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Authors
Scheibe, Daniel A
Was, Christopher
Thompson, Clarissa A

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Does Expressive Writing Blunt the Effects of Math Anxiety on Math Performance? A Conceptual Replication and Extension of Park et al. (2014)

Daniel A. Scheibe (dscheib2@kent.edu)
Department of Psychological Sciences, 600 Hilltop Dr
Kent, OH 44240 USA

Christopher A. Was (cwas@kent.edu)
Department of Psychological Sciences, 600 Hilltop Dr
Kent, OH 44240 USA

Clarissa A. Thompson (cthomp77@kent.edu)
Department of Psychological Sciences, 600 Hilltop Dr
Kent, OH 44240 USA

Abstract

Math anxiety (MA) is negatively related to math performance. One proposed intervention with potential to disrupt the MA-math performance link is expressive writing. The current study aimed to conceptually replicate Park and colleagues (2014). In that study, the authors concluded that expressive writing effectively boosted math anxious students' performance. In our current sample of 168 college students, participants randomly assigned to the expressive writing condition were no more accurate at posttest than were other participants assigned to a math self-concept intervention, active control, or passive control. Additionally, participants in the math self-concept and active control conditions reported lower state MA immediately following the intervention; participants in the expressive writing and passive control conditions reported no differences between pretest and posttest state MA. The current study provides boundary conditions for the effectiveness of expressive writing interventions in ameliorating MA during difficult math tasks and illuminates potential mechanisms underlying MA.

Keywords: math anxiety; expressive writing; math self-concept; problem solving; decision making

Introduction

The common consensus in math anxiety (MA) research is there is no current light-touch intervention known to reliably decrease the negative effects of MA on math performance, apart from expressive writing (Barroso et al., 2020; Dowker et al., 2016; Mammarella et al., 2019; Passolunghi et al., 2019; but see also Ramirez et al., 2018 for other possible interventions). Given the negative effects of MA–feelings of tension and apprehension related to math (Ashcraft, 2002; Richardson & Suinn, 1972)--on performance (e.g., Hembree, 1990), an intervention that could disrupt these negative effects would have significant positive implications for education. Particularly appealing would be a light-touch, easy-to-administer intervention such as expressive writing. The focus of the current study is whether expressive writing is an effective intervention for (a) increasing math performance and (b) decreasing MA. This study aimed to conceptually replicate and extend research by Park et al. (2014). Our secondary goal was to examine whether self-reported state MA fluctuated throughout the experiment.

Expressive writing (EW) is an intervention technique originally derived from clinical settings (Pennebaker & Beall, 1986). The aim of EW is to encourage people to freely write about their negative thoughts and feelings about an upcoming event (e.g., math test) to offload cognitive worry associated with that event. There is some evidence that an EW intervention can increase working memory resources (Klein & Boals, 2001; Yogo & Fujihara, 2008), although these interventions involved multiple sessions of EW, whereas participants in Park et al.'s (2014) study completed only a single experimental session.

Other researchers have also attempted to use an EW intervention in academic settings: Examples include a classroom study (Myers et al., 2021) and an elementary setting (Mesghina & Richland, 2020). Results varied from no effects of EW on math performance and MA (Myers et al.) to negative effects of EW (Mesghina & Richland). These and other mixed findings, coupled with questions about pretest performance and control condition MA incubation (i.e., perseverating on upcoming math tasks) in Park et al. (2014), left open several questions regarding whether EW is an effective intervention, and if so, in what settings, for what type of math content, and for learners of which ages.

Park and colleagues (2014) chose math stimuli in the form of (a X b) - c = d. The current study extended the previous work to include fraction operation problems (e.g., $\frac{1}{4} + \frac{3}{5}$) and rational number reasoning in medical decision-making contexts (Cuite et al., 2008). One of the most common forms of math is basic arithmetic: addition, subtraction, multiplication, and division. A particularly challenging form of these basic operations involves working with fractions. We focus here on fraction operation problems because they are challenging and crucial to numerical understanding (Siegler et al., 2011), and they often induce MA (Sidney et al., 2021). We also included math-related medical decision-making problems because these problems require relational reasoning and are common in real-life math contexts (cf. COVID-19 related math problem solving; Thompson et al., 2021).

