Fall 2012

Brief Mindfulness Intervention on Math Test Anxiety and Exam Scores in a High School Population

Laura Niss
University of Colorado Boulder

Brief Mindfulness Intervention on Math Test Anxiety and Exam Scores in a High School Population

Laura K. Niss
Department of Psychology and Neuroscience
University of Colorado at Boulder

Thesis Advisor: Dr. Joanna Arch
Department of Psychology and Neuroscience

Dr. Tina Pittman-Wagers, Department of Psychology and Neuroscience
Dr. Christine Macdonald, Program for Writing and Rhetoric
Dr. Robert Spencer, Department of Psychology and Neuroscience

August 29, 2012

Abstract

Objective: While many studies have shown the positive effects of extended mindfulness interventions on anxiety reduction in several different populations, none had yet examined the effects of a brief mindfulness intervention on math test anxiety and performance in a high school population. This study examines the effects of anxiety reduction through a brief mindfulness intervention on improving exam scores in high school AP Statistics and Algebra One classes. *Method*: Participants in the Mindfulness intervention condition (n = 53) did a brief (9 minute) guided mindfulness meditation directly before math exams were administered, as well as answering several questionnaires before and after each testing session. Control participants (n = 17) answered similar questionnaires to the mindfulness group before exams. Non-participant controls (n = 54) did not participate in any aspect of the study other than contributing grades to the final analysis. *Results*: Participants in the Mindfulness Intervention showed significant within-group reductions in anxiety from before to after the meditation, $t(52) = 7.83$, $p < .01$. Mindfulness participants also showed within-group improvements in math scores from before to after the intervention, $p < .03$, whereas the Control groups did not: between group differences reached trend status, $p = .08$. *Conclusion*: We conclude from this study that a brief mindfulness intervention significantly reduced math test anxiety in a high school population, with some effects on improving exam scores. Further research is needed to more definitively assess the effectiveness of mindfulness meditation on increasing math exam scores in a larger sample.

Test anxiety has been shown to be a relatively stable trait associated with test performance in many situations, including testing in schools (Lang & Lang, 2010). There are many theories as to why anxiety can prevent students from performing to their fullest capacity, including the Test-Interference Theory (Lang & Lang, 2010), which stipulates that worrying about one's self-efficacy (or otherwise) can occupy cognitive processing that would otherwise be used for problem solving (Ashcraft, Krause 2007). Others posit that it is the ability to inhibit or to direct attention away from worrying thoughts that regulates the effects of math test anxiety on performance (Navarro, 2011; Hopko, Ashcraft, Gute, 1998). In math performance, a related cognitive process that can be compromised by anxiety is working memory capacity, the amount of information one can hold in working memory at any time, which is a cognitive function central to math problem solving (Weger, Hooper, Meier, Hopthrow, 2012). Zheng, Swanson, and Marcoulides (2011), for example, showed that differences in working memory capacity accounted for 26% of variance in algebraic problem solving.

Mindfulness represents one potential antidote to reducing math test anxiety and associated reductions in working memory capacity. Mindfulness is the conscious moment-to-moment, non-judgmental state of being attentive and aware of what is taking place in the present (Brown & Ryan, 2003). Consciousness includes both attention and awareness. Attention is a shifting focus of objects within the constant background of awareness. Mindfulness meditation is the practice of mindfulness. The practice of bare attention, which refers to attention that is separate from conceptual meaning, is an integral part of mindfulness; an example of perfect bare attention would be to hear the sound of a bear growl but not connect the sounds to the animal making it or to the fear one might associate with it (Rapgay & Bystrisky 2009).

Mindfulness meditation - the formal practice of mindfulness through meditation, most commonly focusing on sensations of breathing or other bodily sensations - is being increasingly researched as a stand-alone and integrated treatment for anxiety, stress, and depression in clinical and non-clinical patients. The most researched mindfulness intervention is Mindfulness-Based Stress Reduction (MBSR; Kabat-Zinn, 1990), an eight-week group program that includes mindfulness meditation focusing on the breath, bodily movement (in the form of hatha yoga), and body sensations. MBSR leads to reductions in anxiety, stress, and depression in clinical and non-clinical samples as well as significant increases in self-reported mindfulness. Research by Vollestad, Sivertsen, and Nielsen (2011) showed that of patients diagnosed with anxiety disorders who randomized to a MBSR program, two-thirds demonstrated reduction in self-reported anxiety symptoms and insomnia and increases in mindfulness. Evans, Ferrando, Carr, and Haglin (2011) found significant reductions in anxiety and tension, and an increase in mindfulness in a community-based sample following MBSR compared to scores from a normative sample of adults and psychiatric outpatients who did not participate in the study. A similar study by Warnecke, Quinn, Towle, and Nelson (2011) that taught mindfulness meditations to highly stressed medical students found a negative correlation between daily mindfulness practice and anxiety at the end of the eight week program as well at the 16 week follow-up. The intervention group showed significant reductions in stress and anxiety, indicating that a mindfulness intervention is an effective way to reduce stress and anxiety in a high stress population. In summary, several studies have consistently shown that multifaceted and extended mindfulness interventions have been a viable treatment for anxiety (Evans et al., 2011; Kang, Choi, Ryu, 2009; Vollestad, Sivertsen, Nielsen, 2011). Other studies have specifically looked at the effects of mindfulness meditation and MBSR on stress, depression, and anxiety in medical, premedical and nursing student, demonstrating benefits for these populations, (Shapiro,

Schwartz, Bonner, 1998; Rosenzweig, Reibel, Greeson, Brainard, Hojat, 2003; Kang, Choi, Ryu, 2009).

Several studies have focused on the effects of mindfulness training on cognitive functioning. One intervention, which consisted of guided mindfulness meditation 20 minutes one day a week for four weeks, resulted in a significant reduction in anxiety (Zeiden, Johnson, Diamond, Goolkasian, 2010). Compared to the control group, the mindfulness meditation group also demonstrated significant increases on cognitive performance tasks requiring sustained attention, executive processing efficiency, and verbal fluency. This study suggests that even brief mindfulness meditation training can effectively reduce anxiety and increase cognitive performance. Another study has shown that mindfulness mediation training reduced anxiety and stress and benefited working memory capacity (Jha, Stanley, Kiyonaga, Wong, Gelfand, 2010).

To further investigate the effect of mindfulness meditation on working memory capacity, Weger et al. (2012) gave a five-minute mindful task involving eating two raisins to women before performing a math test with or without an induced stereotype threat. They theorized that stereotype threat reduces the working memory capacity by occupying space that would otherwise be used to solve the math problems. As expected, women who performed the mindfulness task were not negatively impacted by the stereotype threat, but instead they performed better than all conditions that received no stereotype threat.

