Using Brief Guided Imagery to Reduce Math Anxiety and Improve Math Performance: A Pilot Study

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Abstract

The objective of this study was to investigate whether brief guided imagery could provide a short-term reduction in math anxiety and improve math performance. Undergraduates (N = 581) were screened for math anxiety, and the highest and lowest quartiles were recruited to participate in a lab-based study. Participants were assigned to a brief guided imagery or control condition, and math performance, visual working memory, and math anxiety were assessed. Math anxiety decreased from pre to post across both conditions, but not specifically as an effect of the brief guided imagery. There was no increase in math performance as a result of the intervention. Brief guided imagery does not appear to temporarily reduce math anxiety and improve math performance when compared to a control condition.

Key words: anxiety, mathematics, performance, working memory, guided imagery

Mathematics is a core component of most college and university curricula. College students, particularly those in science and technology domains, need to master mathematics to successfully complete their majors. Mastery of these mathematics skills is often important for students to thrive in their future careers as well. Given the importance of math performance for academic and professional success, it would be helpful to understand factors involved with math performance as well as methods to improve math performance.

One factor involved with math performance is math anxiety (Ashcraft & Kirk, 2001; Ashcraft & Moore, 2009; Miller & Bichsel, 2004; Venkatesh & Karimi, 2010; Zhang, Zhang & Chen, 2007). Students with high math anxiety perform poorer on math tests, regardless of their mathematical ability (Artemenko, Daroczy, & Nuerk, 2015; Yeo, 2004). Therefore, an improved understanding of the relation between math anxiety and math performance may aid university and college instructors, counselors, and Student Affairs personnel as they assist students in achieving their academic goals.

Ashcraft and Kirk's (2001) description of math anxiety explains that it affects current math performance by limiting an individual's working memory. Given that working memory is a finite system, an individual can only expend a limited amount of attention and process a limited amount of information when utilizing working memory. The anxiety that students feel while completing a math exam is taking up space in working memory that, for individuals without math anxiety, is used to efficiently complete math problems. If individuals have a lowered working memory capacity, both their reaction time and their accuracy on math exams will suffer. Further research by Miller and Bichsel (2004) suggests that visual working memory is the specific type of working memory that is affected by math anxiety. Visual working memory is the ability to simultaneously hold and manipulate visual information during problem solving exercises. For example, visual working memory is the ability to visualize an addition problem and "carry" numbers when mentally calculating the solution. It appears that math performance and math anxiety are both processed in visual working memory. Thus, if math anxiety specifically affects visual working memory, perhaps students who experience math anxiety exhibit a poorer math performance due to the effort expended in visual working memory (not the mathematical difficulty of the problem) during anxious states; and accordingly, perhaps there is a way that anxiety specifically processed in visual working memory can be reduced (Miller & Bichsel, 2004).

Indeed, recent research suggests that worry utilizes visuospatial working memory and the resulting demand of visual spatial working memory is associated with poorer math performance, particularly among females (Ganley & Vasilyeva, 2014). Furthermore, biological support for the role of anxiety in math performance has been documented via cortisol samples (Mattarella-Micke, Mateo, Kozak, Foster, & Beilock, 2011). Cortisol is a stress-related hormone and is commonly assayed as an indication of stress. Mattarella-Micke et al. (2011) demonstrated the relation between math anxiety, cortisol, and math performance. Results indicated that for those with a high working memory capacity, individuals with high math anxiety and high cortisol levels exhibited poor math performance; however individuals with low math-anxiety and high cortisol levels exhibited better math performance. The authors' interpret these results in terms of appraisal – whether an individual will perform better or worse on a math test depends on how that individual appraises the physiological symptoms (e.g., cortisol) they are experiencing because of their situation (e.g., math test) (Mattarella-Micke et al, 2011).

