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Mathematics attitudes and their unique contribution to achievement: Going over and above cognitive ability and personality

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ABSTRACT

In two studies we investigated whether student-reported mathematics attitudes, conceptualized with the theory of planned behavior, incrementally contributed to students' mathematics grades over and above cognitive ability and the Big Five personality dimensions. College students from Germany (n = 179) and Belarus (n = 202) participated. Results highlighted the importance of attitudes for mathematics achievement, with attitudes toward mathematics incrementally explaining 25% (Germany) and 7% (Belarus) of variance in mathematics grades over and above students' cognitive ability and Big Five personality dimensions. The overall model that included the three construct domains accounted for 45% (Germany) and 27% (Belarus) of variation in mathematics grades. We argue that because attitudes may be more malleable than broad personality and cognitive ability characteristics, our findings are particularly important in the context of intervention development.

1. Introduction

Achieving high levels of mathematics proficiency is essential to both individual success and a country's economy. To date, ample research has been accumulated that highlights non-trivial implications of mathematics proficiency (or lack thereof) for various aspects of individuals' functioning (e.g., Geary, 1996; Fleischman, Hopstock, Pelczar, & Shelley, 2010). Results on an individual level consistently demonstrate that achievement in mathematics is related to well-being, satisfaction with life, health, wages, employability, and longevity (e.g., Rivera-Batiz, 1992; Reyna & Brainerd, 2007). On a national level, economic consequences of underperformance in math are no less serious: Fewer students selecting occupations that require mastery of mathematics may result in serious economical disadvantages in mathematics-related disciplines such as engineering, IT, and finance (Geary, 1996; Philips, Barrow, & Chandrasekhar, 2002; Stake & Mares, 2005). Despite empirical evidence on the importance of mathematics proficiency, recent large-scale international assessments (PISA, TIMSS) demonstrate that students from many nations are not performing at expected levels in mathematics (Naemi et al., in press; Fleischma et al., 2010; Gonzales et al., 2004; Miller, Sen, & Malley, 2007). Hence, it is evident that the gap between well-documented and accepted importance and the de facto proficiency in mathematics needs to be bridged.

To alleviate this problem, researchers have been investing substantial efforts into finding person-based reasons for deficiencies in mathematics performance and determining characteristics that may influence students' attainment in the domain of mathematics. In general, three broad constructs have been identified that consistently relate to student achievement in mathematics: cognitive ability (e.g., Deary, Strand, Smith, & Fernandes, 2007; Luo, Thompson, & Detterman, 2003), personality characteristics (e.g., Heaven & Ciarrochi, 2012; Poropat, 2009), and attitudes toward mathematics (in the remainder of this manuscript also referred to as math attitudes) (e.g., Lipnevich, MacCann, Krumm, Burrus, & Roberts, 2011). In light of the need to identify factors related to proficiency in mathematics, for which interventions can be implemented in instructional settings, attitudes toward mathematics may be particularly promising (for reviews on the malleability of attitudes see Albarracin, Johnson, & Zanna, 2005; Cialdini & Goldstein, 2004). However, the number of psychosocial factors deemed as being critical for education is growing (Lipnevich, MacCann, Bertling, & Roberts, 2012), and thus the question of their unique contribution to academic performances arises. Quite often, these newly discovered predictors strongly relate to existing personality factors, and fail to incrementally explain variance in important educational outcomes (MacCann, Lipnevich, Burrus, & Roberts, 2012; see also "jingle-jungle fallacy," Block, 1995). Hence, it is crucial to show that math attitudes have something to offer above and beyond cognitive ability and personality,

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i.e., explain unique variance in relevant outcomes. This study intended to do just that: In the two studies herein reported we investigated the incremental contribution of math attitudes over and above cognitive ability and the Big Five personality dimensions.

Below, we first review links among cognitive ability, personality dimensions, and achievement. Next, we argue that exploring the incremental contribution of math attitudes in explaining math performance above and beyond these predictors is of key interest for practitioners and researchers alike.

1.1. Cognitive ability and math achievement

The relationship between cognitive factors and academic achievement has been of interest to numerous researchers. Studies have demonstrated that various measures of fluid intelligence accounted for up to 58% of variance in measures of academic achievement (cf. Deary et al., 2007). This finding generalized across cognitive ability tests and cultures (e.g., Laidra, Pullmann, & Allik, 2007; Luo et al., 2003; Krumm, Lipnevich, Schmidt-Atzert, & Bühner, 2012). This is not surprising. Individuals' inductive and deductive reasoning skills are certainly necessary to acquire new knowledge and expertise (e.g., Day, Arthur, & Gettman, 2001) and, thus, to succeed in school (Rohde & Thompson, 2007). In addition to such general requirements, achievement in mathematics relies on one's ability to understand and solve complex tasks that have an inherent logic, thereby increasing cognitive demands in this particular domain of study. Mathematical problems may also have a hierarchical structure (i.e., the parts of the task need to be solved first and kept in mind to be able to solve the overall task) thus increasing the demand on working memory processes (Krumm, Ziegler, & Buehner, 2008; Lu, Weber, Spinath, & Shi, 2011). The latter are the key processes in fluid cognitive functioning (e.g., Kyllonen & Christal, 1990). In sum, it has been shown that cognitive ability, and especially fluid intelligence, is fundamental and necessary for math achievement.

Despite their primacy in mathematics attainment, modifying cognitive abilities to leverage mathematics proficiency appears to be difficult. Although some studies suggest that fluid intelligence (e.g., Freund & Holling, 2011; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008) and narrower cognitive skills (e.g., Hernstein, Nickerson, de Sánchez, & Swets, 1986) can be improved, it is rather difficult to transfer these interventions to classroom settings. For instance, in the intervention study conducted by Jaeggi and colleagues, individuals were trained with a series of working memory tasks, which led to improvements in fluid intelligence. These findings—albeit valuable from a theoretical point of view—do not provide insights as to how to adjust day-to-day instructional practices or have a large-scale implementation of these interventions. Thus, one may conclude that the prominent role of fluid intelligence as a key predictor of math achievement does not reflect its practical relevance for increasing individual students' math achievement. Rather, other predictors are needed that may be directly used to address deficits in math and that provide predictive validity above and beyond fluid intelligence.