When examining the benefits of mindfulness meditation on cognitive function over time, studies show that the longer mindfulness mediation has been practiced, the more benefits one derives. Teper and Inzlicht (2012) studied differences in executive control of meditators versus non-meditators through the error-related negativity, a neural marker of performance monitoring, when participants performed the Stroop task. Meditators had fewer errors and a higher error-

related negativity, indicating that they demonstrated greater executive control. This effect was highly correlated to the number of years participants had been meditating. Several studies also have shown an effect of mindfulness meditation on brain structure and function. A study by Holzel et al. (2011) showed a change in participants' fMRI brain scans after participating in MBSR. There was a significant increase in gray matter in areas that are involved in the modulation of emotion regulation and learning. A study by Kerr et al. (2011) took participants naive in mindfulness meditation and measured activity in the primary somatosensory cortex, believed to be associated with modulation of distracting stimuli, before and after MBSR. The results suggested that MBSR might help to reduce susceptibility to distraction and preserve working memory capacity under stressful situations.

Whereas no previous study has examined the effects of a brief mindfulness intervention on test anxiety and subsequent math performance, extensive research suggests that mindfulness interventions are effective at reducing anxiety and stress as well as benefitting working memory capacity (Jha, Stanley, Kioynaga, Wong, Gelfand, 2010; Weger et al, 2012; Kerr et al, 2011) and executive control (Teper & Inzlicht, 2012; Zeidan et al, 2011). We thus hypothesized that mindfulness meditation represents a potentially promising approach to reducing anxiety and increasing working memory capacity in the context of math performance. Other studies have examined interventions to treat or relieve math anxiety, including inducting a positive mood (Bryan & Bryan, 2001) or providing training in study habits or test taking, but none to date have examined the potential of a brief mindfulness intervention.

In the current study, we investigated the benefits of a brief mindfulness intervention on math test anxiety and test performance in a high school population. We examined two main hypotheses: (a) That a brief mindfulness meditation directly before math exams would decrease

math test anxiety; (b) That a brief mindfulness meditation directly before math exams would improve exam scores. Specifically, we predicted that a brief mindfulness meditation would decrease anxiety and anxious thoughts, thus allowing for greater working memory capacity to be devoted to problem solving, subsequently improving math exam scores. We also examined the effects of age, gender, and engagement in the intervention on anxiety reduction. We hypothesized a positive correlation with engagement in the intervention and anxiety reduction. We had no preconceived hypotheses on the correlation between gender or age and anxiety reduction through the mindfulness intervention.

Methods

This study was approved by the University of Colorado at Boulder Internal Review Board and the Saint Vrain Valley school district Board of Education.

Participants

One-hundred-forty-eight high school students (male $n = 63$, female $n = 65$) in AP Statistics or Algebra One (who all had the same teacher) were eligible to participate in this study. In the AP Statistics class there were $n = 80$ students, for Algebra One $n = 48$ students. Written parental consent was obtained from all participants under 18 years of age, students ages 18 or above could provide their own consent. Voluntary written assent was obtained from all participants as well. Participants were not compensated for sessions during school hours, but were offered $5 for the completion of two online questionnaires to be completed outside of school time. De-identified grades of students who were eligible but did not return the necessary forms were provided by their teacher (with Board of Education and IRB approval) and are included in the analysis. These students will be referred to as Non-participant controls.

Therefore, our samples included *n* = 53 students in the Mindfulness Intervention, *n* = 17 in the Control Condition, and *n* = 54 Non-Participant control, for a total of *n* = 70 consented participants and *n* = 124 students whose (de-identified) grades we accessed. In AP Statistics there was *n* = 17 in the Control Condition, *n* = 40 in the Mindfulness Intervention, and *n* = 20 in the Non-participant Condition. In Algebra One there was *n* = 13 in the Mindfulness Intervention and *n* = 34 in the Non-participant Condition. Twenty-four students were excluded from the final analysis because they had dropped the math class from their schedule. They are not included in the sample sizes above.

Intervention

The mindfulness intervention consisted of a nine minute long guided meditation. Two mindfulness meditations were used to enhance student engagement and interest by not having to listen to the same recording each session. The first led participants to bring their awareness to their breath and to continually redirect attention to their breath whenever their thoughts wandered elsewhere. The second led participants in a body scan, focusing on the sensations of their body as well as their breath. A transcription of each is attached. The mindfulness induction recording was broadcasted to the class using a Bowers and Wilkins Zeppelin Mini iPod Dock and a 2G iPod Nano.

Self-report Questionnaires

The study used four self-report questionnaires to assess constructs of interest. The State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, 1970) and the Subjective Units of Distress Scale (SUDS; Wolpe, 1990) were used to measure participants' anxiety levels. The SUDS was given before and after each intervention session and the STAI was given after each

session. The STAI uses a four-point scale and consists of 20 questionnaires: (1) Never, (2) Sometimes, (3) Often, (4) Almost always. Participants rated questions such as "I feel calm," "I feel tense," and "I feel indecisive," depending on how they felt at that moment. The SUDS uses a Likert scale of 0-100, 0 being "No anxiety" and 100 being "Very extreme anxiety." Participants rated their anxiety depending on how they felt at that moment.

The Exercise Engagement Scale was used to determine the extent that participants engaged in the intervention and was given after each intervention session. It uses a Likert scale of 0-100, 0 being "Not at all" and 100 being "Completely." Participants rated depending on how much they thought they engaged in the intervention.

The Math Enjoyment Scale was used to rate how much students enjoyed math and was given before the intervention on the first and last session. It is a Likert scale of 0-100, 0 being "Strongly dislike" and 100 being "Strongly like." Participants rated by how much they believed they enjoyed math.

Procedure

A week before the first session, the experimenter visited each class to explain the purpose of the study and its voluntary nature as well as to distribute parental consent and participant assent forms. Students were told they were to participate in a listening exercise that may help them perform better on the exam, but that there was no guarantees. Participant assent forms were collected on the same day. Parental consent form collection occurred mostly over two weeks. Eligible participants were encouraged to return parental consent forms, whether they chose to participate or not; to incentivize return rates, we offered homemade cupcakes if 90% of the class returned the forms. However, because of insufficient parental consent form return rates, only

four of the five eligible classes participated, three AP Statistics and one Algebra One class. Due to the logistical challenge of randomizing individuals in the same class to different conditions, random assignment to condition was determined by class rather than by individual. The Control Condition class was chosen by coin toss from the three participating AP Statistics classes. Because there was only one participating Algebra One class, they were assigned to the Mindfulness Intervention group.

The intervention began during the spring semester. Fall grades were used as a baseline analysis as well as the first test of the spring semester, which occurred before the assent and consent process began. These grades are used as a baseline measure. AP Statistics had four tests and Algebra One had three tests for which the intervention was implemented, with each test approximately one month apart.

