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MOTIVATION AND SOCIAL PROCESSES

Domain-general and math-specific self-perceptions of perseverance as predictors of behavioral math persistence

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ABSTRACT
Three studies examine a novel pathway by which the perseverance component of the personality trait *grit* might predict college students' behavioral persistence when solving challenging math problems. Specifically, we focus on the intervening role of what we refer to as *math-specific self-perceptions of perseverance*, which captures students' perceived tendency and ability to persevere on challenging math problems. Across studies, we found that this math-specific construct was correlated with behavioral math persistence, whereas the domain-general perseverance component of grit was not. Despite there being no correlation between one's general perceptions of perseverance and behavioral persistence on math problems, we consistently found significant *indirect* effects of general perceptions through math-specific perceptions of perseverance. That is, in all three studies, grittier students viewed themselves as more capable of persevering on challenging math problems, which ultimately predicted their behavioral persistence at a later time point.

KEYWORDS
Grit; math-specific perseverance; math problem-solving; math persistence

OVER THE LAST FEW decades, much concern has been expressed about the underperformance of U.S. students in mathematics relative to students from other developed nations (e.g., Hanushek et al., 2010). Although, traditionally, researchers have attempted to account for this underperformance in terms of mathematical knowledge and skills (e.g., Geary et al., 1996; Vasilyeva et al., 2015), they have recently begun to offer explanations that focus more on non-cognitive factors, such as effort and persistence (e.g., Boe et al., 2002). This focus appears to have informed the efforts of policy makers, such that recent initiatives aimed at improving the mathematics standards employed in U.S. schools have stressed the importance of fostering students' persistence during problem solving. In fact, the very first Standard for Mathematical Practice advanced by the Common Core State Standards (CCSS) is for students to "make sense of problems and *persevere* in solving them" (CCSS, 2010, p. 6; emphasis added). In addition, the Problem Solving Process Standard proposed by the National Council of Teachers of Mathematics (NCTM) states that, "Students require frequent opportunities to formulate, grapple with, and solve complex problems that involve a significant amount of *effort* … By solving mathematical problems, students acquire ways of thinking, habits of *persistence* and curiosity, and confidence in unfamiliar situations that serve them well outside the mathematics classroom" (NCTM, 2000, p. 4; emphasis added; see also Star, 2015).

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In order to explain why some students tend to persevere on challenging math problems more than others, we examine perseverance at different conceptual levels: as a broad cross-domain personality trait (i.e., the perseverance component of self-perceived grit), as a domain-specific construct (i.e., self-perceived perseverance when solving challenging math problems), and as a domain-specific behavior (i.e., actual persistence when solving math problems). We investigated these constructs in a series of exploratory analyses across three studies. In each study, college students first completed domain-general and math-specific measures of self-perceived perseverance and then, days or weeks later, completed a set of challenging math problems. Our aims here are two-fold. First, we seek to advance prior research on grit by examining whether a domain-specific measure of self-perceived perseverance is a better predictor of behavioral persistence on challenging math problems than the more general measure of self-perceived perseverance that is included in the commonly administered grit scale. Second, we extend these initial analyses by exploring the possibility that there is an indirect association between general self-perceived perseverance (a trait-level personality factor) and behavioral persistence in a particular domain through students' domain-specific self-perceived perseverance.

Grit as a predictor of persistence on math tasks

Defined as "*trait-level perseverance* and passion for long-term goals" (Duckworth & Quinn, 2009, p. 166, emphasis added; see also Duckworth et al., 2007), grit has been widely touted as an important predictor of positive academic outcomes (such as grade point average, retention, and intention to persist in college) across multiple academic domains (Credé et al., 2017; Eskreis-Winkler et al., 2014, 2016; Muenks et al., 2017, 2018).

To assess grit, Duckworth and colleagues developed a self-report scale that (along with its short-form version) represents the primary means by which grit has been assessed in the literature (see Credé et al., 2017). The original scale comprises two distinct subscales: perseverance of effort and consistency of interest. However, a large meta-analysis of the grit literature ($k = 88$, $N = 66{,}807$; Credé et al., 2017), suggests that these subscales do not always load onto a single second-order or general factor (see also Muenks et al., 2017, 2018; Wolters & Hussain, 2015) and that the "perseverance of effort" subscale is generally a better predictor of *broad* academic outcomes (e.g., GPA) compared to the "consistency of interest" subscale *or* to the grit scale as a whole. This led Credé et al. (2017) to suggest that "the primary utility of the grit construct [as a predictor of academic outcomes] may lie in the perseverance facet" (p. 492).

While most studies of grit have focused on broad outcomes, a number of studies have examined the association between grit and specific on-task behaviors that are believed to contribute to academic performance; though these studies have not typically examined the two facets of grit separately. For instance, Duckworth et al. (2011) showed that the effect of overall grit on spelling bee performance was mediated by the total number of hours competitors engaged in deliberate practice.

Several studies assessing on-task behaviors have been conducted specifically in a math context. For instance, Galla et al. (2014) found that overall grit predicted the amount of time high school students spent working on one-digit subtraction problems versus playing a game or watching a movie. Similarly, Lucas et al. (2015) found that overall grit predicted adult participants' decision to continue with a task that involved competing against another individual to solve as many three-digit addition problems as possible in a limited time; but only when the participants thought they were losing. Finally, Eskreis-Winkler et al. (2016) had middle school students solve standard textbook math problems on the computer during a normal class period, and gave them the option to take breaks by surfing the Internet. Each time the students correctly answered five consecutive problems, they advanced to more difficult problems. The results showed that students' overall grit was associated with how much time they spent working on math problems versus surfing the Internet.

Critically, however, such studies have generally not assessed persistence on the kinds of challenging math tasks that are believed to foster deep conceptual learning. Specifically, the rote arithmetic tasks used in the studies by Galla et al. (2014) and Lucas et al. (2015) required participants to overcome feelings of boredom and time pressure, rather than difficulties in finding a problem solution. In fact, Galla et al. explicitly distinguished between "diligence on facile but tedious work tasks," like the one used in their study, and "perseverance in the face of extreme difficulty" (p. 316), which is what we hoped to capture with the math tasks used in the present studies. And while the adaptive feature of Eskreis-Winkler et al. (2016) math task may have ensured that most students were presented with at least some difficult problems, the extent to which students were *consistently* challenged may have varied in accordance with their math abilities (because it presumably took the higher ability students longer to reach a set of problems that they found challenging). Thus, in that study, time-on-task was not necessarily a uniform measure of how much time the students spent persisting on *challenging* problems (though the authors partly addressed this concern by controlling for participants' standardized math test achievement).

Exploring math-specific perseverance as a potential predictor of behavioral persistence on challenging math tasks

Although grit has been shown to predict behavioral persistence on certain types of math tasks (e.g., Eskreis-Winkler et al., 2016; Galla et al., 2014; Lucas et al., 2015), more research is needed to understand how trait-level individual differences in students' general self-perceived propensity to persevere are related to math-specific motivational factors. As some researchers have argued about other traits, such as self-esteem, it is "simply not enough to measure global attitudes and traits while ignoring the large number of variables that mediate and moderate the links between predictor and outcome variables" (Swann et al., 2007, p. 85). In other words, certain facets of a broad personality factor like grit are likely to exert their influence on domain-specific outcomes like math persistence through several indirect paths involving distinct intervening variables.

