To Think and Feel is to Learn: An Investigation of Brief Mindfulness Meditation Training on the Effects of Emotion Regulation and Learning Outcomes

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This study investigates the theoretical links between academic stress, emotion regulation, and learning. Scholars conceptualize mindfulness as comprising two distinct features: focused attention on the present moment and nonjudgmental awareness. Research has found that mindfulness is associated with improved emotion regulation skills, cognitive, and academic performance (Bellinger, DeCaro, & Ralston, 2015; Brown, Ryan, & Creswell, 2007; Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010). Little past work has investigated the potential mechanisms underlying the cognitive benefits, especially related to learning. I tested the effects of a brief mindfulness training on rumination, stress appraisals, and learning outcomes following an academic stress induction in an experimental setting. Undergraduates were randomly assigned to one of three groups: mindfulness meditation (training on focused attention and nonjudgmental awareness); guided attention to music (training on focused attention but not on nonjudgmental awareness); or wakeful rest (no training on focused attention or on nonjudgmental awareness). To the degree that focused attention and nonjudgmental awareness are critical to learning under stress, I expected mindfulness training to have the strongest positive effects—followed by guided attention to music and, lastly, by wakeful rest—on rumination reduction, stress appraisals, and learning. After controlling for individual differences in mindfulness, emotional regulation, worry, math motivation, math anxiety, and prior knowledge, the results did not support these hypotheses. The present work will, thus, address a research agenda for the future that reconceptualizes stress

appraisals, assessing individual differences and contextual factors and collecting data from target samples.

Keywords: mindfulness meditation; learning; emotion regulation; stress appraisals; rumination

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1.0 Introduction

Stress among undergraduate students is a reoccurring and multifaceted experience, and the pressure to perform well can be particularly stressful (Abouserie, 1994; Kohn & Frazer, 1986; Tesser, 1991; Beilock, 2011). *Academic stress* is defined as the mental distress students experience regarding anticipated academic challenges or failure in the pursuit of academic success as it relates to the "pressures to perform, stress relating to workload, academic self-confidence, and time constraints of successful completion" (Bedewy & Gabriel, 2015). This form of stress has been examined in performance contexts (e.g., high-stakes testing situations and evaluative performance feedback) in which high levels of academic stress are often associated with anxiety (Pizzie & Kraemer, 2019). In stressful situations, detriments to cognitive (e.g., attention) processes and subsequent academic performance comes from two emotion regulation mechanisms (Jha et al., 2010). First, *rumination*, or repetitive negative self-referential thinking, is a counterproductive emotion regulation strategy hypothesized to consume cognitive resources needed to succeed (Ramirez & Beilock, 2011). Second, *stress appraisals,* or interpreting stressors as threats compared to a challenge, are hypothesized to lead to suboptimal cognitive/study strategies (Lemoult, Arditte, D'avanzato, & Joormann, 2013; Jamieson, Mendes, Blackstock, & Schmader, 2010). *Mindfulness meditation* training has been shown to effectively target the cognitive and affective qualities needed for better emotion regulation. Mindfulness training is typically cultivated through a practice of meditation; guiding an individual to use a conscious mental mode marked by two central features that are conceptually defined as: 1) *focused attention* to the present and 2) *nonjudgmental awareness* of one's experience (DeCaro, 2018; Brown & Ryan, 2003). Mindfulness training has shown promise for reducing stress (Canby, Cameron, Calhoun, &

Buchanan, 2015; Lindsay, Young, Smyth, Brown, & Creswell, 2018), promoting better emotion regulation (Leyland, Rowse, & Emerson, 2019; Luberto, Cotton, McLeish, Mingione, & O'Bryan, 2014), and improving performance on challenging academic tasks (Weger, 2012). Less work has examined the mechanisms behind its benefits (i.e., knowledge acquisition of novel concepts).

The purpose of the current work is to test whether brief mindfulness training on attention and nonjudgmental awareness can mitigate rumination, promote positive stress appraisals, and improve learning following a stress induction in the lab. Next, I will review the prior work on academic stress, rumination, and stress appraisals.

1.1 Academic Stress: The Effects of Stressful Feedback on Learning and Performance

Prior research has examined the ways in which academic stress affects students' cognition (Beilock & DeCaro, 2007; Ramirez & Beilock, 2011;Calvo & Eysenck, 1992; Hatcher, Prus, Englehard, & Farmer, 1991; Schmader & Johns, 2003). Students frequently need to manage their response to stressful academic feedback delivered typically in the form of evaluation markers, such as grades and social comparison with other students' academic performance (Holschuh, Nist, & Olejnik, 2011). The detriments of stressful feedback occur when the affective response to failure surpasses one's perception of one's ability to perform. For example, studying for a math exam after receiving a failing grade on an assignment triggers cognitive demands that overwhelm emotion regulation and learning processes for some students.

Emotion regulation processes may mediate the relationship between academic stress and learning. Given that academic stress affects cognition, aiding students to regulate emotional stress responses can be a critical step for improvements in learning and subsequent performance under stress.

1.2 Emotion Regulation: The Effects of Rumination on Learning and Performance

Emotion regulation, or the skillset to monitor, evaluate, and respond to a range of emotional experiences, has been theorized to affect students' cognitive performance (Gratz & Roemer, 2004; Gross & John, 2003; Strain & D'Mello, 2011). Rumination is one type of emotion regulation mechanism that inhibits people from efficiently coping with emotional experiences and that has been shown to negatively impact academic performance for students (Beilock, 2008; DeCaro et al., 2010; Ramirez & Beilock, 2011). Rumination is defined as negatively valanced, past-oriented, self-referential, and repetitive thinking that may arise from stress (Ruscio, Seitchik, Gentes, Jones, & Hallion, 2011; Treynor, W., Gonzalez, R., & Nolen-Hoeksema, 2003). Rumination may not only occur in intense academic situations but is a major feature of depression and other clinical disorders (Hallion, Wright, Coutanche, & Joormann, 2019). Rumination serves as a counterproductive emotion regulation strategy that triggers one's repetitive thoughts about negative emotional experiences in the past and prompts worries about the consequences of the outcomes in the future (Ruscio et al., 2015). Stress and rumination may negatively impact on learning in the same way they disrupt academic performance. More specifically, rumination consumes the cognitive resources (e.g., attention processes) students need for optimal learning; regulating a limited amount of information immediately relevant to the task at hand (Broderick, 2005b; Lyubomirsky, Kasri, & Zehm, 2003; Miyake & Shah, 1999; Nolen-Hoeksema & Morrow, 1993; Ramirez & Beilock, 2011).

For example, Ashcraft's (2002) extensive work on math-related academic stress found evidence to suggest that when math-anxious students (i.e., even those equipped with motivation and adequate knowledge to perform) are faced with a new mathematical learning experience, rumination or pervasive anxious thoughts consume their mental resources and they underperform. Others have supported the claim that rumination affects math academic performance (Beilock, 2011; Ramirez & Beilock, 2010), finding that rumination associated with general anxiety from performance pressures consumes working memory processes (i.e., processes of attention and knowledge retrieval) (Beilock, Rydell, & McConnell, 2007; Calvo & Eysenck, 1992; Ramirez & Beilock, 2011). They suggest that individuals who experience anxiety are more likely to use their cognitive resources to manage these intrusive thoughts, rather than attending to the task itself. Looking at academic stress to test this theory, researchers found supporting evidence when they examined students across grade levels in elementary, high school, and college (Putwain, 2007; Bedewy & Gabriel, 2015). One line of work conducted studies to measure students high in working memory, rumination, math anxiety, and math achievement (Beilock & Ramirez, 2011). These sets of studies directly demonstrated that performance feedback interrupts the working-memory processes that affect subsequent math task performance for students high in working memory processes and also high in ruminative thoughts. In another line of work, they conducted a writing intervention to mitigate the effects of rumination on test performance and found two sets of results that support this study (Ramirez & Beilock, 2014). First, students who performed worse on the math and science tests showed more rumination using anxiety-related words and a greater number of sentences expressing negative thoughts and worries. Second, those who self-reported as highly-anxious test takers and who were randomly selected to carry out an expressive writing task (i.e., prompted to report their thoughts and feelings about the task) performed better on the tests than students in the non-expressive writing task (i.e., prompted to write thoughts about mundane life events). Taken together, this work demonstrates that students poor use of emotion regulation by way of rumination consumes cognitive resources needed to optimally perform under stress and interventions that promote focused attention to the task and mitigate rumination can improve academic performance.

This evidence suggests the type, frequency, and orientation of thoughts students have about themselves and the academic stressor affects their performance on the task. Another line of work suggests it is not only the processing of negative-self-referential thoughts that are affected by poor performance on an academic task, but also the interpretations of the stressor(s) that informs one's behaviors. Negative perceptions of academic stress, or negative stress appraisals, might be a way stressful feedback influences student use of rumination as an emotion regulation strategy for managing stress compared to positive stress appraisals that may lead to better learning outcomes. In the following sections, I will outline two types of appraisals students experience in terms of stressful feedback as another mechanism of emotion regulation.

1.3 Emotion Regulation: The Effects of Stress Appraisals on Learning and Performance

One mechanism proposed as being critical to the learning and performance effects of academic stress concerns how people perceive their stress in the form of appraisals (Jamieson et al., 2016). Stress appraisals are the initial predictors of coping strategies against stressors. Stress appraisals involve the interaction between an individual's perceptions of demands (e.g., effort needed to succeed) and coping resources (e.g., skills and abilities) of an environmental stressor (Blascovich & Tomaka, 1996; Chemers, Hu, & Garcia, 2001; Lazarus, DeLongis, Folkman, &

Gruen, 1985; Tomaka, Kibler, Blascovich, & Ernst, 1997). Prior work examines two types of effective and ineffective stress appraisals: positive and negative operationalized as challenge and threat. These are delineated in a biopsychosocial model between the environment and the individual. For example, positive stress appraisals are used when an individual sees a stressor as an obstacle they can overcome, or “challenge appraisals” i.e., when they believe that they have the resources to overcome the stressor(s) and sufficient skills and knowledge to meet situational demands. A challenge appraisal entails the possibility for growth and mastery of learning, followed by positive behaviors such as persistence and effort, and positive emotions such as curiosity and joy. Negative stress appraisals, or “threat appraisals,” are used when the perception of danger surpasses the perception of one’s abilities or resources to cope with the stressor (Lazarus et al., 1985; Jamieson, 2017). Threat is suggested to involve defending one’s self-worth, to disengage with positive behaviors, and to inflict negative emotions such as fear, anger, and anxiety. In the following sections, I support the operationalization of both challenge and threat stress appraisals with evidence from research on students’ academic stress and cognitive performance.