Proposed Mechanisms of Math Anxiety

There is no one universally accepted account of MA (see

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Ashcraft, 2019 for a recent review of models of MA). Park et al. (2014) argued that their intervention was likely effective because EW, "...lessens the likelihood that math-related worries will capture attention during the math task" (p. 108). Said another way, Park and colleagues proposed EW might help students with high MA inhibit task-irrelevant worries, thereby freeing up working memory capacity. This framework fits nicely with Ashcraft and colleagues' (Ashcraft, 2002; Ashcraft & Faust, 1994; Ashcraft & Kirk, 2001) model of MA as taxing working memory resources (now termed *the disruption account*; Ramirez et al., 2018).

The disruption account proposes MA negatively affects math performance by creating cognitive worry, thus disrupting people's true math capability. According to this account, high-math-anxious individuals (HMAs) are less able (compared to low-math-anxious individuals; LMAs) to inhibit task-irrelevant information (e.g., cognitive worry about math) when attempting to complete difficult math tasks. Because Park et al. (2014) positioned their study within the disruption account of MA, and because this framework is currently a prevalent model of MA, the current study approached MA with this lens.

One of the strongest predictors of MA is students' math competence beliefs, (i.e., math self-concept and math self-efficacy; Ahmed et al., 2012). Ahmed and colleagues demonstrated that MA is reciprocally related to math self-concept in 7th grade students. Previous research demonstrated some potential for cognitive reappraisal of arousal in math situations to increase math performance (Jamieson et al., 2010), but no studies that we are aware of have tested a light-touch math self-concept (MSC) intervention on decreasing MA and its negative effects on fraction performance. The current study adds to the literature by conceptually replicating previous work by Park et al. (2014), but also including a MSC condition and an active control condition in which participants wrote about the importance of reading (in addition to the EW and passive control conditions). The MSC intervention was based on a cognitive reappraisal, similar to Jamieson et al.; however, the reappraisal in the current study was purely cognitive (i.e., reappraising participants' MSC) as opposed to reappraisal of physiological stress responses.

As a secondary investigation, the current study examined how MA varies as a trait versus state measure. A state-trait differentiation is important because such a juxtaposition would allow researchers to better understand what drives participants' responses to items like the Single Item Math Anxiety scale (SIMA; Ashcraft, 2002; Núñez-Peña et al., 2014) in which participants are asked: "On a scale of 1 to 10, with 10 being the most anxious, how math anxious are you in general?" In the current study, we assessed whether participants showed variability in their MA ratings across one experimental session (i.e., before vs. after an experimental intervention).

Assessing Math Anxiety

Park et al.'s (2014) participants completed the shortened math anxiety rating scale (sMARS; Alexander & Martray, 1989). Only participants who scored below a 20 (i.e., were low math anxious, LMAs) or over 40 (i.e., were high math anxious, HMAs) were included in their sample. Note that sMARS scores range from 0-100 and any data splitting of a continuous variable (e.g., LMAs and HMAs) presents inherent challenges regarding arbitrary cutoffs. Therefore, in the current study, we analyze the full set of participants and also conduct a median split on pretest MA (see method section) to assess the boundaries of Park et al.'s findings.

Research Questions and Hypotheses

The current study, pre-registered on OSF (https://osf.io/ur2kg/?view_only=15e0e0120f654342a2f90c1045b782ab), measured four primary outcomes: (a) math performance on fraction operation problems, (b) math performance on medical decision-making problems, (c) MA in general, and (d) state MA. Our pre-registered hypotheses were:

H1: Participants in the math self-concept condition (MSC) will perform better on posttest measures compared to participants in the other conditions (i.e., participants in the MSC condition will out-perform participants in the EW condition, and both conditions will out-perform the active and passive control conditions).

H2: MA will fluctuate across the five different SIMA state probes (i.e., there will be variance in participants' self-reported levels of in-the-moment MA throughout the experiment). This hypothesis was non-directional.

Method

Participants

Participants were 197 college undergraduate students from a psychology department subject pool from Kent State University, who participated for course credit. Based on pre-registered exclusion criteria, our final sample consisted of 168 participants (*M* age = 19.38 years, *SD* = 2.82 years). Participants reported they predominantly identified as female: 122 female, 39 male, 3 nonbinary, 2 different identities, and 2 participants did not report their gender.