1.2. Broad personality dimensions and mathematics achievement

Personality factors are only moderately correlated with fluid intelligence (Ackerman & Heggestad, 1997) and therefore may have the potential to explain math achievement above and beyond individuals' cognitive ability. For decades, the most widely accepted conceptualization of personality has been the five-factor (or Big Five) model (e.g., Costa & McCrae, 1992; Tupes & Christal, 1992). The five factors comprising this model are: (a) Openness to Experience defined as the tendency to be open to new feelings, thoughts, and values; (b) Conscientiousness, the tendency to be organized, achievement-focused, and disciplined; (c) Extraversion, defined as the tendency to be friendly, cheerful, social, and energetic; (d) Agreeableness, the tendency to be sympathetic, kind, trusting, and cooperative; (e) Emotional Stability, the tendency to be resilient to negative emotions such as anxiety. These broad personality factors are known to relate to academic achievement (e.g., Poropat, 2009), with Conscientiousness and Openness showing the strongest relationship with academic outcomes (Poropat, 2009; Trapmann, Hell, Hirn, & Schuler, 2007; MacCann, Lipnevich, & Roberts, 2013; von Stumm, Hell, & Chamorro-Premuzic, 2011).

In addition to aggregated indices of scholastic achievement (i.e., grade point average) research have also shown that personality factors related to individuals' achievement in mathematics. In a recent study of Austrian eighth-graders, Conscientiousness accounted for a significant amount of variance in students' math grades, after controlling for intelligence and self-perceived ability in both male and female students (Spinath, Freudenthaler, & Neubauer, 2010; see also Steinmayr & Spinath, 2007). Studies also revealed positive relationships between Openness and math grades. In their study of personality predictors of school grades, Puklek Levpušček, Zupančič, and Sočan (2012) found that Openness and Conscientiousness were significant and positive predictors of students' grades in mathematics. Similarly, Furnham, Monsen, and Ahmetoglu (2009) reported that Openness related to mathematics grades in a sample of British school children. Finally, Heaven and Ciarrochi's (2012) longitudinal investigation also provided evidence for the relationship between Conscientiousness, Openness, and achievement in math.

Ample reasons are cited in the literature for why Conscientiousness and Openness are related to academic performance. For instance, Conscientiousness may be particularly beneficial for math performance as it includes facets that are important for persistent and thorough learning (such as industriousness, perseverance, and procrastination; see MacCann, Duckworth, & Roberts, 2009; Duckworth & Seligman, 2005). Also, Openness has been found to be strongly linked to deep learning (Chamorro-Premuzic & Furnham, 2009), which may be of particular relevance to the domain of mathematics. Furthermore, Mumford and Gustafson (1988) speculate that Openness may facilitate the use of efficient learning strategies (e.g., critical evaluation), which, in turn, enhances academic success.

In sum, personality traits in general, and Conscientiousness and Openness in particular, significantly relate to student academic performance. This link is fairly consistent and stable across cultures and different ages. Although the relevance of personality factors for achievement is inarguable, translating this relationship into interventions is not a simple task (see Walton & Billera, in press). Schools might rather focus on narrower personality facets (e.g., self-discipline, deliberation) or certain mediators of the relationship between personality and school performance, such as learning strategies or motivation (e.g., Mumford & Gustafson, 1988; Farsides & Woodfield, 2003). The current study addressed more specific attributes that may have the potential to explain incremental variance in math achievement above and beyond fluid intelligence and broad personality dimensions.

1.3. Math attitudes and achievement

Fluid intelligence and broad personality dimensions are effective predictors of student achievement in mathematics. Additionally, students' beliefs and expectations regarding the difficulty of math tasks, their perceived value of success, and perceived control over the outcome have been found to substantially relate to their achievement in mathematics (Singh, Granville, & Dika, 2002; Stevenson & Newman, 1986). In other words, students' overall positive or negative evaluations, or attitudes toward mathematics, may be critically important for success in mathematics.

Meta-analytic studies indicate a positive (although rather small) correlation between math attitudes and math performance (Ma & Kishor, 1997). Structural models further suggest a reciprocal relationship (Ma & Xu, 2004), and allude to the causal pathway between math attitudes and achievement (Ma & Kishor, 1997; Mattern &

Schau, 2002), wherein negative mathematics attitudes lead to lower performance. Researchers have posited that small observed effect sizes in meta-analytic reviews of the relation of math attitudes and math performance may be due to the poor psychometric quality of instruments designed to measure math attitudes (Lipnevich et al., 2011), including fluctuating factorial structure and low validity (see Melancon, Thompson, & Becnel, 1994; Tapia, 2004). These problems may stem from a lack of a robust theory driving the development of math attitudes assessments.

To overcome these problems, Lipnevich et al. (2011) employed the theory of planned behavior (see Ajzen, 1991, 2002, 2006) to develop a mathematics attitude questionnaire (MAQ) for middle school students. The theory of planned behavior is based on the assumption that individuals' behavior is determined by their intention to perform a certain behavior. Ajzen proposed three independent determinants of behavior that exert their effects through intention. These determinants are: (1) attitudes (the overall positive or negative evaluation toward an item), (2) subjective norm (the social pressures on the individual to perform a behavior), and (3) perceived behavioral control (the extent to which an individual perceives his/her ability to control the outcome of a behavior). Altogether, the three determinants and intention comprise the four components of the theory of planned behavior. Throughout the article, we follow common conventions and use "attitudes toward mathematics" or "math attitudes" as umbrella terms covering all of the components of the theory of planned behavior (Lipnevich et al., 2011), thereby acknowledging the notion of an attitude as "a summary evaluation of a psychological object" captured in several dimensions (Ajzen, 2001, p. 28). Empirical evidence confirms the viability of the model, with attitudes and perceived behavioral control successfully predicting individuals' intention to carry out the behavior in question (Armitage & Conner, 2001; Trafimow, Sheeran, Conner, & Finlay, 2002). Further, a number of meta-analyses demonstrated that the TpB accounts for 27% of the variance in behavior and for 39% of the variance in self-reported intentions (e.g., Sheeran, 2002). Lipnevich et al. (2011) were able to explain 25% to 32% of variance in mathematics grades of middle school students in Belarus and the US, respectively. Hence, mathematics attitudes play a key role in math achievement.