1.3.1 Threat Appraisals

Researchers in academic contexts have examined students psychological experiences of threat as a way to observe changes in stress responses (Jamieson et al., 2010; Jamieson, Peters, Greenwood, & Altose, 2016b; Schmader & Johns, 2003; Spencer, Steele, & Quinn, 1999; D. S. Yeager, Walton, et al., 2016). Building on previous definitions, researchers assert that threat elicits a negative stress response because the individual is faced with perceptions of having low resources compared to highly demanding tasks. A threat appraisal is a byproduct of stress that bidirectionally impacts the stress response system which proves counterproductive to learning and academic performance. For example, researchers examination of threat appraisals in cross-sectional and longitudinal designs with secondary-school students have showed that threat is related to higher test anxiety, higher academic performance-avoidance goals (avoid performing worse than classmates), lower intrinsic motivation, and poorer examination performance (Bedewy & Gabriel, 2015; Putwain, 2007). In experimental studies, researchers manipulated the feedback students received about a math task by describing said task as more of a challenge (e.g., you have the skills and knowledge to complete this difficult task) than a threat (e.g., you will be graded on your knowledge and skills to complete this difficult task). Math task performance was improved when students received the challenge-framed feedback, subsequently appraising the experience more positively as a challenge appraisal (Blascovich & Mendes, 2000; Tomaka et al., 1997).

1.3.2 Challenge Appraisals

In the same vein as research on threat, there has been a growing body of work examining the association between challenge appraisals and academic performance. Challenge appraisals are perceptions of high resources and low task demands; a byproduct of stress that positively feeds information back to the stress response system. Studies using stress appraisal manipulation as an intervention supported these findings, contending that—compared with threat—challenge appraisals are related to lower self-reports of stress and reports of greater self-confidence for academic performance outcomes on a mental arithmetic task (Blascovich et al., 2000; Jamieson et al., 2016a; Yeager, Lee, & Jamieson, 2016). Some research has been conducted on challenge appraisals in achievement situations, yet less work has examined their relation to learning (Jamieson, Peters, Greenwood, & Altose, 2016). Although prior studies have found associations between stress reduction (e.g., using a social stress task) and mindfulness training for adults

(Weger, 2012), fewer have reported on the mechanism of emotion regulation for stress (e.g., stress appraisals) that may be affected by mindfulness training. The question is, how do students appraise their stress and what do they learn? The present study aims to fill this gap and test whether mindfulness training may cause differences in the appraisal of stress and improve learning and academic performance outcomes.

1.4 Mindfulness Aids Emotion Regulation

Mindfulness training is one way to alleviate the negative effects of rumination and mitigate against threat appraisals (Bellinger et al., 2015; Weinstein, Brown, & Ryan 2009). Mindfulness, a construct with origins that can be traced back over centuries of nonsecular traditions in the East, is cultivated through the practice of meditation (Kabat-Zinn, 2003). A conscious mode of mindfulness is theorized to prevent one from allocating too much time to worrying and elaborating on ideas and conditions over which one has no control and is thought to provide one with an open and meaningful awareness of what is (Bishop et al., 2006; Kabat-Zinn, 2003). One way in which this is practiced is by giving a person guided verbal instructions to focus their attention, moment-by-moment, on conscious experience.

This study posits that mindfulness training may improve learning and performance outcomes by allowing one to attend to beliefs or attributes perceived as a skillset with an open awareness of one's coping skills (e.g., evaluating emotional significance) and regulatory strategies (e.g., determining control of the situation) (Garland, Gaylord, & Fredrickson, 2011). For example, perceived skillset can include an individual's effective use of coping skills and strategies that may lead one to identify enhanced resources (challenge appraisal) (Jamieson, 2017; Jamieson et al., 2016a), buffering against perceptions of exceeding demands (threat appraisal) (Chemers et al., 2001). In tandem, mindfulness protects against rumination, the production of negative thoughts that are repetitive and self-referential facing a stressor, especially if perceptions of enhanced skills are high (Garland, Farb, Goldin, & Fredrickson, 2015). In learning environments, I hypothesize mindfulness leads to two emotion regulation processes that are suggested to work in tandem, but that may also work alone 1) rumination reduction and 2) decreases in negative stress appraisals thus enhancing students use of challenge appraisals using positive thoughts and behaviors of excitement, determination, and effort to master the content. In sum, I predict that through mindfulness meditation, both focused attention and nonjudgmental awareness will aid students in their emotion regulation that allows for greater cognitive capacity and perceived skillset to make effective use of more positive stress appraisals. Rumination reduction may serve a proxy for use of positive stress appraisals, however, since little research has been conducted to suggest this claim, I explore the relation of rumination and stress appraisals. Reduced rumination is predicted to enable a student to become aware of the resources needed to cope with the academic demand subsequently improving their learning and performance outcomes.

1.5 The Effects of Brief Mindfulness Training

One area under debate in the literature concerns the length of training required to see the enhanced effects of mindfulness (Carmody & Baer, 2010; Van Dam et al., 2017). Past research has shown three to four, mindfulness sessions (five to ten minutes in length) can have an effect on emotion regulation and cognitive performance (Carmody & Baer, 2009; Gorman & Green, 2016; Creswell, in press). For example, a lab study examined the experimental effects of a brief mindfulness-based skill training on stress and mathematical performance. Weger et al. (2012) gave a five-minute mindful sensory task to women before they performed a mathematics test. Researchers induced stereotype threat as a form of acute stress with women in one group, providing them with threatening information about their identified gender's math "ability." Similar to the underlying cognitive effects of rumination—hypothesized to be a mechanism of stereotype threat—they predicted that stereotype threat consumes cognitive resources resulting in a cognitive load that disrupts the working memory processes needed to perform the mathematical calculations (Aronson, Fried, & Good, 2002; Good, Aronson, & Inzlicht, 2003; Steele, 1997). They found two central findings that support the claims raised in the present study: first, that even a short mindfulness training buffered reported levels of threat (i.e., stereotype threat) for women primed with the stereotype; second, they found that the training buffered against the negative performance effects of stereotype threat. More specifically, stereotype threatened women who underwent the mindfulness training ultimately performed better on the math test relative to women with no exposure to stereotype threat.

An important detail gaining traction in mindfulness-based research studies draws attention to the importance of examining the duration of mindfulness training required to elicit effects on specific cognitive and emotional processes, the same processes suggested to be involved in these examined constructs. For example, Zeidan et al. (2010) conducted four short training sessions over a few weeks with participants who had no prior meditation experience. They found that compared to the controls, brief mindfulness training promoted sustained attention and reduction in emotional reactivity (i.e., anxiety). Similarly, Josefsson, Lindwall, and Broberg (2014) conducted a study with brief mindfulness training across multiple sessions and found effects for participants' greater sustained attention and awareness.

These studies provide additional support for the effects that brief mindfulness training(s) may have on students' cognitive processes and emotion regulation skills, which the present study propose will facilitate better learning and performance. I intend to investigate the central features rooted in mindfulness meditation that may lead to enhanced effects of these processes and skills.

Lastly, a prior study conducted in our lab found effects for a brief mindfulness training (compared to an audiobook control group) on learning when controlling for prior knowledge and individual differences. Seventy-nine undergraduate students were assigned to one of two groups: a 20-minute mindfulness meditation training group or an audiobook control group, (i.e., controlling for verbal sensory information and attention). The design and materials of the current study were almost identical to this study, with the exception of new controls and adjusted placement of stress-induced feedback. These results showed the mindfulness meditation training group compared to the control group improved on the learning and performance of a challenging mathematics concept following a stressful learning experience.

1.6 Present Study

Mindfulness training may alleviate adverse psychological responses to academic stress by practicing nonjudgmental awareness of the present moment. I predict this training frees up cognitive capacity to regulate ruminative thoughts and feelings, enabling productive and positive interpretations of stressful feedback via challenge appraisals—and subsequently allows students enhanced control of an academic demand for successful learning and performance.

In this experiment, the mindfulness training audio consisted of verbal guided instructions that focused on attention to the present moment and nonjudgmental awareness of thoughts and emotions. This study used two comparison groups: guided attention to music and wakeful rest. The former was designed to control for the attention training the mindfulness meditation group received. Participants were trained on attention to certain elements of a given musical excerpt (e.g., “Listen to the drums and pay attention to the piano and saxophone playing at the same time”). Participants who were trained on the wakeful rest condition received no nonjudgmental awareness or attention training; they received instead instructions asking the participants to sit quietly and think about any thoughts that arose as mirrored in previous studies that examined its positive effects on memory and learning.

1.6.1 Hypotheses

The goal of this study is to examine the effects of a brief mindfulness meditation training on stress appraisals, rumination, and learning outcomes following a stressful academic induction. To the degree that focused attention and nonjudgmental awareness are both critical to learning under stress, after controlling for individual differences in mindfulness, emotional regulation, worry, math motivation, and prior knowledge, the central hypotheses are:

H1.) The mindfulness meditation group is predicted to show less self-reported rumination than the guided attention to music group. The latter is predicted to show less rumination than the wakeful rest group.

H2.) The mindfulness meditation group is predicted to show more positive stress appraisals (seeing a stressful situation as a challenge as opposed to a threat) than the guided attention to music group. The latter is predicted to show more positive stress appraisals than the wakeful rest group.

H3.) The mindfulness meditation group is predicted to show better learning and performance outcomes of novel math concepts relative to the guided attention to music group. The guided attention to music group is predicted to show better learning and performance outcomes than the wakeful rest group. Figure 1 represents the hypotheses as they relate to the measured outcomes of the study.

