Management of Mathematics Anxiety: Virtual Relaxation Interventions

Tonya Davis
Department of Psychology and Counseling
Alabama A&M University
Normal, USA.

Salam Khan
Department of Physics, Chemistry and Mathematics
Alabama A&M University
Normal, USA.

Abstract

For many students Math engenders feelings of intense worry, psychosomatic complaints and avoidance behaviors. While these behaviors serve as early warning signals for many, excessive worry can become debilitating and lead to Anxiety and unsuccessful engagement with Mathematics. Therefore, devising effective interventions aimed at improving engagement, learning, and teaching are paramount in reducing Math anxiety levels. Mounting research in educational and psychological contexts suggests Virtual reality interventions are effective in reducing various types of anxiety such as social anxiety, specific phobias, post-traumatic stress disorder, general anxiety, and panic disorders. The aim of the present research was to investigate the impact of a classroom based intervention using virtual reality scenarios on academic performance in an undergraduate Elementary Statistics course. A pre-test/post-test design was employed. The treatment group completed the Math Anxiety Rating Scale and used virtual reality goggles on handheld devices to watch calming scenarios. Results suggest virtual reality strategies may help moderate the relationship between Math anxiety and academic performance by lowering at least one of the barriers associated with Math engagement.

Keywords: Alternative Methods, Math Anxiety Reduction, Virtual Reality Intervention, Academic Performance, Ethnic Minority College Students.

Introduction

Math is central to many degree areas in science, technology, engineering and mathematics and as society becomes more and more complex, adults must have basic mathematical skills and math-related competencies to function in many spheres of their lives. The onus is on schools and universities to develop programs and services leading to a workforce that is technologically competitive with other countries (Volderman et al., 2011). Math anxiety is a global phenomenon interfering with this notion and impacts nearly 25% of college students and 80% of community college students in the United States and abroad (Brown, Shreiber, Barbrain, 2018; Dowker, Sarkar, & Looi, 2016; Yeager, 2012). Further, Math anxiety can influence cognitive performance, psychological well-being, and physical health (Cipora et al., 2015; Pekrun, Goetz, Titz, & Perry, 2002). Math anxiety and low math performance have both been linked with a constellation of difficulties such as decreased cognitive reflection, difficulties with risk perception (Brand, Schiebener, Pertl, & Delazer, 2014; Jones, Childers, & Jiang, 2012; Morsanyi, Busdraghi, & Primi, 2014). Researchers note anxiety may initially reduce intrinsic motivation for some students whereas with other students the anxiety can become severely intrusive. Thus, it is critical to understand how and when Math anxiety emerges.

Math Anxiety Interventions

Ashcraft (2002) defined math anxiety as " a feeling of tension, apprehension or fear that interferes with math performance" (p.181).

Chang and Beilock (2016) further describe math anxiety as a deficit in the ability to process numbers or number related tasks. Mounting research suggest that math anxiety is a trait itself, related to but distinct from both general anxiety and test anxiety (Wu, Willcutt, Escovar & Menon, 2013). Among college students, the specific impact of math anxiety includes students taking fewer math courses, low achievement, poor math competencies and limited career choices (Ashcraft & Kirk, 2001; Paechter et al., 2017; Scarpello, 2005).

A number of behavioral and psychophysiological interventions strategies have been developed over the years to reduce math anxiety such as computer adaptive practice tests (Chang & Beilock, 2016; Jansen et al., 2013), listening to music (Gan et al. 2015), cognitive behavioral therapy (Karimi, 2009), systematic desensitization (Dugas & Robichaud, 2007), and individual math tutoring (Supekar et al., 2015). Technology-infused interventions have been found to be effective in reducing social anxiety, specific phobias, post-traumatic stress disorder, general anxiety, and panic disorders (Maples-Keller, Bunnell, Kim, & Rothbaum, 2017). A limited number of studies have investigated the infusion of virtual relaxation strategies to reduce math anxiety and improve performance in college students taking math classes. Given the infusion of technology into counseling services, employing multi-modal counseling interventions in conjunction with Virtual reality relaxation techniques (Deckro et al 2002; Amores et al., 2018) has shown efficacy (Sharabi, & Margalit, 2016). The reach of technology reduces many barriers while offering the allure of safety and convenience of service which may lead to improved academic and mental resilience as students adjust themselves more efficiently and appropriately to the college environment**.** The purpose of the study was to investigate the impact of a virtual relaxation scenarios on Math anxiety and academic performance in undergraduate Statistics courses. Specific research questions we will investigate include:

1. What is the impact of a brief virtual relaxation intervention on Math anxiety scores using the Math Anxiety Rating Scale Revised (MARS-R)?
2. Is there a statistically significant difference in the math performance scores of students who participated in the VR intervention program?

THEORETICAL FRAMEWORK

The study is grounded in Cognitive Interference theory (Spielberger & Vagg, 1995) and Attentional Control theory (Owens, Stevenson, Hadwin & Norgate 2012) which suggests anxiety has a negative impact on working memory. Working memory plays an important role in concentration and in following instructions. Specifically, Interference theory states that cognitive interference causes stress, slow learning, poor performance, social maladjustment, and other negative behavioral outcomes (Sarason, Pierce, & Sarason, 1996; Sarason et al.,1988). Individuals that experience high levels of test anxiety are more likely to have adverse performance outcomes on cognitive tasks such as completion of math tests (Owens et al., 2012). Attentional control theory focuses on the effects of anxiety on attention and cognitive performance (Eysenck, & Derakshan, 2011) and posits that anxiety impedes on attentional control by impairing information processing (Eysenck, Kerakshan, Santos, & Galvo, 2007). Individuals with high math anxiety are therefore likely to experience an attention displacement that could impact their overall performance on math tasks and tests (Dobalian, & Rivers, 2008)

Anxiety and Academic Performance

Math anxiety serves as a strong predictor related to math performance (Childers, & Jiang, 2012). Math anxiety are more likely to experience significant anxiety and cognitive interference while taking math classes or tests (Andrews & Brown, 2015; Burghes,2011)which can impact working memory and the ability to learn across several subject areas such as reading and math (Paechter et al., 2017). Given the vast number of students enrolled in developmental mathematics courses, identifying factors that interfere with math competencies is paramount (Brown, Schreiber, & Barbarin, 2018). The impact of Math anxiety symptoms can occur across a continuum causing significant disruption to some and little to no disruptions to other. However, research has shown that Math anxiety can impact decision making as well as vocational choices. Given the achievement gaps and unrepresented racial and ethnic minorities in STEM areas, examining the impact of Math anxiety across racial and ethnic minorities may shed light on reasons for reluctance to select math and science- related majors as well as vocational choices. African-Americans students are less likely to enroll in college majors with Mathematics and Science (Morsanyi, Busdraghi, & Primi, 2014; Scarpello, 2005). Among racial and ethnic minorities, African-American students perform lower in college level mathematics courses. In a 2016 report by Public Broadcasting Service (*PBS*) of African-American college students, only 7% were entering the field of mathematics.

Research shows that roughly 42% of African-American college students take developmental or remediation courses in Mathematics (Bautsch, 2013). Moreover, research also shows that students taking remediation courses in reading or mathematics are less likely to be academically successful. Thus, likely intensifying the mathematics anxiety levels of African-Americans students in college settings given that many often enroll in remedial mathematics courses during their freshman year.