Experimental Design and Procedure

The current experimental design was a 4-way (experimental condition: MSC, EW, active control, passive control) pretest-posttest design. All participants completed identical measures at pretest and posttest. The only significant variation in procedure for the four conditions was participants' instructions for the 7-minute intervention.

The current experiment lasted approximately 60 minutes (median = 53 minutes) and was administered online through Qualtrics and the SONA system. Participants completed pretest measures, a 7-minute intervention, posttest measures, and a brief demographic survey (see Figure 1 for survey flow).

Measures

Measures of the current study are discussed in three groups: (a) Measures of self-reported MA, (b) measures of ability, and (c) intervention prompts.

Self-Reported MA Immediately following informed consent, participants completed the pretest SIMA (Ashcraft, 2002; Núñez-Peña et al., 2014). Participants responded on a scale ranging from 1="Not anxious" to 10="Very anxious."

The SIMA is an efficient way to gauge participants' general MA (Ashcraft, 2002). We also adapted the wording of the SIMA to create a *state* MA measure to assess how MA fluctuated throughout the experiment. The only change from the SIMA was that the wording "in general" was changed to "at this moment." Participants completed this state MA measure five times throughout the experiment.

In addition to the pretest SIMA measure, and the five state-SIMA probes, participants completed three different MA measures at posttest: (a) the shortened MA rating scale (sMARS), (b) a researcher-generated (currently being validated) MA scale for completing math in various contexts (e.g., formal vs. informal), and (c) four MA interview questions. For the sake of brevity, only the sMARS is discussed in the current study.

The sMARS (Alexander & Martray, 1989) is a popular 25-item measure of MA based on the original MA scale, the MA rating scale (MARS; Richardson & Suinn, 1972). sMARS and MARS are highly correlated (r = .97; Alexander & Martray; Cipora et al., 2019), yet the sMARS has only 25 relative to 98 items. In addition to the pervasive use of the sMARS in the MA literature (Cipora et al.), we chose to use this inventory because Park et al. (2014) also used the sMARS as a pre-screening tool. The sMARS asks individuals to rate how much "fear or apprehension" they feel in different situations involving math (e.g., "Studying for a math test"). Scale reliability in our sample was excellent, α = .96.

Measures of Math Ability Measures of ability in the current study involved a measure of working memory capacity (WMC) and two types of math problem solving.

Participants completed a pretest measure of WMC (Fitzsimmons et al., 2020) that involved constantly updating a span of digits and reciting the final four digits. After two practice items, participants completed three 7-digit problems, three 9-digit problems, and three 11-digit problems in a randomized order. Participants saw each digit on screen for one second before that digit disappeared and the next appeared. At the end of each problem, participants were given an open-ended response box and asked to recall the four most recently-presented digits. Partial accuracy scoring was used to create the WMC accuracy index (e.g., if "3615" was the correct answer, and the participant responded with "3815," that would be a score of 3 out of 4).

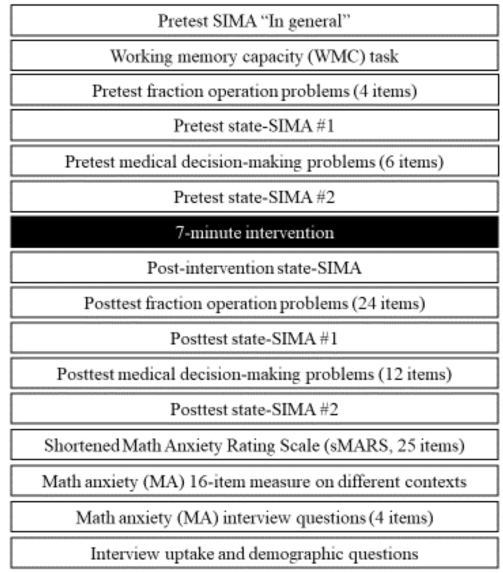

Figure 1: Order of experimental tasks.

In addition to the inclusion of WMC capacity, another novel contribution of the current study was incorporating different math performance stimuli. We included fraction operation problems adapted from Siegler and colleagues (2011) because participants rate fractions as more anxiety provoking than other types of math (Mielicki et al., 2022). Thus, participants completed four fraction operation problems at pretest (one problem of each operation) and 24 fraction operation problems at posttest (six problems of each operation). Example problems included: "What is ¼ + ⅗?" and "What is 9/36 X 27/45?"