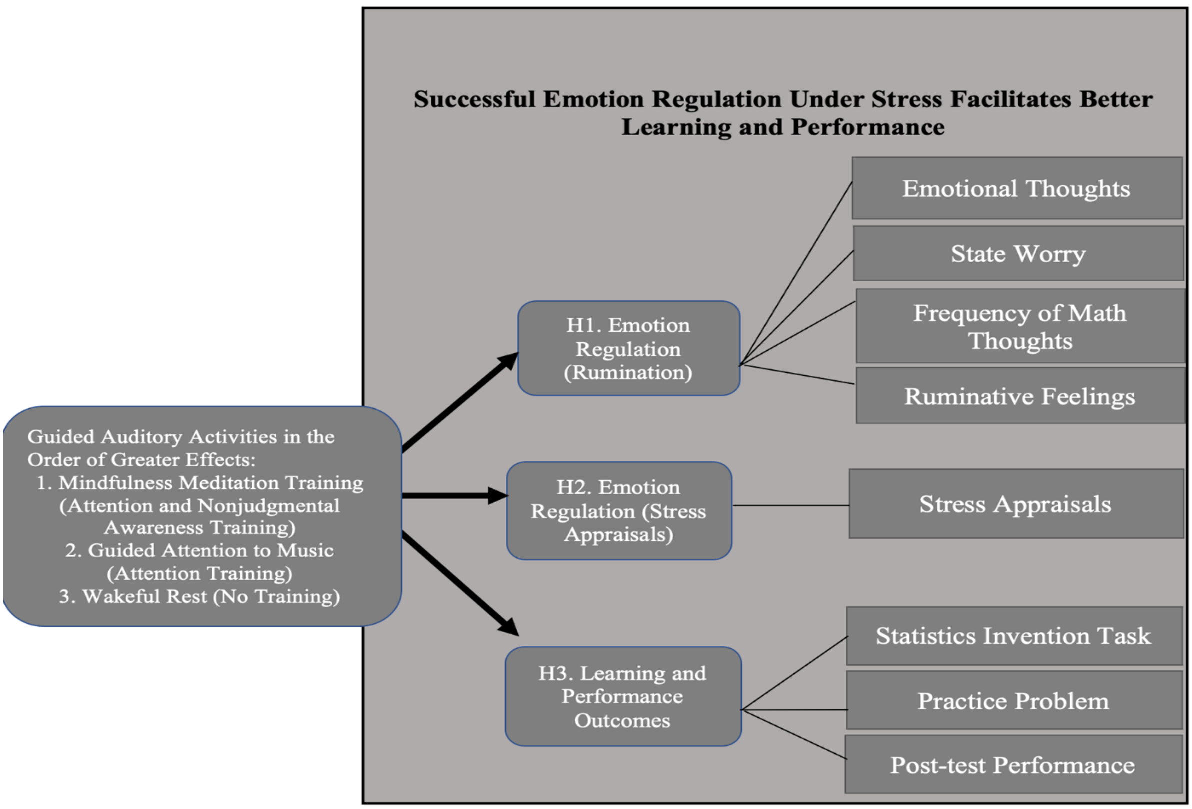


Figure 1. Graphical representation of the hypotheses.

2.0 Method

2.1 Participants

One hundred and eight undergraduate students aged 18–29 (*M* age = 19 years, *SD* =1.79) years old from the University of Pittsburgh agreed to participate for class credit. Data from four participants were excluded because either the participant(s) did not follow instructions or they experienced technical difficulties. Of the remaining 104 participants: 62% self-identified as women (38% as men); 67% as Non-Hispanic White; 8% as African American/Black; 10% as Asian Indian; 3% as Latino/a; 15% as Asian/Pacific Islander, 2% as American Indian/Native American, and 3% responded Other.

2.2 Design

The experiment had a between-subjects, pretest/post-test design with participants randomly assigned to one of three conditions: mindfulness meditation (n=33), guided attention to music (n=35), or wakeful rest (n=36). There were no significant differences between the conditions across any of the demographic variables including participants' gender, χ^2 (2, N=104) = 2.3, p = .31, or race, χ^2 (2) =3.9, p =.13. For both gender and race, dichotomous variables were created that included two groups: women and men for the gender variable and non-Hispanic White/underrepresented for the race variable. The materials and procedures were identical for all three conditions except for the guided auditory activities. Figure 2 shows a depiction of the experimental design.

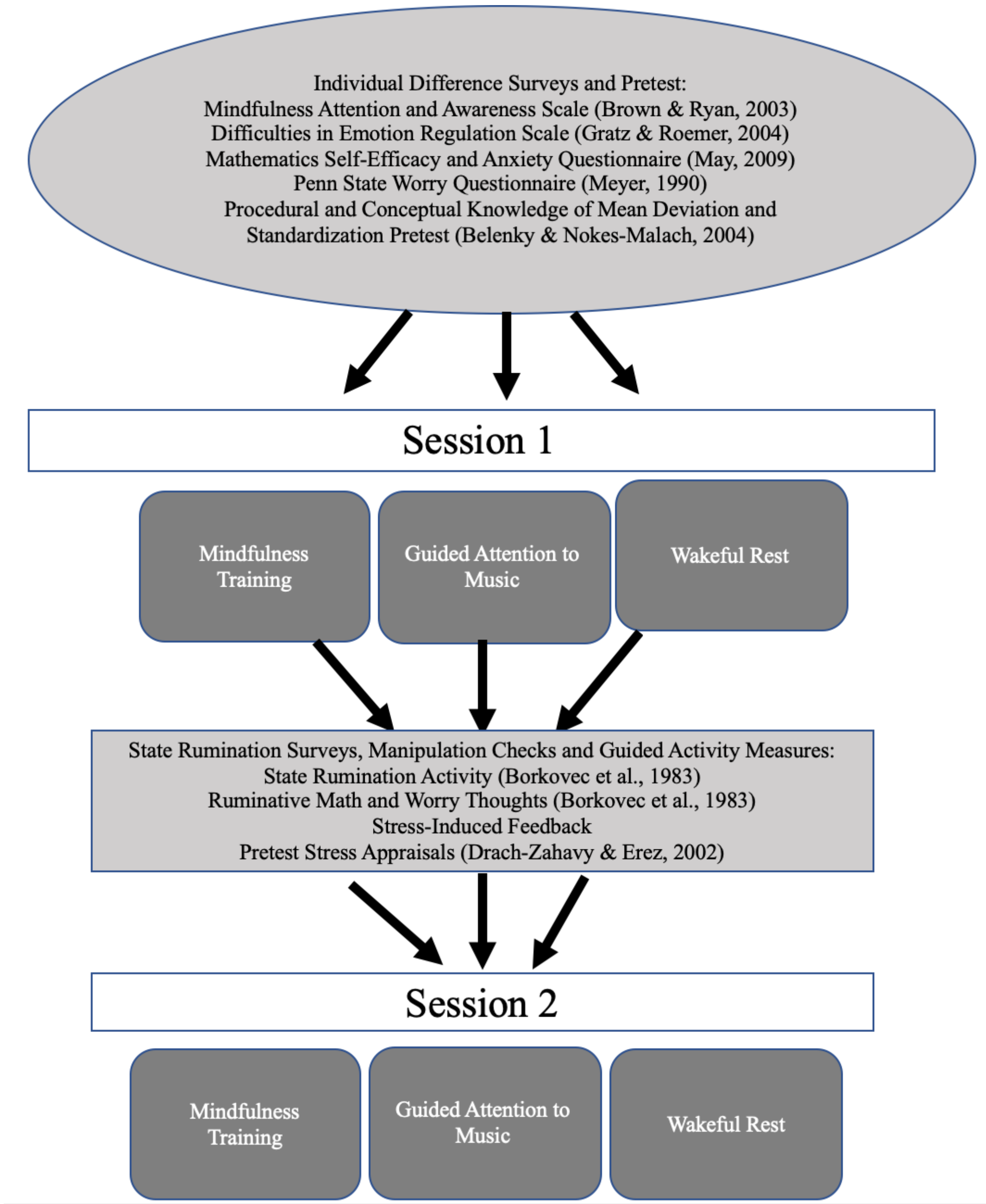


Figure 2. Design and procedure.

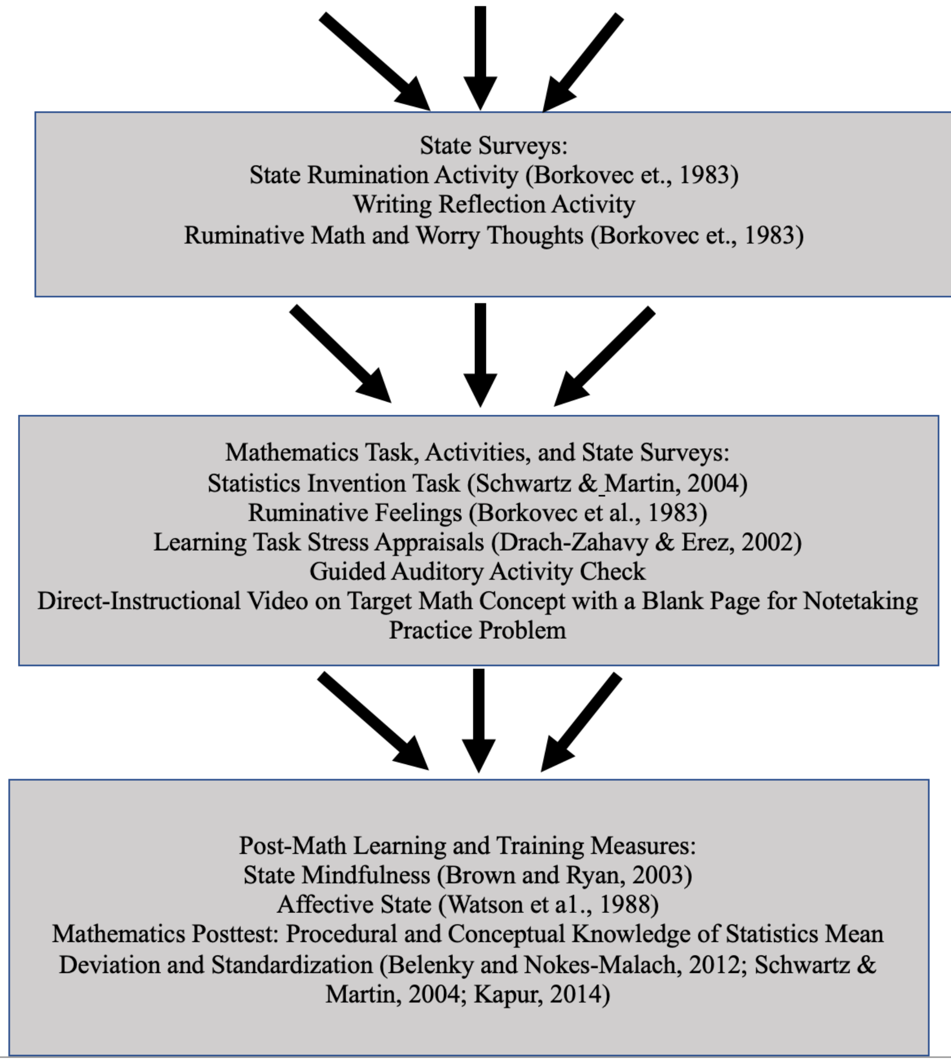


Figure 2. (continued)

2.3 Materials

Materials consisted of the following: self-report surveys, pre- and post-mathematics assessments, guided auditory activities, and mathematics learning tasks, instruction, and activities. The surveys, guided auditory activity instructions, tasks and activities, and mathematics video instruction were administered on a desktop computer via Qualtrics. The mathematics learning and assessment materials were administered with paper-and-pencil booklets. Participants were given calculators to use on the math assessments, instruction, and activities. Next, I describe the materials and assessments in the order the participants received them in the study.