Virtual Relaxation Techniques

Extant research has indicated that exposure-based therapies (i.e, systematic exposure to specific feared situations in order to reduce fearful reactions) are efficacious in treating anxiety disorders and should be the first line of defense when treating anxiety disorders (Kaplan, & Tolin, 2011; Maples-Keller, Bunnell, Kim, & Rothbaum, 2017; Meyerbroker & Emmelkamp, 2010). Previous research has also supported the use of a variety of techniques to reduce math anxiety such as cognitive restructuring and systematic desentization (Suarez-Pellicioni, Nunez-Pena, & Colome, 2016). Virtual interventions have shown promise in treating anxiety disorders as well as other psychiatric disorders (Amores, Richer, Zhao, Maes, & Eskofier, 2018;Verkijika, & De Wet, 2015). VR activities involving real-time feedback using head-mounted displays, and body-motion sensors designed to provide simulations within the virtual environment are referred to as immersive while Non-immersive VR activities utilize televisions/computer screens, joysticks, and smartphone applications (Zeng, Pope, Lee, & Gao, 2018). Given the advanced technology associated with mobile devices that support 3D level graphics, smartphone applications designed and utilized for immersive virtual reality treatment, alongside low cost wearables can serve as pathways for delivering interventions outside of a formal office setting (Zeng et al., 2018).

Methods

Participants: Fifty-nine (N= 59) undergraduate students enrolled in a statistics course at a southeastern college volunteered to participate in the study. Participants ranged in age from 18 to 23 with a Mean age of (*M* =20.5). The sample included Males (N=11; 18.64%) and Females (N=48; 81.36%). With regard to ethnicity, there were (N=58; 99%) African-American students and White students (N=1; 1%). The classification of students were as follows: Freshman (N= 6; 10%); Sophomores (N=28; 48%); Juniors (N=15; 25%) Seniors (N= 10; 17%).

Sampling: Purposive sampling techniques were utilized to select participants for the study. A purposive sampling design was used to understand the of Math anxiety in undergraduate psychology students phenomenon (Creswell, 2013; Strauss & Corbin, 1998). Research has indicated that students with Math anxiety are likely to be enrolled in entry level math and statistics courses (Bautsch, 2013).

Instrumentation

Demographics Survey: A general demographic survey was administered to all participants from the study to obtain information about gender and level in the academic program.

Math Anxiety Rating Scale-Revised (MARS-R): The MARS-R is a 24-item assessment measuring general trait anxiety, specific/situation state anxiety, and Math anxiety in math related situations. The MARS-R yields a composite score based on two domains; (1) Learning Math anxiety (LME), and Math Evaluation Anxiety (MEA). The MARS-R has demonstrated strong reliability estimates in undergraduate populations with a Cronbach alpha of (*a* =.98). Items are measured along a 5-point Likert-type scale ranging from *1* (*No anxiety*) to *5* (*High anxiety*) which corresponds to the process of learning and anxiety and Math Evaluation Anxiety (MEA), which corresponds to anxiety related to testing situations. Math Anxiety was measured before and after the relaxation intervention using the *Math Anxiety Rating Scale -Revised* (MARS-R; Plake & Parker, 1982). A mathematics test on statistics was administered afterwards, followed by another administration of the MARS-R.

Math Performance: Math performance was assessed using a 12-item quiz which was administered at pre- test before the relaxation scenario and again at post -test after the relaxation intervention.

Procedures

After receiving approval from the university's Institutional Research Board (IRB), instructors of statistics courses received a letter describing the study. All students enrolled in undergraduate elementary statistics courses were invited to participate in the study. After obtaining consent for the study participants completed a demographics survey and a baseline Math Anxiety rating scales at pre-test and post-test after the intervention. The demographics survey and Math Anxiety survey (MARS-R) took approximately 15 to 20 minutes to complete and were done during class time. Next, participants were randomly assigned to either the control group or the VR relaxation intervention group.

During the intervention group, participants viewed the relaxation scenarios via personal mobile devices using VR goggles. Students were given Oculus virtual-reality goggles and VR-based relaxation calming scenarios for 5 minutes using a mobile based exposure system in the classroom. The scenarios were chosen from Oculus software programs that creates virtual reality scenarios on a variety of platforms. The VR Relaxation scenarios included guided tours through nature with accompanying calming nature sounds.