One potential intervening variable pertains to students' beliefs about their perseverance when solving math problems. That is, in addition to the domain-general beliefs about perseverance (e.g., "I am a hard worker"), students likely hold domain-specific beliefs about their tendency or ability to persist when working on math problems that are difficult or that take a long time to complete. We refer to this construct as *math-specific self-perceived perseverance* (for similar constructs, see Cormier et al., 2019; Schmidt et al., 2019) and contrast it with *domain-general self-perceived perseverance*, which is equivalent to the "perseverance of effort" subscale of Duckworth's grit measure. Throughout the paper we sometimes use the shortened terms "math-specific perseverance" and "domain-general perseverance" to refer to these self-perception constructs.

It is important to note that, as a *self-perception* variable, math-specific perseverance is distinct from *behavioral* persistence on specific math tasks. That is, we do not view these two variables as separate indicators of a single underlying construct. Our measure of math-specific perseverance captures students' beliefs about their tendency to persevere on any type of challenging math problem (e.g., "When I don't understand a problem, I keep working until I find the answer"), as well as their sense of efficacy for completing problems that involve high levels of effort (e.g., "I feel I can do math problems that take a long time to complete"). In contrast, behavioral measures assess students' *actual* persistence on a *particular* task, in a particular context. Such persistence likely reflects a number of situation-specific considerations, in addition to more stable motivational beliefs, such as math-specific perseverance. Another reason we believe that it is important to distinguish between self-perceived tendencies and actual behavior is because these constructs can influence each other in a reciprocal manner over time, as suggested by Bandura (Bandura,

1978) and by self-concept researchers (Marsh & Martin, 2011; Shavelson et al., 1976). On the one hand, a student's belief that she is the kind of person who can persevere when faced with difficult math problems should lead her to spend more time working on a challenging math task. On the other hand, when a student repeatedly observes herself persisting on challenging math tasks, she should ultimately come to see herself as having a high level of math-specific perseverance.

The relations between domain-general perseverance, math-specific perseverance, and behavioral math persistence

Although past problem-solving success may lead students to draw inferences about their math ability in a bottom-up manner, this is only one factor contributing to their math-specific perseverance. Broad traits, such as conscientiousness or the perseverance facet of grit, are likely to exert a more top-down influence on students' self-perceptions in the context of specific domains, such as math. For instance, students who perceive themselves as being generally inclined to persist in the face of difficulty may infer that this trait will enable them to persevere and overcome challenges when solving math problems. In addition, this association between domain-general and math-specific perseverance may help to explain any influence that domain-general perseverance has on students' behavioral math persistence.

Consistent with this possibility, a recent study by Usher et al. (2019) conducted with elementary and middle school students showed that domain-general perseverance was indirectly associated with objective indicators of math performance (i.e., standardized test scores) through students' more subjective perceptions of their math self-efficacy. However, it is important to note that this study assessed students' broad beliefs about their math-related abilities as opposed to their specific beliefs about math perseverance; further, it focused on general indicators of math performance that were designed to assess accumulated knowledge and skills as opposed to directly observing persistence on difficult math tasks, as in the present studies. High scores on the math tests used by Usher et al. (2019) could therefore indicate (a) a tendency to persevere while learning new math skills, (b) high levels of persistence while completing a standardized test that presumably included problems varying in difficulty, or (c) other factors unrelated to persistence (e.g., low levels of math anxiety). Thus, what remains to be seen is whether domain-general self-perceptions of perseverance are associated with *behavioral persistence* in solving math problems and whether this association can be partly attributed to students' specific beliefs about their tendency or ability to persevere on challenging math problems.

The answer to this question could be useful to both researchers and educators in making decisions about which aspects of personality and motivation to assess in order to best predict students' behavior on challenging math assignments. The present research may also be informative to researchers seeking to understand the paths by which a key facet of grit influences important long-term academic outcomes, such as grade point average and retention (see Abuhassàn & Bates, 2015).

Overview of the present studies

As mentioned above, this paper has two aims. The primary aim is to compare domain-general and math-specific self-perceptions of perseverance as predictors of college students' behavioral persistence on challenging math problems. Furthermore, as discussed above, it is also important to enhance the field's understanding of *how* an important trait-level individual difference factor (i.e., the perseverance facet of grit) is related to persistent behavior on the kinds of challenging math tasks that are believed to foster deep conceptual learning. Therefore, the second aim of the paper is to explore whether domain-general perseverance may be indirectly related to behavioral persistence, through math-specific perseverance.

Toward these aims, we discuss the results of three studies that were originally conceived as part of separate projects designed to investigate multiple motivational and personality factors that might influence persistence on challenging math problems. Though the studies were not designed with the current framing in mind, because of the conceptual similarity of their methods and the striking consistency in the pattern of findings, we feel that it is informative to discuss these exploratory analyses together.[1] Study 1, which was conducted with a sample of U.S. college students, examined domain-general and math-specific perseverance in relation to a *time*-based measure of behavioral math persistence. Specifically, we recorded how much time the students spent trying to complete two highly challenging math problems (e.g., Aspinwall & Richter, 1999; Lucas et al., 2015; Roney et al., 1995). Study 2a, which was conducted with a sample of U.S. college students, examined domain-general and math-specific perseverance in relation to a *preference*-based measure of persistence. Specifically, after an initial attempt to complete a challenging task, participants were offered a choice between continuing to work on the same math task or switching to an unrelated verbal task (e.g., Hong et al., 1999; Lucas et al., 2015; Tulis & Fulmer, 2013).

Study 2b employed the same measure of behavioral persistence as in Study 2a, but recruited participants from a population (i.e., Russian college students) that is known to differ from the population sampled in the first two studies in terms of its cultural orientation and motivational tendencies (as discussed in the introduction to Study 2; Elliot et al., 2001; Matsumoto et al., 1997; Minkov et al., 2017). Comparing the results of Study 2b to the results of the first two studies thus allowed us to examine whether the associations we observed between perseverance variables generalized to a culture in which students' underlying reasons for persevering may differ from the reasons that typically motivate U.S. students to persist. In sum, across our three studies, we investigate the relations between domain-general perseverance, math-specific perseverance, and behavioral math persistence using two different measures of persistence and with two different student populations.

Study 1

In Study 1, we examined whether domain-general and math-specific self-perceived perseverance (assessed via self-reports during Session 1) predicted the amount of time students spent trying to solve two challenging math problems during Session 2.

Method

Participants

A total of 188 students enrolled in sections of a course at the school of education at a private research university in Massachusetts participated for course credit. Of these, 50 either did not complete Session 2 or completed a preliminary version of the study materials that did not contain all of the items from the final version. Another participant was missing data due to computer error. Therefore, the final sample included 137 college students who completed both parts of the study (83.9% female; age: $M = 19.01$, $SD = 1.20$, range = 18–24; 70.6% White, 14.0% Asian, 6.6% Hispanic/Latinx, 4.4% Black, 4.4% multiracial) – one participant did not report ethnicity/race during Session 1.[2]

Procedure and materials

The study consisted of two lab-based sessions, held an average of 15.7 days apart ($SD = 3.7$; range: 10 to 33 days). In Session 1, we assessed a number of individual differences in personality and motivation, including domain-general perseverance and math-specific perseverance.[3] The measures were presented in a randomized order and the items within the two focal measures were

Table 1. Zero-order correlations between primary Session 1 and 2 measures, Study 1.