2.3.1 Individual Difference Measures

Participants responded to the mindfulness and emotion regulation surveys using a six-point Likert scale from one (*almost never*) to six (*almost always*) and to the math self-efficacy and anxiety assessment and worry surveys using a six-point Likert scale from one *(strongly disagree)* to six *(strongly agree)*. To ensure items related to each other for the measurement of one construct, the number of items for each survey were reduced by selecting a subset of the most theoretically relevant / representative items in the literature that had the highest loadings on the construct dimensions. This strategy was employed to reduce potential survey fatigue and at the same time assess a number of constructs. Example items for each survey are presented in Table 1.

Table 1. Example Items from the Individual Difference Surveys

Self-Report	Item Example
Trait mindfulness	1. I could be experiencing some emotion and not be conscious of it until sometime later. 2. I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.
Emotion regulation	1. When I'm upset, I become embarrassed for feeling that way. 2. When I'm upset, I become irritated with myself for feeling that way.
Math self-efficacy and anxiety	1. I believe I am the type of person who can do mathematics. 2. I feel confident when taking a mathematics test. 3. I worry that I will not be able to do well on mathematics tests. 4. I worry that I will not be able to get a good grade in a mathematics course.
Trait worry	1. My worries overwhelm me. 2. Once I start worrying, I cannot stop.

Mindfulness. To assess individual differences in mindfulness, ten (10) items from the 15-item Mindfulness Attention Awareness Scale (MAAS) were selected (Brown & Ryan, 2003). These items measure one's tendency towards open-minded awareness and deliberate attention to the present moment of internal and external experiences. One item was dropped because it had low reliability (Cronbach's α=.13) and did not strongly relate to the other items ("I find myself listening to someone with one ear, and doing something else at the same time"). This item appears to focus on the attentional aspect of multi-tasking rather than attending to the present moment. After dropping the item, the nine-item survey approached adequate reliability (Cronbach's α=.67).

Emotion regulation. To examine individual differences in emotion regulation, nine (9) items were selected from the 41-item Difficulties in Emotion Regulation Scale (DERS) (Gratz & Roemer, 2004), which included awareness, attentional control, and behaviors of negative emotions. One item was dropped because reliability was low (Cronbach's α=.10) ("When I'm upset, I take time to figure out what I'm really feeling"). After dropping the item, the eight-item (8) survey had adequate reliability (Cronbach's α=.75).

Math self-efficacy and anxiety. To assess individual differences in math-related affect, seven (7) items from the Math Self-Efficacy and Anxiety Questionnaire (MSEAQ) (May, 2009) measured two dimensions across a single construct, motivation and anxiety in math, which resulted in high reliability (Cronbach's α=.91).

Trait worry. To measure individual differences in unmanageable and overwhelming worry, seven (7) items were adapted from the 16-item Penn State Worry Questionnaire (PSWQ) (Meyer et al., 1990) (Meyer, Miller, Metzger, & Borkovec, 1990) which showed high reliability (Cronbach's α=.91).

2.3.2 Procedural and Conceptual Prior Knowledge of Math Concepts

Mathematics pretest. The mathematics pretest consisted of four statistics problems adapted from previous studies on learning and knowledge transfer (Belenky & Nokes-Malach, 2012; Schwartz & Martin, 1988). For the first two problems, participants received a series of numbers and were asked to calculate the mean and mean deviation. Each problem was scored as either incorrect or correct for a total of two (2) points, with participants earning one (1) point for calculating the mean and mean deviation, respectively. The third problem was a word problem that included summary scores and asked participants to calculate the mean deviation. Participants' calculations of mean deviation were scored, and up to three (3) points were awarded. The fourth problem was a word problem testing standardization. In this problem, participants were provided a mathematical observation, mean, and average deviation of scores from two separate distributions and asked to compare them to determine which score was more extreme. Participants could earn 1 point by naming the correct player with the more extreme score and two (2) points for accurately calculating standardized scores for a total of three (3) possible points. This problem was isomorphic to a post-test problem that had a different cover story (see Appendix A).

2.3.3 Guided Auditory Activities

Participants received one of the following three audio activity instructions: mindfulness meditation, guided attention to music, or wakeful rest. Each consisted of two eight-minute sessions that were described as "guided auditory activities." See Table 2 for a summary of these activity instructions.

Mindfulness meditation. The mindfulness meditation guided audio training was adapted from a previous study on mindfulness and stress (Lindsay, Young, Smyth, Brown, & Creswell, 2018b). Participants were instructed to develop moment-to-moment attention of their breath during the first 8-minute session and nonjudgmental awareness on their emotional states during the second 8-minute session. For example, participants were encouraged to: "Bring an open curiosity to your emotional experience…There is no need to try and change anything; observe what is there. By noticing what emotions are present and not judging them, you can develop a new relationship with your emotions."

Guided attention to music. Participants in the guided attention to music condition were guided over instructional audio designed by the current study's lab to train focused attention on different aspects of their moment-to-moment experience without practicing nonjudgmental awareness. For example, participants were told to: "Pay attention to the drums…focus only on the drums. Bring your attention back to the string instruments. Pay attention to the ups and downs played by the string instruments."

Table 2. Summary of Guided Auditory Activities Instructions

Guided Auditory Activity	Session 1: Instruction	Session 2: Instruction
Mindfulness meditation	Focus attention on physical sensations and breathing in one's present experience.	Focus attention on emotion regulation with nonjudgmental awareness of one's present experience.
Guided attention to music	Focus attention on features of the music.	Focus attention on features of the music.
Wakeful rest	Sit quietly, thinking about whatever comes to mind, and remain awake.	Sit quietly, thinking about whatever comes to mind, and remain awake.

Wakeful rest. Participants in the wakeful rest auditory activity condition received audio instructions to stay awake and think about whatever they wanted to (Dewar, Alber, Butler, Cowan, & Della Sala, 2012). For example, participants were told: "You can think about whatever you want. We ask that you stay awake and sit quietly until the next activity." Importantly, unlike the mindfulness and guided attention to music groups, participants in the wakeful rest group were not given any training on focusing their attention to the present moment. Similar to the guided attention to music group, participants were also not provided with any practice in nonjudgmental awareness of their emotional state.

2.3.4 State Rumination Activity, Thoughts Check, and Guided Auditory Activity Measures

State rumination activity. To measure rumination during the guided auditory activities, a self-report state survey of rumination was adapted from well-established studies on worry and rumination (Nolan-Hoekesema, 2000; Borkovec, Robinson, Pruzinsky, & DePree, 1983). Twice during each guided auditory activity session, participants were instructed via a prompt to write down whatever topic they were thinking about at that moment. This was followed by an emotionally valanced item to rate the content of their thinking as negative, neutral, or positive. See Table 3 for the prompts and example items of this survey.

Ruminative math and worry thoughts. After each eight-minute guided auditory activity session, participants were asked four items that assessed the amount of effort on the activity and frequency of the following: mind wandering, general worry, and performance on the math pretest (adapted from Borkovec et al., 1983). To examine participants' rumination about math performance and global worry, the only items that were analyzed were those related to the assessment of rumination including: frequency of worry ("Estimate the percentage of time you worried during the last eight (8) minutes.") and the frequency of math performance thoughts ("How much did you think about your performance on the math test in the last eight (8) minutes?"). Participants responded to the frequency of worry item using a percentage scale from zero *(None of the time)* to one hundred *(All of the time)*. For the frequency of math thoughts, participants responded using a six-point Likert scale from one *(Almost never)* to six *(Almost always)*. See Table 3 for the items of this survey.

Writing reflection activity. After the second guided auditory activity session, participants were prompted to report on what they learned from the guided auditory activities. In addition, they were asked to reflect on and write down how they might apply what they learned in a challenging academic situation. This was a writing exercise designed to further support interventions utility and value in implementation. Given the purpose of the current work, these data will not be discussed. See Table 3 for the prompts.

Guided auditory activity check. After the second guided auditory activity session, participants in all conditions were asked to answer a set of items designed by the lab to measure the trained features of mindfulness as an attention and engagement check. These items captured the following: acceptance of distractions, focused awareness and presence on their moment-to-moment experience, letting go of thoughts, and developing nonjudgmental awareness. Participants responded to the survey from one *(strongly disagree)* to six *(strongly agree)* and with moderate internal reliability (Cronbach's α=.60). See Table 3 for the example items of this survey.

2.3.5 Stress-Induced Feedback and Pretest Stress Appraisals Measure

Stress-induced feedback. Participants were provided written feedback on their scored mathematics pretest performance to review immediately after the first guided auditory activity that stated: "Your score on the test was X (participant's raw score) out of 10. The criterion for passing this test was nine (9) points and many students who take this test pass this criterion." False feedback served to reinforce potential feelings of failure on the pretest assessment and examine subsequent stress appraisals (see Appendix B).

Pretest stress appraisals. The pretest stress appraisals survey consisted of six (6) items adapted from a 12-item survey, in which performance on the pretest was described as either challenging (i.e., ability, low demands) or threatening (i.e., inability, high demands) (Drach-Zahavy & Erez, 2002). Participants responded on a six-point Likert scale from one *(strongly disagree)* to six *(strongly agree)*. Due to the low internal reliability of the items (Cronbach's α=.11), the structure of this measure was assessed and the number of constructs were determined using an exploratory factor analysis conducted in *SPSS*. Although the sample size was small and unlikely to have enough power for an adequate factor analysis, an exploratory factor analysis was conducted in which a single-factor model was compared with a two-factor model to determine whether challenge and threat are separable. To extract the number of factors, the Guttman-Kaiser criterion approach was used. This approach yielded the optimal number of factors for these data with eigenvalues greater than 1.0 for the correlation matrix (Guttman, 1954; Kaiser, 1991). In addition, the Parallel Analysis recommended a two-factor solution for the appraisal items, and the scree plot indicated a two-factor solution: challenge and threat.

To assess challenge (four items) and threat (two items), appraisal responses were averaged for each construct separately. For the challenge appraisals, one of the items was removed from the four-item appraisal survey because it had very low item-to-construct reliability and the measurement was not aligned with the other items as participants likely misinterpreted the meaning of this question to imply a different, perhaps negative association to the word challenge ("The math test seemed like a challenge to me"). After dropping this item, the three-item challenge appraisal survey (Cronbach's α=.43) improved in reliability. For threat appraisals, two (2) items were included in the survey (Cronbach's α=.80) and had adequate reliability. See Table 3 for the example items of this survey.