On test days for the Mindfulness Intervention group, the experimenter arrived at the beginning of class. The teacher left the room with all non-participating students and waited in an adjacent room until the end of the session. Once the teacher had exited with non-participant students, the experimenter explained that participants were about to participate in a brief listening exercise. The experimenter then gave each participant the pre SUDS questionnaire (in the first session participants also answered a baseline STAI, and in the first and last session participants were given the Math Enjoyment Scale). Once collected the experimenter reminded participants to be silent, respectful of others, and to pay full attention to the recording before playing the mindfulness intervention. During the recording the experimenter waited silently on the side of the room. Once the recording ended, participants were given the post SUDS, the STAI and the Exercise Engagement Scale. Once all participants finished the questionnaires, the

teacher returned with the other students (remaining as quiet as possible) and immediately began the test.

Within the AP Statistics class that was randomized to the Control condition, participants remained in the classroom and were given one SUDS and the STAI after the teacher had left the room with non-participant controls (prior to the math test). Once participants had finished filling out the questionnaires the teacher returned silently with the other students and immediately began the test. Non-participants waited in a separate room with the teacher during sessions. They were not allowed to use phones, iPods, etc., to review test information, or to ask the teacher questions about the test.

Results

Mindfulness and Test Anxiety Reduction

We first measured baseline anxiety using a UNIANOVA analysis of the SUDS taken before the first intervention session to examine whether pre-test anxiety was similar between the Control and Mindfulness conditions prior to the mindfulness intervention; we co-varied using the baseline STAI measurement taken before the intervention in session one. There was no significant difference in baseline anxiety across Control and Mindfulness Intervention condition, $F(13, 40) = .06$, $p = .79$, and $\eta_p^2 < .01$.

We measured anxiety reduction *within* the Mindfulness Intervention group using a dependent t-test of pre SUDS and post SUDS for each test session as well as the mean pre and post SUDS across all sessions. There was a significant reduction in self-reported anxiety after every mindfulness intervention session. Session One, $t(41) = 6.35$, $p < .01$. Session Two,

$t(45) = 6.39$, $p < .01$. Session Three, $t(38) = 4.73$, $p < .01$. Session Four, $t(30) = 6.54$, $p < .01$. Mean across all sessions $t(53) = 7.83$, $p < .01$ (see Table 1 and Figure 1).

Effect of gender, engagement in intervention, and class on anxiety reduction.

We performed ANOVA analyses for each testing session (in which we used the mindfulness intervention) to examine the effect of gender, self-reported engagement in the intervention (Exercise Engagement Scale), and class (AP Statistics versus Algebra One) on the difference between pre and post SUDS anxiety scores. In Session One there was no significant difference in anxiety scores by Gender, $F(1, 46) = 2.44$, $p = .12$, $\eta_p^2 = .05$, Engagement, $F(12, 29) = .95$, $p = .51$, $\eta_p^2 = .27$, or Class, $F(1, 46) = .66$, $p = .55$, $\eta_p^2 = .01$ (see Table 2.1). In Session Two there was a significant difference by Engagement, $F(14, 31) = 3.1$, $p = .004$ with a large effect of $\eta_p^2 = .57$. There was a borderline significant difference by Gender, $F(1, 44) = 3.05$, $p = .06$, $\eta_p^2 = .06$. There was no significant difference by Class, $F(1, 44) = .41$, $p = .52$, $\eta_p^2 < .01$ (see Table 2.2). In Session Three there was a nearly significant difference by Engagement, $F(13, 25) = 2.0$, $p = .05$ with a large effect size of $\eta_p^2 = .50$. There was no significant difference by Gender, $F(1, 39) = .42$, $p = .51$, $\eta_p^2 = .01$, or by Class, $F(1, 38) = .41$, $p = .52$, $\eta_p^2 = .02$ (see Table 2.3). In Session Four there was no significant difference by Gender, $F(1, 29) = 2.32$, $p = .138$, $\eta_p^2 = .07$, or by Engagement, $F(13, 17) = .84$, $p = .61$, $\eta_p^2 = .39$ (see Table 2.4). Algebra One did not participate in the fourth session. When examining the means across all sessions' SUDS difference, there was no significant difference by Gender, $F(1, 51) = 1.69$, $p = .19$, $\eta_p^2 = .03$, by Engagement, $F(38, 14) = 1.01$, $p = .5$, $\eta_p^2 = .7, 1$ or by Class, $F(1, 51) = .07$, $p = .71$, $\eta_p^2 < .01$ (see Table 2.5).

Mindfulness and Grades

For each class and across all classes, a dependent t-test was performed *within* each group comparing mean test scores from the first semester (i.e., prior to any intervention), to mean test scores from the second semester, tests taken after the mindfulness intervention. A between-group repeated measures ANOVA then assessed differences between groups in first versus second semester (post intervention) grades. Test scores were based on 100 points. Many participants assigned to the Mindfulness Intervention condition did not participate in the mindfulness intervention for all tests due to absences and make-up exams. Therefore we tested two different Mindfulness Intervention condition groups: All participants who did the mindfulness intervention for at least one test (MI 1) and participants who did the mindfulness intervention for at least three out of four possible testing sessions (MI 2).

Combined classes grades. We performed a dependent t-test, there was no significant difference between semester one and semester two mean scores *within* the Non-participant condition across all classes, $t(53) = -.02$, $p = .98$. There was a significant difference *within* the Mindfulness group, $t(52) = -2.4$, $p = .02$. We used a Repeated Measures ANOVA to determine if there was a significance between condition (MI 1 versus Control versus Non-participant) for pre - versus post-mindfulness intervention grades. The group x time interaction was non-significant, $F(2, 121) = 1.04$, $p = .35$, $\eta_p^2 = .01$. There was a non-significance *within-group* for MI 2 versus Control versus Non-participant, with $F(1, 104) = .76$, $p = .46$, and $\eta_p^2 = .01$.

AP Statistics grades. There was no significant difference between semester one and semester two mean scores *within* the Control, $t(16) = .05$, $p = .95$, and Non-participant, $t(19) = -1.31$, $p = .20$, conditions. There was a significant difference within both MI 1,

$t(39) = -3.12$, $p = .003$, and MI 2 $t(27) = -2.21$, $p = .03$. The mean increase in scores was *MI 1*(40) = 1.21 and *MI 2*(28) = .95 (see Figure 2 and Table 3).

We used a Repeated Measures ANOVA to determine if there was a significance between condition (MI 1 versus Control) for pre - versus post-mindfulness intervention grades. The group x time interaction approached significance, $F(1, 55) = 3.06$, $p = .08$, with a medium effect, $\eta_p^2 = .05$. MI 2 versus Control was non-significant, $F(1, 43) = 1.86$, $p = .18$, but there was a small to medium effect size of $\eta_p^2 = .04$.