	1	2	3
Session 1 Measures			
1. Domain-general perseverance	–		
2. Math-specific perseverance	.24**	–	
Session 2 Measure			
3. Time-on-task (behavioral persistence)[a]	−.10	.25**	–
Mean	3.88	3.33	18.65[a]
Standard Deviation	.60	.72	6.09
Internal Consistency (α)	.80	.88	–

$N = 137$, $^{*}p < .05$, $^{**}p < .01$.
[a]Behavioral persistence reflects the square root of the mean time (in seconds) participants spent on the two problems.

randomized. At the end of Session 1, participants completed a demographic questionnaire. In Session 2, we administered the behavioral persistence task and a second demographic questionnaire on computers. As mentioned above, these sessions were part of a larger project centered on identifying variables that predict math problem-solving persistence and, as such, included two experimental conditions and several other measures that are not of primary interest given the present aims (see supplementary materials for details).[4] Descriptive statistics and zero-order correlations for all measures described below are presented in Table 1.

Domain-general perseverance (Session 1)

Domain-general self-perceived perseverance was assessed using the six-item perseverance of effort subscale from Duckworth and colleagues' (2007) original grit measure. Items included "I am a hard worker" and "I have achieved a goal that took months of work"; note that for the latter item, the word "years" in the original scale was changed to months (in all three studies), in order to better reflect the kinds of goals students pursue in their classes. Participants responded using a 1 ("Not like me at all") to 5 ("Very much like me") scale. We computed an index of domain-general perseverance by averaging participants' ratings across all six items.

Math-specific perseverance (Session 1)

Math-specific self-perceived perseverance was assessed using an 8-item scale that assessed students' beliefs about how they tend to respond to challenging math problems. It consisted of the 6-item "I can solve time-consuming mathematics problems" subscale of the Indiana Mathematics Beliefs Scales (e.g., "I find I can do hard math problems if I just hang in there"; Kloosterman & Stage, 1992) with the addition of one item that has been used as part of the Motivation/Persistence subscale of the Computer Attitude Questionnaire ("When I don't understand a problem, I keep working until I find the answer"; Knezek & Christensen, 1996) and one unpublished item ("If I am struggling to solve a problem, I try to think of alternative ways to solve it"; see Appendix for all items). Participants responded using a 1 = ("Not like me at all") to 5 = ("Very much like me") scale, and we computed an index of math-specific perseverance by reverse-coding three negatively-worded items and then averaging participants' ratings across all eight items.

Note that this measure differs from the measure of math-specific perseverance used in the study by Schmidt et al. (2019) that we cited in the Introduction. Whereas the present items explicitly reference the solving of challenging or time-consuming math problems, the items in Schmidt et al.'s scale were adapted from Duckworth's Grit-S scale (e.g., "In mathematics I work hard") and, thus, assess broader self-perceptions that may be inclusive of other aspects of math (e.g., seeking extra help from one's math instructor), in addition to problem-solving behavior.

Behavioral persistence in math (Session 2)

We recorded how much time the students spent trying to complete a highly challenging math task as our index of persistence. It was critical that the problems in the task be extremely challenging, such that they require substantial time and effort even from highly competent individuals; otherwise, it would be unclear whether a particular student finished a task quickly because she gave up prematurely or because she is highly competent. Based on pilot work, we selected one problem that was very unlikely to be solved correctly within the allotted time and another that was unsolvable (see Appendix).

Before starting the task, participants were informed that they could stop and move on to the next problem at any point, but would not be able to click back to revisit the previous problem. They were also told that, after a certain amount of time, the computer would automatically advance them to the next problem. Participants were given 16 minutes to solve each problem, though they were not informed about this time limit. If participants were still working on a problem at the end of the 16-minute period, the program automatically advanced them to the next screen. On this screen, participants were asked to explain their solution; they were allotted two minutes to respond. As in prior work (e.g., Aspinwall & Richter, 1999; Battle, 1965; Roney et al., 1995), the amount of time participants spent on each problem was used as the measure of behavioral persistence.

Results

Factor analyses

To assess whether the items in the domain-general perseverance and math-specific perseverance scales measured two distinct constructs, we first conducted an exploratory factor analysis (EFA) using principal axis factoring, an initial eigenvalue threshold of 1 (i.e., the Kaiser rule), and direct oblimin rotation. We found that all items loaded cleanly onto the expected two factors (loadings $\geq .3$ in the pattern matrix), with no cross-loadings. We then conducted a confirmatory factor analysis (CFA) using maximum likelihood estimation and allowed the two factors to covary. The model showed acceptable fit $\chi^2(76) = 116.31$, CFI = .94, RMSEA = .06, SRMR = .05, and fit the data significantly better than a model with only one factor or a two-factor model in which the factors were *not* allowed to covary, $\chi^2(77) > 124.72$, $ps < .001$. See the supplementary materials for more details about these analyses.

Descriptive statistics regarding behavioral persistence in math

Next, we examined whether the two math problems students worked on were as challenging as intended. Indeed, we found that only 1.5% of students correctly solved the solvable problem and only 5.1% correctly recognized that the other problem was unsolvable (in contrast, 3.6% of students suspected that the solvable problem might be unsolvable). Interestingly, some students seemed to believe that they had correctly answered one or more of the problems, when in fact they had provided an incorrect answer or the problem could not actually be solved.

With respect to the amount of time participants spent solving each of the two problems, there was a great deal of variability (from ~22 seconds to 16 minutes). The mean time spent on the solvable problem was approximately 332.23 seconds ($SD = 266.00$) and the mean time for the unsolvable problem was approximately 437.04 seconds ($SD = 290.46$). Time was positively skewed for both problems. That is, most participants spent less than 400 seconds (73.0% for the solvable problem, and 53.3% for the unsolvable problem), but several used the maximum amount of time allowed (8.8% for the solvable problem and 11.7% for the unsolvable problem).

To address this skewness, we conducted square-root transformations of both variables (Ratcliff, 1993). Both before and after transformation, there were no outliers greater than 3 *SD*