Table 3. Example Items Measuring Rumination, Guided Auditory Activity Engagement, and Stress Appraisals

Self-Report	Example items
State rumination activity	1. What is the topic you are thinking about *RIGHT NOW? No more than one sentence.* 2. Please rate the thought(s) above.
Ruminative math and worry thoughts	1. How effortful was this activity? 2. Estimate the percentage of time you worried during the last eight (*8) minutes* (from 0%=none of the time to 100%=all of the time). 3. Estimate the percentage of time your mind wandered during the last eight (*8) minutes* (from 0%=none of the time to 100%=all of the time). 4. How much did you think about your performance on the math test in the last eight (*8) minutes*?
Writing reflection activity	1. What did you learn from this guided auditory activity? 2. How might this activity help you in a challenging or difficult academic situation?
Guided auditory activity check	1. When engaged with this activity, I practiced letting go of distracting thoughts. 2. When engaged with this activity, I practiced focusing on the here and now.
Pretest stress appraisals	1. The math test seemed like a challenge to me. 2. The math test provided me an opportunity to strengthen my self-esteem. 3. The math test seemed like a threat to me. 4. The math test threatened my self-esteem.

2.3.6 Learning Materials, Ruminative Feelings, and Learning Task Stress Appraisal Measures

The learning materials consisted in three activities about mean deviation, including an invention task, direct-instruction video, and a practice problem (see Appendices C, D, and E). A rubric was made to assess the various tasks and activities and score participants responses as incorrect or correct. The coding reliability was high for each learning activity (k > .80).

Disagreements were resolved via discussion, and the rubric was revised accordingly. The remaining data were coded by the primary rater.

Statistics invention task. This task provided participants with the opportunity to learn about the conceptual features of mean deviation (Belenky & Nokes-Malach, 2012; Schwartz & Martin, 1988). Participants received raw data from four different pitching machines presented on grids and were asked to invent a procedure for computing a quantity that expressed the reliability index for each machine. Participants were first asked their initial guess regarding which one they found most reliable, followed by what types of information they predicted would be necessary to arrive at that conclusion. Lastly, they were asked to invent a mathematical procedure to determine which of the machines was most reliable. This served as a learning task for several reasons. First, the statistics invention task has been shown to facilitate conceptual learning and knowledge transfer of mean deviation (Belenky & Nokes-Malach, 2012). Second, although it is associated with preparing participants to learn from subsequent direct instruction, the process of constructing an equation is challenging and may be interpreted in different ways. Therefore, I hypothesize that this type of open-ended learning task might lead to stress and prompt different kinds of stress appraisals among the participants in each condition. The invention task was scored based on the number of conceptual features participants accurately noted, one (1) point per feature (accuracy, precision, and the number of pitches) for a total of three (3) points. To calculate reliability, their invention of a mathematical procedure was scored (regardless of whether that procedure was ultimately correct or not), and they received one (1) point for each data set to which they applied it for a total of four points (see Figures 3 and 4; Appendix C).

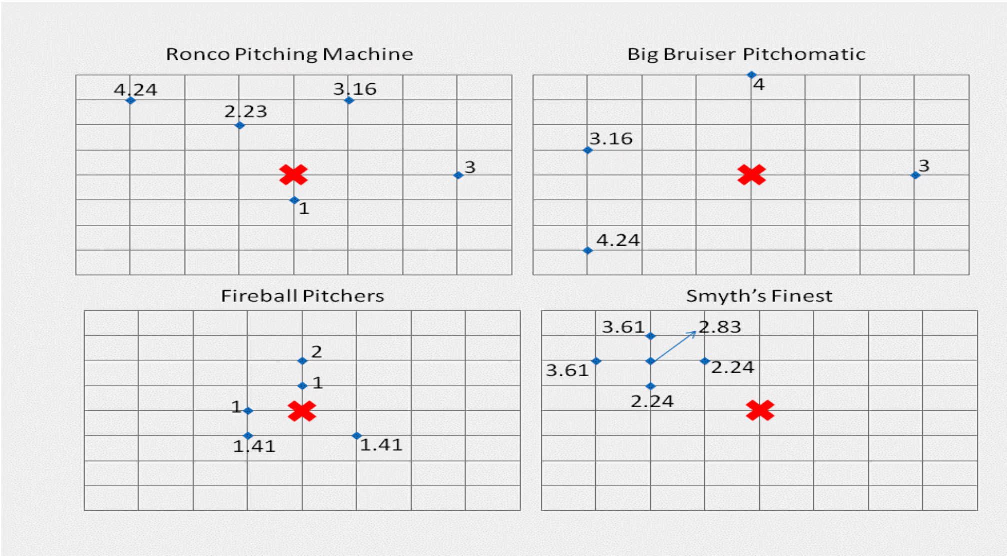


Figure 3. Image of the data sets given in the statistics invention task.

Adapted from Schwartz and Martin (2004, p. 135).

2. A standardized score helps us compare different things. For example, in a swim meet, Cheryl's best high dive score was an 8.3 and her best low dive was a 6.4. She wants to know if she did better at the high dive or the low dive. To find this out, we can look at the scores of the other divers and calculate a standardized score (see Table C1).

To calculate a standardized score, we find the average and the mean deviation of the scores. The average tells us what the typical score is, and the mean deviation tells us how much the scores varied across the divers. Table C2 presents the average and mean deviation values.

The formula for finding Cheryl's standardized score is her score minus the average, divided by the mean deviation. We can write:

$$\frac{\textbf{Cheryl's Score} - \textbf{average score}}{\textbf{Mean deviation}} \quad \textbf{or} \quad \frac{\textbf{X} - \textbf{M of } x}{\textbf{M deviation of } x}$$

Table C1

Diver	High Dive	Low Dive
Cheryl	8.3	6.4
Julie	6.3	7.9
Celina	5.8	8.8
Rose	9	5.1
Sarah	7.2	4.3
Jessica	2.5	2.2
Eva	9.6	9.6
Lisa	8	6.1
Teniqua	7.1	5.3
Aisha	3.2	3.4

Figure 4. The learning resource on standardization.

Adapted from Schwartz and Martin (2004, pp. 177–178).

Ruminative feelings. A three-item survey of ruminative feelings was administered in the study. One item was adapted from a state survey of uncontrollable and pervasive worry (Borkovec et al., 1983). Two items measuring frustration and stress were developed by the lab to capture the perceptions of participants' affect during difficult learning experiences. Participants were asked to answer these questions midway through the statistics invention task, and once the participants completed the questions, the experimenter prompted them to return to the task. Participants responded to these items using a six-point Likert scale from one *(strongly disagree)* to six *(strongly agree)* with adequate reliability (Cronbach's α=.87). See Table 4 for example items.

Learning task stress appraisals. To measure the stress appraisals that occurred during the statistics invention task (almost identical to the pretest appraisals survey), a six-item version of the survey was administered and focused only on the average responses for the two constructs: challenge (three items) and threat (two items) separately. For the challenge stress appraisal measure, one of the items was eliminated from the three-item survey because it had very low reliability and was not aligned in measurement with the other items as participants likely misinterpreted the meaning of the item ("The statistics invention task seemed like a challenge to me"). After removing it, the two-item survey (Cronbach's α=.63) improved with adequate reliability. For the threat stress appraisal measure, two (2) items were included in the survey (Cronbach's α=.85) and had adequate reliability. See Table 4 for example items.

Direct-instruction and practice problem. Direct-instruction served as a learning opportunity for the math target concept and consisted of a narrated PowerPoint video that taught participants about the mean deviation formula demonstrated through a worked example. Following the direct-instruction worked example, participants practiced what they learned with a practice problem on paper, during which they had the option to re-watch the video while they completed the practice problem. This problem was scored as either incorrect or correct, with participants earning one point for accurately calculating mean deviation for each problem, and then one point for naming which one had the smallest mean deviation for a total of three points (see Appendixes D and E).

2.3.7 Post-Learning and Performance

Mathematics post-test. The mathematics post-test consisted of six (6) statistics problems. The first problem was a multiple-choice question that assessed participants' understanding of the relationship between mean deviation and consistency. The question was scored with one point for correct responses or no points for incorrect responses. The second problem was a worked example on standardization adapted from previous learning studies (Belenky & Nokes-Malach, 2012; Schwartz & Martin, 1988) Schwartz & Martin, 2004. This problem described the steps to calculate a standardized score with an illustrative example followed by an example problem. The problem was scored as either incorrect or correct; one point for correctly calculating each standardized score and one (1) point for selecting the highest score for a total of three (3) points. For the third problem, participants were given five data sets and asked questions about which data set(s) had the smallest, largest, and identical mean deviations. They could earn up to three (3) points for correct answers; one (1) point for each sub-question. For the fourth problem, participants received a word problem on standardization. This was an isomorphic problem to the standardization question on the pretest. Participants could earn a total of three (3) points for correct answers, one (1) point for identifying the answer, and (1) point for calculating each standardized score.

This problem is a strong test of knowledge transfer because the participants needed to recognize not only what type of problem it was (i.e., standardization not mean deviation), but also that the procedure learned earlier in the test needed to be applied to this situation in order to correctly solve it. The fifth and sixth problems were adapted from Kapur's (2014) study on learning and transfer from failure. For the fifth problem, participants were given a word problem that provided the number of observations, mean, and mean deviation. Participants were asked a variety of questions about changes to the mean and mean deviation if the observations were changed in particular ways (i.e., each number increased by 2 or multiplied by 5). The problem was scored as either incorrect or correct, 1 point for each sub-question for a total of four (4) points. For the sixth problem, participants received a word problem on standardization that included a set of observations, means, and mean deviations for three separate distributions, and they were asked to compare them to determine the best and worst performance. Participants' responses were scored as incorrect or correct, with one (1) point for answering each sub-question for a total of two (2) points (see Figure 5 and Appendix F)

> **Driving Test**
>
> Susan and Robin are two teenagers who both just took their state driver's license road test. They are arguing about who got a better score on their test, which is scored out of 100 possible points. Susan got an 88 taking the driving test with Mr. Wheelie. The mean score Mr. Wheelie gave out that day was a 74, and the mean deviation was 12 points. The mean deviation indicates how close all the people taking the test were to the average. Robin earned an 82 on Mrs. Axel's driving test. On that day, the mean score Mrs. Axel gave out was a 76, and the mean deviation was four (4) points. Both Mr. Wheelie and Mrs. Axel tested one hundred teenagers that day. Who do you think did better, Susan or Robin? Use math to help back up your opinion. Please use scrap paper if you need additional space for your calculations or graphs.

Figure 5. One of two isomorphic transfer post-test problems.

Adapted from Schwartz and Martin (2004, p. 135).

2.3.8 Post-Training Measures

State mindfulness. For the mindfulness state survey, a five-item version of the 15-item MAAS (Brown & Ryan, 2003) was adapted for this study. These items measured open-minded awareness and attention to the present moment and showed adequate reliability (Cronbach's α=.79). Participants responded to the survey using a six-point Likert scale from one (1) *(strongly disagree)* to six (6) *(strongly agree)*. See Table 4 for example items.