In addition to decontextualized fraction operations, participants also completed medical decision-making problems involving rational-number operations, adopted from research on risk communication (Cuite et al., 2008). Participants completed three each–one at pretest and two at posttest–of the following problem types involving hypothetical math-based risk assessment: (a) Comparing two risks, (b) Halving a risk, (c) Tripling a risk, (d) Adding two risks together, (e) Tradeoffs between the effects of taking a new drug, and (f) Sequences involving conditional probability of risk. An example halving problem was: "Your risk of cancer C is 24 in 10,000, but a new drug would cut that risk in half. What would your new risk be?"

Intervention Prompts The central aim of the current study was twofold: To conduct a conceptual replication of Park et al. (2014) and test a novel math self-concept (MSC) intervention, which could be compared to Park and colleagues' expressive writing (EW) intervention. Participants were randomly assigned to one of four intervention conditions: MSC, EW, an active control, or a passive control.

The MSC condition featured a novel, light-touch intervention focused on highlighting participants' existing math skills. A main assumption that guided the creation of this intervention is that when asked about how math anxious they are, people often recall formal math testing scenarios. To undermine this focus on formal math settings, the MSC intervention explicitly instructed participants to consider *informal* math settings (e.g., “Please guide your writing by focusing on informal math situations where you felt competent and experienced little to no worry about math”). The primary goal of this intervention was to increase participants’ MSC, thus providing a buffer to act against cognitive worry at posttest. When possible, the wording of the MSC intervention paragraph was designed to mirror the wording of the EW intervention.

The EW intervention paragraph was adopted from Park and colleagues (2014). Participants were instructed to let themselves freely explore their thoughts and emotions to prepare for the posttest math problem. In contrast to the MSC condition, the EW condition directed participants to consider academic situations (e.g., “You might relate your current thoughts to the way you have felt during other similar situations at school or in other situations in your life.”). The EW intervention purportedly alleviates WMC burden by allowing participants to disclose their worrisome thoughts about the upcoming math tasks (Park et al., 2014; Ramirez & Beilock, 2011).

The original control condition in Park et al. (2014) involved participants sitting in silence for seven minutes after reading the following prompt: “At this point in the study, please sit quietly and do nothing for 7 minutes. Imagine that you are sitting in a classroom setting preparing to complete a math exam.” Participants were also instructed not to use their phone and avoid other distractions–attention checks were included as exclusion criteria. In addition to our conceptual replication of Park et al.’s passive control condition, we also included an active control to counteract any effects of anxiety incubation.

Participants in the active control condition read a paragraph similar to the one MSC participants read, with one major exception. The focus of the active control paragraph was about reading, not math. This condition was designed to create an active time-on-task control focusing on reading to take participants' minds off math.

Results

The primary goal of the current study was to conceptually replicate and extend findings from Park et al. (2014) regarding the effectiveness of an expressive writing intervention on math outcomes. We first present analyses checking for random assignment to condition. Next, we present our primary ANCOVA examining differential effects of experimental conditions on MA and math performance. Lastly, we compare low math anxious (LMA) to high math anxious (HMA) participants in an attempt to conduct similar analyses as those done byPark et al.

Checking for Random Assignment at Pretest

Per our pre-registration, we checked for random assignment to the four experimental conditions. Participants did not vary by experimental condition on MA as measured by the SIMA: $F(3,164)=0.20$, $p=.894$, math self-concept: $F(3,164)=0.38$, $p=.767$, or fraction operation accuracy: $F(3,152)=0.09$, $p=.965$. However, participants did differ by experimental condition on medical decision-making accuracy at pretest: $F(3,162)=3.13$, $p=.027$. Participants in the passive control condition ($M=4.47$, $SD=0.99$) were significantly more accurate on pretest medical decision-making problems compared to participants in the EW condition ($M=3.72$, $SD=1.53$). Thus, we included pretest medical decision-making accuracy as a covariate in our primary models.

Posttest Math Performance by Condition

After engaging in their randomly assigned experimental condition, participants completed fraction operations and medical decision-making problems and rated their MA. We report findings for each of these dependent variables in turn. Pre-registered covariates in all models were (a) pretest WMC, (b) pretest MA, and (c) pretest math performance–operationalized as medical decision-making accuracy.

