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Typical intellectual engagement and achievement in math and the sciences in secondary education☆

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ABSTRACT

Typical Intellectual Engagement (TIE) is considered a key trait in explaining individual differences in educational achievement in advanced academic or professional settings. Research in secondary education, however, has focused on cognitive and conative factors rather than personality. In the present large-scale study, we investigated the relation between TIE and achievement tests in math and science in Grade 9. A three-dimensional model (reading, contemplation, intellectual curiosity) provided high theoretical plausibility and satisfactory model fit. We quantified the predictive power of TIE with hierarchical regression models. After controlling for gender, migration background, and socioeconomic status, TIE contributed substantially to the explanation of math and science achievement. However, this effect almost disappeared after fluid intelligence and interest were added into the model. Thus, we found only limited support for the significance of TIE on educational achievement, at least for subjects more strongly relying on fluid abilities such as math and science.

Individual differences in academic performance have been linked to a plethora of cognitive, conative, and affective factors. The use of cognitive abilities to predict school performance has a long tradition, dating back to the first intelligence test (Binet & Simon, 1904). Since then, the power of cognitive factors such as fluid intelligence or domain-specific knowledge for the prediction of performance in secondary and tertiary education has been repeatedly demonstrated (e.g., Hambrick, 2004; Kuncel, Hezlett, & Ones, 2004). Conative factors such as academic self-concept or subject-specific interest also affect students' performance. For instance, math self-concept in Grade 7 explained math achievement in Grade 10 over and above math ability in Grade 7 (Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005). In contrast to cognitive and motivational constructs, personality and other affective factors still play a minor role in educational research.

Several reasons can be given for this circumstance: First, as cognitive abilities are by far the most powerful predictors of academic achievement (e.g., Furnham, Monsen, & Ahmetoglu, 2009), the potential benefit of noncognitive variables such as personality constructs in terms of incremental validity appears marginal. Second, because nonability traits operationalized with measures of typical behavior (e.g., questionnaires; see Cronbach, 1949) are prone to *faking good* and social desirability effects, they have received less attention in the high-stakes contexts (e.g., college admission) that have steered a lot of research. Finally, compared to other noncognitive characteristics (e.g., interest or self-efficacy), personality is understood as a set of more stable behavioral dispositions which are only marginally sensitive to intervention and schooling. In the context of educational research with pupils, however, the focus lies explicitly on the more malleable aspects of human behavior.

1. Typical Intellectual Engagement: A Promising Candidate

The term personality represents a broad set of diverse constructs. Among the constructs that are particularly promising for predicting individual differences in academic performance are the so-called intellectual investment traits such as need for cognition, the Big Five trait openness, and typical intellectual engagement (TIE). In this paper, we focus on typical intellectual engagement (Ackerman & Goff, 1994; Goff & Ackerman, 1992). TIE describes a person's engagement in intellectual activity and his or her interest in and need for a profound understanding of complex issues. Therefore, TIE characterizes the attraction/aversion that an intellectually demanding task exerts on an individual. Individuals with high engagement receive better grades, score significantly higher on standardized ability tests (Chamorro-Premuzic, Furnham, & Ackerman, 2006b; Wilhelm, Schulze, Schmiedek, & Süß, 2003), and possess better general knowledge (Chamorro-Premuzic, Furnham, & Ackerman, 2006a).

The construct TIE seems predestined for the prediction of scholastic achievement. From a theoretical point of view, TIE should have a

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positive impact on the acquisition of skills and knowledge in adulthood. The willingness to solve complex issues, to contemplate and to deal with new information mirrors the conditions required for successful learning. For two persons with the same level of cognitive ability, TIE might be a key construct for explaining interindividual differences in learning and academic achievement. Furthermore, as a measure of typical behavior, TIE may "play an important cumulative role in knowledge acquisition and retention" (Rolfhus & Ackerman, 1999, p. 513) and may provide a link between cognitive and conative factors, building clusters or "trait complexes" (Ackerman & Heggestad, 1997). In PPIK theory (intelligence-as-process, personality, interests, and intelligence-as-knowledge; Ackerman, 1996), so-called intellectual investment traits are conceived as crucial for the transition from process to knowledge (Ackerman & Rolfhus, 1999; Rolfhus & Ackerman, 1999; von Stumm & Ackerman, 2012).

From an empirical perspective, TIE has been shown to be moderately correlated with scholastic and academic performance. For example, TIE was positively correlated with grade point average, college admission test scores (Wilhelm et al., 2003), and course measures of academic performance such as tutorial reports, essays, or project reports (Chamorro-Premuzic et al., 2006b). A recent meta-analysis reported substantial relations of TIE with crystallized intelligence and knowledge (von Stumm & Ackerman, 2012). Accordingly, intellectual curiosity as indicated by TIE was identified as the "third pillar of academic performance" in addition to intelligence and effort (von Stumm, Hell, & Chamorro-Premuzic, 2011, p. 574).