Table 4. Example Items Measuring Rumination, Stress Appraisals, State Mindfulness, and Affect

Self-Report	Item Example
Ruminative feelings	1. I am worried that I am performing poorly on this statistics invention task. 2. I am frustrated that I am not making progress on this statistics invention task.
Learning task stress appraisals	1. The statistics invention task seemed like a challenge to me. 2. The statistics invention task provided me an opportunity to strengthen my self-esteem. 3. The statistics invention task threatened my self-esteem. 4. The statistics invention task seemed like a threat to me.
State mindfulness	1. I was finding it difficult to stay focused on what was happening. 2. Throughout the learning activities, I found myself not paying attention at times.
Affective state	1. During this study I have felt INTERESTED. 2. During this study I have felt EXCITED.

Affective state. The Positive and Negative Affect Schedule (PANAS) is a twenty-item survey that measures the general mood state for positive and negative affect (Watson, Clark, & Tellegen, 1988). This commonly used psychological survey includes both subscales for positive affect (Cronbach's α=.87) and negative affect (Cronbach's α=.83), both of which showed adequate reliability. Participants responded to these items using a six-point Likert scale from one (1) *(very slightly or not at all)* to six (6) *(extremely)*. See Table 4 for example items.

2.4 Procedure

Participants were first given five (5) minutes to complete a set of individual difference surveys related to dispositional features of mindfulness, emotion regulation, a combined measure of mathematics self-efficacy and anxiety, and worry. Following the surveys, participants were given ten (10) minutes to complete a mathematics pretest on mean, mean deviation, and standardization. After the pretest, participants were randomly assigned to one of three guided auditory activities either mindfulness meditation, attention to music, or wakeful rest. In each condition, participants received two eight-minute training sessions.

During the first session, at the two-minute and four-minute mark, all participants were asked to answer the rumination survey about the content and the emotional valence of their thought(s). After the first auditory training session, everyone was given two (2) minutes to complete a survey that asked them to assess their thoughts during the activity (e.g., frequency of worry and thoughts about math test performance). Participants then received written feedback on their pretest score designed to induce stress. After the feedback, participants took four (4) minutes to complete a stress appraisal survey.

Participants then began the second eight-minute guided auditory activity session. During this session, they again answered thought items assessing rumination at two (2) and four (4) minutes. Next, participants took four (4) minutes to complete another battery of four questions about general worry and frequency of thoughts about the math test, and in addition, answered open-ended prompts about what they learned and how they might apply the use of the guided auditory activity in a challenging academic situation. Following this, all participants were given four minutes to complete a guided auditory activity check survey to assess the degree to which they engaged and focused on the activity and also used elements of attention and nonjudgmental awareness.

After completion of the second session, they were given ten (10) minutes to finish the statistics invention task. Five minutes into the task, participants were asked to fill out a one-minute rumination survey assessing their thoughts and feelings about the task. Following the completion of the statistics invention task, participants were given four minutes to complete a stress appraisal survey. Next, participants received a learning activity on mean deviation—the target concept previously assessed in the task—through a direct-instruction video three-and-a-half (3.5) minutes in length. Upon completion of the video, they were given five (5) minutes to complete a practice problem.

Participants were then given 25 minutes to complete a mathematics post-test on the target concept of mean deviation and knowledge transfer of standardization. Following the post-test, participants were provided with 5 minutes to complete a set of surveys on mindfulness and affect and a demographic assessment. Prior to completion of the experiment, participants were fully debriefed and told that their performance on the pretest assessment was, in fact, similar to that of the average participant (i.e., that vast majority does not score nine points or above). Figure 2 shows an overview of the procedure.

3.0 Results

To test the effect of the mindfulness meditation training on emotion regulation and learning outcomes, I conducted analyses of covariance (ANCOVAs) controlling for participants' pretest scores and individual difference measures. I predicted greater positive effects on measures of rumination reduction, positive stress appraisals, enhanced learning and performance. I expected group differences in descending order with greatest effects attributed to mindfulness training, followed by guided attention to music, then wakeful rest on rumination reduction, positive stress appraisals, and better learning outcomes.

First, I conducted a set of MANOVAs for each individual difference measure and pretest assessment of prior knowledge using condition as the independent factor to test for differences between condition groups. For this preliminary analysis, I predicted there would be no differences among the groups for each measure.

I set the alpha level at .05 and report effects for *p* values less than .05 and marginal differences for *p*-values less than .10 (Keppel & Wickens, 2004). Assumptions underlying ANCOVAs and ANOVAs were tested. The homogeneity-of-variance assumption was violated in one ANCOVA. However, this test is typically robust to such violations when the sample size is moderately large ($n > 10$) and the groups are approximately equal, as they are in this study (Keppel & Wickens, 2004; pg.149). There were no other assumption violations. Importantly, the homogeneity-of-regression assumption held for all analyses. For all effects, I report effect sizes (Cohen's *d* or partial eta squared, $\eta^2 p$). I interpret effects as: small when $\eta^2 p < 0.06$ or $d < 0.2$; medium when $0.06 < \eta^2 p < 0.14$ or $0.2 < d < 0.8$; and large when $\eta^2 p > 0.14$ or $d > 0.8$ (see Cohen, 1988; Olejnik & Algina, 2000).

3.1 Individual Difference Surveys

I begin by testing whether the mean individual difference measure scores of mindfulness, emotion regulation, self-efficacy and anxiety, and trait worry differ by condition. Figure 6 shows descriptive results for each group's average endorsement of a specific construct. I conducted a multivariate ANOVA with the condition as the independent variable and the average responses on each of the four individual difference measures as the dependent variables. Analyses showed there were no significant differences across the three groups, Wilks' λ F (10,194) = .98, p >.05.

Results of the Pearson correlations indicated small to moderate positive correlations across the constructs (see Table 5). Each of these was rescaled for positive outcomes. Higher scores on one individual difference measure were associated with higher scores on another individual difference measure.

Table 5. Correlations Between the Four Individual Difference Measures of Trait Mindfulness, Emotion Regulation, Math Self-Efficacy and Anxiety, and Trait Worry

Variable	1	2	3	4
1. Trait mindfulness	—			
2. Emotion regulation	.49**	—		
3. Math-self efficacy and anxiety	.21*	.23*	—	
4. Trait worry	.51**	.65**	.31**	—

.

Note. 1. Trait Mindfulness=Mindfulness Attention Awareness Scale (MAAS); 2. Emotion Regulation = Difficulties in Emotion Regulation Scale (DERS); 3. Math Motivation and Anxiety=Math Self-Efficacy and Anxiety Questionnaire (MSEAQ); 4. Trait Worry=Penn State Worry Questionnaire (PSWQ). Each of these was rescaled for positive outcomes. All values are statistically significant at *p < .05 and *p < .01.

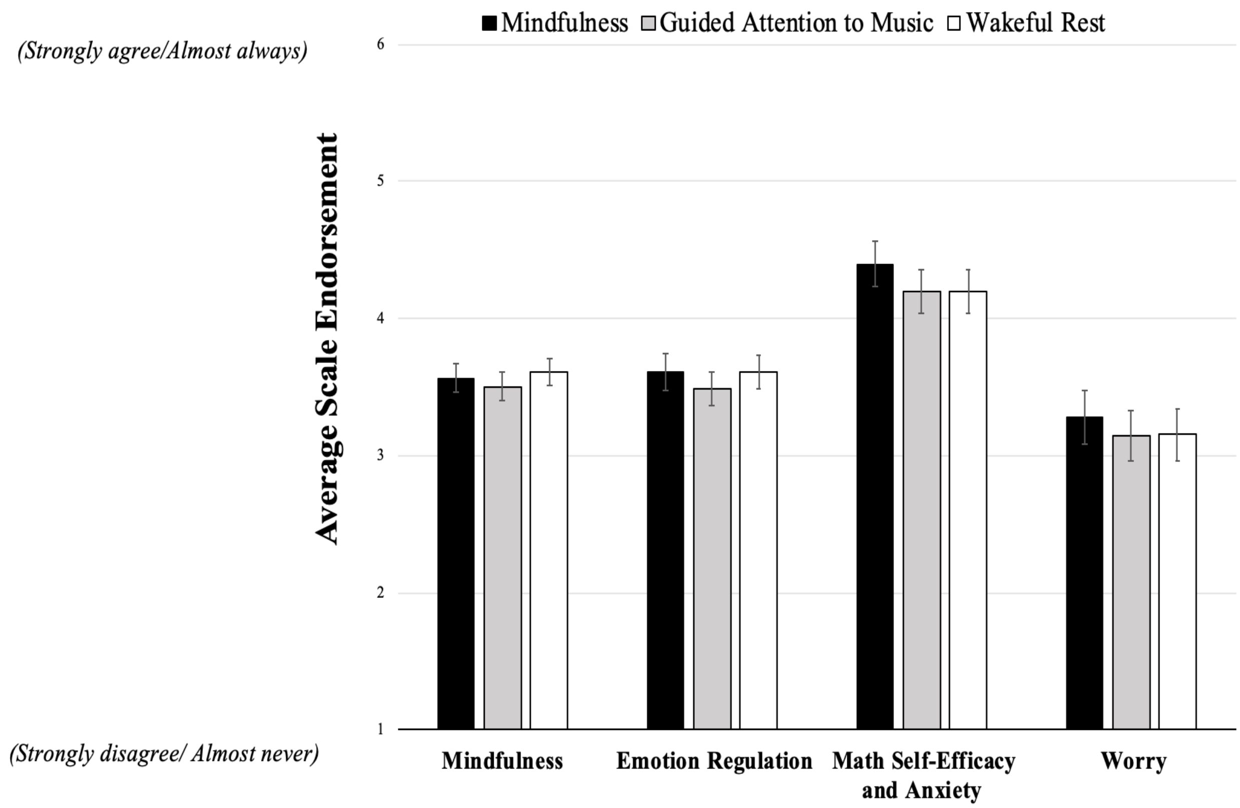


Figure 6. Average endorsement of individual difference measures. Trait Mindfulness=Mindfulness Attention Awareness Scale (MAAS), Emotion Regulation Difficulties in Emotion Regulation Scale (DERS), Math Self-Efficacy and Anxiety=Math Self-Efficacy and Anxiety (MSEAQ), Trait Worry=Penn State Worry Questionniare (PSWQ) for each group (mindfulness, guided attention to music, wakeful rest) by condition. Error bars represent one standard error of the mean.

