



Relational integration as a predictor of academic achievement

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ABSTRACT

The current study aimed at applying a broad model of cognitive functions to predict performance in science and language courses at school as well as performance in a science course at university. We hypothesized that performance in science courses was predominantly related to the cognitive function known as relational integration, whereas performance in language courses should be best explained by individuals' short-term memory capacity. The sample consisted of 161 German undergraduate students who were asked to complete 33 cognitive tasks. School grades were also obtained. The analyses revealed that relational integration incrementally explained variance in science grades. Short-term memory acted as a predictor of language grades. However, mental speed was also substantially related to language grades. Predicting university exam scores revealed that short-term memory yielded an incremental predictive power. We conclude that academic performance requires different cognitive functions depending on a domain of study.

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Being successful in secondary and tertiary education is fundamental for students' future career (e.g., Kuncel, Hezlett, & Ones, 2001; Roth & Clarke, 1998; Schuler, Funke, & Baron-Boldt, 1990), particularly when admission to colleges and professional programs (e.g., trainee programs) depends on grades and degrees obtained. In general, predictors of academic performance are typically dichotomized into cognitive and non-cognitive characteristics (Rindermann & Neubauer, 2001; Robbins et al., 2004; Rothstein, Paunonen, Rush, & King, 1994). Typically, cognitive variables – in particular general mental ability and fluid intelligence – have been shown to explain more variance in individuals' achievement than non-cognitive abilities (e.g., Kuncel et al., 2001; Rohde & Thompson, 2007) although non-cognitive predictors such as Big-5 personality dimensions add significantly to this prediction (e.g., Laidra, Pullmann, & Allik, 2007; Poropat, 2009).

In a number of studies, various measures of intelligence, or more specifically fluid intelligence, accounted for up to 58% of explained variance in measures of academic achievement (cf. Deary, Strand, Smith, & Fernandes, 2007). However, the applied measures of fluid intelligence do not denote a specific cognitive function or process, and have been criticized for being too broad (Oberauer, Schulze, Wilhelm, & Süß, 2005). Hence, by relating broad components of intelligence (such as fluid intelligence) to academic achievement, the cognitive processes involved cannot be identified. As a consequence, scientists who examine effective predictors of academic achievement directed their attention to distinct cognitive processes that are assumed

to be limiting factors of fluid intelligence (e.g., Krumm, Ziegler, & Bühner, 2008; St. Clair-Thompson & Gathercole, 2006). The most prominent and frequently examined limiting factors of fluid intelligence are represented by the concepts of mental speed and working memory (Schweizer, 2005). In the current study we aim to identify cognitive processes particularly relevant to various aspects of academic achievement. To this end, we apply basic cognitive processes that are subsumed under a broad model (Krumm et al., 2009) as predictors of several indicators of academic achievement (including school grades and university exam grades).

1. Mental speed and working memory as limiting factors of intelligence

Research on individual differences in intelligence discusses approaches that aim at describing intelligence (e.g., Carroll, 1993). These approaches comprise several cognitive abilities (e.g., mental speed) in a general model of intelligence. Other approaches aim at explaining (fluid) intelligence by a set of limiting factors that may be considered the cognitive basis of intelligence (e.g., the mental speed approach, cf. Vernon, 1987). In the current research, we consider mental speed and working memory as limiting factors and *not* as sub-facets of fluid intelligence.

The mental speed approach to identifying the cognitive basis of general mental ability presumes that the speed of information processing determines the quality of higher cognitive functioning. This is due to the fact that information can only be held mentally present for a short period of time and needs to be processed within this limited amount of time. Individuals higher in mental speed are less likely

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to experience information decay before it has been properly encoded or processed (cf. Vernon, 1987). Danthiir, Wilhelm, Schulze, and Roberts (2005) summarized existing literature on the relationship between mental speed and fluid intelligence. The researchers found that typical zero-order correlations ranged from .30 to .50. These correlations indicate that mental speed might be the cognitive basis of fluid intelligence. Hence, in the current study we consider mental speed a relevant cognitive function which predicts academic achievement.

The working memory approach to identifying the cognitive basis of fluid intelligence posits that information may be unavailable for higher mental processing because of the limited capacity of the working memory system to temporarily store and retrieve information – and not just because of the low processing speed (cf. Oberauer, Süß, Wilhelm, & Wittman, 2003). The reported correlations between working memory and measures of fluid intelligence vary considerably (from .50 to .90) (e.g., Bühner, Krumm, & Pick, 2005; Colom, Abad, Rebollo, & Chun Shih, 2005; Engle, Tuholski, Laughlin, & Conway, 1999) but usually exceed those reported for the relationship between mental speed and fluid intelligence (e.g., Ackerman, Beier, & Boyle, 2005; Krumm et al., 2009; Kyllonen & Christal, 1990).