Results

Results of the two-independent samples t-test examining the impact of the relaxation intervention on math anxiety reduction and math test performance statistically significant difference shows that mean post-test MAR-S differs between Treatment (M = 2.31, SD = .850, n = 29) and Control (M = 3.17 SD = .791, n = 30) at the .05 level of significance (t = -4.008, df = 57, p < .05, 95% CI for mean difference -1.284 to -1.285). On average the treatment group tend to have a lower MARS-S score than the control group. Participants in the study were also administered a math quiz before and after the VR 3D Relaxation scenario experiment.

For the second research question, Is there a statistically significant difference in math anxiety and math performance of students who participated in the VR intervention program?

Results of the analysis of the participants quiz scores are also reported in Table 3. The results of the independent samples t-test shows that mean post -test quiz Score differs between Treatment (M = 60.1724, SD = 7.64885, n = 29) and Control (M = 31.4333, SD = .791, n = 30) at the .05 level of significance (t = 14.248, df = 57, p < .05, 95% CI for mean difference 24.701, -24.702). On average the treatment group tend to have a higher math quiz score than the control group.

Table 1: *Respondents by College*

Colleges	Respondents	Percentage %
College of Education, Humanities, and Behavioral Sciences (CEHBS)	30	51%
College of Business and Public Affairs (CBPA)	21	35%
College of Biology and Environmental Sciences (CBES)	8	14 %
Total	**59**	**100%**

Table 2: *Results of t-tests and Descriptive Statistics PRETEST and POST TEST MARS-R SCORE by Group*

Outcome	Group						95% CI for Mean Difference	t	df
	Treatment			Control					
	M	SD	n	M	SD	n			
PRETEST MARS SCORE	2.66	1.010	29	2.57	.898	30	-.409, -.410	.356	57
POST-TEST MARS SCORE	2.31	.850	29	3.17	.791	30	-1.284, -1.285	-4.008*	57

* p < .05.

Table 3: *Results of t-tests and Descriptive Statistics PRETEST and POST TEST QUIZ SCORES by Group*

Outcome	Group						95% CI for Mean Difference		
	Treatment			Control					
	M	SD	n	M	SD	n		t	df
PRETEST QUIZ SCORE	35.1379	4.642	29	35.3667	9.645	30	.2287, -.410	-.113	57
POST-TEST QUIZ SCORE	60.1724	7.64885	29	31.4333	7.83750	30	24.701, -24.702	14.248*	57

* $p < .05$.

Discussion

In the present study, we investigated the effects of a virtual reality relaxation intervention on math anxiety and math performance. First, we examined whether the virtual relaxation scenario was effective in reducing math anxiety in two groups of students, one which received the intervention and a control group. We expected participants receiving intervention to experience less test anxiety than participants in control groups, who did not receive the intervention. The results of the data analyses confirmed our expectations, as participants who received the intervention had reported significantly lower math test anxiety in comparison to participants in the control group. The results of our analysis are in line with previous research, which showed that participants that received of an anxiety reducing intervention did well on test compared to those that did not reported less anxiety than before the intervention (Krrispenz & Dickhauser, 2016;Smernoff et al., 2015). The results of our study however, did significantly add to the literature since relatively few studies exist that have examined the used of classroom-based, virtual relaxation interventions to assess the impact of math anxiety and performance.

Second, we also assessed whether there is a difference in test outcomes (quiz scores) following the relaxation intervention. Outcomes suggest individuals who received the relaxation intervention had higher quiz scores after the intervention as well as in comparison with those that did not. Thus, it can be inferred that students that received the intervention tend to feel more relaxed, perceive themselves to be more in control. This result is similar to those of previous studies that found that participants in intervention groups who received some type of psychological intervention experienced less anxiety and had better post-assessment test scores compared with their pre-assessment scores (Saravanan & Kingston, 2014).

Limitations

This study included a few limitations such as a small sample size. The sample was predominately African-American and drawn from a large HBCU in Northern Alabama, which limits the generalizability of the results of this study. It is also noted that the study utilized two short relaxation trials and thus the results and conclusions are preliminary. Future studies should include additional trials of the relaxation scenarios to further understand the impact on working memory deficits.