Algebra One grades. There was no significant difference in semester one and semester two mean scores for the Non-participant group, $t(33) = .54$, $p = .59$ and MI 1 group, $t(12) = -1.05$, $p = .31$. There was a significant difference however in the MI 2 group, $t(7) = -2.5$, $p = .03$ (see Figure 3 and Table 4).

Again we used a Repeated Measures ANOVA to determine if there was a difference between condition (MI 1 versus Non-participant control) for pre - versus post-mindfulness intervention grades. The group x time interaction for MI 1 was non-significant, $F(1, 45) = 1.39$, $p = .24$, $\eta_p^2 = .03$. MI 2 versus Non-participant control was also non-significant, $F(1, 40) = 1.53$, $p = .22$, $\eta_p^2 = .03$.

Discussion

We will begin by discussing the implications of the data to our first hypothesis: that a brief mindfulness intervention given directly before a math test will decrease anxiety. The data supports that our initial hypothesis was correct in believing a mindfulness meditation would significantly decrease anxiety scores. The mean decrease in anxiety of 13 points represented a

36% decrease in reported anxiety, a substantial decline. Because anxiety was measured by a self-report questionnaire, we can conclude that participants felt an observable decrease in their test anxiety. There was no significant difference by gender or class, which denotes that there was no significant difference among age, as all Algebra One students were of Freshmen standing (ages14-15) and most AP Statistics students were Seniors (ages 17-18) with a smaller number of Juniors (ages 16-17).

In exploring which factors contributed to anxiety reduction, it appears that engagement in the intervention could have been a contributing factor to anxiety reduction, but our findings did not all reach statistical significance. Two out of four sessions showed a significant or almost significant difference in anxiety scores by engagement, while the mean across all the sessions did not. The data appears to support a correlation between engaging 75% or more in the mindfulness meditation and greater benefits to anxiety reduction. Participants who rated their engagement at or above 75% had an anxiety reduction of 0-55 points, and participants who rated engagement between 45-60% and had an anxiety reduction of 8-50 points (on a scale of 100). In contrast, participants who rated their engagement below 45% ranged in anxiety reduction from 0-5 points. Thus, participants who engaged only moderately in mindfulness showed greater improvements than those who engaged minimally. In that participants who engaged very little or not at all showed little to no anxiety reduction, we can conclude that the mindfulness intervention was more effective at reducing anxiety than sitting quietly in a calm room. This is supported by previous mindfulness research, which has shown mindfulness meditation training to significantly decrease anxiety (Evans et al., 2011; Vollestad, Sivertsen, Nielsen, 2011). While engagement is not always directly correlated with an increase in grades, it does appears that participants who had a higher than average reduction in anxiety experience showed almost twice as much

improvement in their grades, with a grade increase of 1-2% for all mindfulness intervention participants and 2-3% for participants with an average anxiety reduction of 15 or more points. This was the first study to show its effectiveness as a very brief intervention prior to exams in a public school setting.

Our second hypothesis predicted that the brief mindfulness intervention would improve math exam scores. The within-group analysis clearly supported our hypothesis that a mindfulness intervention would improve math exam scores. Further, in the between group analysis, there was a nearly significant difference between conditions among AP Statistics students. There was no significant difference between conditions in the Algebra One class, though patterns were in the predicted direction and samples sizes were smaller, thus reducing statistical power.

It is possible to consider that the mindfulness intervention was most beneficial to students who typically had higher than average anxiety, and therefore the best chance to benefit from an anxiety reduction intervention. This is in line with research that suggests high levels of math anxiety interfere with working memory capacity and therefore the ability to perform tasks requiring this cognitive function. In a study by Lyons and Beilock (2011), participants were separated into high and low math anxiety groups and then performed a math task and a language task. Both groups performed equally well on the language task while high math anxiety participants performed significantly lower on the math task. The brain regions associated with high math anxiety and lower performance are regions that control attention shifting and the inhibitory process. This is related to the idea that it is the math anxious person's inability to shift their attention from their anxiety or inhibit worrying thoughts that hurt math performance. It is possible within this study that participants who on average had high test anxiety and experienced

at least a moderate reduction in anxiety (15 or more points in self-reported anxiety), reduced worrying thoughts and increased their working memory capacity enough to improve their test performance. This hypothesis now awaits direct testing.

Study Limitations

Because this study took place within a public high school setting, we were presented with many logistical challenges specific to real-world research with minors. Collecting parental consent was the biggest inhibitor to expanding our participant pool, collecting more data, and thus increasing statistical power to examine group differences. More than half of the eligible participants did not return the parental consent form. Because all but three eligible participants voluntarily assented to participate in the study, we can conclude that it was not their unwillingness to participate but likely adolescent negligence that presented this difficulty in returning parental consent forms. Of eligible participants, 47% returned parental consent forms, including students who could give their own. No parental consent forms were returned stating they did not want their child to participate. It was also probable that parents of some eligible participants did not read English or did not have time to consider their child's participation in the study. There were considerably more AP Statistics participants because many were 18 years of age and able to give their own consent. It was because of this lack of parental consent that there was few participating students to be randomized to the control group.

In three of four participating classes, half of the students were not participants. Because of this, it would have been very difficult to randomize the participants of one class into different conditions. We therefore randomized condition by class rather than individual participant. This presented a problem when analyzing the data on exam scores, as the different classes had

significantly different grades to begin with. Specifically, the AP Statistics control class had significantly higher grades than the other two classes. Baseline differences complicated our attempt to compare grades by condition, and may have resulted in ceiling effects for the Control condition. On another note, three of the classes consisted mostly of seniors, who often complained to us of "senioritis," which may have counteracted any positive effect the mindfulness intervention may have had.

We had similar difficulty in getting participants to complete two questionnaires outside of school time, which were not reported here. Even though participants were paid $5 to complete the questionnaires, few completed both. The questionnaires were to be used to collect data on age, daily mindfulness, personality traits, socio-economic status, and other demographic information, which would have enriched our understanding of the intervention's impact.

There were two other difficulties we encountered in this study. Many students missed test days and retook the test on difference days. Less than half of all mindfulness intervention participants were present on testing days for every test where the mindfulness intervention was given. Therefore, we did not have a consistent group who received the mindfulness intervention. Another difficulty that all high schools face was cheating. Some students were caught cheating during the semester that the intervention took place, and we were informed by their teacher that many more were suspected of cheating as well. It is unclear how much cheating affected students' grades, or whether cheating differed systematically by condition and how this may have impacted study outcomes.

There are multiple improvements that could be made for future studies. First, the mindfulness intervention would benefit from taking place over the entire school year instead of

one semester to maximize the number of data points. Second, future studies would benefit from sufficiently large sample sizes to randomize by individual rather than class, with an equal number in the experimental and control groups. Incentives could be employed to encourage participants should attend as many test days as possible (rather than attend make up exams). While difficult, cheating must be prevented as much as possible. Having students answer socio-demographics, personality trait, and dispositional mindfulness questionnaires before and after the interventions begins would provide helpful additional data to inform the results.