Previous research has supported the use of systematic desensitization and cognitive restructuring to reduce math anxiety and improve math performance (see the following for a review: Hembree, 1990; Suarez-Pellicioni, Nunez-Pena, & Colome, 2016). Furthermore, relaxation techniques such as guided imagery have been used to treat a variety of anxiety-related problems, including test anxiety, and have demonstrated improvement in academic performance (Sapp, 1994). During a guided imagery exercise, an individual imagines various pleasant scenarios (e.g., the beach with waves lapping the shore, a peaceful meadow in spring) while focusing on relaxation. Thus, as the exercise relies on conjuring visual images and holding them in an individual's mind, it engages visual working memory. An intervention that utilizes visual working memory, such as guided imagery, aimed at temporarily decreasing math anxiety could assist math-anxious students with their academic pursuits. Specifically, if individuals who suffer from math anxiety could free space within their visual working memory at the time they need to complete math problems, they may have more cognitive resources currently available for optimal math performance, and may consequently improve their math scores.

Previous research studies investigating relaxation techniques to reduce anxiety and improve performance have included a cognitive component and were provided in multiple sessions over several weeks including practice outside of the treatment sessions (Bander, Russell, & Zamostny, 1982; Russell, Wise, & Stratoudakis, 1976; Sapp, 1994). As a result, each study involved many hours of relaxation over a long period of time. However, the reduction in math performance associated with math anxiety may not be a stable characteristic but rather a temporary effect of increased arousal (Suarez-Pellicioni, Nunez-Pena, & Colome, 2016). Therefore, if brief guided imagery sessions are found to be successful in reducing state-like anxiety and improving immediate math performance, this technique could be more easily self-administered by students prior to math exams. We acknowledge that a *brief* guided imagery session may not change students' overarching attitudes towards math and math anxiety, but perhaps such a brief session may assist students in reducing situational anxiety and improve upon immediate math tasks.

A recent review of math anxiety studies by Suarez-Pellicioni, Nunez-Pena, & Colome (2016) concluded that "The ultimate objective of research on MA should be intervention" (pp. 15). To support this goal, the current study sought to investigate the effect of a *brief* guided imagery session, a relaxation technique that involves visual working memory, temporarily alleviating math anxiety and improving immediate math performance among undergraduate students at a science and technology campus. We hypothesized that (1) guided imagery would significantly decrease math anxiety and improve math performance compared to the control condition; (2) individuals high in math anxiety would significantly decrease their math anxiety and improve math performance compared to individuals low in math anxiety; (3) individuals with high visual working memory capacity would significantly decrease their math anxiety and improve math performance compared to individuals with low visual working memory capacity; and (4) individuals high in math anxiety and low in visual working memory capacity would have significantly slower math problem-solving time compared to individuals low in math anxiety and high in visual working memory capacity.

Method

Participants

Participants were undergraduate student volunteers enrolled in a general psychology course over multiple semesters at a midwestern science and technology university. Students received partial course credit for participation. The study was approved by the university's Institutional Review Board, and all participants gave informed consent prior to participation.

Students (N=581) completed an online, self-report measure of math anxiety (MARS-R) (Plake & Parker, 1982) via Qualtrics, a secure online survey tool. The MARS-R was used as a pre-screener to assess students high and low in math anxiety. Students (N=127) in the lower and upper quartile of math anxiety were invited to participate in a second, lab-based study. Approximately half (N=58) of the invited students (57% male) completed the lab-based study and received additional partial course credit for their participation. The participants' mean age was 20.00 years old, and their class standings were 52% freshmen, 17% sophomore, 14% junior, and 17% senior. Additionally, the participants' majors were 52% engineering, 26% science/math, 16% business, 6% social sciences/humanities/undecided.

Measures

Math Anxiety. Via computer, math anxiety was measured before and after the relaxation intervention using the Revised Mathematics Anxiety Rating Scale (MARS-R) (Plake & Parker, 1982). The MARS-R is a 24 item measure of math anxiety and demonstrated a coefficient alpha reliability estimated at .98 among undergraduate students (Plake & Parker, 1982).