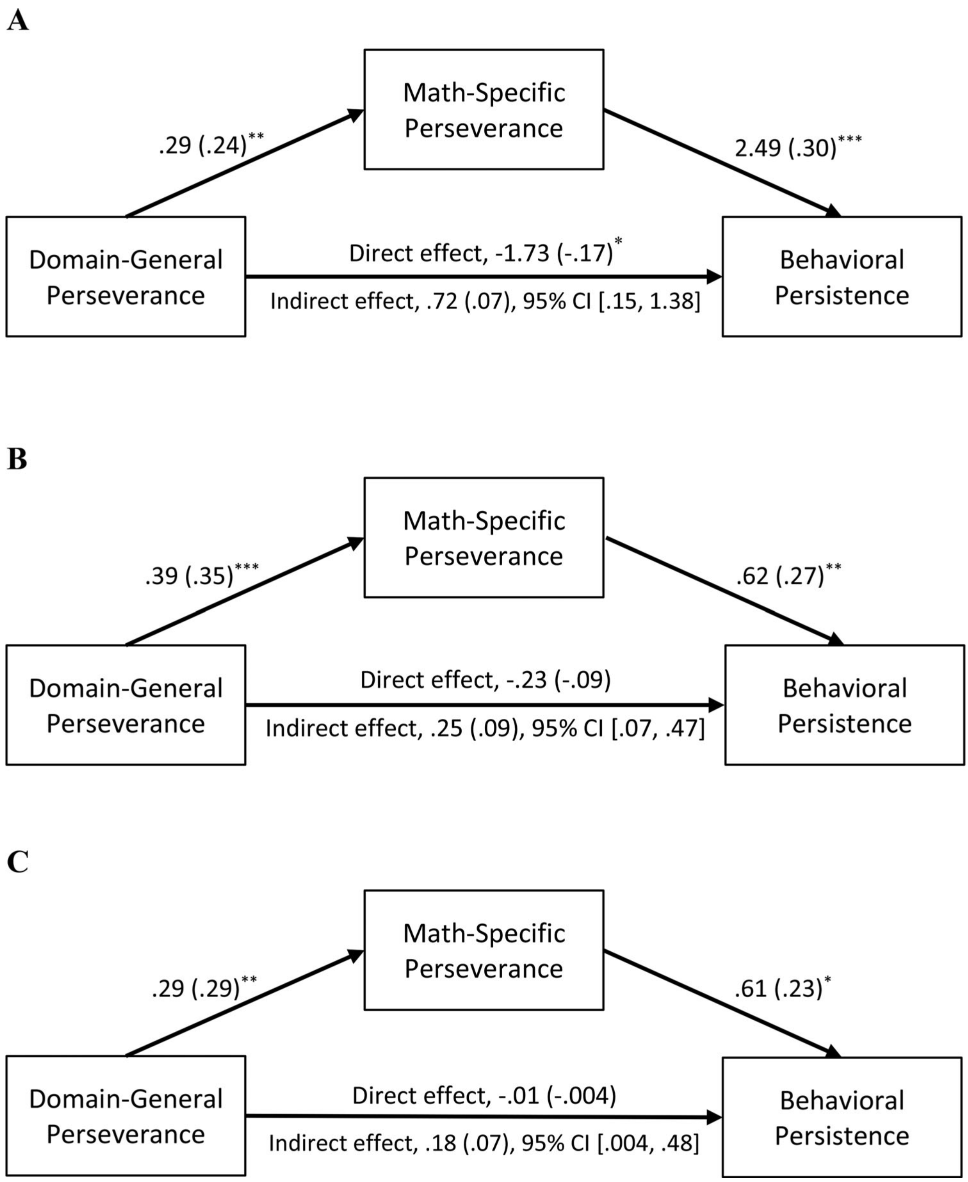

Figure 1. Intervening variable models illustrating the indirect effects of domain-general perseverance on math problem-solving persistence through math-specific perseverance in Study 1 ($N = 137$) (A), Study 2a ($N = 156$) (B), and Study 2b ($N = 89$) (C). For each path, we report the unstandardized coefficient followed by the standardized coefficient in parentheses. For the indirect effects, the standardized coefficients are completely (rather than partially) standardized. In addition, the 95% confidence intervals correspond to the unstandardized coefficients for these effects. The regression coefficients for each indirect path were taken from models that included all predictors preceding the path. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

above or below the mean for either variable. Analyses conducted with these transformed variables showed that the zero-order associations between behavioral persistence and the primary Session 1 variables[5] were not moderated by problem type (solvable vs. unsolvable) or problem order (unsolvable first vs. solvable first), $Fs < .84$, $ps > .36$. Thus, we created a single persistence variable to use in subsequent analyses by averaging the raw times for the two problems and then computing a square-root transformation of the mean.

Domain-general and math-specific perseverance as predictors of behavioral persistence in math

The correlations between the three main constructs assessed in Study 1 appear in Table 1. As shown, math-specific perseverance was significantly correlated with domain-general perseverance. That is, the stronger students' trait-level tendency to persevere, the more they viewed themselves as being able to persevere on challenging math problems. More critically, math-specific perseverance was also significantly correlated with persistence. In other words, the more confident students were in their math abilities and the more they perceived themselves as capable of persevering on challenging math problems (in Session 1), the more time they spent working on the math task in Session 2.[6]

In contrast with prior research, which did not involve consistently challenging math problems (e.g., Eskreis-Winkler et al., 2016; Galla et al., 2014; Lucas et al., 2015), the correlation between domain-general perseverance and math persistence was *not* statistically significant. That is, we did not find a direct association between students' trait-level propensity for perseverance and the time they spent working on challenging math problems.

Although we did not find a direct association between domain-general perseverance and behavioral persistence, we were still interested in whether domain-general perseverance may exert an *indirect* effect on persistence through math-specific perseverance. As Hayes and Rockwood (2017, p. 43–44) explain, the association between the predictor and the outcome "is the sum of the direct effect and all possible indirect effects, of which there may be many, and various combinations of sizes of direct and indirect effects can produce a total effect equal to zero … [Thus] if [the direct association between X and Y] is zero … this does not mean X doesn't affect Y." Rather, "if there are theoretical reasons to predict the presence of an indirect effect … researchers should explore these effects regardless of the significance of the total or direct effect" (Rucker et al., 2011; p. 368; see also MacKinnon et al., 2000; Shrout & Bolger, 2002; Zhao et al., 2010).

As discussed throughout the introduction, there is good theoretical reason and empirical precedent behind the notion that a broad, general factor like domain-general perseverance may exert an indirect effect on a domain-specific outcome like math behavioral persistence through more proximal, domain-specific factors like math-specific perseverance (see e.g., Swann et al., 2007). We therefore tested an intervening variable model (see Hayes, 2009; MacKinnon et al., 2000; Mathieu & Taylor, 2007), with domain-general perseverance included as the predictor, math-specific perseverance as the intervening variable, and task persistence as the outcome. This analysis was conducted using Hayes' (2018) PROCESS macro for SPSS (v3.4), which randomly selected 5,000 samples with replacement from the complete data, estimated regression coefficients for each of the bootstrap samples, and averaged them across all samples. As shown in Figure 1a, the 95% confidence interval for the indirect effect excluded zero, suggesting that domain-general perseverance had a statistically significant positive indirect effect on task persistence via math-specific perseverance. Note that when this indirect effect was accounted for, the remaining association between domain-general perseverance and task persistence became significantly negative. We discuss this finding in the General Discussion; however, it did not emerge in Studies 2a-2b. See the supplementary materials for additional analyses of intervening variable models.

The results of Study 1 therefore indicate that math-specific self-perceived perseverance is a better predictor than domain-general self-perceived perseverance of students' behavioral persistence on challenging math problems. In fact, while math-specific perseverance was significantly correlated with behavioral persistence on our difficult math problems, domain-general perseverance was not (contrary to prior work examining grit in less challenging math problem-solving contexts; e.g., Eskreis-Winkler et al., 2016; Galla et al., 2014; Lucas et al., 2015). Although domain-general perseverance was not correlated with math persistence, we did find a positive indirect effect of domain-general perseverance on math persistence via math-specific perseverance, suggesting that the grittier students were, the more they perceived themselves as capable of persevering on challenging math problems, which in turn predicted how much time they actually spent working on the math task.

One caveat to these findings is that some participants seemed to believe that they had solved a particular problem correctly even though they had not done so. In certain cases, this may have been due to poor metacognitive monitoring or participants not reading the directions carefully enough (e.g., ignoring the constraint in the unsolvable problem that "each digit should be used only once"). To the extent that a false belief in the accuracy of their solution may have led some participants to move on from the problem prematurely, this issue may have added noise or a confound to our measure of behavioral persistence in Study 1. For instance, it is possible that metacognitive monitoring ability was positively correlated with *both* math-specific perseverance (Arslan et al., 2013; Muenks et al., 2017; Wolters & Hussain, 2015) and our measure of behavioral persistence, thus partly accounting for the positive relation we observed between these variables. Such a possibility underscores the importance of examining the association between students' self-perceptions of perseverance and a different measure of behavioral persistence – one which is perhaps less likely to be affected by students' monitoring skills.