Conclusion

Though not all findings reached statistical significance, it appears that even an irregularly administered mindfulness intervention may have a small but positive effect on exam scores. Further, the brief mindfulness intervention significantly reduced math test anxiety in high school students. While more research needs to be done to determine the effect of a brief mindfulness intervention on math exam scores, we would recommend this intervention as an anxiety reduction technique for math test anxiety within a high school population, with the possible effect of also increasing exam scores.

Acknowledgements

The author would like to thank Gayle Niss, whose willingness to participate and involve her students in a mindfulness intervention enabled this study. Without her help and cooperation this study would have been impossible. The author would also like to thank the members of the committee, Dr. Joanna Arch, Dr. Robert Spencer, Dr. Tina Pittman-wagers, and Dr. Christine Macdonald, for reading the thesis, participating in the oral defense, and for their time. It is with sincere gratitude that the author gives thanks to Dr. Joanna Arch. This study and thesis have

greatly benefited from her guidance and assistance. Her help throughout this process was much appreciated.

References

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

Brown, K., Ryan, R. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology,* 84(4), 822-848.

Bryan, T., Bryan, J. (2001). Positive mood and math performance. *Journal of Learning Disabilities,* 24(8), 490-494.

Evans, S., Ferrando, S., Carr, C., Haglin, D. (2011). Mindfulness-based stress reduction (MBSR) and distress in a community-based sample. *Clinical Psychology and Psychotherapy,* 18, 553-558.

Holzel, B., Cormody, J., Vangel, M., Congleton, C., Yerramsetti, S., Gard, T., Lazar, S. (2011). Mindfulness practice leads to increases in regional brain gray matter density. *Psychiatry Research: Neuroimaging,* 191, 36-42.

Jha, A., Stanley, E., Kiyonaga, A., Wong, L., Gelfand, L. (2010). Examining the protective effects of mindfulness training on working memory capacity and affective experience. *Emotion,* 10(1), 54-64.

Kang, Y., Choi, S., Ryu, E. (2009). The effectiveness of a stress coping program based on mindfulness meditation on the stress, anxiety, and depression experienced by nursing students in Korea. *Nurse Education Today,* 29, 538-543.

Kerr, C., Jones, S., Wan, Q., Pritchett, D., Wasserman, R., Wexler, A., Willaneuva, J., Shaw, J., Lazar, S., Kaptchuk, T., Littenberg, R., Hamalainen, M., Moore, C. (2011). Effects of mindfulness meditation training on anticipatory alpha modulation in primary somatosensory cortex. *Brain Research Bulletin,* 85, 96-103.

Lang, J., Lang, J. (2010). Priming competence diminishes the link between cognitive test anxiety and test performance: Implication for the interpretation of test scores. *Psychological Science,* 21(6), 811-819.

Lyons, I., Beilock, S. (2011). Mathematics anxiety: Separating the math from the anxiety. *Cerebral Cortex,* doi:10.1093/cercor/bhr289.

Navarro, J., Aguilar, M., Alcalde, C., Ruiz, G., Marchena, E., Menacho, I. (2011). Inhibitory processess, working memory, phonological awareness, naming speed, and early arithmetic achievement. *The Spanish Journal of Psychology,* 14(2), 580-8.

Rapgay, L., Bystrisky, A. (2009). Classical mindfulness: An introduction to its theory and practice for clinical application. *Annals of the New York Academy of Science,* 1172, 148-62.

Rosenzweig, S., Reibel, D., Greeson, J., Brainard, G., Hojat, M. (2003). Mindfulness-based stress reduction lowers psychological distress in medical students. *Teaching and Learning Medicine: An International Journal,* 15(2), 88-92.

Shapiro, S., Schwartz, G., Bonner, G. (1998). Effects of mindfulness-based stress reduction on medical and premedical students. *Journal of Behavior Medicine,* 21(6), 581-99.

Spielberger, C. D., Gorsuch, R.L., and Lushene. R.E. (1970). The state-trait anxiety inventory: Test manual. *Consulting Psychologists Press*.

Teper, R., Inzlicht, M. (2012). Meditation, mindfulness and executing control: The importance of emotional acceptance and brain-based performance monitoring. *Social Cognitive and Affective Neuroscience Advance Access,* doi:10.1093/scan/nss045.

Vollestad, J., Sivertsen, B., Nielsen, G. (2011). Mindfulness-based stress reduction for patients with anxiety disorders: Evaluation in a randomized controlled trial. *Behavior Research and Therapy,* 49, 281-288.

Warnecke, E., Quinn, S., Towle, N., Nelson, MN. (2011). A randomized controlled trial of the effects of mindfulness practice on medical student stress levels. *Medical Education,* 45 (4), 381-8.

Weger, U., Hooper, N., Meier, B., Hopthrow, T. (2012). Mindful maths: Reducing the impact of stereotype threat through a mindfulness exercise. *Consciousness and Cognition,* 21, 471-475.

Wolpe J. (1990). The Practice of Behavior Therapy (4th ed.). New York: Pergamon.

Zeiden, F., Johnson, S., Diamond, B., David, Z., Goolkasian, P. (2010). Mindfulness meditation improves cognition: Evidence of brief mental training. *Consciousness and Cognition,* 19, 597-605.

Zheng, X., Swanson, H., Marcoulides, G. (2011). Working memory components as predictors of children's mathematical word problem solving. *Journal of Experimental Child Psychology,* 110, 481-498.

Table 1

Pre versus Post SUDS t-test

Session	*n*	Pre	Post	*t*	*p*-value
1	42	33.48	16.05	6.35	< .001
2	46	32.36	20.35	6.39	< .001
3	39	38.97	26.77	4.73	< .001
4	31	46.35	32.16	6.54	< .001
Mean	53	35.72	22.65	7.83	< .001