We conducted an ANCOVA by experimental condition on posttest fraction-operation accuracy (for the 24 posttest fraction problems). Results indicated no significant effect of experimental condition: $F(3,138)=0.48$, $p=.700$. That is, participants in all conditions (MSC, EW, active control, and passive control) performed *equally well* on posttest fraction operations. Next, we conducted a parallel ANCOVA by experimental condition on medical decision-making accuracy (for the 12 posttest medical decision-making problems). Like fraction performance, participants did not differ by experimental condition on posttest medical decision-making accuracy: $F(3,152)=1.17$, $p=.324$.

Conceptual Replication of Park et al. (2014)

Comparing posttest performance across the four experimental conditions is central to hypotheses for the current study; however, the primary conclusion from Park et al. (2014) was, “...a single bout of expressive writing is an effective intervention to reduce the prevailing performance gap seen most strongly between HMAs and LMAs on high-demand math problems” (p. 108). In other words, their primary conclusion was that expressive writing effectively reduced the gap in math performance between participants with high and low levels of MA. Thus, we split our participants into two groups, high math anxious (HMAs) and low math anxious (LMAs) individuals, to attempt to replicate Park et al.’s findings.

A one-way ANOVA on fraction-operation performance at posttest revealed no significant differences between experimental conditions for LMAs, $F(3,53)=0.59$, $p=.624$, or HMAs, $F(3,67)=0.81$, $p=.492$. Similarly, a parallel ANOVA on medical decision-making performance at posttest revealed no significant differences between experimental conditions for LMAs, $F(3,60)=1.97$, $p=.128$, or HMAs, $F(3,76)=1.18$,

p=.325. Thus, participants did not differ by experimental condition on either type of posttest math performance, when considering a median split of LMAs and HMAs.[1] See Table 1 for the descriptive statistics after the median split.

The important element for the conceptual replication of Park et al.'s (2014) work is if we were able to *reduce the gap* between HMAs and LMAs. Thus, the prediction in support of the effectiveness of the EW intervention would be that HMAs and LMAs would perform equally well on posttest math; however, LMAs would perform significantly better than HMAs in the control conditions. In the current study, LMAs typically performed better on posttest fraction operation problems than did HMAs. Independent samples t-tests comparing LMAs to HMAs within each experimental condition revealed a trend of LMAs to out-perform HMAs on posttest fraction operation performance (see Table 1); however, when a manual correction for multiple t-tests was applied[2], none of the t-tests reached significance at $p < .0125$. Likewise, for medical decision-making performance, LMAs nominally out-performed HMAs in each experimental condition at posttest, yet when an adjustment for multiple t-tests was applied, none of the differences reached significance at p<.0125.

Table 1: Attempted Replication of Park et al.'s (2014) Table 1 – Accuracy Rates Across Conditions

		MSC	EW	AC	PC
Fraction Operation Problems	LMAs	75.7% (23.5%)	66.7% (23.5%)	75.4% (20.5%)	68.5% (21.7%)
	HMAs	56.0% (30.9%)	45.4% (25.6%)	51.4% (32.1%)	61.0% (35.2%)
Medical Decision-Making Problems	LMAs	74.4% (21.4%)	59.4% (18.5%)	63.0% (14.6%)	65.8% (14.1%)
	HMAs	58.8% (17.8%)	50.4% (19.0%)	51.3% (19.2%)	57.8% (15.4%)

Note. This table is based on a median split of participants on the pretest SIMA: Scores of 1-5 are considered "LMAs" (n=66), scores of 7-10 are considered "HMAs" (n=83), and scores of 6 (median score on the SIMA; n=19) are not included in these analyses. SIMA median scores tend to be closer to the middle of the scale (5-6 range; Sidney et al., 2021) than do the reported middle-range sMARS scores according to Park et al. (21-40 range). The acronyms are as follows: MSC = math self-concept, EW = expressive writing, AC = active control, and PC = passive control. Standard deviations are in parentheses.

Park et al. (2014) included test anxiety as a covariate in their models, although their results were similar without the covariate (p. 106). To attempt to conceptually replicate Park and colleagues' findings in our primary analyses, we ran ANCOVAs using the same pre-registered covariates from our primary analysis–pretest WMC, pretest MA, and pretest medical decision-making performance–after a median-split of the data.