Math Performance. Performance was assessed before and after the intervention with 60 math problems involving addition (Ashcraft & Kirk, 2001). The pre-and post-tests consisted of different math problems and the two versions were matched for level of difficulty. Participants solved the math problems verbally and were timed. They were not allowed to use scratch paper to assist in solving the problem. The purpose of participants solving the problems verbally and without scratch paper was to force them to use their working memory capacity during operations such as "carrying" a number while solving the addition problem (Ashcraft & Kirk, 2001). This procedure is established in the literature (see Ashcraft & Krause, 2007). In this study, it was utilized to assess anxiety when completing simple addition problems that college students should know, not to assess the sophistication of one's mathematical abilities. That is, we aimed to test anxiety on items one should know, not the ability to perform complex computations. Although many students may use scratch paper in the classroom, in order to test visual working memory ability, we restricted the use of scratch paper. Thus, any level of anxiety associated with the lack of scratch paper would be exhibited across both groups.

Visual Working Memory Capacity. Using a paper-folding task (Charlesworth & Nathan, 1984; Ekstrom, French, Harman, & Dermen, 1976) visual working memory was assessed via paper-pencil tests, and tests were scored by a research assistant. Participants were divided into high and low groups using a median split.

Subjective Units of Math Anxiety (SUMA). SUMA were measured four times, pre- and post- both math performance tests, on a scale from 0 (*complete absence of anxiety*) – 100 (*anxiety could not be higher*). The SUMA scale was modified after the Subjective Units of Distress Scale, a widely used self-report measure of anxiety levels (Salthouse, Babcock, Mitchell, Palmon, & Skovronek, 1990).

Lab-based Procedure

A trained undergraduate research assistant led single-participant sessions lasting approximately 60 minutes each. All participants completed the informed consent and provided demographic information prior to participation. Participants were randomized to either the Guided Imagery or Control Condition.

The lab-based protocol was conducted as follows: (1) Math anxiety assessment, (2) Paper-folding task, (3) SUMA, (4) Math performance test, (5) SUMA, (6) Guided Imagery or Control Condition, (7) SUMA, (8) Math performance test, (9) SUMA, and (10) Math anxiety assessment. The math anxiety assessment and demographic information were collected via computer. All other measures were conducted with hard-copy materials. All participants completed the lab-based protocol in the same room/setting; however, given that these were single-participant sessions, only one participant completed the lab-based protocol at a time.

Intervention

During both the guided imagery and control sessions, participants sat in a large, reclining chair and were instructed to make themselves comfortable. Participants were asked to keep their eyes closed, although if participants felt uncomfortable closing their eyes, they were allowed to keep their eyes open. This practice of encouraging participants, but not mandating them, to close their eyes is not uncommon when conducting relaxation sessions.

Participants in the guided imagery intervention condition listened to a pre-recorded, guided imagery session via headphones. The session was recorded by the first author and included visualization of a variety of relaxing images (e.g., the beach, a meadow). The guided imagery script was obtained from Charlesworth & Nathan (1984). The recording lasted 20 minutes. Participants in the control condition were asked to close their eyes, but to remain awake for 20 minutes.

Results

Math Anxiety Scores (MARS-R)

Pre-test alone. Participants' math anxiety was measured using the MARS-R, and their scores were analyzed using a 2 math anxiety (high vs. low) x 2 (visual working memory (high vs. low) between-subjects ANOVA. The mean MARS-R score was 52.46 (SD=16.77) with a range of 24-120. Participants were categorized into *high* and *low* math anxiety groups based on the math anxiety pre-screener discussed in the *Participants* section, so this examination of the pre-test alone made sure our groups were still high and low in math anxiety at the time of the lab session. Unsurprisingly, there was a statistically significant main effect of math anxiety, with participants who were invited to the study because they scored high in math anxiety on the pre-screener (M = 68.21, SD = 15.23) reporting higher math anxiety than participants who were invited to the study because they scored low in math anxiety on the pre-screener (M = 47.10, SD = 22.07), $F(1, 54) = 14.91$, $p < .001$, $\eta_p^2 = .215$. There was no statistically significant main effect of visual working memory $F(1, 54) = 0.931$, $p = .339$, and there was no statistically significant interaction $F(1, 54) = 0.178$, $p =$ .675.