Figure 1

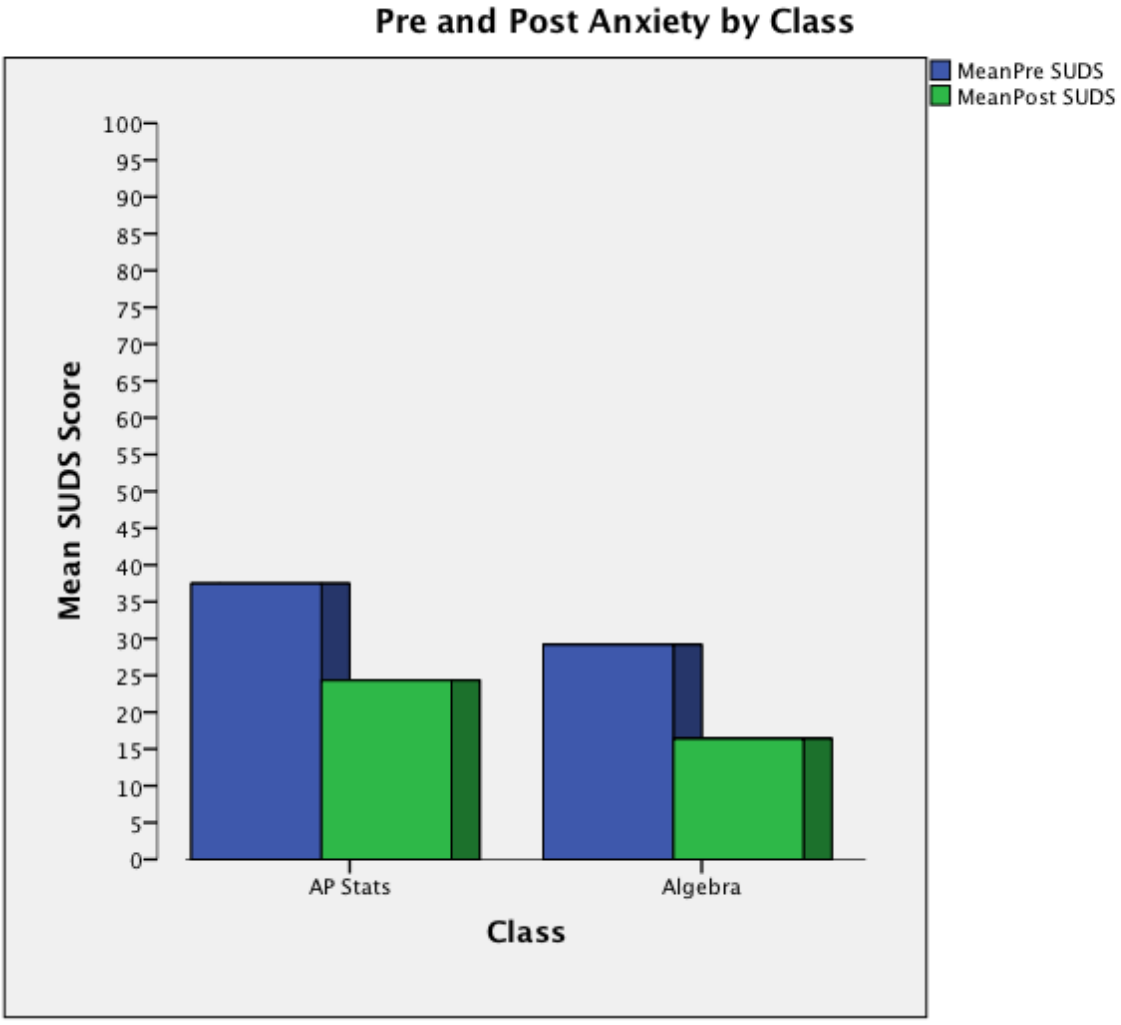

Table 2.1

Session 1 SUDS Difference ANOVA

Independent V.	***n***	***F***	***p*-value**	η_p^2
Gender	Male = 21 Female = 23	2.449	.125	.055
Engagement	n =43	.953	.511	.276
Class	Stats = 31 Algebra = 12	.669	.418	.016

Table 2.2

Session 2 SUDS Difference ANOVA

Independent V.	***n***	***F***	***p*-value**	η_p^2
Gender	Male = 24 Female = 23	3.058	.087	.064
Engagement	n = 47	3.107	**.004**	.576
Class	Stats = 35 Algebra = 12	.413	.524	.009

Table 2.3

Sessions 3 SUDS Difference ANOVA

Independent V.	***n***	***F***	***p*-value**	η_p^2
Gender	Male = 19 Female = 21	.423	.519	.011
Engagement	n = 40	2.052	**.058**	.506
Class	Stats = 31 Algebra = 9	.413	.524	.021

Table 2.4

Sessions 4 SUDS Difference ANOVA (AP Statistics only)

Independent V.	***n***	***F***	***p*-value**	η_p^2
Gender	Male = 16 Female = 15	2.322	.138	.074
Engagement	n = 31	.846	.615	.393

Table 2.5

Mean SUDS Difference ANOVA

Independent V.	***n***	***F***	***p*-value**	η_p^2
Gender	Male = 28 Female = 27	1.691	.199	.031
Engagement	n = 55	1.013	.511	.706
Class	Stats = 43 Algebra = 12	.078	.718	.001

