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Differential relevance of intelligence and motivation for grades and competence tests in mathematics☆

Christin Lotz*, Rebecca Schneider, Jörn R. Sparfeldt

Saarland University, Department of Educational Science, Campus A5 4, D-66123 Saarbrücken, Germany

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ABSTRACT

Past research suggested that cognitive and motivational variables are differentially relevant for educational success when relying on competence tests or grades as achievement indicators. This differential relevance has not yet been investigated by, for example, advanced statistical methods. Therefore, reparameterization and Wald-tests were applied to statistically compare the standardized path coefficients of intelligence, academic self-concept, and interest on a scholastic competence test and grades in mathematics in a sample of $N = 245$ high school students. Additionally, increments of each variable beyond the other variables were examined using Cholesky factoring. Results revealed that intelligence was the strongest predictor of the scholastic competence test results, whereas self-concept was the strongest predictor of grades. Intelligence explained unique variance in the competence test and grades, whereas self-concept exhibited a unique increment only for grades. The differential relevance of cognitive and motivational variables for different achievement indicators (competence tests or grades) is discussed.

1. Introduction

Educational success is largely determined by cognitive variables such as intelligence (e.g., Jensen, 1998a) and motivational variables such as academic self-concepts or interests (e.g., Spinath, Spinath, Harlaar, & Plomin, 2006). Past studies revealed evidence that cognitive and motivational variables are differentially relevant, depending on which achievement indicator (tests or grades) was used: Whereas intelligence seems to be more relevant than motivation for scholastic competence tests (Jansen, Lüdtke, & Schroeders, 2016; Steinmayr & Meißner, 2013), academic self-concepts (Helmke, 1992; Steinmayr & Meißner, 2013) or academic interests (Jansen et al., 2016) seem to be more relevant than intelligence for grades. Nevertheless, most prior studies that claimed such a differential relevance of intelligence and motivation for educational success reported the differences between regression coefficients only numerically, but did not apply inferential statistical tests. Yet, only Steinmayr and Meißner (2013) statistically compared the coefficients of intelligence and mathematics self-concept, revealing a significantly higher relevance of intelligence than self-concept for a mathematics competence test. However, concerning grades, the coefficients of self-concept and intelligence did not statistically differ although the numerical pattern was almost perfectly inverted compared to the scholastic competence test. As to interests, the numerically reported differential relevance has not been statistically examined, yet. Furthermore, previous studies that numerically reported the differential relevance of interest did not systematically control for the substantial amounts of shared variance among interest, self-concept, and intelligence. Additionally, examining the unique increments of the three predictors would deepen the understanding of the interplay between cognitive and motivational variables as predictors of different achievement indicators for educational success.

Therefore, this study examined the differential relevance of intelligence, self-concept, and interest on scholastic competence tests and grades in the core school subject mathematics in four steps: In separate models, we first statistically tested the differential relevance of intelligence and self-concept, and second, of intelligence and interest. Third, considering the substantial amounts of shared variance between self-concept and interest, we statistically tested the differential relevance of all three predictors in concert. Fourth, we examined the unique effects (increments) of each predictor beyond the others on the scholastic competence test and grades.

1.1. Prediction of educational success by intelligence

Intelligence, in the sense of *g*, is known to be the most important psychological predictor of educational success and to account for more

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* Corresponding author at: Saarland University, Campus A5 4, D-66123 Saarbrücken, Germany.
E-mail address: c.lotz@mx.uni-saarland.de (C. Lotz).

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variance than any other single factor independent of *g* (e.g., Jensen, 1998b; Kuncel, Hezlett, & Ones, 2004; Mackintosh, 2011). The close relation between intelligence and educational outcomes is theoretically explained by the *g*-demands of learning itself. For example, students have to grasp concepts and meanings, learn to deal with novel material, and transfer previously learned knowledge and skills to new situations, which is all intrinsic to *g* (Jensen, 1998b).

Educational success is typically assessed by teacher's grades or scholastic competence tests (Steinmayr, Meißner, Weidinger, & Wirthwein, 2014). Regarding grades, a meta-analysis found a substantial mean correlation of $\rho = .54$ between intelligence and school grades (Roth et al., 2015). Regarding scholastic competence tests, the correlations usually range between .60 for achievement subtest scores and .70 for composite scores (Naglieri & Bornstein, 2003) or were even higher (Baumert, Lüdtke, Trautwein, & Brunner, 2009; Frey & Detterman, 2004). Thus, these intelligence-test-correlation coefficients numerically exceeded the average intelligence-grade-correlation coefficients. A recent study, relying on figural reasoning, found a similar differential result pattern across five school subjects within one large sample ($N = 39{,}192$ ninth grades; e.g., mathematics: $\beta_{tests} = .56$, $\beta_{grades} = .26$; Jansen et al., 2016). One reason for the very strong association between intelligence and scholastic competence tests might be the moderating role of intelligence during the cumulative process of knowledge acquisition whose results are measured by scholastic competence tests (Baumert et al., 2009).

In sum, intelligence seems to be differentially relevant, depending on the achievement indicator (tests or grades) which has not been statistically tested before. Even though *g* explains large amounts of variance in scholastic achievement and even though high intelligence provides excellent prerequisites for educational success, a high level of intelligence is, nevertheless, "only a necessary but never a sufficient condition" for doing well in school (Jensen, 1998a, p. 122). Thus, other variables play an important role for predicting educational success beyond intelligence.