On posttest fraction operations, participants' performance did not differ by experimental condition for LMAs, $F(3,50)=1.16$, p=.335, or HMAs, $F(3,63)=0.41$, p=.750. Participants' performance on pretest fraction operations predicted their performance on posttest fraction operations for both LMAs, $F(1,50)=43.61$, p<.001, partial η^2=.47, and HMAs, $F(1,63)=147.21$, p<.001, partial η^2=.70. For posttest medical decision-making, experimental condition had no effect on math performance for LMAs, $F(3,56)=1.13$, p=.344, or HMAs, $F(3,71)=0.19$, p=.901. Similar to fraction operations, medical decision-making accuracy at pretest predicted medical decision-making accuracy at posttest for both LMAs, $F(1,56)=29.74$, p<.001, partial η^2=.35, and HMAs, $F(1,71)=37.58$, p<.001 partial η^2=.35. Thus, our data suggest that the effect, if any, of experimental condition, has no further explanatory power on math performance after accounting for pretest math performance, WMC, and pretest MA. This may have occurred given that fractions are an especially difficult type of math, and we did not provide participants with any experiences to improve their fraction performance.

Effect of Condition on State Math Anxiety

Our second hypothesis was that math anxiety would fluctuate across the five different state-SIMA questions throughout the current study. To test this, we ran a repeated measures ANOVA across the five data points. A Greenhouse-Geisser adjustment was applied due to violation of the test of sphericity. Results indicated a significant, non-linear effect of time on state MA, $F(3.3,542.3)=27.16$, p<.001. Participants reported significantly lower MA following the intervention (M=5.07, SE=0.23) compared to the other four time points (M's ranged from 6.09 to 6.54, SE's ranged from 0.22 to 0.23).

To test whether experimental condition had an immediate effect on MA, participants responded to a state SIMA probe immediately following the intervention. A one-way ANOVA on participants' state MA immediately following the intervention revealed a significant effect of experimental condition: $F(3,164)=3.62$, p=.015, η^2=.06. Pairwise comparisons using a Bonferroni adjustment revealed that participants in the active control condition (M=3.86, SD=2.77), in which participants wrote expressively about the

[1] We tested the same ANOVA models for both math performance measures at pretest: The same trends emerged. That is, there were no significant differences between experimental conditions after splitting participants at the median on the pretest SIMA: All F's < 2.4, all p's > .05.

[2] To manually correct for multiple t-tests, we divided the alpha level by the number of t-tests conducted.

importance of *reading* in everyday life, reported less state MA than did participants in the EW condition (M=5.79, SD=2.90), p=.012, likely because the intervention distracted participants from engaging with math. The effect of experimental condition on post-intervention state MA was most influential for HMAs: $F(3,79)=3.86$, p=.013, η^2=.13. In summary, experimental condition affected post-intervention state MA, especially for HMA individuals, but only when participants wrote about reading, not math.

Discussion

We did not find support for any benefits of EW, nor did we find support for the novel MSC intervention. Participants performed equally well on both measures of posttest math performance regardless of experimental condition. This finding remained consistent after participants were categorized as LMAs (i.e., SIMA ratings 1-5) vs. HMAs (i.e., SIMA ratings 7-10). A secondary aim of the current study was to measure state MA across different time points to non-directionally explore how participants' report of in-the-moment MA fluctuated throughout the experiment. Results supported variation in MA throughout the experiment in that participants reported lower state MA immediately following the intervention (compared to the other four state-SIMA probes). This difference was particularly strong in the active control (i.e., writing about the importance of reading in daily life) and MSC conditions.

Implications

Possible explanations for the discrepancies between the findings in Park et al. (2014) and our findings include differences in math performance measures, specifically that fraction arithmetic problems are more difficult than whole-number arithmetic problems, different format (online versus in person), different median-split metrics, and potentially not having a large enough sample size to be representative of a real, yet small, effect. Note that the nature of a conceptual replication is largely subjective. Our findings suggest that there are likely boundary conditions for Park et al.'s findings; however, we did not directly replicate their methodology. It is possible that our findings are constrained by methodological differences–future research is warranted for stronger conclusions.