Figure 2

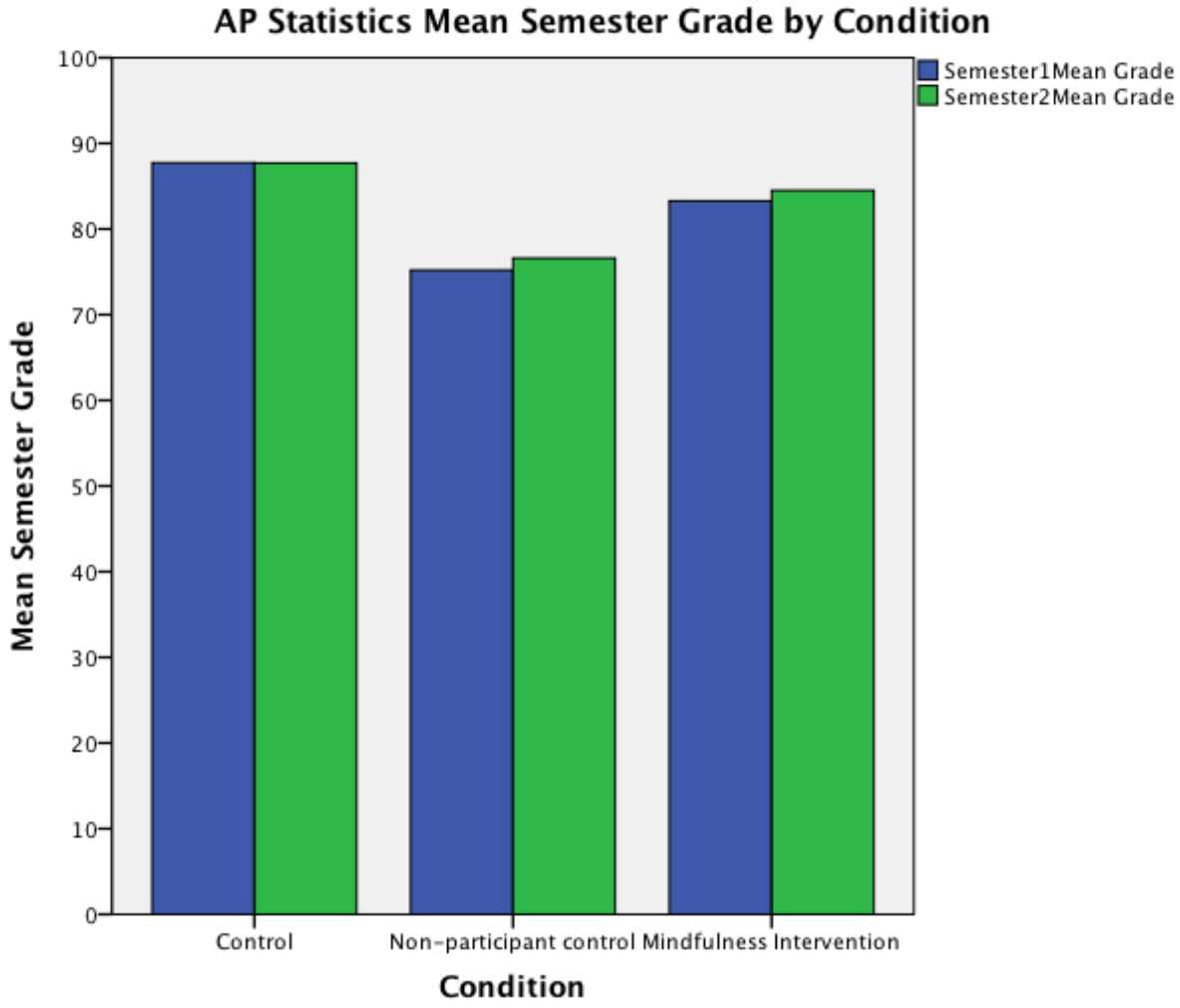

Table 3

AP Statistics Pre versus Post-intervention Mean Semester Grades

Condition	*n*	S1 mean grade	S2 mean grade	*t*	*p*-value
Control	17	87.73	87.7	.054	.958
Non-participant	20	75.18	76.58	-1.31	.206
MI 1*	40	83.29	84.51	-3.12	**.003**
MI 2**	28	84.45	85.41	-2.21	**.036**

* Participants who attended at least one mindfulness intervention testing session
** Participants who attended at least three mindfulness intervention testing sessions

Figure 3

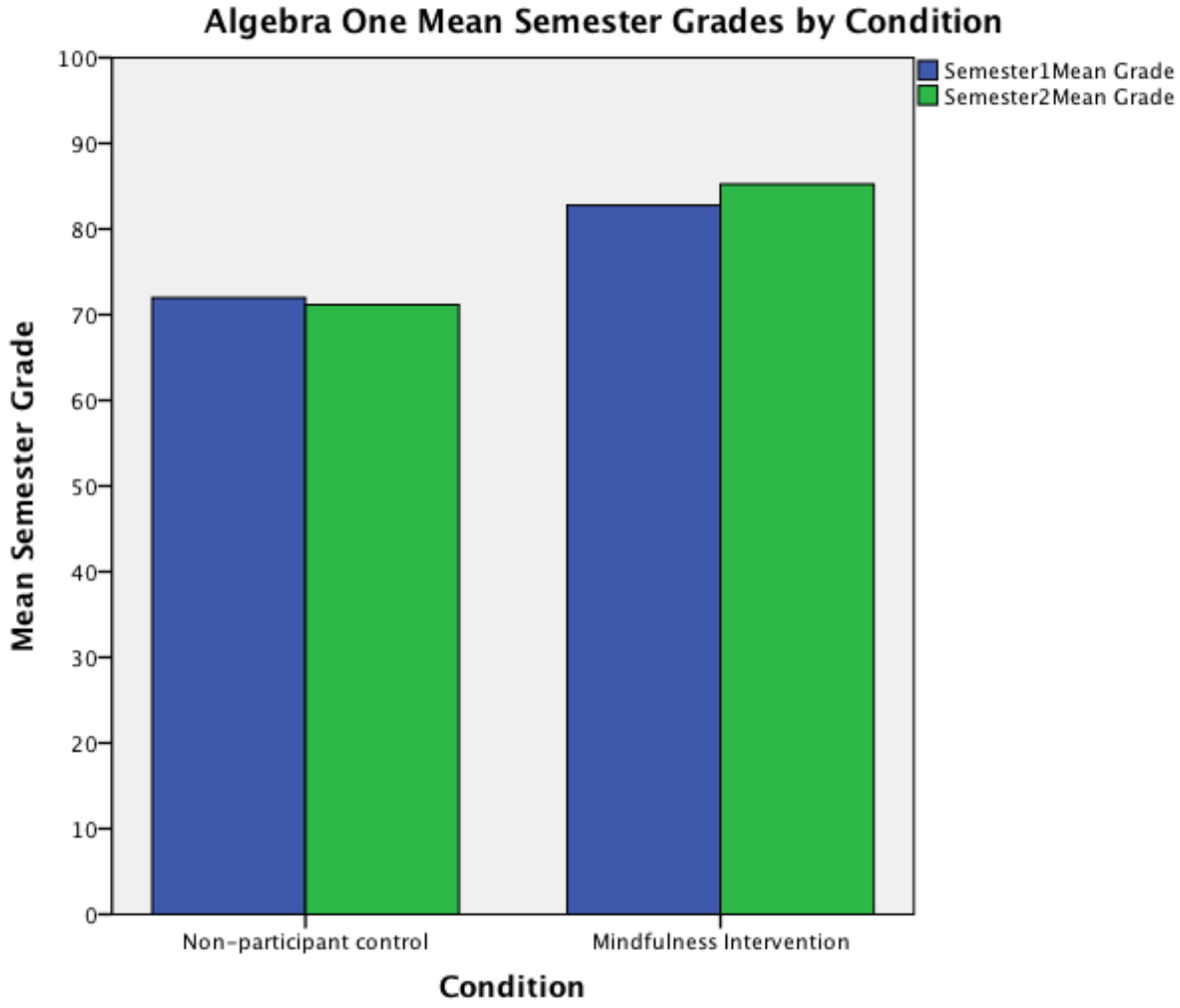

Table 4

Algebra One Pre versus Post-intervention Mean Semester Grades

Condition	*n*	S1 mean grade	S2 mean grade	*t*	*p*-value
Non-participant	34	71.96	71.17	.54	.591
MI 1*	13	82.76	85.23	-1.05	.312
MI 2**	8	83.67	86.78	-2.55	**.038**

* Participants who attended at least one mindfulness intervention testing session