The importance of studying whether attitudes are related to math performance lies in the relative malleability of this variable. Social psychologists demonstrated that attitudes may be effectively altered through interventions (see Kyllonen, Lipnevich, Burrus, & Roberts, 2014; Albarracin et al., 2005; Cialdini & Goldstein, 2004). In fact, researchers demonstrate that relatively simple classroom interventions can improve students' attitudes toward mathematics. For example, Sowell (1989) as well as Hembree and Dessart (1986) showed that the use of concrete materials (such as geoboards or bean sticks) or handheld calculators positively change students' math attitudes. It has also been shown that teachers play a key role in shaping students' math attitudes (cf. Butty, 2001; Farrell, 2006), for example through their own attitudes toward math (e.g., Simon & Schifter, 1993; Vinson, 2001).

Whereas the potential for modifying attitudes in instructional settings has been fairly well-established, the question that remains unanswered is whether mathematics attitudes incrementally contribute to performance in mathematics over and above individuals' cognitive abilities and broad personality dimensions. From a conceptual point of view, math attitudes differ substantially from Big Five personality dimensions and cognitive ability and thus can be expected to explain incremental variance. Whereas the Big Five personality dimensions capture individuals' characteristics that manifest across a variety of situations, math attitudes are defined as "a cluster of beliefs and affective orientations related to mathematics"(Gunderson, Ramirez, Levine, & Beilock, 2012, p. 153). So, math attitudes differ from the Big Five personality dimensions in that they (a) are beliefs and affective orientations rather than descriptors of typical traits and (b) relate to a specific domain (mathematics). Cognitive ability, on the other hand, refers to individuals' capacity to perform cognitive processes such as reasoning, problem solving, etc., and therefore differs conceptually from individuals' typical beliefs and affective orientations. In light of such conceptual disparities, we expect that math attitudes will make a unique contribution to math performance over and above cognitive ability and broad personality dimensions.

1.4. Aims of the current study

A significant research base reviewed in the preceding sections indicates that cognitive and non-cognitive characteristics play an important role in explaining student mathematics achievement. The relationship between general cognitive ability, personality factors, and attitudes toward mathematics is complex and, to our knowledge, there are no studies to date that examined these three attributes in unison when explaining variability in student mathematics grades. In our studies we attempted to redress this issue. Based on the preceding review of literature, we formulated the following hypothesis over two studies: Student-reported mathematics attitudes incrementally explain individuals' mathematics achievement over and above cognitive ability and personality factors.

2. Study 1: German sample

2.1. Method

2.1.1. Participants

A total of 179 undergraduate students (29% male) of the University of Trier, Germany, participated in this research. The average age was 22.6, $SD = 2.33$, with student ages ranging from 19 to 31 years of age. The majority studied Psychology (65%) and was enrolled in a Bachelor program (75%). At the time of data collection (November 2010) students' mean academic training was 3.78 semesters ($SD = 2.39$, ranging from 1 to 16 semesters). They obtained their high school degree (German Abitur) from schools across Germany. Students were chosen as participants as their personality and intellectual ability is less prone to developmental changes (cf. Salthouse, 2012; Soto, John, Gosling, & Potter, 2011), while they are still confronted with substantial requirements in mathematics (e.g., in statistics courses). Participation was voluntary; students received course credits and/or feedback for participation. Outlier analysis (following Tabachnick & Fidell, 1996, we considered z-scores above or below 3.29 as univariate outliers) suggested not to eliminate any data points.

2.1.2. Measures

2.1.2.1. Mathematics Attitude Questionnaire (MAQ). The German version of the mathematics attitude questionnaire (Lipnevich et al., 2011) was used. Item translation from the original English version into German was carried out by one of the authors. The translated questionnaire was then back-translated by an independent, professional translator. Any differences between the original instrument and the back-translation were discussed and adjusted accordingly (Brislin, 1986). The MAQ assesses the four components of the theory of planned behavior. The MAQ was originally developed for middle school students but can be considered appropriate for older students as well. Several items were modified to reflect content appropriate for college students.

Six items of the MAQ measured attitudes (e.g., "I enjoy studying math"), 5 items measured subjective norms (e.g., "My friends think that math is an important subject"), 5 items measured perceived behavioral control (e.g., "If I invest enough effort, I can succeed in math"), and 6 items measured intentions (e.g., "I will try to work hard to make sure I learn math"). Students were asked to rate each item on a 5-point scale from 1 (*Strongly Disagree*) to 5 (*Strongly Agree*). The total scores were calculated by summing students' responses for each of the four components. The reliability and the four-factor structure of the MAQ were confirmed in two culturally diverse samples (cf. Lipnevich et al., 2011).

2.1.2.2. Big Five Inventory (BFI). The German version of the big five inventory (Rammstedt, 1997, cf. John, Donahue, & Kentle, 1991) was used to measure broad personality dimensions (i.e., Extraversion, Neuroticism, Conscientiousness, Agreeableness, and Openness to experience). A total of 45 items was administered. Each item consisted of an item stem ("I see myself as someone who …") and statements prototypical for the personality dimension in question, such as "… is outgoing, sociable" (Extraversion), "… is relaxed, handles stress well" (Neuroticism, reverse keyed), "… does a thorough job" (Conscientiousness), "… tends to find fault with others" (Agreeableness, reverse keyed), or "…has an active imagination" (Openness to experience). Students rated each item on a 5-point scale ranging from 1 (*Disagree Strongly*) to 5 (*Agree Strongly*).