Pre-test to Post-test. Changes in participants' math anxiety scores between the pre-test and the post-test were analyzed using a 2 (time: pre-test vs. post-test) x 2 (math anxiety: high vs. low) x 2 (intervention: guided imagery vs. control) x 2 (visual working memory: high vs. low) mixed-groups ANOVA. Overall, there was a statistically significant reduction in math anxiety from pre-test ($M = 60.56$, $SD = 20.55$) to post-test ($M = 57.19$, $SD = 20.22$), $F(1, 50) = 6.57$, $p = .013$, $\eta_p^2 = .116$. There were no statistically significant interactions between time (pre-test vs. post-test) and anxiety level, intervention, or visual working memory (all p's $> .182$).

SUMA Scores

Participants were asked to rate their subjective units of math anxiety four times throughout the study. SUMA 1 took place before the math pre-test, SUMA 2 took place after the math pre-test, SUMA 3 took place post-intervention and before the math post-test, and SUMA 4 took place after the math post-test. Overall, the highest self-reported math anxiety was on SUMA 2 ($M = 41.17$, $SD = 29.11$) and the lowest self-reported anxiety was on SUMA 3 ($M = 12.24$, $SD = 14.86$). SUMA scores were analyzed using 2 math anxiety (high vs. low) x 2 intervention (guided imagery vs. control) x 2 visual working memory (high vs. low) between-subjects ANOVAs. There were marginally significant differences between high and low anxiety individuals on SUMA 1, [$F(1, 50) = 3.62$, $p = .063$, $\eta_p^2 = .067$], SUMA 2, [$F(1, 50) = 2.83$, $p = .099$, $\eta_p^2 = .054$], and SUMA 4, [$F(1, 50) = 3.28$, $p = .076$, $\eta_p^2 = .062$], with high anxiety individuals self-reporting greater levels of anxiety in all cases. The difference in anxiety levels on SUMA 1 indicates the pre-existing difference in math anxiety levels before any testing, the difference on SUMA 2 indicates the difference between high and low math anxiety individuals after a math test, the lack of statistically significant difference for SUMA 3 indicates that the intervention relaxed participants to an equal amount of anxiety, and the difference on SUMA 4 indicates that high math anxiety individuals were still more anxious of math after the math post-test. There were no statistically significant interactions between any of the SUMAs and visual working memory or intervention condition (all p's $> .297$).

Math Accuracy

Pre-test alone. Participants' scores on the math pre-test were analyzed using a 2 math anxiety (high vs. low) x 2 visual working memory (high vs. low) between-subjects ANOVA. There was a statistically significant main effect of visual working memory capacity, with participants of high capacity ($M = 58.34$, $SD = 1.82$) outperforming participants of low capacity ($M = 57.00$, $SD = 2.93$), $F(1, 54) = 4.04$, $p = .049$, $\eta_p^2 = .07$. There was no statistically significant main effect of math anxiety, $F(1, 54) = 0.047$, $p = .829$, and there was no interaction between math anxiety and visual working memory, $F(1, 54) = 0.005$, $p = .947$.

Pre-test to Post-test. Changes in participants' math scores between the pre-test and the post-test were analyzed using a 2 time (pre-test vs. post-test) x 2 math anxiety (high vs. low) x 2 intervention (guided imagery vs. control) x 2 visual working memory (high vs. low) mixed-groups ANOVA. There was no statistically significant change in math performance from pre-test to post-test, and no main effects of math anxiety, visual working memory, or intervention (all p's $> .100$). There was a marginally significant interaction between visual working memory and intervention condition, $F(1, 50) = 4.96$, $p = .030$, $\eta_p^2 = .090$, but it was not in the predicted direction, as participants with low visual working memory had higher math scores in the control condition than in the guided imagery condition. This may indicate that the guided imagery session failed to alleviate the occupied space in the participants' visual working memory, or that the low visual working memory individuals found the guided imagery session actively distracting compared to low visual working memory individuals in the control condition. No other interactions were statistically significant (all p's $> .250$).