Studies 2a and 2b

The results of Study 1 provide some initial support for one pathway by which domain-general self-perceived perseverance may exert an influence on behavioral persistence on domain-specific tasks like challenging math problems (i.e., via math-specific self-perceived perseverance). Given the novelty and exploratory nature of these findings, we use the remaining two studies to both replicate Study 1's results and to demonstrate the generalizability of this path to different measure of persistence and a distinct population.

As opposed to assessing behavioral persistence in terms of time-on-task (as in Study 1), Studies 2a and 2b assessed students' preference for continuing to work on a challenging math task. We conceptualize the difference between the time-based measure used in Study 1 and the preference-based measure used in the present studies in terms of the distinction made by theorists between volitional and motivational processes (e.g., Corno, 1993, 2001; Kuhl, 1984). Time-on-task captures students' persistence in terms of working toward a goal that they are currently committed to achieving and is, thus, volitional in nature. In contrast, our task preference measure captures the students' persistence in terms of their decision to recommit themselves to their original goal and is, thus, motivational in nature. Given that "different information processing principles seem to account for performance before and after the point of commitment" (Corno, 1993, p. 14), it is possible that the effects of domain-general and math-specific self-perceived perseverance on behavioral persistence may vary depending on *when* the latter is assessed.

In addition, we present evidence that this pathway between domain-general perseverance and behavioral persistence generalizes across distinct populations. Specifically, while Study 2a was conducted with a sample of American college students, in Study 2b, we present a close replication of Study 2a with a sample of Russian college students. Because these populations are known to vary in terms of their cultural orientations and motivational tendencies (Elliot et al., 2001; Matsumoto et al., 1997; Minkov et al., 2017), students from one population may have different reasons for persevering on challenging math tasks than students from the other population. For example, students from a more individualistic culture (like the U.S.) may choose to persevere in order to distinguish themselves from their peers and increase their sense of personal accomplishment, whereas students from a more collectivistic culture (like Russia) may instead persevere in order to adhere to group norms or expectations. Considering that students' underlying reasons

Table 2. Zero-order correlations between primary Session 1 and 2 measures in (a) Study 2a and (b) Study 2b.

(a)	1	2	3	4[ab]	5
Session 1 Measures					
1. Domain-general perseverance	–				
2. Math-specific perseverance	.35**	–			
Session 2 Measures					
3. Math task score (percent)	−.17*	.09	–		
4. Task choice (behavioral persistence 1)[ab]	−.04	.20*	.24**	–	
5. Task preference (behavioral persistence 2)	.01	.24**	.24**	.85**	–
Mean	3.89	4.12	26.5%	56.6%	4.19
Standard Deviation	.66	.75	11.4%	49.7%	1.75
Internal Consistency (α)	.85	.87	–	–	–

(b)	1[c]	2	3	4[ac]	5
Session 1 Measures					
1. Domain-general[c] perseverance	–				
2. Math-specific perseverance	.29**	–			
Session 2 Measures					
3. Math task score (percent)	−.10	-.04	–		
4. Task choice (behavioral persistence 1)[ac]	−.01	.12	.05	–	
5. Task preference (behavioral persistence 2)	.06	.25*	.08	.88**	–
Mean	3.51	3.44	23.8%	30.4%	3.46
Standard Deviation	.62	.63	11.2%	46.3%	1.68
Internal Consistency (α)	.73	.77	–	–	–

$N = 156$ for Study 2a, $N = 91$ for Study 2b, $^{*}p < .05$, $^{**}p < .01$.
[a]Because task choice is a dichotomous variable, all correlations with other variables are point-biserial.
[b]Because not all participants completed the task choice measure in Study 2a, the degrees of freedom for correlations involving this variable was 150.
[c]Because not all participants completed the domain-general perseverance and task choice measures in Study 2b, the degrees of freedom for correlations involving these variables ranged from 75 to 87.

for adopting particular goals can affect the behaviors they engage in to achieve these goals (Sommet & Elliot, 2017), it is worth examining whether students' self-perceived tendency to persist toward challenging goals (either generally or in the math domain) predicts similar patterns of behavior across different cultures – though this was not one of our original reasons for conducting the study in Russia.

Method

Participants

Study 2a. A total of 204 students enrolled in sections of two courses (occurring in separate semesters) participated for course credit. The courses were taught at the school of education at a private research university in Massachusetts. The data from some participants were excluded for the following reasons: 33 did not complete Session 2, 1 previously completed Study 1, 3 did not complete Session 2 within the stipulated amount of time following Session 1, 5 were exposed to key information about Session 2 of the study before completing it, and 1 did not indicate consent on the online consent form during Session 1 (see the supplementary materials for more details). Therefore, the final sample included 161 college students who completed both parts of the study (87.0% female; age: $M = 19.64$, $SD = 1.05$, range = 18–22).

Study 2b. Participants were undergraduate students recruited from communication and sociology courses at a Russian research university. A total of 134 students participated in the study, but 24 missed Session 1 and 14 missed Session 2. Our final sample therefore consisted of 96 students (85.4% female). The mean age was approximately 19.4 years old ($SD = 1.4$).[7]

Procedure and materials

Study 2a. Study 2a consisted of two sessions held a minimum of 3 days apart ($M = 6.1$, $SD = 3.2$; range: 3 to 22 days). In Session 1, which was conducted online, we again assessed a number of individual differences in personality and motivation, including the same measures of math-specific perseverance and domain-general perseverance (in that order) as in Study 1. The order of items within each scale was not randomized across participants. Note that math-specific perseverance was administered with a 1 ("Strongly disagree") to 6 ("Strongly agree") scale in this study. In Session 2, which was conducted in the lab using paper and pencil, participants completed a number of measures including the preference-based math persistence task described below. These sessions (along with the sessions in Study 2b) were part of a larger project centered on identifying variables that predict math problem-solving persistence and, as such, included two experimental conditions and several other measures that are not of primary interest given the present aims (see supplementary materials for details). Descriptive statistics and zero-order correlations for all measures are presented in Table 2a.

Study 2b. Study 2b consisted of two sessions, held one week apart for all participants, that were very similar in design to Study 2a. Both sessions were administered using paper and pencil at the end of regular class time. In Session 1, participants completed measures of domain-general perseverance and math-specific perseverance, along with several other scales. In Session 2, participants completed the same preference-based math persistence task used in Study 2a (for additional measures, which differed somewhat from Study 2a, see the supplementary materials). The same math-specific perseverance scale, math persistence task, and instructions used in Study 2a were translated into Russian by the fifth author and then back-translated by the fourth author to check for accuracy. Domain-general perseverance was measured using a 5-item Russian version of Duckworth and colleagues' perseverance subscale that has been validated in recent research (Tyumeneva et al., 2019). Note that the translation of the Russian scale back to English indicated that the wording of some of the items varied from the original scale (see Table S1 in the supplementary materials). Participants responded to both the domain-general perseverance and math-specific perseverance measures using 1 ("not like me at all") to 5 ("very much like me") scales. Two participants did not rate the last item on the domain-general perseverance scale; they were excluded from all analyses involving this measure. Descriptive statistics and zero-order correlations for all measures are presented in Table 2b.