3.2 Mathematics Pretest Performance

To determine whether the groups differed in their prior statistics knowledge, I compared their performance on the pretest. I used the four-problem pretest and divided the questions into sub-scores to assess the problem type of the following: mean, mean deviation, and standardization, respectively. For the pretest score on the mean, mean deviation, and standardization scores on the pretest using the Kruskal-Wallis *H* Test, there were no main effect of group, χ^2's (2, *N*=104) < 1.1, *p's* < .58. This shows that the groups did not significantly differ in their performance on the pretest, suggesting they had similar prior knowledge of mean, mean deviation, and standardization concepts. For descriptive results of the pretest overall score and problem type see Figure 7.

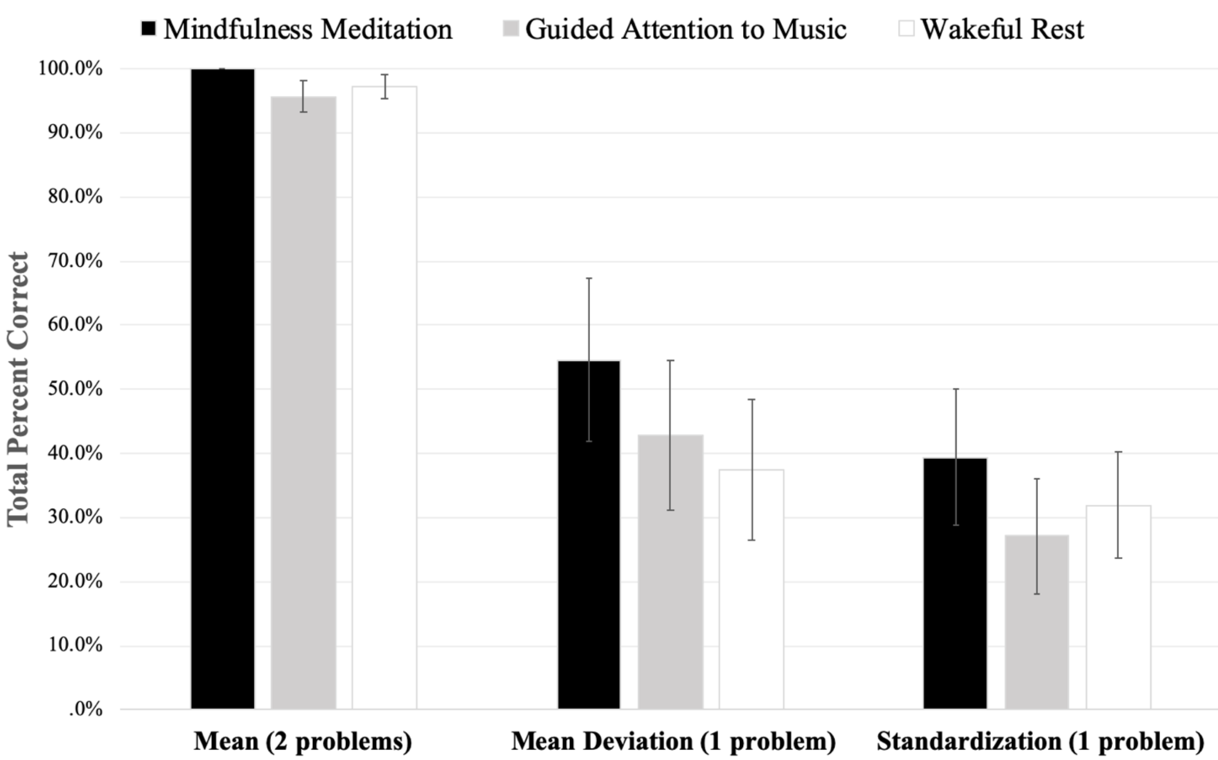


Figure 7. Total percent correct scores for pretest by problem type for each group. Two questions with two parts consisting of mean and mean deviation problems were scored as incorrect or correct for a total of four (4) possible points. From these questions, the results only include the two mean part problems for a total of two (2) possible points. One mean deviation problem was scored from zero (0) or three (3) points (zero points for incorrect responses or a full three points for correct responses). One standardization problem was scored from zero to three points (up to three points for partial or correct responses). Error bars represent one standard error of the mean.

Differences in rumination.

H1.) Participants in the mindfulness meditation group will report the greatest positive effects in reduction of rumination, followed by the guided attention to music group and then the wakeful rest group.

Here I examined whether the condition affected participants' rumination. The measurement of rumination had four subcomponents which included endorsements of the following: emotional valence, ruminative feelings, worry, and frequency of thoughts about math performance.

3.2.1 Emotional Thoughts Label

The emotional thoughts label scale assessed the valence of the ruminative thoughts participants report during two different time points (at the two- and four-minutes mark). The valence of one's thought content was measured using the following scale: one (*negative*), two (*neutral*), and three (*positive*), where higher scores indicate more positive emotion and lower scores more negative emotion. In Figure 8, I collapsed across both the two- and the four-minute mark of each session to include two composite sum scores for both guided auditory activity sessions.

I conducted a two (2) (session: one vs. two) X three (3) (condition: mindfulness meditation, guided attention to music, and wakeful rest) mixed-design ANCOVA. The results showed no significant effects of the covariates: pretest, trait mindfulness, emotion regulation, math self-efficacy and anxiety, or trait worry ($F's < .26$, $p's > .05$). Analyses showed a medium effect of condition, $F(2, 96) = 8.4$, $p = .001$, $\eta^2 p = .15$, meaning there were significant differences between groups. There was also a small effect of session, $F(1, 96) = 4.9$, $p = .03$, $\eta^2 p = .05$. This reflected that participants ratings were more positive in the first session than in the second. These effects were qualified by a small interaction of session by condition, F (2, 96) = 4.0, p =.02, $\eta^2 p$ = .08, indicating the change in ratings of positive emotion from session one to session two differed according to the condition.

Following up on this interaction, pairwise comparisons with Bonferroni corrections were used in order to determine differences between groups over time. This test indicated positive emotion significantly decreased for the guided attention to music group from session one to session two (Session 1: *M* = 2.6, *SD* =.45; Session 2: *M* = 2.1, *SD* =.54) whereas mindfulness meditation (Session 1: *M* = 2.1, *SD* =.37; Session 2: *M* = 2.0, *SD* =.53) and wakeful rest (Session 1: *M* = 2.0, *SD* =.50; Session 2: *M* = 2.0, *SD* =.56) did not.

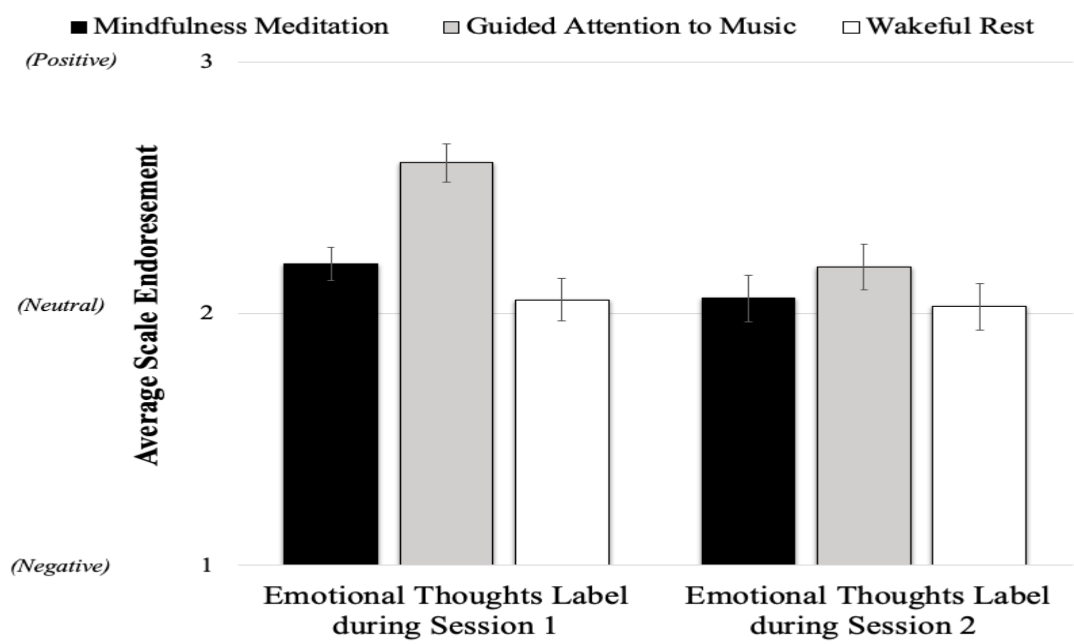


Figure 8. Average endorsement of Likert score one (negative), two (neutral), three (positive) for emotional thoughts label by session (two minutes or four minutes) for each group.

Error bars represent one standard error of the mean.

3.2.2 State Worry

The state worry scale assessed the percentage of time participants generally experienced worry during both activity sessions. Participants endorsed a percentage scale (0–100%), where higher percentage scores indicate more worry and lower scores indicate less worry. In Figure 9, I include two composite sum scores across the guided auditory activity sessions.

I conducted a two (2) (session: one vs. two) X three (3) (condition: mindfulness meditation, guided attention to music, and wakeful rest) mixed-design ANCOVA. First, analyses showed all of the following covariates were not significant: pretest, trait mindfulness, emotion regulation, math self-efficacy and anxiety, or trait worry, (*F's*$<$*2.1, p's*$>$*.05)*. Second, there were no main effects or interactions of the session or condition on the worry items (*F's*$<$*1.6, p's*$>$*.05)*.

