastic performance, on the one hand, and intelligence and scholastic performance, on the other hand (Luo et al., 2003a). Similarly, Rindermann and Neubauer (2000) observed a correlation between processing speed and school performance ($r = .37$) that was only slightly lower than a correlation between intelligence and school performance ($r = .43$). Results reported by Luo and Petrill (1999) also suggest that “the predictive power of *g* will not be compromised when *g* is defined using experimentally more tractable [elementary cognitive tasks] ECTs” (p. 157). However, the relative strength of processing speed as a single predictor of school achievement (as compared to intelligence) still remains doubtful, as some studies report significantly lower association between processing speed and school achievement than between intelligence and school achievement. For example, Rindermann and Neubauer (2004) reported the associations with school achievement of $\beta = .09$ and $\beta = .53$ for processing speed and intelligence, respectively. Colom, Escorial, Shih, and Privado (2007) observed only low zero-order correlations between school grades and processing speed as measured by simple short-term recognition tasks. Of nine school subjects, grades in mathematics showed highest correlations with the measures of processing speed, although even these correlations were quite low ($r = -.12$ and $r = -.17$). In the latter study, latent processing speed was not a significant predictor of academic performance, while a combined latent variable for fluid intelligence and memory span capacity accounted for about 29% of variance of school achievement.

Finally, the most intriguing issue on the relationships between processing speed, intelligence, and school achievement is their consistency with the causal mental speed hypothesis. From this point onward, certain theoretical assumptions start playing a major role, as any kind of testing of mediation effects is completely senseless in the absence of strong theoretical and methodological backgrounds. The mental speed theory provides a strong background for this kind of study (Brand, 1981; Deary, 1995; Jensen, 1982, 2006, 2011); it suggests that processing speed is a basic factor that underlies higher-order cognitive ability, which in turn influences one's success or failure in school. This theoretical model results in another set of questions that can be addressed through empirical studies.

The first question concerns the relationship between intelligence and school achievement, with processing speed