Behavioral persistence in math (Session 2 of both studies). For our preference-based measure of math persistence, we looked for a set of problems that could be framed as a math task, would be very difficult to complete in the allotted time, and would leave participants feeling uncertain about their performance. We ended up selecting 12 of Raven's Standard and Advanced Progressive Matrices (Raven, 1976a, 1976b) that varied in difficulty. The problems were presented as a "non-verbal math reasoning test." Before the matrices were presented, participants were given instructions about how to go about solving the problems and completed a practice problem with the experimenter. They were told that the problems on the actual test ranged from relatively easy to really hard, that they had 5 minutes to complete the problems, and that most people are not able to complete all 12 in that amount of time. Finally, they were informed that their score would be based on how many problems they solved correctly and that we wanted them to do their very best. Participants' scores on the task reflect the percentage of the 12 problems that they solved correctly.

After the 5 minutes had expired, participants were told that they had a "choice of what task to do" next: they could either (A) "continue working on the items that [they] didn't finish or that [they] were unsure about from the previous test," or (B) complete "a verbal test that is not related to math reasoning." Participants were first asked to indicate their choice of what task to do next by circling A or B. Circling A indicated participant's decision to *persist* in completing the math-framed reasoning task and was coded as 1; the choice of Task B was coded as 0. After making their dichotomous choice, participants were asked to indicate how much they preferred one option over the other using a 7-point scale (1 = "Strongly Prefer A"; 4 = "No preference"; 7 = "Strongly Prefer B").[8] This item was included to increase the sensitivity with which we could measure task preferences. For all analyses including this variable, participants' ratings were reverse coded, such that higher values indicated a greater preference to persist on the math task.

Note that 5 participants in Study 2a and 5 in Study 2b provided a rating for the second item that conflicted with their choice from the first item—for example, they circled B as the task they wanted to complete next, but then expressed a preference for A on the subsequent rating scale. Because the contradiction could not be resolved based on the recorded data, we present analyses of task persistence that were conducted both with these participants excluded and without them excluded (where indicated). In addition, there were 4 participants in Study 2a and 12 in Study 2b[9] who did not circle A or B, but who did go on to rate their task preference. These participants were excluded from the analyses of task choice, but were included in the analyses of task preference.

Results

Factor analyses

To assess whether the items in the domain-general perseverance and math-specific perseverance scales measured two distinct constructs, we conducted an EFA for each study. When we ignored extraneous above-threshold factors and forced a two-factor solution in Study 2a, all items loaded cleanly onto the appropriate factors, with no cross-loadings. When we did the same in Study 2b, most items tended to load cleanly onto the appropriate two factors, although one of the domain-general perseverance items cross-loaded and one of the math-specific perseverance items did not load onto either factor.

Next, we conducted CFAs for each study. In both cases, the two-factor model did not fit as well as it did in Study 1: $\chi^2(76) = 174.60$, CFI = .90, RMSEA = .09, SRMR = .08 [Study 2a] and $\chi^2(64) = 114.88$, CFI = .82, RMSEA = .09, SRMR = .09 [Study 2b]. However, for both studies, the model fit the data significantly better than a model with only one factor or a two-factor model in which the factors were *not* allowed to covary, $\chi^2 > 125.48$, $ps < .001$. For more details about both sets of analyses, including our factor retention decisions for the EFAs, see the supplementary materials.

Descriptive statistics regarding math persistence

We first examined whether the math task students worked on was as challenging as intended. Indeed, we found that of the 161 participants who completed both sessions in Study 2a and the 96 participants who completed both session in Study 2b, the mean percentages of correct answer were 26.4% ($SD = 11.3\%$) and 24.3% ($SD = 11.8\%$), respectively. These low scores reflect the fact that, on average, participants in both studies only gave responses for a little more than half of the problems (Study 2a: $M = 7.27$, $SD = 2.09$; Study 2b: $M = 5.88$, $SD = 2.14$) in the allotted time. Furthermore, the mean percentages of problems solved correctly out of problems attempted were 46.9% ($SD = 23.2\%$) and 53.3% ($SD = 24.1$), respectively. These findings confirm that our math task was experienced as challenging by both American and Russian participants.

Of the 152 participants in Study 2a who indicated which task they would like to complete next (i.e., circled A or B) and who did not provide a conflicting response on the subsequent Likert preference item, 56.6% chose to "continue working on … the previous test," thus demonstrating a desire to persist on the math task. For the preference rating, the mean of the 156 participants who did not give a conflicting response was 4.19 ($SD = 1.75$), indicating the lack of a preference for the A or B task on average, $t(155) = 1.35$, $p = .18$.

By contrast, of the 79 participants in Study 2b who indicated which task they would like to complete next (i.e., circled A or B) and who did not provide a conflicting response on the preference item, approximately 69.6% chose B (i.e., "a verbal test that is not related to math reasoning"), thus demonstrating a *lack* of persistence on the math-framed reasoning task. For the preference rating, the mean of the 91 participants who did not give a conflicting response was 3.46 ($SD = 1.68$), indicating a slight, but significant preference for the B task on average, $t(90) = 3.07$, $p = .003$.

Domain-general and math-specific perseverance as predictors of behavioral persistence in math

In Table 2, correlations are reported for the 156 participants in Study 2a and the 91 who did not give conflicting responses on the persistence measure. In both studies, we found that domain-general perseverance was significantly correlated with math-specific perseverance, replicating the results of Study 1. That is, the stronger students' trait-level tendency to persevere, the more they viewed themselves as being able to persevere on challenging math problems.

Most critically, we found that math-specific perseverance significantly predicted the continuous measure of behavioral persistence in both studies (see Table 2). Note that initial analyses of these variables that included the participants who gave conflicting results yielded a significant association in Study 2a, $r(159) = .22$, $p = .005$, but only a marginal association in Study 2b, $r(94) = .18$, $p = .08$. In addition, because some participants did not make a choice (i.e., circle A or B) before rating their task preference and because these participants may have misinterpreted the preference rating scale (like the participants who gave conflicting responses), we conducted another set of analyses that excluded both sets of participants. In this case, the correlation between math-specific perseverance and task preference remained significant in Study 2a, $r(150) = .26$, $p = .001$, and marginally significant in Study 2b, $r(77) = .21$, $p = .07$. Finally, with respect to the association between math-specific perseverance and the dichotomous measure of behavioral persistence (which was presumably less sensitive than the continuous measure), the point-biserial correlation was significant in Study 2a, but not Study 2b (see Table 2). Overall, the results of both studies replicated those of Study 1, finding that the more students perceived themselves as capable of persevering on challenging math problems (Session 1), the more they preferred to continue working on the challenging math task in Session 2.[10]

Also replicating Study 1, but in contrast with prior research on less challenging math contexts (e.g., Eskreis-Winkler et al., 2016; Galla et al., 2014; Lucas et al., 2015), the correlations between domain-general perseverance and the two indexes of behavioral math persistence were not statistically significant in either study (see Table 2). In other words, we did not find a direct relation between students' trait-level propensity for perseverance and their preference to continue working on a challenging math task.