Implications for Practice

This study has pedagogical and mental health implications for educators and allied health professionals. Math anxiety can negatively impact a student's math attitudes, math performance and math achievement. That is why educators must look for ways to identify students who are struggling with mathematics anxiety. The findings regarding the improvement of math test scores has implications for testing as well as the use of technology. Technology can be a useful pedagogical tool.

If college educators suspect students have mathematics anxiety, then giving personal attention in helping these students could be a great benefit to the students particularly students who participate in developmental mathematics courses. With the infusion of technology, implications exist for teaching self-management strategies to manage anxiety in conjunction with relaxation techniques. Given these preliminary findings, an important consideration for college professors may be to incorporate technology related relaxation interventions as part of their instructional regimen to reduce student anxiety. Students that are supported in this way may experience a decrease in feelings of anxiety. The findings also emphasized the need for teachers to become increasingly aware of the potential negative consequences of unaddressed math anxiety among undergraduate students. With increasing numbers of college students facing a convergence of stressors associated with academic and mental health, there is need for educational institutions to adopt and integrate cutting edge, and empirical tested instructional technology and pedagogy that provides students with the ability to address their academic stressors.

References

Amores, J., Richer, R., Zhao, N., Maes, P., & Eskofier, B. M. (2018). Promoting Relaxation Using Virtual Reality, Olfactory Interfaces and Wearable EEG.

Andrews, A., & Brown, J. (2015). The effects of math anxiety. *Education*, *135*(3), 362-370.

Ashcraft, M. H. (2002). Math anxiety: Personal, educational, and cognitive consequences. *Current directions in psychological science*, *11*(5), 181-185.

Bautsch B. (2013). Reforming remedial education. Retrieved fromhttp://www.ncsl.org/documents/educ/REMEDIALEDUCATION_2013.pdf

Brand, M., Schiebener, J., Pertl, M-T., & Delazer, M. (2014). Know the risk, take the win: How executive functions and probability processing influence advantageous decision making under risk conditions. *Journal of Clinical and Experimental Neuropsychology*, *36*, 914-929. doi:10.1080/1 3803395.2014.955783

Brown, J., Schreiber, C., & Barbarin, O. (2018). Culturally Competent Mathematics Instruction for African American Children. *Promising Practices for Engaging Families in STEM Learning*, 49.

Burghes, D. (2011). International comparative study in mathematics teacher training. *Reading: CfBT Education Trust*.

Chang, H., & Beilock, S. L. (2016). The math anxiety-math performance link and its relation to individual and environmental factors: a review of current behavioral and psychophysiological research. *Current Opinion in Behavioral Sciences*, *10*, 33-38.

Cipora, K., Szczygieł, M., Willmes, K., & Nuerk, H. C. (2015). Math anxiety assessment with the abbreviated math anxiety scale: applicability and usefulness: insights from the polish adaptation. *Frontiers in Psychology*, *6*, 1833.

Deckro, G. R., Ballinger, K. M., Hoyt, M., Wilcher, M., Dusek, J., Myers, P., … Benson, H. (2002). The evaluation of a mind/body intervention to reduce psychological distress and perceived stress in college students. Journal of American College Health, 50, 281–287. doi:10.1080/07448480209603446

Devine, A., Fawcett, K., Szucs, D., & Dowker, A. (2012). Gender differences in mathematics anxiety and the relation to mathematics performance while controlling for test anxiety. *Behavioral and Brain Functions, 8*, 33. doi:10.1186/1744- 9081-8-33

Dobalian, A., & Rivers, P. A. (2008). Racial and ethnic disparities in the use of mental health services. *Journal of Behavioral Health Services & Research,* 35, 128–141.

Dugas, M. J., & Robichaud, M. (2007). *Cognitive-behavioral treatment for generalized anxiety disorder: From science to practice*. Taylor & Francis.

Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics anxiety: what have we learned in 60 years?. *Frontiers in psychology*, *7*, 508.

Gan, S. K. E., Lim, K. M. J., & Haw, Y. X. (2016). The relaxation effects of stimulative and sedative music on mathematics anxiety: A perception to physiology model. *Psychology of Music*, *44*(4), 730-741.