2.1.2.3. Berlin Structure of Intelligence Test (BIS Test). Four subtests of the Berlin Intelligence Structure Test (Jäger et al., 2006a, 2006b) were administered to assess students' reasoning ability, as one of the best indicators of fluid intelligence (Caroll, 1993). Specifically, two numerical (Number Series, Computational Reasoning) and two figural subtests (Analogies, Charkow) consisting of 9 to 15 tasks were conducted. The Number Series subtest consisted of a series of numbers with an inherent logic, which needed to be detected and applied to proceed the series. The Computational Reasoning subtest employed mathematical text problems that needed to be solved. The Analogies subtest consisted of two geometric figures with an inherent logic, which needed to be identified and applied to complement the third given figure by a fourth. The Charkow subtest employed a series of abstract figures with an inherent logic, which needed to be detected and applied to proceed the series. The tasks were presented as a speeded power test with generous time limits. A composite score over the 4 task types was built by averaging *z*-standardized scores per task type.

2.1.2.4. Mathematics achievement. We used mathematics grades as an indicator of mathematics achievement. Students self-reported their mathematics grades. We relied on self-reported grades as Kuncel, Credé, and Thomas (2005) showed that, unlike self-reported grades in other domains, self-reports of math grades correlated highly with actual math grades. Of note, grades from the final certificate (German "Abiturzeugnis") represent cumulative achievement from the last two school years and are thus more reliable than individual course grades. Grades were coded in the German grade-scale ranging from 1 to 6 reflecting the following performance categories: *very good* (1), *good* (2), *satisfactory* (3), *adequate* (4), *inadequate* (5), and *fail* (6). For the correlation and regression analyses, grades were recoded so that high scores reflect high performance.

2.1.3. Procedure

Tests were administered in proctored group settings by trained research assistants. Groups consisted of up to 20 students. Testing took between 1.5 and 2 h to complete, starting with tests of fluid intelligence (four subtests of the BIS-test), which were followed by the Big Five personality questionnaire (the BFI) and a questionnaire on demographic data and math grades. Finally, students filled out a questionnaire on math attitudes (the MAQ). All assessments were presented in a paper–pencil format. The sequence of test administration and item ordering with tests remained the same throughout the data collection.

2.1.4. Data analysis steps

2.1.4.1. Structural equation modeling. Due to the fact that MAQ was translated into German specifically for this study, we estimated a structural equation model to examine whether the structure implied by the TpB holds in the current sample. Structural equation modeling was conducted with AMOS 20.0 (Arbuckle, 2011). Estimation method was maximum likelihood. Model fit was evaluated based on a range of different cut-off values for fit indices as suggested by researchers in the structural equation modeling literature: (a) Acceptable fit: RMSEA ≤ .08, SRMR ≤ .09, and CFI ≈ .90; (b) Good fit: RMSEA ≤ .05 (or 90% C.I. of the RMSEA including .05), SRMR ≤ .09, and CFI ≥ .95 (e.g., Beauducel & Wittmann, 2005; Browne & Cudeck, 1992; Hu & Bentler, 1999; Marsh, Hau, & Wen, 2004).

2.1.4.2. Hierarchical linear regression. In order to examine the incremental contribution of the four components of the theory of planned behavior in explaining mathematics grades above and beyond reasoning ability and Big Five personality dimensions, a hierarchical linear regression predicting students' mathematics grades was conducted. We entered age and gender as control variables in Step 1, students' cognitive ability test scores in Step 2, Big Five personality dimensions in Step 3, and the four theory of planned behavior components in Step 4. The sequence of entering constructs into the hierarchical regression analysis was guided by the main goal of the study (i.e., to explore the incremental contribution of math attitudes above and beyond cognitive ability and personality).

2.2. Results

2.2.1. Descriptive statistics and bivariate correlations

Means, standard deviations, and reliability estimates are presented in Table 1. Except for Agreeableness, all the scales yielded alphas above .75 indicating sufficient reliability. Bivariate correlations of the main variables are shown in Table 2 (above the diagonal). Among the theory of planned behavior scales, intentions, perceived behavioral control, and attitudes were significantly correlated with the mathematics grade (*r*s from .31 to .55, $p < .01$).

2.2.2. Structural equation model

To confirm the factor structure of the MAQ in the German version of the questionnaire, a structural equation model was specified according to the assumptions of the TpB (see Fig. 1). This model yielded an acceptable to good overall model fit (χ^2 [200] = 374.88, $p < .01$, RMSEA = .07 [.059–.081], SRMR = .075, CFI = .91). Intentions were explained by attitudes ($\lambda = .62$, $p < .001$) but not by subjective norms ($\lambda = .10$, $p = .192$) and perceived behavioral control ($\lambda = -.07$, $p = .522$). All

Table 1
Descriptive statistics and reliability estimates of the main variables for the German and the Belarusian sample.

	Mean		SD		Alpha	
	G	*B*	*G*	*B*	*G*	*B*
Intentions[a] (TpB)	2.91	2.31	0.81	0.83	.86	.79
Control[a] (TpB)	3.54	3.77	0.82	0.97	.80	.78
Attitudes[a] (TpB)	2.92	2.32	1.04	0.94	.90	.80
Norms[a] (TpB)	2.97	2.80	0.66	0.83	.77	.67
Extraversion[a]	3.35	3.90	0.36	0.74	.87	.81
Neuroticism[a]	2.97	3.06	0.35	0.81	.85	.76
Conscientiousness[a]	3.35	3.47	0.34	0.67	.86	.78
Agreeableness[a]	3.35	3.60	0.40	0.61	.74	.65
Openness[a]	3.56	3.80	0.43	0.59	.78	.70
Reasoning ability	6.03	4.64	1.76	1.31	.78[b]	.67[b]
Math grade	2.43[c]	6.51[d]	1.09	1.39	–	–

Notes. Reliability is Cronbach's Alpha. TpB = theory of planned behavior. SD = standard deviation. G = German sample. B = Belarusian sample.

[a] Scale from 1 to 5.

[b] Estimated with Spearman–Brown formula to account for the fact that this score is obtained from a test battery.

[c] Scale from 1 to 6 with higher numbers indicating better achievement (these grades were taken from the final school certificate; grades are aggregated over the last two school years).

[d] Scale from 1 to 10 with higher numbers indicating better achievement (self-reported grades of the previous semester).

Table 2
Bivariate correlations (German and Belarusian sample).

