Learning and Individual Differences 43 (2015) 140–148

Contents lists available at ScienceDirect

Learning and Individual Differences

journal homepage: www.elsevier.com/locate/lindif

Motivation: A predictor of PISA's mathematical competence beyond intelligence and prior test achievement

Katharina Kriegbaum [a,*], Malte Jansen [b,1], Birgit Spinath [a]

[a] Department of Psychology, Heidelberg University, Germany
[b] Institute for Educational Quality Improvement, Humboldt-Universität zu Berlin, Germany

ARTICLE INFO

Article history:
Received 29 December 2014
Received in revised form 29 May 2015
Accepted 17 August 2015

Keywords:
PISA
Mathematical competence
Intelligence
Motivation

ABSTRACT

This study examined the relative importance of different motivational constructs for the prediction of mathematical competence in adolescents and their incremental power beyond intelligence and prior achievement. We employed both a cross-sectional and a one-year longitudinal approach using data from PISA 2003 and 2004, a nation-wide representative dataset. The sample consisted of 6020 fifteen-year-old German students who provided self-reports on their math-specific self-concept, self-efficacy, interest, and goal orientations in addition to the core PISA standardized achievement tests. Data were analyzed with structural equation models. Cross-sectionally, all motivational constructs incrementally contributed to the prediction of mathematical competence beyond intelligence (explained variance: 1%–29%). After controlling longitudinally for intelligence and prior achievement, self-efficacy, self-concept, interest, and learning goals significantly predicted subsequent mathematical competence one year later. Relative weights analyses compared the predictive power of all variables simultaneously and showed that intelligence (cross-sectional) and prior achievement (longitudinal) explained the largest portion of variance in mathematical competence, followed by task-specific self-efficacy as the strongest motivational predictor. These results confirm that motivation plays an important role in predicting academic achievement.

1. Introduction

Laypeople and experts in teaching and learning alike are convinced of the importance of motivation for learning and achievement. However, the relative importance of motivation compared to other prerequisites, such as intelligence, differs depending on the achievement measure. There is ample evidence that various motivational constructs predict school grades over and above intelligence and prior achievement (e.g., Gottfried, 1990; Schicke & Fagan, 1994; Steinmayr & Spinath, 2009). Grades are known to be influenced not only by students' ability but also by other student characteristics, such as motivation. In comparison to grades, standardized achievement tests are known to be more strongly predicted by intelligence (e.g., Helmke, 1992; Steinmayr & Meißner, 2013). Therefore, it is a stronger test of the predictive power of motivation over and above intelligence to take achievement test results as achievement criteria. Several studies have investigated the incremental power of different motivational constructs in predicting achievement on standardized tests (Lloyd & Barenblatt, 1984; Schicke & Fagan, 1994; Trautwein et al., 2012; Murayama, Pekrun, vom Hofe, & Lichtenfeld, 2013; Steinmayr & Meißner, 2013). However, each of these studies either focused on only one motivational construct or examined the incremental validity of motivation only cross-sectionally or in selective samples (e.g., students from only one school type).

The present study aimed to explore the incremental validity of different motivational constructs above and beyond intelligence and prior achievement when predicting mathematical competence in PISA tests. The study differs from prior studies in the following ways: First, we investigated not one but several motivational constructs, i.e. ability self-concept, self-efficacy, interest and goal orientations at the same time and compared how much criterion-related variance was attributed to each of them. This is the first study to simultaneously use these motivational constructs as well as intelligence and prior achievement to predict standardized test achievement. Second, we used a longitudinal approach, measuring students' mathematical competence twice (at the end of ninth grade and at the end of tenth grade). This allowed us to examine the extent to which the change in standardized test achievement was predicted by motivation. Third, we used the PISA-I-Plus dataset which is fully representative of the fifteen-year-old German secondary student population (6020 students). To have a representative sample is important because otherwise pre-selection of students according to criteria such as prior achievement restricts the variance of some predictors more than that of others and thus leads to distorted results when comparing the predictive power of each variable.

* Corresponding author at: Department of Psychology, Heidelberg University, Hauptstraße 47-51, 69117 Heidelberg, Germany.
E-mail address: Katharina.Kriegbaum@psychologie.uni-heidelberg.de (K. Kriegbaum).
[1] Malte Jansen is now at the German Institute for International Educational Research (DIPF).

http://dx.doi.org/10.1016/j.lindif.2015.08.026
1041-6080/

1.1. Intelligence and motivation as predictors of academic achievement

An impressive number of studies have shown that intelligence is a strong predictor of academic achievement, with an average correlation of $r = .50$ (Gustafsson & Undheim, 1996; Kuncel et al., 2004). The predictive power of intelligence is especially strong when measuring achievement with standardized tests, with correlations ranging from $r = .61$–$.90$ (Deary et al., 2007; Frey & Detterman, 2004; Rindermann, 2006). In the current study, we use data from the Program for International Student Assessment (PISA) as a performance criterion for mathematical achievement. For PISA, a strong association between intelligence and mathematical competence has repeatedly been reported (Rindermann, 2006, 2007). In fact, the association between intelligence and competence has been found to be so strong that Rindermann (2006) went so far as to conclude that the PISA studies measure nothing but intelligence. Even though it has been convincingly argued that school achievement as measured by PISA-tests is theoretically and empirically different from intelligence (Baumert et al., 2007; Prenzel, Walter, & Frey, 2007). The fact that this discussion came up shows how strongly intelligence and standardized test achievement are associated.