The variation in these studies may be attributed to differences in the authors' conceptualization of working memory. Some authors posit that working memory can simply be conceptualized as the capacity of short-term memory (cf. Colom, Abad, Quiroga, Shih, & Flores-Mendoza, 2008), whereas others claim that working memory is best described by a set of distinct cognitive functions that limit higher mental processing (Oberauer et al., 2003). Several potential candidates for such limiting functions were associated with the concept of working memory (e.g., executive functions, see Friedman et al., 2006; or relational integration, see Bühner et al., 2005). Hence, we posit that examining determinants of academic achievement beyond fluid intelligence requires careful consideration of working memory facets. Given the current debate in working memory research, we decided to apply a broad model of cognitive functions that includes most of the current working memory conceptions.

2. A model of mental speed, working memory and reasoning

Krumm et al. (2009) attempted to identify common factors in a broad set of cognitive tasks that ranged from very simple elementary choice tasks to complex reasoning tasks. This was not a new approach; broad factors reflecting cognitive abilities were reported by many

authors, including Horn and Noll (1994) and Carroll (1993). However, previous studies did not explicitly focus on those cognitive functions that are assumed to be the cognitive basis of fluid intelligence, namely, mental speed and working memory-related functions. In their investigation, Krumm et al. (2009) also considered recent models of working memory that yielded very high predictive power in explaining fluid intelligence. The cognitive functions that the researchers examined included several mental speed task classes, sustained attention, executive functions, short-term storage, and facets of working memory (see Schweizer, 2005 for the functions' relevance as a cognitive basis of g). Based on a sequence of exploratory and confirmatory factor analyses, Krumm et al. (2009) proposed a model with three orthogonal factors to best explain their empirical data. These factors were: relational integration, short-term storage, and mental speed (see Fig. 1).

According to Oberauer et al. (2003) relational integration reflects individuals' ability to build a mental representation of several elements that are related to each other and to integrate new elements into it. According to Oberauer et al. (2003, p. 169) interpreting a table containing a three-way interaction is an example of a task that requires relational integration: One needs to compare pairs of numerical values, differences between pairs, and differences of differences. Several researchers repeatedly showed that relational integration was highly related to reasoning (e.g., Bühner et al., 2005; Süß, Oberauer, Wittmann, Wilhelm, & Schulze, 2002). The second factor (Krumm et al., 2009), short-term storage, is predominantly defined by short-term storage tasks (with and without additional processing requirements), which require participants to temporarily store and retrieve information. The third factor – mental speed – showed loadings on all the tasks. This was not surprising because all the tasks were more or less speeded. The highest loadings on this factor were observed for simple cognitive tasks (e.g., the sustained attention and perceptual speed tasks) in which performances are largely determined by the participants' speed (see Fig. 1).

In sum, the model proposed by Krumm et al. (2009) brought together cognitive functions (mental speed, short-term storage, executive functions and components of working memory) that were frequently and successfully applied as predictors of intelligence (e.g., Ackerman et al., 2005; Conway, Cowan, Bunting, Theriault, & Minkoff, 2002). Hence, this model is a good basis for simultaneously examining the predictive power of several cognitive functions in explaining academic achievement, thereby helping us to gain better understanding of the cognitive processes that are relevant to academic achievement. In the current research, we intend to examine whether the three factors proposed by

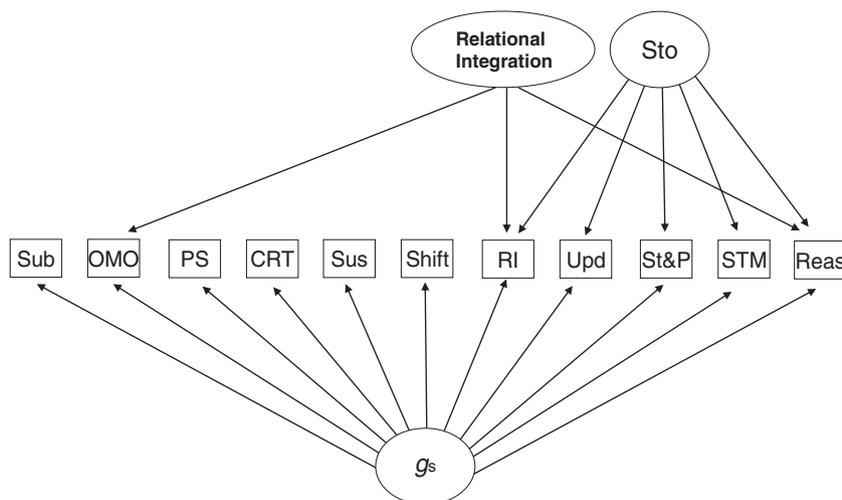


Fig. 1. Three orthogonal factors explaining cognitive task performances (Krumm et al., 2009). Notes. Abbreviations: Sub = substitution, OMO = odd-man-out, PS = perceptual speed, CRT = choice reaction time, Sus = sustained attention, Shift = shifting, RI = relational integration, Upd = updating, St&P = storage in the context of processing, STM = short-term memory, Reas = reasoning, g_s = general (mental speed) factor, Sto = storage.

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