The original impetus for this study was the powerful implications of Park et al.'s (2014) findings: Given that their intervention is a highly cited light-touch intervention for the negative effects of MA, it is worth further investigation. However, there remained several open questions from Park and colleagues' study that were worth investigating. For example, to test the efficacy of the original control condition, we included an active control condition focused on an unrelated reading intervention (as opposed to sitting quietly for seven minutes which could have exacerbated math anxiety, thus leading to significant post-intervention differences in math performance). Park and colleagues cite that their reasoning for choosing the EW manipulation was that they wanted to mimic real-life testing situations, although they concede that it is possible that their control condition might have "incubated anxiety" (p. 109). This alternate explanation for their findings was one reason we attempted to replicate their work. The current study provides some evidence that EW might not decrease MA or boost performance of math-anxious students.

Future Directions

One step toward developing effective interventions would be to better understand what people think of when they self-report on their MA. Participants' scores on the pretest SIMA most highly correlated with formal MA items (r=.74, p<.001) and MSC items (r=-.78, p<.001). Thus, it appears there is at least some evidence that when people think of MA they first think about formal testing situations (e.g., taking the math portion of the GRE) and who they are as a "math person" (e.g., math self-concept). Future studies should specifically target formal math settings, informal math settings, and how people identify as math learners.Overshadowing of ordinary life situations by academic situations is a critical shortcoming of the state of science on MA. More specific MA measurement tools might be particularly helpful for individual diagnosis and intervention implementation (Cipora et al., 2019).

The current study aimed to conceptually replicate Park et al. (2014); however, it is possible that procedural and analytical deviations affected our results. For example, although we did include attention checks, a question regarding calculator use, and intervention uptake questions, it is possible that the online format affected the quality of our results. Future studies could focus on the content of the writing participants produced during the intervention and examine whether including five state-MA prompts resulted in participant reactivity. Furthermore, a more in-depth discussion of when, why, and how to split continuous measures, such as the SIMA, should be pursued.

Finally, future research should consider the role of MSC paired with math interventions. Recent meta-analytical and bidirectional evidence in the MA literature suggests that ideal interventions will target both increasing math skills to lessen deficits and decreasing MA (Namkung et al., 2019). One such intervention could combine math instruction with a MSC intervention to encourage students to think of themselves more like "math people" as they also improve in basic mathematics skills.

The current study yielded no significant improvement on math outcomes (performance and anxiety) for participants in EW or MSC conditions, compared to active and passive control conditions. Further, we provide data on how MA fluctuates throughout a pretest-posttest experiment. Thus, these findings extend understanding of MA and how to develop interventions to combat MA's adverse effects.

References

Ahmed, W., Minnaert, A., Kuyper, H., & van der Werf, G. (2012). Reciprocal relationships between math self-concept and math anxiety. *Learning and Individual Differences, 22*(3), 385-389.

Alexander, L., & Martray, C. (1989). The development of an abbreviated version of the mathematics anxiety rating scale. *Measurement and Evaluation in Counseling and Development, 22*, 143-150.

Ashcraft, M. H. (2002). Math anxiety: personal, educational, and cognitive consequences. *Directions in Psychological Science, 11*, 181-185.

Ashcraft, M. H. (2019). Models of math anxiety. In I. C. Mammarella, S. Caviola, & A. Dowker (Eds.), *Mathematics anxiety: what is known and what is still to be understood* . New York: Routledge.

Ashcraft, M. H. & Faust, M. W. (1994). Mathematics anxiety and mental arithmetic performance: an exploratory investigation. *Cognition & Education, 8*, 97-125.

Ashcraft, M. H. & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. *Journal of Experimental Psychology: General, 130*, 224-237.

Barroso, C., Ganley, C. M., McGraw, A. L., Geer, E. A., Hart, S. A., & Daucourt, M. C. (2020). A meta-analysis of the relation between math anxiety and math achievement. *Psychological Bulletin, 147*, 134-168.

Cipora, K., Artemenko, C., & Nuerk, H-C. (2019). Different ways to measure math anxiety. In I. C. Mammarella, S. Caviola, & A. Dowker (Eds.), *Mathematics anxiety: what is known and what is still to be understood.* New York: Routledge.

Cuite, C. L., Weinstein, N. D., Emmons, K., & Colditz, G. (2008). A test of numeric formats for communicating risk probabilities. *Medical Decision Making, 28*, 377-384.

Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics anxiety: what have we learned in 60 years? *Frontiers in Psychology, 7*, 1-16.

Fitzsimmons, C. J., Thompson, C. A., & Sidney, P. G. (2020). Do adults treat equivalent fractions equally? Adults' strategies and errors during fraction reasoning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 46*, 2049-2074.