1.2. Prediction of educational success by motivational variables

Motivational variables were frequently shown to predict educational success and to account for substantial amounts of variance beyond intelligence (e.g., Kriegbaum, Jansen, & Spinath, 2015; Spinath et al., 2006; Steinmayr & Spinath, 2009). One widespread theoretical framework is the well-elaborated expectancy-value theory (Eccles et al., 1983; Wigfield & Eccles, 2000). This model posits that the expectancy to succeed in a task and the value assigned to the task determine achievement-related behavior. With regard to the expectancy component, reflecting students' self-perceived competences or their ability self-concepts, moderate relations with scholastic achievement were reported ($.30 \leq r \leq .60$; Guay, Marsh, & Boivin, 2003; Valentine, DuBois, & Cooper, 2004). Referring to the value component, reflecting intrinsic motivational-affective variables such as interests, associations with scholastic achievement were weak to moderate ($.20 \leq r \leq .30$; Jansen et al., 2016; Schiefele, Krapp, & Winteler, 1992). Furthermore, students' self-concepts and interests are structured particularly school subject specific (Bong & Clark, 1999) and are strongly related within one domain (Eccles & Wigfield, 1995; Rost, Sparfeldt, & Schilling, 2007; Trautwein et al., 2012). For example, correlations of $r = .74$ (Rost et al., 2007) or $r = .80$ (Trautwein et al., 2012) were reported for high school students in mathematics.

Referring to different achievement indicators, motivational variables seem to be associated stronger with grades than with scholastic competence tests (Jansen et al., 2016; Jansen, Schroeders, & Lüdtke, 2014; Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005). Student characteristics such as study habits, effort, and persistence are more likely to influence teacher-given grades than scholastic competence tests. Moreover, grades are "the more salient source of individual feedback" (Marsh et al., 2005, p. 399) because grades are typically well-known to students due to their immediate form of feedback. Thus, according to the reciprocal effects model which states that scholastic achievement affects subsequent motivation which, in turn, affects subsequent achievement (Marsh et al., 2005), the mutual motivation-achievement reinforcement might be stronger for grades than for scholastic competence tests.

Empirical studies, specifically addressing the motivational variables self-concept or interest, gave evidence for their closer relation to grades than to scholastic competence tests. Regarding self-concept, meta-analytical results showed that school subject-specific self-concepts were numerically closer related to grades than to scholastic competence tests (e.g., mathematics: $r_{grades} = .50$; $r_{tests} = .37$; Möller, Pohlmann, Köller, & Marsh, 2009). For German samples, a study with $N = 6{,}036$ 10th graders revealed that school subject-specific self-concepts were numerically closer related to grades than to scholastic competence tests in three science school subjects (e.g., physics: $\beta_{grades} = .41$, $\beta_{tests} = .11$; Jansen et al., 2014). School subject-specific interests also revealed numerically higher regression coefficients on grades compared to scholastic competence tests in five school subjects (e.g., mathematics: $\beta_{grades} = .42$, $\beta_{tests} = .23$; Jansen et al., 2016). When considering both expectancy-value components in mathematics (Marsh et al., 2005), the differential pattern was revealed only for self-concept: The regression coefficients on grades (study 1/2: $\beta = .24/.26$) were numerically higher than those on scholastic competence tests ($\beta = .09/.16$), whereas interest showed regression coefficients around zero on both criteria. Probably, the substantial correlation between self-concept and interest (study 1/2: $r = .56/.58$) caused the drop of the formerly substantial interest-achievement-coefficients.

In line with expectancy-value theory, self-concepts seem to be more closely associated with school performance, whereas interests are more predictive of achievement-related choices or efforts (Eccles et al., 1983). Because everyone has to do courses in mathematics, choices are quite limited in the school context. Thus, self-concepts might be more important than interests for predicting educational success. Examining mathematical achievement, it was shown that interest in mathematics neither contributed to the prediction of grades (Meece, Wigfield, & Eccles, 1990) nor teacher ratings of competences (Spinath et al., 2006) after controlling for the common variance with mathematics self-concept, although interest had been substantially related to achievement when considered individually.

Taken together, when considering either self-concept or interest, both seem to be differentially relevant by showing higher relations to grades than to scholastic competence tests in mathematics which, nevertheless, needs to be statistically tested. Because interest seems to lose its predictive power on scholastic achievement when controlling for the common variance with self-concept, an examination of the increments of self-concept and interest for grades and scholastic competence tests might shed light upon the importance of their unique variance proportions for different achievement indicators.

1.3. Differential relevance of intelligence and motivational variables for scholastic competence tests and grades

An even more conclusive picture emerges, when examining the differential relevance of cognitive and motivational variables in concert. For example, the study by Helmke (1992) investigated $N = 813$ ten-to-thirteen-year-olds and showed that cognitive variables accounted for 38% of the variance in a mathematics competence test, whereas mathematics self-concept accounted for 32%. When predicting mathematics grades, the pattern of result was inverted: cognitive variables accounted for 20% of the variance, whereas self-concept accounted for 57%. However, because cognitive variables were a conglomerate of reasoning and former elementary school grades, the interpretation of these results might be limited. Nevertheless, comparable results were revealed for interest and intelligence (assessed with a measure of figural reasoning; Jansen et al., 2016): Intelligence exhibited numerically