	1	2	3	4	5	6	7	8	9	10	11
1. Intentions (TpB)	–	.29**	.55**	.19**	.05	.09	.25**	.19**	−.09	.07	.40**
2. Control (TpB)	.38**	–	.55**	.04	.05	−.10	.06	.14	.00	.33**	.31**
3. Attitudes (TpB)	.53**	.47**	–	.21**	.04	−.06	.15	.17*	−.03	.36**	.55**
4. Norms (TpB)	.21**	.02	.04	–	−.07	−.07	−.06	.16*	.05	−.02	.11
5. Extraversion	.01	.01	−.04	−.04	–	−.27**	.19*	−.07	.35**	−.04	−.06
6. Neuroticism	−.08	−.06	−.10	.04	−.43**	–	−.12	−.07	−.05	−.18*	.05
7. Conscientiousness	.12	−.01	.02	.13	.18**	−.23**	–	.16*	−.06	.02	.14
8. Agreeableness	.19**	−.05	.09	.03	.19**	−.17*	.33**	–	.00	.05	.17*
9. Openness	−.04	.05	.10	.04	.33**	−.24**	.09	−.08	–	−.13	−.21**
10. Reasoning ability	.07	.17*	.21**	−.07	.04	−.12	−.09	−.12	.11	–	.24**
11. Math grade	.13	.19**	.33**	−.01	−.05	.06	.10	−.03	.04	.41**	–

Notes. Correlations above the diagonal refer to the German sample, correlations below the diagonal to the Belarusian sample. TpB = theory of planned behavior.
** $p < .01$ (two-tailed).
* $p < .05$ (two-tailed).

items showed substantial loadings on their respective factors. Thus, the factorial model of the TpB was confirmed in the current sample. The latent attitude variable correlated significantly with perceived behavioral control ($\phi = .66$) and with subjective norms ($\phi = .22$). Interestingly, however, only one component of the TpB (attitudes) was significantly related to intentions. Thus, the structural model of the TpB was not confirmed.

2.2.3. Hierarchical regression predicting grades from cognitive ability, Big Five personality dimensions, and components of the theory of planned behavior

Table 3 shows the results of a hierarchical regression explaining mathematics grades with age and gender as control variables at Step 1, reasoning ability at step 2, Big Five personality dimensions at Step 3, and components of the theory of planned behavior at Step 4. Control variables accounted for 12% of the variation in mathematics grades, with reasoning ability explaining an additional 6% of the variation. Personality dimensions did not provide incremental validity beyond reasoning. In line with our hypothesis, the components of the theory of planned behavior yielded a significant incremental contribution of about 21% above and beyond reasoning ability and personality dimensions. Among those components, attitudes showed a significant beta weight (.414, $p < .001$). Neither intentions nor perceived behavioral control nor subjective norms were significantly related to students' mathematics grades. In sum, 43% of variance in mathematics grades was explained by control variables, reasoning, personality, and attitudes toward mathematics.

2.3. Discussion

Results of Study 1 showed that the relationship between attitudes toward mathematics, as indexed by the four components of the theory of planned behavior, and mathematics grades of German students are largely independent of students' reasoning ability and broad personality

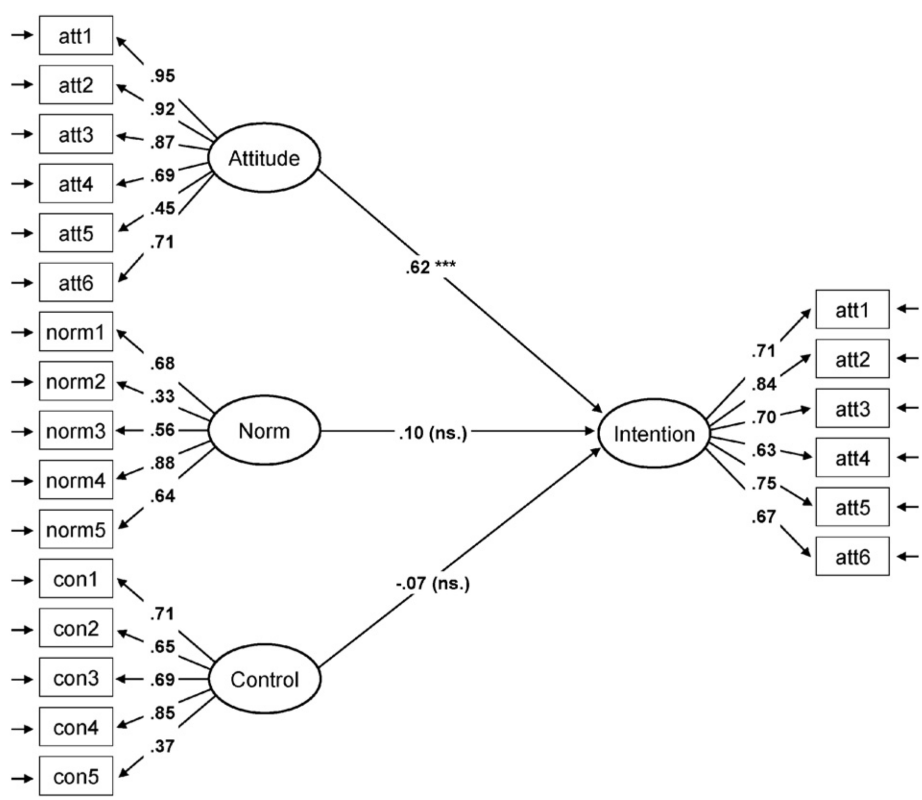

Fig. 1. Standardized solution obtained for the theory of planned behavior model 1 in the German sample. *Notes.* The latent variables Attitude, Norm, and Control are allowed to correlate freely. Error variances and covariances are omitted. Correlated errors were allowed between con3 and con5, between con4 and con5, and between norm2 and norm3.

Table 3
Hierarchical multiple linear regression predicting mathematics grades from reasoning, Big-Five personality dimensions, and mathematics attitudes.