** Participants who attended at least three mindfulness intervention testing sessions

Mindfulness Meditation 1: Breath

Now we're going to do an exercise for a bit under 10 minutes. Before we being, make sure you put away anything you might be holding, a pen or cell phone, for example, and settle into a comfortable sitting position, sitting with your back upright, but not too tight, your legs uncrossed, your feet flat on the floor, and your hands resting comfortably in your lap. Now gently close your eyes and please follow along with my instructions as best you can. Notice yourself, notice your feet against the floor, or your back against the chair. Notice the clothing against your skin, and let yourself relax and become curious about yourself, seated here, the sensations, the touch. And relax any areas of tightness of tensions. And now begin to tune into your breath and body, feeling the natural flow of breath. You don't need to do anything to your breath, not long, not short, just natural. And notice where you feel your breath in your body. It might be in your abdomen, it might be in your chest, or throat, or nostrils. See if you can feel the sensations of your breath, one breath at a time. When one breath ends, the next breath begins. Now as you do this, you might notice that your mind may start to wander, you might start to think of other things. About something you did, or something you need to do. If this happens, it is not a problem, it is very natural. Just notice that your mind has wandered. You can say thinking, or wandering softly in your head. And then gently redirect your attention right back to the breathing. Intentionally creating an attitude of gentleness and patience toward yourself. Focus your awareness on the sensations of slight stretching as the abdomen rises with each in-breath, and of gentle deflation as it falls with each out breath. Perhaps noticing the slight pause at the end of the in-breath, and the slight pause and the end of the out-breath and the beginning of the next in-breath. Focus on the actual sensations of the breath entering and leaving the body. There is no need to try to control the breathing in any way. Simply let the breath be natural. Just experience the sensations of the breath as they are. As best you can, also bring this sense of allowing into the rest of your experience. there is nothing to be fix, no particular state to be achieved. As best you can, simply allow your experience to be your experience, without needing to change it in any way. Use the breath as an anchor to reconnect with the here and now each time you notice that your mind has wandered and is no longer following the breath. Cultivate a sense of gentleness for yourself, and for whatever you are experience right now. Everything is acceptable. You are fine no matter what you experience. Please bring this sense of allowing into the rest of this class and the rest of your day. Now allow your attention to expand to the sensations of sitting in the chair, to this room. Now when you are ready, slowly and gently open your eyes.

Mindfulness Meditation 2: Body Scan

Now we're going to do an exercise for a bit under 10 minutes. Before we begin, make sure you put away anything you might be holding, a pen or cell phone for example, and settle into a comfortable, relaxed sitting position, sitting with you back upright, but not too tight, your legs uncrossed, your feet flat on the floor, and your hands resting comfortable in your lap. Now gently close your eyes and please follow along with my instructions as best as you can. Bring your awareness to yourself. Focus your attention on the sensations of touch or pressure where you make contact with the chair, or the floor, or the sensation of your hands, resting against yourself, or your desk. Gently bring your attention to the sensations of your breath, feeling the natural flow of breath, the natural rhythm, letting the breath breathe itself. There is no need to control the breath, simply notice it. Notice how your body moves in response to the breath: your chest expanding, and relaxing, your abdomen rising and falling. Your might find that your mind begins to wander. You may find yourself thinking about something you did, or something you need to do. This is perfectly natural. Simply notice where your thoughts go, and then gently bring back your awareness to yourself, and your breath. Intentionally cultivating an attitude of patience and gentleness towards yourself. Use your breath as an anchor, whenever your mind wanders, gently bring it back to the sensations of your breath, focusing on the actual sensations of the breath entering, and the breath leaving the body. Now slowly expand your awareness to the rest of your body. Notice your feet touching the floor, the sensations of touch where your feet make contact with your socks or shoes, and their weight against the floor. Notice any warmth or coolness, comfort or discomfort in that area. No need to change any sensations, just notice them. Slowly move your awareness up your legs, starting with your calves. Notice the clothing against your skin, or the temperature. Continue to move your focus up your legs, to your knees, to your thighs. Bring your attention slowly up through the rest of your body, focusing on the sensations of your skin, or your muscles, or any other feeling your mind is drawn to. Move from your bottom.... to your lower back and abdomen... notice the feeling of your breath in your abdomen and chest, or in your stomach, or ribs...Notice the sensations of your back, as it rests against the chair, or the feeling of your shirt against your skin... continue to move your attention upwards to your shoulders, arms, and neck. You may notice that you often carry tension in these areas. There is no need to change these sensations of tension, or to try to relax them. Just notice it, make room for them, perhaps send your exhale out to that area in your mind, and continue to focus your attention on your body. Slowly move your focus down your arms and into your hands, and your fingers. Without moving them, notice the sensitivity in your fingers tips, how they differ from your palm or your arm... Now bring your awareness back up your arms, across your shoulders, up your neck, and place your attention on your face. You may notice the sensitivity of your lips, or a smell coming from the room. You may feel your hair against your skin, or notice the dim light through your eyelids. Simply notice whatever sensations you find. Now bring your attention to your breath coming through your nose or your mouth. Notice the air as it flows into your lungs, and out of your lungs. Use the breath as an anchor to gently reconnect with the here and now each time you notice that your mind has wandered. Cultivate a sense of gentleness and acceptance for yourself and for whatever you are experiencing right now. Everything is acceptable, you are fine no matter what you experience. Please bring this sense of allowing into the rest of this class and the rest of your day… Now allow your attention to expand to the sensations of sitting in the chair, to this room. Now when you are ready, slowly and gently open your eyes.

SUDS Anxiety Scale

Please indicate your anxiety on a 0 to 100 scale, where 0 = feeling completely calm and relaxed with no anxiety, 50 = moderate anxiety, and 100 = the most extreme anxiety you've ever felt.

No Anxiety	Mild Anxiety	Moderate Anxiety	Strong Anxiety	Very Extreme Anxiety
0	25	50	75	100

ANXIETY RATING:_____

Exercise Engagement Scale

On a scale of 0 to 100, to what extent did you try to do this listening exercise?

Not at all	A little	Moderately	Mostly	Completely
0	25	50	75	100

Your answer: _____

State Trait Anxiety Inventory (STAI-Y1)

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to indicate how you feel right now, that is, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings the best.

		Almost Never	Sometimes	Often	Almost Always
1.	I feel calm.	1	2	3	4
2.	I feel secure	1	2	3	4
3.	I feel tense	1	2	3	4
4.	I feel strained	1	2	3	4
5.	I feel at ease	1	2	3	4
6.	I feel upset	1	2	3	4
7.	I am presently worrying over possible misfortunes	1	2	3	4
8.	I feel satisfied	1	2	3	4
9.	I feel frightened	1	2	3	4
10.	I feel comfortable	1	2	3	4
11.	I feel self-confident	1	2	3	4
12.	I feel nervous	1	2	3	4
13.	I am jittery	1	2	3	4
14.	I feel indecisive	1	2	3	4
15.	I am relaxed	1	2	3	4
16.	I feel content	1	2	3	4
17.	I am worried	1	2	3	4
18.	I feel confused	1	2	3	4
19.	I feel steady	1	2	3	4
20.	I feel pleasant	1	2	3	4

Math Enjoyment Scale

Please indicate how much you enjoy math on a 0 to 100 scale

Strongly dislike Dislike Neither Like Strongly like

0 ---------- 25 ---------- 50 ---------- 75 ---------- 100

Your answer: _____