Research has also identified motivation as a significant predictor of academic achievement. Whereas ability self-concepts are more strongly related to school grades with $r = .40$–$.60$ and less strongly related to standardized test achievement with $r = .30$–$.40$ (Frenzel et al., 2006; Marsh et al., 2005; Möller et al., 2009), self-efficacy has been shown to be a better predictor of standardized achievement ($r = .50$) than of school grades ($r = .30$) (Frenzel et al., 2006; Jansen et al., 2015). It can be argued that this is a consequence of both the operationalization of self-efficacy and the effects of different frames of reference. As for the operationalization, self-efficacy items are formulated to match typical tasks that are part of the competence tests, too. It could be the case that the similarity between self-efficacy and test items moderates the relation between self-efficacy and standardized test achievement (Stankov et al., 2012). With regard to frames of reference, students use information about their classmates' performance (external frame of reference) and their own performance in other domains (internal frame of reference) to evaluate their performance. This has an effect on their academic self-concepts (Marsh, 1987). In contrast, the influence of frame of reference effects is minimized when it comes to self-efficacy because the focus is on a student's competences in relation to the specific criterion tasks (Bong & Skaalvik, 2003; Marsh et al., 1997). Furthermore, interest and instrumental motivation have been shown to be weakly to moderately ($r = .20$–$.30$) associated with school grades and PISA competences (Frenzel et al., 2006; Köller et al., 2001; Marsh et al., 2005; Spinath et al., 2014). Additionally, learning goals and performance-approach goals are positively related to school grades, whereas performance-avoidance goals and work avoidance are negatively associated with school grades (Elliot & Church, 1997; Elliot & McGregor, 2001; Spinath et al., 2002). In sum, the present research confirms that different motivational constructs are significant predictors of standardized test achievement, like PISA competences, and school grades.

1.2. The incremental power of motivational concepts in predicting academic achievement

Importantly, motivation has been shown to contribute to a portion of academic achievement variance that is not explained by intelligence. Regarding school grades both in specific subjects as well as grade point average, different motivational constructs (i.e. ability self-perceptions, intrinsic motivation, subjective task values, learning goals, work avoidance and achievement motives) have been shown to be predictive beyond intelligence and prior achievement (e.g., Chamorro-Premuzic et al., 2010; Freudenthaler et al., 2008; Greven et al., 2009; Luo et al., 2010; Spinath et al., 2006; Spinath et al., 2010; Steinmayr et al., 2011; Steinmayr & Meißner, 2013; Steinmayr & Spinath, 2009). Whereas most motivational constructs explain less variance in grades than intelligence, ability self-perceptions explain a comparably high or even higher amount of unique variance in school grades than intelligence (Helmke, 1992; Steinmayr & Meißner, 2013; Steinmayr & Spinath, 2009).

Fewer studies have investigated whether different motivational constructs predict standardized test achievement beyond intelligence. Lloyd and Barenblatt (1984) found that intrinsic motivation explained additional variance (7.2%) in standardized test achievement over and above intelligence. Similarly, intrinsic motivation has been found to predict mathematics achievement (Gottfried, 1985) as well as reading competence (Deutsches PISA-Konsortium, 2001, pp. 129) after controlling for intelligence. Moreover, Murayama et al. (2013) demonstrated that intrinsic motivation, but not intelligence, was related to increases in achievement over 5 years. Trautwein and colleagues (2012) found that subjective task values (according to Eccles et al., 1983) predict mathematics achievement after controlling for intelligence. As another motivational construct, ability self-perceptions have repeatedly demonstrated incremental validity over intelligence when predicting standardized test achievement (Gose et al., 1980; Helmke, 1992; Schicke & Fagan, 1994; Steinmayr & Meißner, 2013; Trautwein et al., 2012). For example, Steinmayr and Meißner (2013) showed that of the total explained variance ($R^2 = .48$), intelligence accounted for 60% of unique variance in standardized test achievement, whereas ability self-perceptions only accounted for 19%, and 21% was explained by both predictors. In all of the studies described in this section, intelligence contributed more to explained variance than motivation.

Taken together, this pattern of data suggests that motivation has incremental power when predicting standardized test achievement. However, intelligence can be expected to be the best predictor of standardized test achievement. Additional empirical work is needed to systematically compare the relative power of different motivational constructs. These variables can to be put to an especially strong test by choosing standardized test achievement as the dependent variable and controlling not only for intelligence but also for prior achievement. This can only be done in a longitudinal approach. These issues were addressed in the current study.

1.3. Research questions and hypotheses

The aim of the current study was to determine the predictive power of different motivational constructs on mathematical competence in PISA. It is important to investigate the relative power of motivational constructs compared to intelligence, as some researchers doubt that other psychological constructs, like motivation, can make an independent contribution to the prediction of academic success over and above intelligence (Gagné & St. Pére, 2002). Moreover, in comparison to intelligence, motivation is more easily influenced by teachers. Because there are so many different motivational constructs, it is necessary to show which of them explain the most variance in school achievement. Based on such results, teachers or specific interventions could focus on fostering the most powerful motivational constructs. Furthermore, the incremental validity of some of the motivational constructs assessed in our study has not been investigated before.

In a first step, we explored the extent to which different motivational constructs predict achievement after controlling for intelligence and prior achievement. In a second step, the relative importance of each predictor was determined.

Based on the literature reported above, the following hypotheses were generated:

1) Cross-sectionally, motivational constructs (self-concept, self-efficacy, interest, instrumental motivation and goal orientations) were expected to incrementally predict standardized mathematics achievement after controlling for intelligence.