Predictor	Math grade (German sample)		Math grade (Belarusian sample)	
	ΔR^2	β	ΔR^2	β
Step 1	.120**		.001	
Age		−.289**		.023
Gender		.144		.016
Step 2	.058**		.158**	
Reasoning		.252**		.399**
Step 3	.039		.042	
Extraversion		−.035		−.044
Neuroticism		.039		.147
Conscientiousness		.063		.170*
Agreeableness		.115		.012
Openness		−.126		.031
Step 4	.214**		.065**	
Intentions (TpB)		.106		−.036
Control (TpB)		.036		.027
Attitudes (TpB		.414**		.269**
Norms (TpB)		.033		−.047
Total R^2	.430**		.266**	

Notes. Gender was coded as 1 = male and 2 = female.
** $p < .01$ (two-tailed).
* $p < .05$ (two-tailed).

dimensions. Our hypothesis posited that the components of the theory of planned behavior would explain variability in mathematics grades over and above the effects of cognitive ability and personality, and, hence, was supported by the results.

Consistent with prior research, students' cognitive ability was significantly related to mathematics grades (Rohde & Thompson, 2007; Lu et al., 2011). However, the percentage of the explained variation in mathematics grades was significantly lower in our study than that reported in the literature. We found that 6% of variance in students' math grades was explained by cognitive ability, whereas studies have reported percentages of variance explained ranging from 16% to 34% (Rohde & Thompson, 2007). Such seeming discrepancy may partly be explained by the variation in school tracks in Germany. Students obtained their high school degree from different federal states, which differ in their educational standards. Thus, our data contained a hierarchical structure for which we did not control (due to low number of students coming from certain federal states). More importantly, however, the effects of clustered data were equal across the steps of the hierarchical regression analysis, thus also impacting the components of the theory of planned behavior. In addition, restriction of range in both mathematics grades and reasoning scores might have affected the results. The sample mainly comprised psychology students who were accepted to the program on the grounds of their high academic standing. Thus, the amount of explained variance may be rather conservative.

Our study also revealed that personality factors, as a set, did not incrementally contribute to math performance over and above students' cognitive ability. These results are consistent with findings from Lu et al. (2011) study. The researchers found that the amount of variance explained in elementary students' math scores was 36.4% by cognitive factors, whereas the incremental validity of non-cognitive constructs was negligible. It may be the case that facets of the five factors, such as self-discipline and achievement striving for Conscientiousness, would have served as a more robust predictor of mathematics grades. Interestingly, we found that Openness was significantly and negatively related to math grades (when considered individually, and not as part of an overall set of personality characteristics). This is contrary to the findings in the literature showing that Openness correlates strongly and positively with achievement (e.g., Steinmayr & Spinath, 2007; Puklek Levpušček et al., 2012). The pattern of the relationship revealed in this research is not due to coding errors or any other sample-specific data abnormalities, but something that is worth examining in future studies. This, however, does not undermine our main finding showing that the theory of planned behavior components increment over personality and reasoning in explaining grades. That is, the significant negative correlation between Openness and grades took up but a small portion of variance, and after controlling for it, we still found a robust pattern of incremental explanation.

Hence, the most important finding of this investigation was that the components of the theory of planned behavior incrementally explained 21% of variance in mathematics grades unaccounted by cognitive ability and broad personality dimensions. Thus, our hypothesis was supported. The amount of incrementally explained variance is remarkably high for non-cognitive variables and confirms results reported in Lipnevich et al. (2011). The attitudes component of the theory of planned behavior was the only component that significantly related to math performance, with other theory of planned behavior components showing non-significant contributions. The latter finding is consistent with recent investigations, wherein attitudes showed the strongest link to achievement (Lipnevich et al., 2011; Davis, Ajzen, Saunders, & Williams, 2002). It is important to note that perceived behavior control is also theorized as a key determinant of behavior. However, it did not emerge as such in the current study. This might be attributed to the use of performance criteria rather than concrete behavioral measures in our investigation. Overall, Study 1 presented initial evidence demonstrating that attitudes toward mathematics can explain mathematics achievement that over and above personality and cognitive ability. Before we discuss possible interventions, we replicate the aforementioned results in another sample.

3. Study 2: Belarusian sample

Study 2 was conducted to examine whether the pattern of prediction revealed with the German students remains the same for the Belarusian sample.

3.1. Method

3.1.1. Participants

A total of 202 students (23% male) from the Belarusian State University in Minsk, Belarus participated. The average age was 19.30 (SD = 2.40, ranging from 17 to 26 years of age). The vast majority of participants majored in either Psychology (45%) or History (47%). At the time of data collection (November 2010 to May 2011) students' mean academic training was 3.53 semesters (SD = 2.15, ranging from 2 to 9 semesters). They obtained their high school degree from schools across Belarus. Participation was part of instructional activities, and was voluntary and anonymous. Outlier analysis (following Tabachnick & Fidell, 1996, we considered z-scores above or below 3.29 as univariate outliers) suggested eliminating one data point.

3.1.2. Measures

3.1.2.1. Mathematics Attitudes Questionnaire (MAQ). The Russian version of the theory of planned behavior-based mathematics attitudes questionnaire was used, which included the same items and scales as reported for the German sample. The structural equivalence and validity of the Russian version was confirmed in a cross-cultural study (cf. Lipnevich et al., 2011).

3.1.2.2. Big Five Inventory (BFI). The Russian 44 item version of the big five inventory (John et al., 1991) was used to measure broad personality dimensions (i.e., Extraversion, Neuroticism, Conscientiousness, Agreeableness, and Openness to experience). Response options were identical to those in Study 1.

3.1.2.3. Berlin Structure of Intelligence Test (BIS Test). The same four subtests of the Berlin Structure of Intelligence Test (Jäger et al., 2006a, 2006b) as in the German sample were administered to assess students' reasoning ability (see Study 1). The tasks were of figural or numerical content and did not rely on language ability (Jäger et al., 2006a, 2006b). All instructions were translated into Russian by the first author and reviewed by a Russian-speaking psychologist to ensure clarity.

3.1.2.4. Mathematics achievement. Students were instructed to report mathematics grades they received in the previous semester. As in study 1, we relied on self-reported grades because self-reports of math grades have been found to correlate highly with actual math grades (Kuncel et al., 2005). The Belarusian grade system ranges from 1 to 10, with 10 being the best grade. All students reported their grades ($N = 202$).