2. Research Questions

Hitherto, TIE has been studied mainly in adult samples with a high educational level (i.e., university students). We want to expand the knowledge on TIE by examining the impact of TIE on achievement in math and three natural sciences—biology, chemistry, and physics—in a heterogeneous sample of students at the end of compulsory education. TIE has been seen as particularly informative in explaining performance differences in advanced academic or professional settings that require consolidated cognitive effort and constant commitment (Ackerman & Beier, 2004). However, the influence that TIE exerts in secondary education has rarely been studied. In general, little is known about the development and significance of TIE in this period of time when first decisions with respect to later academic or vocational training are made and formerly homogeneous learning environments begin to diverge. In contrast to a population of university students, the representative sample of students in secondary education examined in this study is not ability-restricted in any sense; therefore, the impact of TIE on achievement might be more pronounced. On the other hand, compared to adulthood the learning environments in secondary school are still relatively homogeneous given that learning is guided by curricula and school attendance is mandatory in Germany. Furthermore, the impact of TIE on educational achievement may be cumulative in nature. These arguments advocate a lower impact of TIE in secondary than in tertiary education.

In order to examine the influence of different learning environments on TIE in secondary education more thoroughly, we also compare *Gymnasium* (i.e., the academic-track school type) to all remaining school types (nonacademic-track schools). Given at least strong measurement invariance of the instrument across school types, we compare both groups: Beside higher means of the latent variables, we assume a more pronounced differentiation of the TIE facets in the academic-track subsample (Ceci, 1991). In this context, we also consider gender differences by means of multi-group confirmatory factor analysis. Since girls have been repeatedly shown to outperform boys in reading achievement (e.g., Brunner et al., 2013) and in accordance with previous research (Wilhelm et al., 2003), one could assume an advantage of girls on this TIE facet. However, previous findings on gender differences in TIE are inconsistent (Chamorro-Premuzic et al., 2006a).

Based on the initial 59-item questionnaire (Goff & Ackerman, 1992), Wilhelm et al. (2003) developed a 18-item short scale in German measuring three core facets of TIE—*reading*, *contemplation*, and *intellectual curiosity*. We adapted the questionnaire to the target population of secondary students and addressed some drawbacks found in earlier studies (i.e., items with cross-loadings, ambiguous or complicated wordings; Wilhelm et al., 2003). Due to the substantial revision of the questionnaire items we investigated the psychometric quality and internal structure of the revised measure first in order to make valid statements about the construct.

Our main research question was aimed at quantifying the impact of TIE on academic performance in an unselected student sample over and above the powerful predictors usually employed in educational research. Since problem solving and modeling in mathematics and the sciences depend to a large degree on abstract thinking and scientific curiosity, a positive relation between the personality construct TIE and scholastic achievement in these subjects seems plausible.

3. Method

3.1. Design and Participants

Data were collected in May and June 2012 in the *German National Educational Assessment 2012*, a large-scale nation-wide educational assessment study in math and the sciences based on the *National Educational Standards in Germany* (Pant et al., 2013). Aims and scope of the study are comparable to the *National Assessment of Educational Progress* (NAEP). Standardized tests and questionnaires were administered in a balanced incomplete block design (Gonzalez & Rutkowski, 2010). The test session took a total of 3 h; 2 h for the achievement tests and 1 h for a student questionnaire and additional measures.

Analyses presented in this paper were based on a subsample of $n =$ 7,207 ninth-grade students from 389 schools who completed the TIE questionnaire. All common school types from the German secondary educational system were included in the sample: 36.3% of the students attended academic-track *Gymnasium*, the remaining school types included vocational-track and mixed-track schools. Participation was mandatory for the achievement tests (participation rate: 92%) but voluntary for the questionnaires in most federal states (participation rate: 79%). Students were not rewarded or graded in any way. Mean age was 15.5 years ($SD = 0.6$; $n = 7{,}206$), and half of the sample was female (49.4%). The subsample can be seen as representative for the population of German ninth-graders with respect to migration status (66.5% always spoke German at home, $n = 5{,}845$) and socio-economic status ($M = 51.8$, $SD = 20.6$, $n = 5{,}802$).

3.2. Measures

3.2.1. TIE questionnaire

TIE was assessed with a thoroughly revised version of Wilhelm et al.'s (2003) German short scale. Students indicated their agreement/disagreement with 18 statements on a 4-point scale ranging from *strongly agree* to *strongly disagree*. Item translations are given in Table 2; the original German version is provided in the online supplement.

3.2.2. Achievement tests

Achievement in mathematics, biology, chemistry, and physics was assessed with standardized tests based on the *National Educational Standards for Mathematics and Science in Germany* (Pant et al., 2013). For math, we used the *global scale*; in the sciences, we used the dimension *scientific inquiry* in biology, chemistry, and physics; example items are given in the online supplement. The math part consisted of 374 items including closed response items (i.e., true/false and multiple-choice), short answer und extended answer items. The science part comprised 118 biology, 134 chemistry, and 134 physics items.