Although we did not find a direct association between domain-general perseverance and behavioral persistence in either study, we were again interested in whether domain-general perseverance indirectly predicted persistence through math-specific perseverance. We therefore conducted tests of intervening variable models as in Study 1. Both studies replicated Study 1: the 95% confidence intervals for the indirect effects excluded zero, suggesting that domain-general perseverance had an effect on task persistence via math-specific perseverance, even though there was no direct effect (see Figure 1b,c). Taken together, the results of Studies 2a and 2b therefore provide further evidence (with a different dependent measure and across two populations) that math-specific self-perceived perseverance may be a better predictor than domain-general self-perceived perseverance of students' behavioral persistence on challenging math problems.[11]

General discussion

Across three studies conducted with distinct measures and with different populations, we found that math-specific self-perceived perseverance was significantly correlated with participants' behavioral persistence on challenging math problem-solving tasks. In contrast, the domain-general perseverance component of grit did *not* directly predict behavioral persistence, contrary to our expectations. Although there was no direct association between domain-general perseverance and persistence, we consistently found a significant indirect effect of domain-general perseverance on persistence through math-specific perseverance. Furthermore, the size of this effect was remarkably similar across the three studies. These findings suggest that the grittier students were (at a trait level), the more they perceived themselves as capable of persevering on challenging math problems, which in turn predicted how much they actually persisted on a challenging math task. Importantly, this pattern held regardless of whether persistence was measured in terms of time-on-task (Study 1) or in terms of participants' preference for continuing with the task (Studies 2a-2b), and whether participants were American (Studies 1–2a) or Russian (Study 2b).

General trait versus domain-specific predictors of behavioral persistence

Our finding that domain-general self-perceived perseverance only indirectly predicted behavioral persistence in the math domain through math-specific self-perceived perseverance is consistent with Bandura's (2012) assertion that personality traits are sometimes too general to adequately predict specific behaviors—that "the convenience of all-purpose global tests of personal attributes is gained at the cost of explanatory and predictive power" (p. 358). Thus, for researchers and educators interested in predicting students' levels of effort and persistence on tasks in a particular domain, they may be better off assessing domain-specific factors rather than a domain-general factor like grit. This is in line with Wigfield's (1997) discussion of "the importance of looking at motivation within particular domains" (p. 65).

Relatedly, the findings also raise important questions about the role of grit in predicting and producing different kinds of outcomes. As discussed, grit has been widely touted as an important predictor of positive academic outcomes (such as grade point average, retention, and intention to persist in college) across multiple academic domains (Credé et al., 2017; Eskreis-Winkler et al., 2014, 2016; Muenks et al., 2017, 2018). However, the current results join more recent contributions from the grit literature in suggesting that specific outcomes might be better predicted by more domain-specific perseverance constructs (e.g., Cormier et al., 2019; Muenks et al., 2018; Schmidt et al., 2019; Usher et al., 2019). More critically, the present findings—especially the indirect association between the perseverance facet of grit and behavioral persistence in math via math-specific perseverance—complement the recent findings of Usher et al. (2019) by suggesting that the ability of domain-general perseverance to predict narrow or specific outcomes may run through more proximal domain-specific factors.

Future work should seek to further explore whether the direct predictive power of domain-general perseverance (as well as the overall grit scale) wanes at greater levels of outcome specificity. For instance, it is worth noting that the mean observed correlation between domain-general perseverance and high school/college GPA in the meta-analysis by Credé et al. (2017) was .20, whereas the correlations between general perseverance and a more domain-specific outcome (standardized math scores) in the study by Usher et al. (2019) only ranged from .01 to .10 (though this study was conducted with younger students). Similarly, the correlations in the current studies between general perseverance and an even more specific outcome (persistence on particular math problems) only ranged from −.10 to .06.

Persistence on challenging versus easier math problems

In addition to the possibility that the relation between general grit and behavioral outcomes may weaken with the increased domain-specificity of these outcomes, there are also other factors that may affect the predictive power of general grit (or its perseverance component). In particular, with respect to the mathematical domain, the type of perseverance required may vary depending on the nature of the math task. Consider, for example, the studies that did show a direct association between domain-general perseverance and math persistence (Eskreis-Winkler et al., 2016; Galla et al., 2014; Lucas et al., 2015). As discussed earlier, these studies used tasks that did not consistently pose a high level of mathematical challenge (i.e., presenting middle school students with standard textbook problems, high-school students with one-digit subtraction, and adult participants with three-digit addition problems). Given that these tasks may not have been inherently challenging from a mathematical perspective, what may have created the perception of challenge were broad situational demands—namely, the fact that participants in these tasks had to sustain their attention over a 45-minute period (Eskreis-Winkler et al., 2016), complete a tedious and boring task (Galla et al., 2014), or solve as many problems as possible in a short amount of time while being outperformed by a competitor (Lucas et al., 2015).

In these cases, participants may have viewed the tasks as reflecting a general challenge of having to remain attentive, overcome boredom, work within strict time constraints, or outperform a more skilled opponent. Participants' persistence in the face of such challenges may have reflected their domain-general perseverance. In contrast, the participants in our studies were presented with tasks that were challenging due to the nature of their content (i.e., challenging math word problems in Study 1 and challenging math-framed reasoning problems in Studies 2a-2b) and our results confirmed that they were in fact experienced as challenging. Thus, students' decisions to persist were more likely to reflect a domain-specific determinant of math persistence—specifically, their self-perceived tendency to persevere on challenging math problems.

Practical significance

While the results were consistent across the present studies, the effect sizes were relatively modest. That being said, the effects observed in the studies were on par with the effect sizes typically reported in the grit literature. In fact, the moderate correlations (Cohen, 1992) between measures of math-specific perseverance and behavioral persistence (*r*s = .24-.25) were slightly larger than the mean correlation that Credé et al. (2017) found between domain-general perseverance and general indicators of academic performance across 11 studies (r_{obs} = .20). In addition, a wealth of research has shown that even "small effects may have enormous implications in a practical context" and that "small effects in ongoing processes may accumulate over time to become large effects" (Prentice & Miller, 1992, p. 163; see also Cohen & Sherman, 2014; Yeager & Walton, 2011). One way in which the effects observed in the current studies may accumulate is through the potential reciprocal relations between self-perceived math perseverance and actual behavioral persistence. As discussed in the Introduction, a student's self-perception that she is someone who tends to persevere when faced with difficult math problems should lead her to spend more time working on such problems, which, in turn, could serve to reinforce this self-perception.

Limitations and future directions

Although the studies presented here provide fairly consistent results regarding the relations between domain-general perseverance, math-specific perseverance, and behavioral persistence in math, it is important to acknowledge limitations of this work and consider opportunities for future research. First, the samples in our studies were primarily female. As prior research has found that women report weaker math self-concepts than men (Else-Quest et al., 2010), future research should seek to replicate the present results with more gender-balanced samples.

Second, although we found an indirect effect of domain-general perseverance on behavioral persistence through math-specific perseverance in all three studies, domain-general perseverance and math-specific perseverance were assessed at the same time point. Thus, as with all correlational data, the causal links suggested by these intervening variable analyses should be considered tentative. For instance, although we have argued that high levels of domain-general perseverance may lead people to become more determined in the math domain, it is certainly possible that students' domain-specific beliefs also contribute to their general conception of themselves as gritty and perseverant in a bottom-up manner.[12] Future research should more carefully investigate the causal direction of the associations observed in the present studies by using experimental or longitudinal designs.