Math Problem-Solving Time

Pre-test alone. Participants' math test completion times on the pre-test were analyzed using a 2 math anxiety (high vs. low) x 2 visual working memory (high vs. low) between-subjects ANOVA. There were no statistically significant main effects of math anxiety or visual working memory, and there was no statistically significant interaction (all p's $> .291$).

Pre-test to Post-test. Changes in participants' math test completion times between the pre-test and the post-test were analyzed using a 2 time (pre-test vs. post-test) x 2 math anxiety (high vs. low) x 2 intervention (guided imagery vs. control) x 2 visual working memory (high vs. low) mixed-groups ANOVA. Overall, participants were marginally significantly quicker (in seconds) at post-test ($M = 163.19$, $SD = 62.04$) than at pre-test ($M = 170.67$, $SD = 58.51$), $F(1, 50) = 4.41$, $p = .041$, $\eta_p^2 = .081$. There was a marginally significant interaction between time (pre-test vs. post-test) and intervention condition, $F(1, 50) = 3.03$, $p = .088$, $\eta_p^2 = .057$; however, once again it was not in the predicted direction, as participants in the control condition were quicker at post-test than participants in the guided imagery condition. There were no other statistically significant main effects or interactions (all p's $> .153$).

Discussion

In summary, math anxiety was temporarily lowered after exposure to a brief guided imagery exercise or being asked to sit quietly for 20 minutes. However, the data do not suggest that a brief guided imagery relaxation intervention is more successful than a control condition at alleviating anxiety and therefore improving immediate math performance. Although there was an overall decrease in math anxiety from pre-test to post-test, this decrease was not greater for the intervention (guided imagery) condition than the control condition, nor was it greater for high anxiety individuals than low anxiety individuals. The self-reported anxiety ratings from the SUMA scores echo what the MARS-R scores indicated—that participants were more relaxed overall after the guided imagery or control session, but that anxiety was no different depending whether they were in the guided imagery or control group and whether they were high or low anxiety at the beginning of the study. Also, the increase in anxiety from SUMA 3 to SUMA 4 suggests that although participants felt relaxed after the intervention or control, their anxiety may have increased as soon as they were presented with a math task again. Therefore, the effects of the intervention or control do not seem to be durable. The lack of main effects or interactions for the intervention condition suggest that participants did not find the guided imagery condition to be more relaxing than the control condition of sitting peacefully and quietly in a chair. This could provide evidence for brief relaxation interventions not being successful at reducing anxiety compared to longer relaxation interventions reported in previous research (Bander, Russell, & Zamostny, 1982; Russell, Wise, & Stratoudakis, 1976; Sapp, 1994).

There was also no evidence from either math accuracy or math problem-solving time analysis that the intervention was successful at improving math performance. The result related to math accuracy is not surprising, given that our math measure, which had proven successful at differentiating high and low anxiety individuals in previous research (see Ashcraft & Krause, 2007) did not show differences between high and low anxiety participants. In fact, one marginally significant analysis showed a trend for the guided imagery session to actually be detrimental to the math accuracy of low visual working memory individuals, which is the opposite of what was initially predicted. There was also a marginally significant trend for participants in the control condition to be quicker at solving the math problems on the post-test than participants in the guided imagery condition. This again suggests that perhaps the guided imagery intervention was distracting to the participants and had the opposite effect of what was intended.

Overall, math anxiety decreased after exposure to the intervention and control conditions. However, of our four main hypotheses, none of them were fully supported. Our first hypothesis was the guided imagery would significantly decrease math anxiety and improve math performance compared to the control condition, which was not the case, as we found no significant improvements for math performance in the guided imagery condition. Our second hypothesis was that individuals high in math anxiety would significantly decrease their math anxiety and improve math performance compared to individuals low in math anxiety, and this was also unsupported, as there were no significant differences between high and low anxiety individuals on math performance. The third hypothesis was that individuals with high visual working memory capacity would significantly decrease their math anxiety and improve math performance compared to individuals with low visual working memory capacity. We found no evidence for high visual working memory capacity individuals receiving a greater reduction in their math anxiety or improved performance post-intervention compared to low visual working memory capacity individuals. The final hypothesis, that individuals high in math anxiety and low in visual working memory capacity would have significantly slower math problem-solving time compared to individuals low in math anxiety and high in visual working memory, was also unsupported, as the only trend related to problem-solving time was in the opposite direction.