3.2. Procedure

Test procedure was equivalent to the procedure reported for the German sample. Again, the sequence of test administration and item ordering with tests remained the same throughout the data collection. All measures were administered by a licensed cognitive psychologist.

3.3. Data analysis steps

3.3.1. Structural equation modeling

The structure of the theory of planned behavior was previously tested in the Belarusian sample using structural equation modeling (see Lipnevich et al., 2011). Hence, the results of SEM are not reported here, but are available upon request.

3.3.2. Hierarchical linear regression

Identical to Study 1, a hierarchical linear regression was conducted with mathematics grades as the dependent variable. Again, we entered age and gender as (step 1), students reasoning ability test scores (step 2), big five personality dimensions (step 3), and the four components of the theory of planned behavior (step 4).

3.4. Results

3.4.1. Descriptive statistics and bivariate correlations

Descriptive statistics and reliability estimates are shown in Table 1. By and large, means and standard deviations were similar to the German sample. However, the standard deviations of the Big Five personality dimensions were substantially higher in the Belarusian sample, which supports our assumption about the range restriction in the German sample. Reliability estimates of four scales (subjective norms, perceived behavioral control, reasoning, and agreeableness) were above .65. Please note that certain restrictions in reliability (alphas being below .70 for subjective norms, reasoning, and agreeableness) were distributed across all three domains of predictors, thus not specifically affecting one domain (personality, reasoning, or theory of planned behavior). Among the components of the theory of planned behavior, perceived behavioral control and attitudes were significantly related to mathematics grades ($rs = .19$ and $.33$, $p < .01$). The correlation matrix is presented in Table 2.

3.4.2. Hierarchical regression predicting grades from reasoning, Big Five personality dimensions, and components of the theory of planned behavior

Results obtained from the hierarchical regression analysis closely mirrored findings from Study 1, albeit the overall amount of explained variance was lower. Reasoning ability accounted for about 16% of the variation in mathematics grades. Personality dimensions did not increment over reasoning. The components of the theory of planned behavior yielded a significant incremental contribution of 7% explained variance above and beyond reasoning and personality dimensions. As with the German sample, among the components of the theory of planned behavior, attitudes showed a significant beta weight (.277, $p < .001$) whereas intentions, perceived behavioral control, and subjective norms were not significantly related to students' mathematics grades. Altogether, 27% of variance in mathematics grades was accounted for by reasoning, personality, and attitudes toward mathematics.

3.5. Discussion

As with Study 1, results of Study 2 revealed that attitudes toward mathematics, as indexed by the four components of the theory of planned behavior, made a unique contribution to mathematics grades of Belarusian students independently of students' reasoning ability and personality dimensions. This evidence provided additional support to our hypothesis, which posited that the components of the theory of planned behavior would explain mathematics grades over and above the effects of reasoning ability and personality.

Interestingly, reasoning ability explained 16% of variance in math grades. This finding is very much consistent with existing literature on the topic. Rohde and Thompson (2007), for example, found that between 16% and 34% percent of variance in academic achievement was accounted by individuals' general and specific cognitive ability. As with Study 1, personality did not increment over and above cognitive ability. Math attitudes, on the other hand did incrementally relate to mathematics grades over and above cognitive ability and personality factors, accounting for additional 6% of variance. The theory of planned behavior component of attitudes was the only component that was significantly related to mathematics grades — a finding consistent with previous studies (e.g., Lipnevich et al., 2011) and Study 1.

Interestingly, the amount of explained variance by the theory of planned behavior components was much lower in Study 2 than in Study 1. This might be due to the generally lower amount of variance accounted for by all predictors in Study 2. One might speculate about differences in the meaning and validity of school grades across different cultures and educational systems. Further, in the German sample, students reported aggregated high school grades while in the Belarusian sample students self-reported their previous semester's grades. These are important differences that might have impacted the results. Of great importance, however, is that finding showing that attitudes toward mathematics incrementally explained Belarusian math grades and, hence, their relevance over and above reasoning ability and broad personality dimensions is supported in two independent and culturally diverse samples.

4. General discussion

The two studies examined the hypothesis of whether mathematics attitudes incrementally explained students' mathematics grades over and above individuals' cognitive ability and personality factors. Further, we were interested to find out whether the pattern of relations would be similar across two countries — Belarus and Germany. Results highlight the importance of attitudes for math achievement, with attitudes toward mathematics incrementally explaining between 7% (Belarus) and 25% (Germany) of variance in mathematics grades over and above students' cognitive ability and personality factors. To put these findings into perspective, studies showed that broad non-cognitive characteristics accounted for about 10% of variation in academic performance (e.g., Noftle & Robins, 2007). In our studies, even after controlling for cognitive ability and personality, the amount of variance in mathematics grades explained by mathematics attitudes was higher (for Germany, 16%) or nearly as high (for Belarus, 6%). The overall model that included cognitive ability, personality, and mathematics attitudes explained 43% and 27% of variation in mathematics grades for Germany and Belarus, respectively.

Previous research has demonstrated the importance of mathematics attitudes in accounting for mathematics achievement. Ma and Kishor (1997) presented meta-analytic evidence showing significant but small correlations between attitudes toward mathematics and mathematics performance. The authors speculated that insufficient quality of questionnaires used to measure math attitudes might have attenuated correlations between the two variables. Lipnevich et al. (2011) addressed this problem by designing and validating the math attitudes questionnaire that has proven to be theoretically sound and empirically validated and that was also used in the present study. Prior studies found that this questionnaire explained a substantial proportion of variance in math performance (25% to 32%; Lipnevich et al., 2011). Earlier studies, however, did not examine whether mathematics attitudes would increment over and above cognitive ability and personality — the two characteristics consistently linked to student performance in mathematics (Deary et al., 2007; Poropat, 2009). Our study demonstrated that, indeed, mathematics attitudes make substantial contributions to understanding math achievement even after controlling for two of the most robust predictors of students' scholastic achievement.