Relatedly, it is also important to consider potential unmeasured third variables. As discussed, a broad personality factor like domain-general perseverance is likely to exert its influence on domain-specific outcomes like math persistence through several indirect paths involving distinct intervening variables. While the present studies provide consistent evidence supporting one such path—through math-specific perseverance—there are likely other important intervening variable to consider. This point is supported by the results of Study 1, where the direct association between domain-general perseverance and persistence went from non-significant to significantly negative when math-specific perseverance was accounted for. As an illustration of how a predictor variable may influence an outcome variable in opposite directions via two separate indirect pathways, consider McFatter's (1979) discussion of the numerous potential relations between intelligence and performance. Whereas more intelligent people are generally assumed to have higher levels of certain cognitive abilities and are therefore expected to perform better on intellectual tasks, the same people may also exhibit a lower tolerance for boredom, which could ultimately lead to disengagement and hurt performance. As a result, the indirect effect of intelligence on performance through cognitive ability would be positive, while its indirect effect through boredom would be negative. Combined, these two effects may cancel each other out in some cases, resulting in a total effect of intelligence on performance that is equal to zero. And there are likely many others cross-cancelling paths by which intelligence might positively and negatively affect performance at the same time. This may also be true of domain-general perseverance: while its indirect effect on math persistence through math-specific perseverance may be positive (as the present studies suggest), domain-general perseverance may also have indirect effects on persistence that are negative. For example, students with higher levels of domain-general perseverance have been shown to be more strategic in how they use their academic time (Wolters & Hussain, 2015), which may result in them spending less time (i.e., persisting less) on academic tasks that are not associated with their actual courses (i.e., lab-based math problems). Future research should therefore continue to test for intervening variables between domain-general perseverance and important academic outcomes.

Another potential limitation is that, whereas some of the items from our math-specific perseverance scale were framed in terms of a self-perceived tendency to persevere (e.g., "When I don't understand a problem, I keep working till I find the answer"), other items used efficacy-related language (e.g., "I feel I can do math problems that take a long time to complete"). This language may account for the overlap between some items from our scale and a general measure of math confidence/self-efficacy (see Footnote 3 and supplementary materials). However, it is important to point out that the efficacy-framed items included in our scale used language that was specifically about being able to *persevere* on challenging or time-consuming math problems, in contrast to common measures of math confidence/self-efficacy (e.g., Usher et al., 2019).

It is possible that there is little difference between a perceived tendency and a perceived ability to persevere when assessing persistence at the level of specific problem-solving behavior. Indeed, the fact that the reliability coefficients for the math-specific scale were fairly high (particularly in the two U.S. studies) supports this possibility. Additional research is needed to contrast this possibility (whereby there is little psychological difference between the perceived tendency and ability to persevere) with the alternative possibility that students do not distinguish between their ability to persevere on challenging math problems and their more general sense of efficacy in the math domain. However, the need for further clarification does not undermine the central aims of the present paper. The purpose was not to validate the measure of a novel construct, but to demonstrate that students' perceptions of their perseverance when solving challenging math problems may be a stronger and more proximal predictor of their behavioral persistence compared to their domain-general perceptions of their perseverance.

Finally, as previously discussed, the three studies reported here were originally conducted as part of two separate projects. While the overlap in methods made it appropriate to examine them together, the fact that these were initially separate projects with separate aims means that most of the analyses conducted for the present paper were post hoc and exploratory in nature. Indeed, we only formalized the conceptual relations between domain-general perseverance and math-specific perseverance after beginning to interpret the results of the three studies. But, again, the results were very consistent across all three studies, which varied in terms of both culture and our assessment of persistence. It is therefore our hope that the present findings can serve as a starting place for future hypothesis-driven studies of the relations between domain-general perseverance, math-specific perseverance, and math problem-solving persistence.

Notes

1. For a full list of measures and procedures for all three studies, along with some additional analyses, see the supplementary materials. For more information about the exploratory and post hoc nature of our analyses, about the evolution of our conceptual framing, and about exclusions, also see the supplementary materials. A set of analyses for Study 1 pertaining to participants' growth mindsets were published in Shen, Miele, and Vasileyeva (2016).
2. The participants who completed Session 1, but not Session 2, did not vary significantly from the final sample in terms of domain-general perseverance, math-specific perseverance, or age. There was a marginal difference between these groups in terms of gender composition (see the supplementary materials for details).
3. Math confidence—a self-perception variable (see Marsh et al., 1988; Pajares & Miller, 1994; West et al., 1980) which seems to overlap with math-specific perseverance to some extent—was one of the additional individual difference variables assessed in Studies 1 and 2. Although math confidence significantly predicted behavioral persistence, it did not exhibit a consistent relation with domain-general perseverance. See the supplementary materials for details regarding the measurement and analysis of this construct.
4. All three studies involved a feedback/challenge manipulation that was administered prior to the persistence measure (see Shen et al., 2016). As detailed in the supplementary materials, there were no main effects of the manipulations on the primary outcome measures in any of the studies, nor did the manipulations moderate the relation between any of the primary predictors in the present paper and the outcome measures. This is contrast to findings by Lucas et al. (2015), who found that grit was only associated with persistence in the failure condition.
5. This includes the math confidence variable examined in the supplementary materials.
6. It may be of interest to some readers to note that openness to experience, which we assessed in Session 1 of the present study (but not in the other studies), exhibited significant correlations with domain-general perseverance and math-specific perseverance and a near significant correlation with behavioral persistence (see the supplementary materials).
7. Demographic information on race/ethnicity were not collected for either of these studies. As explained in the supplementary materials, the mean age reported for Study 2b represents an estimate.
8. In Study 2a, one participant's rating was coded as 2.5 because he/she marked both 2 and 3.
9. The greater percentage of participants who skipped the choice item (compared to Study 2a) can be attributed to a difference in formatting.
10. It may be of interest to some readers that math *value*, which we assessed in Session 1 of Study 2a (but not in Session 1 of the other studies), was strongly correlated with math-specific perseverance and

significantly predicted behavioral persistence (a similar pattern to what we observed with math confidence; see the supplementary materials).

11. For all three studies, we conducted additional regression analyses to examine the potential interaction effects of math-specific perseverance × task/test performance and/or math-specific perseverance × math confidence on persistence. These analyses yielded inconsistent results. For the results of these analyses and for a description of other regression models we examined across the studies, see the supplementary materials.
12. Relevant to this, we found a significant *negative* indirect effect of math-specific perseverance on behavioral persistence through domain-general perseverance in Study 1, but not Studies 2 and 3 (see the supplementary materials).

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Appendix

Behavioral Persistence Task (Study 1)

Solvable Problem

A car travels downhill at 72 mph (miles per hour), on the level at 63 mph, and uphill at only 56 mph. The car takes 4 hours to travel from town A to town B. The return trip takes 4 hours and 40 minutes.

Find the distance between the two towns.

Answer: 273 miles

Unsolvable Problem

Make two three-digit numbers using the following digits − 1, 3, 4, 5, 6, 9 – so that one of these three-digit numbers is exactly five times greater than the other (each digit should be used only once).

Math-Specific Perseverance (Studies 1, 2a, and 2b)

(Formatting, including underlining, varied between administrations of the scale)

Please read each item carefully and rate the extent to which the item describes you using the following scale [the scale that appears below it]. There are no right or wrong answers. We are interested in your opinions.

1. If I am struggling to solve a problem, I try to think of alternative ways to solve it.
2. When I don't understand a problem, I keep working until I find the answer.
3. If I cannot do a math problem in a few minutes, I probably can't do it at all. (R)
4. Math problems that take a long time don't bother me.
5. If I can't solve a math problem quickly, I quit trying. (R)
6. I feel I can do math problems that take a long time to complete.
7. I find I can do hard math problems if I just hang in there.
8. I'm not very good at solving math problems that take a while to figure out. (R)