These results do not contradict Ashcraft and Kirk's (2001) description of math anxiety or Miller and Bichsel's (2004) previous research indicating that math anxiety is processed in visual working memory; however, they do not provide support for their data either. Instead, the results of our study suggest that a brief guided imagery session is not more effective at alleviating anxiety that is consuming resources in visual working memory capacity than a control condition. Based on these results, relaxation in the form of a brief guided visual imagery session is not effective as a tool for improving anxiety-related math performance.

Limitations

As with all research, there were limitations to this study. First, utilizing only two conditions (guided imagery vs. relaxation) restricts our ability to differentiate the possibility that participants in the control condition were relaxing without conjuring images in their visual working memory. Future studies would benefit from a third condition in which participants are instructed to mentally repeat a word or phrase as a distraction from self-conjuring images. Second, it is possible that participants in both conditions felt that they were unable to relax or that participants in the intervention condition were distracted from engaging in the guided imagery exercise. Perhaps, the inability to relax or distraction of participants is related to the relatively brief, 20-minute guided imagery/control session. As reported previously in the literature, successful use of relaxation techniques have been more in depth in content and longer in length (Bander, Russell, & Zamostny, 1982; Russell, Wise, & Stratoudakis, 1976). Alternatively, the lab-based environment may have impacted the participants' engagement in relaxation. We attempted to make the laboratory environment comfortable. Relaxation is often preferred in warm, comfortable rooms with minimal opportunity for distraction (West, 1980). Perhaps the laboratory environment was not ideally suited for relaxation. Third, perhaps the data reflected demand characteristics of the participants. Specifically, the basic lab procedure of assessing math performance and anxiety both before and after being asked to sit quietly for 20 minutes and relax may have suggested to participants that self-reporting lower anxiety was desirable. Although we utilized a measure of math performance that had proven successful in previous research (Ashcraft & Kirk, 2001) perhaps an alternative measure would provide a higher degree of discrimination between high and low anxiety individuals with regard to their math performance.

Conclusions

We wanted to test whether a brief guided imagery session could be at least temporarily helpful in alleviating math anxiety and improving math performance among college students. A brief intervention, if successful, could be easily self-administered repeatedly by students. However, none of the data indicate that this would be a useful intervention for students who are trying to alleviate math anxiety or improve their math performance. There was a short-term reduction in anxiety; however, it was not greater for the guided imagery condition than the control condition. To date, the most successful interventions aimed at alleviating math anxiety and improving math performance have been more long-term, and have included systematic desensitization or cognitive restructuring (Suarez-Pellicioni, Nunez-Pena, & Colome, 2016; Hembree, 1990; Sapp, 1994). Future research should continue to investigate methods to reduce math anxiety and improve math performance. Recent findings suggest that helping students learn how to control math anxiety while in the classroom appear more successful than intensive math training or an attempt at a blanket elimination of anxiety (Lyons & Beilock, 2011). Moving forward with the goal of finding successful math anxiety interventions, our research indicates that a brief guided imagery approach utilizing relaxation that can be repeated by the students themselves would not be beneficial for students in alleviating their math anxiety.

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References

Artemenko, C., Daroczy, G., & Nuerk, H.C. (2015). Neural correlates of math anxiety-an overview and implications. *Frontiers in Psychology, 6*, 1-8. doi: 10.3389/fpsyg.2015.01333

Ashcraft, M. H., & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. *Journal of Experimental Psychology: General, 130*(2), 224-237. doi:10.1037/0096-3445.130.2.224

Ashcraft, M. H., & Krause, J. A. (2007). Working memory, math performance, and math anxiety. *Psychonomic Bulletin & Review, 14*(2), 243-248.