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education, 21*, 33-46.

Jamieson, J. P., Mendes, W. B., Blackstock, E., & Schmader, T. (2010). Turning the knots in your stomach into bows: Reappraising arousal improves performance on the GRE. *Journal of Experimental Social Psychology, 46*, 208-212.

Klein, K., & Boals, A. (2001). Expressive writing can increase working memory capacity. *Journal of Experimental Psychology: General, 130*, 520-533.

Mammarella, I. C., Caviola, S., & Dowker, A. (2019). Concluding remarks. In I. C. Mammarella, S. Caviola, & A. Dowker (Eds.), *Mathematics anxiety: what is known and what is still to be understood.* New York: Routledge.

Mesghina, A., & Richland, L. E. (2020). Impacts of expressive writing on children's anxiety and mathematics learning: Developmental and gender variability. *Contemporary Educational Psychology, 63*, 1-10.

Mielicki, M. K., Scheibe, D. A., Fitzsimmons, C. J., Sidney, P. G., Wilkey, E., Mojtaba, S., Alves, I., Coolen, I., Ansari, D., & Thompson, C. A. (2022). *Task features change the relation between math anxiety and number line estimation performance with rational numbers: a large-scale online study* [Manuscript submitted for publication]. Department of Psychology, Rutgers University.

Myers, S. J., Davis, S. D., & Chan, J. C. K. (2021). Does expressive writing or an instructional intervention reduce the impacts of test anxiety in a college classroom? *Cognitive Research: Principles and Implications, 6*, 1-22.

Núñez-Peña, M. I., Guilera, G., & Súarez-Pellicioni, M. (2014). The single-item math anxiety scale: an alternative way of measuring mathematical anxiety. *Journal of Psychoeducational Assessment, 34*, 306-317.

Namkung, J. M., Peng, P., & Lin, X. (2019). The relation between mathematics anxiety and mathematics performance among school-aged students: a meta-analysis. *Review of Educational Research, 89*, 459-496.

Park, D., Ramirez, G., & Beilock, S. L. (2014). The role of expressive writing in math anxiety. *Journal of Experimental Psychology: Applied, 20*, 103-111.

Passolunghi, M. C., Źivković, M., & Pellizzoni, S. (2019). Mathematics anxiety and working memory: what is the relationship? In I. C. Mammarella, S. Caviola, & A. Dowker (Eds.), *Mathematics anxiety: what is known and what is still to be understood*. New York: Routledge.

Pennebaker, J. W., & Beall, S. K. (1986). Confronting a traumatic event: Toward an understanding of inhibition and disease. *Journal of Abnormal Psychology, 95*, 274-281.

Ramirez, G., & Beilock, S. L. (2011). Writing about testing worries boosts exam performance in the classroom. *Science, 331*, 211-213.

Ramirez, G., Shaw, S. T., & Maloney, E. A. (2018). Math anxiety: past research, promising interventions, and a new interpretation framework. *Educational Psychologist*, *53*, 145-164.

Richardson, F. C., & Suinn, R. M. (1972). The mathematics anxiety rating scale: psychometric data. *Journal of Counseling Psychology, 19*, 551-554.

Sidney, P. G., Thompson, C. A., Fitzsimmons, C., & Taber, J. M. (2021). Children's and adults' math attitudes are differentiated by number type. *The Journal of Experimental Education*, *89*, 1-32.

Siegler, R. S., Thompson, C. A., & Schneider, M. (2011). An integrated theory of whole number and fractions development. *Cognitive Psychology*, *62*, 273-296.

Thompson, C. A., Taber, J. M., Sidney, P. G., Fitzsimmons, C. J., Mielicki, M. K., Matthews, P. G., Schemmel, E. A., Simonovic, N., Foust, J. L., Aurora, P., Disabato, D. J., Seah, T. H. S., Schiller, L. K., & Coifman, K. G. (2021). Math matters: A novel, brief educational intervention decreases whole number bias when reasoning about COVID-19. *Journal of Experimental Psychology: Applied*, *27*, 632-656.

Yogo, M., & Fujihara, S. (2008). Working memory capacity can be improved by expressive writing: A randomized experiment in a Japanese sample. *British Journal of Health Psychology*, *13*, 77-80.