Hill, J.(n.d.). Are Issues of Equity in Mathematics the Same across Racial, Ethnic, Class, and Gender Boundaries? Retrieved from http://www.http://mste.illinois.edu/hill/papers/issues.html

Janssen, H. L., Reesink, H. W., Lawitz, E. J., Zeuzem, S., Rodriguez-Torres, M., Patel, K., ... & Persson, R. (2013). Treatment of HCV infection by targeting microRNA. *New England Journal of Medicine*, *368*(18), 1685-1694

Jones, W. J., Childers, T. L., & Jiang, Y. (2012). The shopping brain: Math anxiety modulates brain responses to buying decisions. *Biological Psychology*, *89*, 201-213. doi:10.1016/j. biopsycho.2011.10.011

John Wirt et al., The Condition of Education 2004, NCES 2004-077 (Washington, D.C.:U.S. Department of Education, National Center for Education Statistics, U.S.

Joseph A. (2017). Definition of math anxiety. Retrieved from https://sciencing.com/definition-math-anxiety-5666297.html Government Printing Office, 2004).

Kaplan, J.S. & Tolin, D.F., (2011). Exposure Therapy for Anxiety Disorders.*Psychiatric Times*, *28* (9). Retrieved from http://www.psychiatrictimes.com/anxiety/exposure-therapy-anxiety-disorders Maples-Keller, J. L., Bunnell, B. E., Kim, S. J., & Rothbaum, B. O. (2017). The use of virtual reality technology in the treatment of anxiety and other psychiatric disorders. *Harvard review of psychiatry*, *25*(3), 103-113.

Meyerbröker K, Emmelkamp P.M., (2010). Virtual reality exposure therapy in anxiety disorders: A systematic review of process-and-outcome studies. *Depress Anxiety*, 27: 933-944.

Morsanyi, K., Busdraghi, C., & Primi, C. (2014). Mathematical anxiety is linked to reduced cognitive reflection: A potential road from discomfort in the mathematics classroom to susceptibility biases. Behavioral and Brain Functions, 10, 31-43. doi:10.1186/1744-9081-10-31

Norris, E. (2012) Solving the Maths Problem: International Perspectives on Mathematics Education. London: Royal Society of Arts.

Paechter, M., Macher, D., Martskvishvili, K., Wimmer, S., & Papousek, I. (2017). Mathematics Anxiety and Statistics Anxiety. Shared but Also Unshared Components and Antagonistic Contributions to Performance in Statistics. *Frontiers in Psychology*, *8*, 1196. http://doi.org/10.3389/fpsyg.2017.01196

Scarpello, G. V. (2005). The effect of mathematics anxiety on the course and career choice of high school vocational-technical education students.

Sharabi, A., Sade, S., & Margalit, M. (2016). Virtual connections, personal resources, loneliness, and academic self-efficacy among college students with and without LD. *European Journal of Special Needs Education*, *31*(3), 376-390.

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

Supekar, K., Iuculano, T., Chen, L., & Menon, V. (2015). Remediation of childhood math anxiety and associated neural circuits through cognitive tutoring. *Journal of Neuroscience*, *35*(36), 12574-12583.

Verkijika, S. F., & De Wet, L. (2015). Using a brain-computer interface (BCI) in reducing math anxiety: Evidence from South Africa. Computers & Education, 81, 113-122.

Vorderman, C., Porkess, R., Budd, C., Dunne, R., & Rahman-Hart, P. (2011). A world-class mathematics education for all our young people. *London. Accessed March*, *21*, 2016.

Yeager, D. S. (2012l). Productive persistence: A practical theory of community college student success. Paper presented at the 2012 annual meeting for the American Educational Research Association, Vancouver, BC, Canada

Zeng, N., Pope, Z., Lee, J. E., & Gao, Z. (2018). Virtual Reality Exercise for Anxiety and Depression: A Preliminary Review of Current Research in an Emerging Field. *Journal of clinical medicine*, *7*(3), 42.