Ashcraft, M. H., & Moore, A. M. (2009). Mathematics anxiety and the affective drop in performance. *Journal of Psychoeducational Assessment, 27*(3), 197-205. doi:10.1177/0734282908330580

Bander, R. S., Russell, R. K., & Zamostny, K. P. (1982). A comparison of cue-controlled relaxation and study skills counseling in the treatment of mathematics anxiety. *Journal Of Educational Psychology, 74*(1), 96-103. doi:10.1037/0022-0663.74.1.96

Charlesworth, E.A. & Nathan, R.G. (1984). Stress management: A comprehensive guide to wellness. New York, NY: Ballantine Books.

Ekstrom, R.B., French, J.W., Harman, H.H, & Dermen, D. (1976). *Kit of factor-referenced cognitive tests.* Princeton, NJ: Educational Testing Service.

Ganley, C. M., & Vasilyeva, M. (2014). The role of anxiety and working memory in gender differences in mathematics. *Journal of Educational Psychology, 106*, 105-120. doi: 10.1037/a0034099

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal For Research In Mathematics Education, 21*(1), 33-46. doi:10.2307/749455

Lyons, I. M., & Beilock, S. L. (2012). Mathematics anxiety: Separating the math from the anxiety. *Cerebral Cortex, 22*, 2102-2110. doi: 10.1093/cercor/bhr289

Mattarella-Micke, A., Mateo, J., Kozak, M. N., Foster, K., & Beilock, S. L. (2011). Choke or Thrive? The relation between salivary cortisol and math performance depends on individual differences in working memory and math-anxiety. *Emotion, 11*(4), 1000-1005. doi: 10.1037/a0023224

Miller, H., & Bichsel, J. (2004). Anxiety, working memory, gender, and math performance. *Personality and Individual Differences, 37*(3), 591-606. doi:10.1016/j.paid.2003.09.029

Plake, B. S., & Parker, C. S. (1982). The development and validation of a revised version of the Mathematics Anxiety Rating Scale. *Educational And Psychological Measurement, 42*(2), 551-557. doi:10.1177/001316448204200218

Russell, R. K., Wise, F., & Stratoudakis, J. P. (1976). Treatment of test anxiety by cue-controlled relaxation and systematic desensitization. *Journal Of Counseling Psychology, 23*(6), 563-566. doi:10.1037/0022-0167.23.6.563

Salthouse, T. A., Babcock, R. L., Mitchell, D. R., Palmon, R., & Skovronek, E. (1990). Sources of individual differences in spatial visualization ability. *Intelligence,14*(2), 187-230. doi:10.1016/0160-2896(90)90004-D

Sapp, M. (1994). The effects of guided imagery on reducing the worry and emotionality components of test anxiety. *Journal Of Mental Imagery, 18*(3-4), 165-179.

Suarez-Pellicioni, M., Nunez-Pena, M. I., & Colome, A. (2016). Math anxiety: A review of its cognitive consequences, psychophysiological correlates, and brain bases. *Cognitive, Affective, and Behavioral Neuroscience, 16*, 3-22. doi: 10.3758/s13415-015-0370-7

Venkatesh, K. G., & Karimi, A. (2010). Mathematics anxiety, mathematics performance and overall academic performance in high school students. *Journal of the Indian Academy Of Applied Psychology, 36*(1), 147-150.

West, M. A. (1980). The psychosomatics of meditation. *Journal of Psychosomatic Research, 24*(5), 265-273. doi:10.1016/0022-3999(80)90016-1

Yeo, K.K.J. (2004). Do high ability students have mathematics anxiety?. *Journal of Science and Mathematics Education in Southeast Asia, 27*(2), 135-152.

Zhang, X., Zhang, R., & Chen, Y. (2007). Relation of mathematics anxiety, mathematical beliefs and mathematics achievement. *Chinese Journal of Clinical Psychology, 15*(3), 287-289.

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