In terms of its practical value, one of the most important implications of this study is that attitudes represent – in comparison with personality and cognitive ability – a relatively malleable characteristic, and hence, may be altered through instructional interventions. For example, there is a long tradition of research in the field of social psychology revealing that attempts to change individuals' attitudes tend to be successful (see Albarracin et al., 2005, for review). Lipnevich et al. (2011) discuss a number of classroom interventions that may be used to enhance students' mathematics attitudes. These include using novel tools and concrete materials when mastering new mathematical concepts and employing cooperative learning techniques. Attitude change may also be achieved through presenting information contrary to the initially formed (negative) attitude, through stimulating in-depth discussions about the attitude object, and increasing direct experience with the attitude object (cf. Glasman & Albarracín, 2006). These and other techniques that are aimed at changing student attitudes may contribute to increased performance in math.

There were several findings in these studies that are particularly intriguing. For example, studies show that different components of the theory of planned behavior demonstrate different magnitudes of relation to intentions, although this differs across contexts and situations (Ajzen, 1991; Davis et al., 2002). Armitage and Conner's (2001) meta-analysis revealed that intention showed the strongest link to behavior, which, in turn, was most strongly explained by attitudes ($\rho = .49$) and control ($\rho = .43$), and showed the weakest relationship with subjective norms ($\rho = .34$). Our study has shown that of the four components of the theory of planned behavior, only the attitudes component was related to student achievement in math. Neither perceived behavioral control nor subjective norm correlated with grades in either German or Belarusian samples. A potential explanation for these unusual results is that the grades were collected prior to the MAQ, with Belarusian students reporting their current math grades and German students reporting their grades aggregated over two years. Hence, the assessment of attitudes preceded the outcomes (grades). Future studies may redress this issue and administer MAQ assessments prior to collecting student grades. One might argue that specific interventions are still rather uncommon during the time frame of our data collection, i.e. during end of school and first years at university. In fact, continuous direct behavioral experience (i.e., attending math courses) should increase accessibility of and, subsequently, stability of attitudes (Glasman & Albarracín, 2006). Hence, attitudes may remain an effective predictor of math grades despite the fact that the grades temporally preceded attitudes in our study. However, we cannot preclude the alternative explanation of grades shaping attitudes (e.g., Olson & Zanna, 1993). In fact, the attitudes component of the TpB may be particularly prone to being shaped by prior behavior. Adopting this reverse causal direction view, the current results may also be interpreted as providing insights into the malleability of math attitudes through grades after controlling for general mental ability and broad personality dimensions. In any case, our finding underscores the close link between math attitudes and math performance. Still, further research is needed on the causal direction of this contingency.

Further, and quite interestingly, the control component of the theory of planned behavior was not significantly related to mathematics grades. This construct is theoretically similar to academic self-concept and locus of control, both of which have been consistently shown to explain performance in a variety of subjects (e.g., Marsh & Craven, 2006; Möller, Retelsdorf, Köller, & Marsh, 2011). Possibly, items included into the attitudes sub-scale already capture the part of the control facet (as indicated by the high correlation between attitudes and perceived behavioral control), which is related to academic self-concept. Future studies could investigate academic self-concept and locus of control, in conjunction with the theory of planned behavior assessment.

5. Limitations and future directions

Due to the specifics of study design, the two reported studies could not be used to establish causal relationship between attitudes and mathematics achievement. Longitudinal inquiries are in order. Multiwave investigations could employ longitudinal modeling of the link between attitudes and achievement, providing evidence of causal direction (or lack thereof) between the two variables. Additionally, the grades were collected prior to attitudes, and future studies should ensure that theory of planned behavior components and other variables are assessed prior to the study outcomes.

As in most correlational studies, other factors may have influenced the magnitude of the relationship between the employed predictors and the criterion. In our case, math performance is certainly prone to other school-, teacher, or student-related factors. However, we account for some very important student-related factors (cognitive ability and personality). Also, we consider it unlikely that other factors may have exerted their influence in a systematic way (across the schools and countries included in the current study) that they would have inflated the contingency between math grades and attitudes toward math. On the contrary, low performing students may have received en passant interventions on attitudes, thus – if effective – rather alleviating than inflating the relationship between attitudes and performance.

One may speculate that some of our results were biased due to common-source and common-method variance. Both, math attitudes and personality were assessed with self-report questionnaires. However, inflated correlations between those two construct domains would only have lowered the chance to find incremental contribution. Thus, we can consider the incremental contribution of math attitudes to be a conservative estimate of its actual explanatory power.

According to Ajzen (2006) the TpB component of intentions is what effectively predicts behaviors. Our studies did not include specific mathematics-related behaviors, but, rather, the direct results of such behaviors. In other words, mathematics achievement represents the result of behaviors such as the number of hours devoted to mathematics study, the number of times students seek help from teachers, parents, or peers, and number of absences from math class. We did not have access to these behaviors, although research suggests they are implicitly represented and indexed through achievement (e.g., Benbow & Arjmand, 1990). Future studies may include explicit measurements of mathematics-related behaviors. This will help us to better understand ways in which mathematics-related behaviors translate into mathematics achievement.

Finally, the samples consisted of university students aged between 17 and 31 years. Albeit our findings are generally in line with those reported by Lipnevich et al. (2011), who assessed 12 to 15 year old children, Ma and Kishor's (1997) meta-analytical results suggests different effects of math attitudes on math performance across grades. Specifically, they observed an increase in effect sizes from upper elementary grades to junior high grades and a decrease of effect sizes from junior to senior high grades. Extrapolating this inverted U-shaped trend, one may consider the current results as rather conservative estimates of the link between math attitudes and math achievement. Also, little is known about the relative malleability of math attitudes across age groups. However, one may speculate that attitudes may be more malleable in younger ages with less prior experience in math, which in turn can shape attitudes (cf. Ma & Xu, 2004). Thus, the herein reported incremental contribution of math attitudes needs replication in younger age groups and should be complemented by studies addressing the relative malleability across age groups.

6. Conclusion

In sum, our studies demonstrated that mathematics attitudes contributed to students' mathematics performance over and above personality and cognitive ability, thus bringing educators' attention to this critical characteristic. The fact that attitudes may be far more malleable than broad personality and cognitive ability characteristics make our findings particularly important in the context of intervention development. We would like to encourage educators and researchers alike to further explore this construct and thus help students' to increase their performance in mathematics.

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