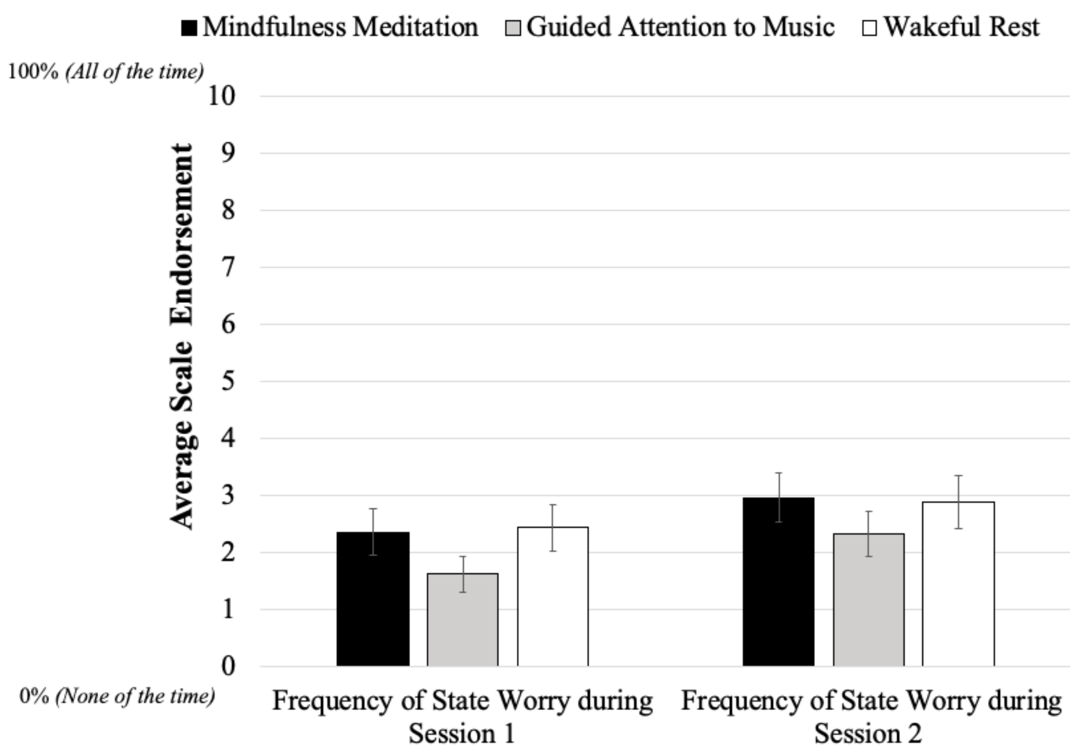


Figure 9. Average endorsement of percentage scale 0 (0%) to 10 (100%) for the frequency of state worry by session for each group. Error bars represent one standard error of the mean.

3.2.3 Frequency of Math Thoughts

The frequency of the math thoughts scale assessed perceptions about the frequency (in terms of time) with which participants thought about their math test performance during both sessions of the guided auditory activities (see Figure 10 for descriptive results). Participants endorsed a six-point Likert scale either rating statements from one (*almost never*) to six (*almost always*) where higher scores indicate more math performance thoughts and lower scores indicate less math performance thoughts. I conducted a two (2) (session: one vs. two) X three (3) (condition: mindfulness meditation, guided attention to music, and wakeful rest) mixed-design ANCOVA. Analyses showed all of the following covariates and interactions were not significant: pretest, trait mindfulness, emotion regulation, math self-efficacy and anxiety, or trait worry. Second, there were no main effects or interactions for the sessions or condition on the frequency of math thoughts (F's$<.51$, p's$>.05$).

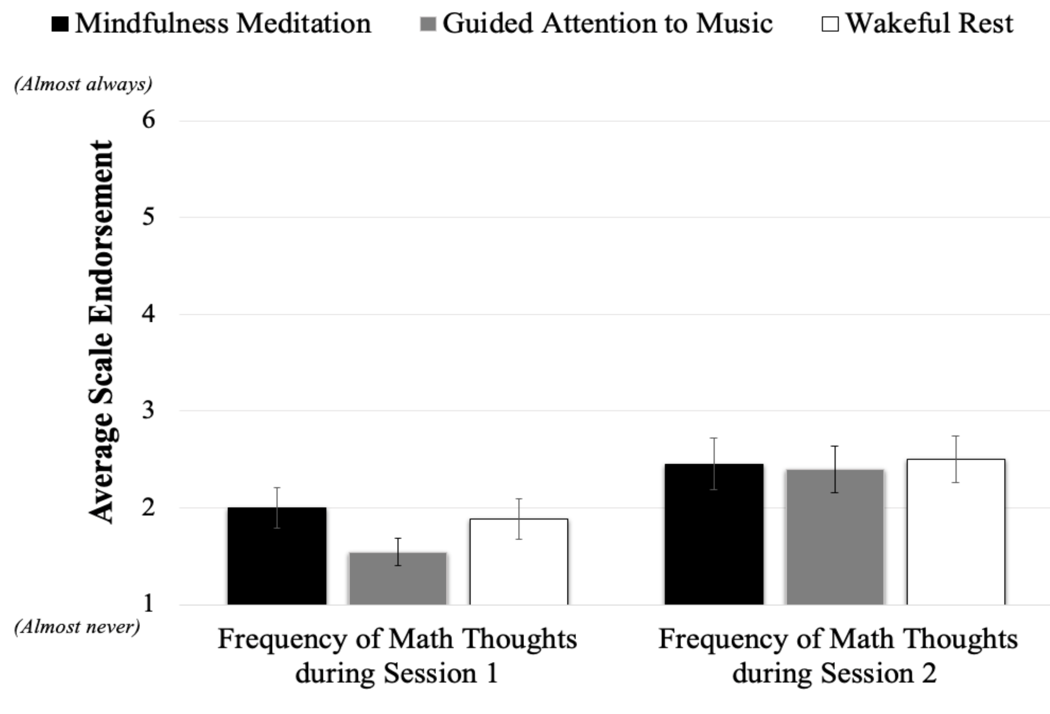


Figure 10. Average endorsement of Likert scores from one (almost never) to six (almost always) for the frequency of math thoughts by session for each group. Error bars represent one standard error of the mean.

3.2.4 Ruminative Feelings

The ruminative feelings measure assessed negative feelings of worry, frustration, and stress about the statistics invention task at the first time point after completion of the learning task (see Figure 11 for descriptive results). Participants endorsed a six-point Likert scale either rating statements from one (*strongly disagree*) to six (*strongly agree*) where higher scores indicate more negative feelings of (worry, frustration, and stress) and lower scores indicate fewer negative feelings.

To examine the effect of condition on feelings about an instructional learning activity, I used a between-subjects ANCOVA controlling for individual differences of prior knowledge, math motivation, and emotion regulation. The results showed that the math self-efficacy and anxiety covariate was significant, F (1, 100) = 9.0, p =.003, η^2p = .08, meaning participants' math self-efficacy and anxiety scores were related to the endorsement of ruminative feelings. Additionally, the results showed marginal effects for the following covariates: mindfulness, F (1, 96) = 3.2, p =.08, η^2p = .03, and emotion regulation, F (1, 96) = 3.4, p =.06, η^2p = .04, meaning participants' trait mindfulness and emotion regulation scores were marginally related to the endorsement of ruminative feelings. Results did not show effects or interactions for the following covariates: pretest or trait worry, (*F's<.25, p's>.05)*.

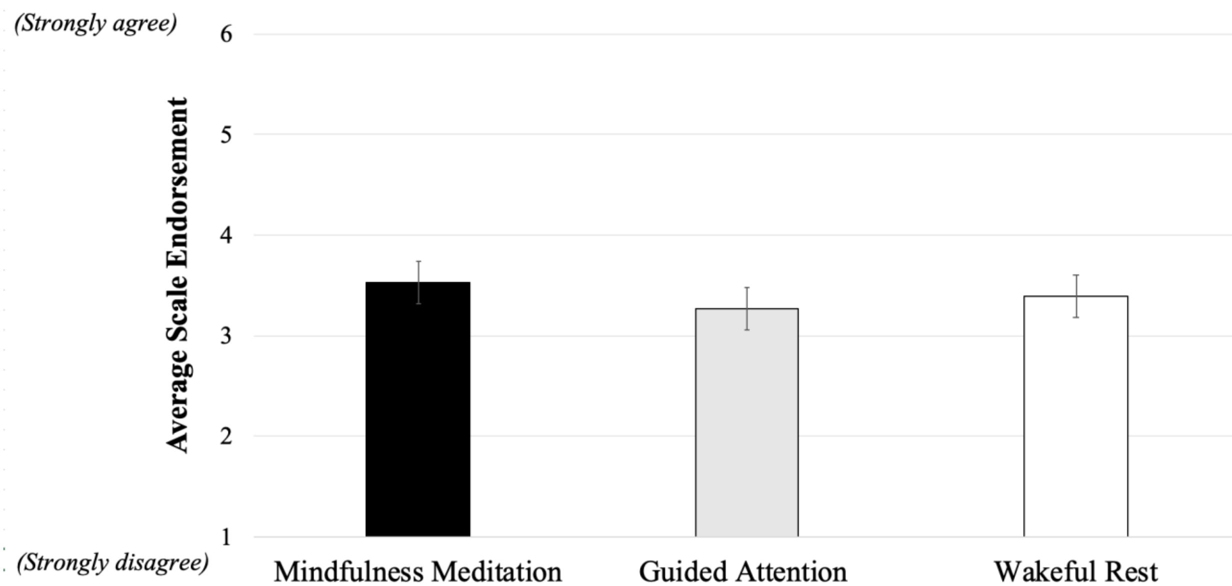


Figure 11. Average endorsement of Likert scores from one (almost never) to six (almost always) for ruminative feelings by condition. Error bars represent one standard error of the mean.

3.3 Differences in Stress Appraisals

H2.) Participants in the mindfulness meditation group will report the greatest differences in using more productive and positive stress appraisals, compared to use of negative stress *appraisals (e.g., challenge vs. threat), followed by the guided attention to music group and then the wakeful rest group.*

In this set of analyses, I examined how participants in each group appraised their stress. I used a self-report measure of stress appraisals at two different time points (after the stressful performance feedback and then after the statistics invention task).

Challenge and threat were examined as two separate constructs and were included in the analyses at two different time points: immediately after the pretest and after the statistics invention task. Participants could endorse a six-point Likert scale either rating statements from, one (*strongly disagree*) to six (*strongly agree*) where higher scores showed more positive stress appraisals for the challenge construct, and higher scores reflected more negative stress appraisals on the threat construct. Refer to Figures 13 and 14 for the descriptive results of the stress appraisal survey measures.

3.3.1 Challenge Appraisals

To investigate the effect of condition on participants' self-reported challenge stress appraisals I conducted a two (2) (timing of the stressor: after the stressful performance feedback vs. the statistics invention task) X three (3) (condition: mindfulness meditation, guided attention to music, wakeful rest) mixed-design ANCOVA. Results for the challenge appraisals construct showed the following significant effects of pretest scores and individual difference covariates. There was an effect of the pretest covariate, F (1, 99) = 8.2, p =.005, $\eta^2 p$ = .08. Additionally, there was an effect of the math self-efficacy and anxiety covariate, F (1, 99) = 17.8, p =.001, $\eta^2 p$ = .15. Taken together, endorsement of both pretest scores, as well as math self-efficacy and anxiety covariates predicted the average scores of the challenge appraisals. The mindfulness, emotion regulation, and worry covariates were not significant, (*F's<1.2, p's>.05).* There was no effect of condition, session, and the interaction of session by condition, (*F's<.33, p's>.05*).

The results do not support the tested hypothesis in that I found no changes in endorsements of average challenge appraisals from the first session to the second session for the mindfulness group compared to both guided auditory activity groups. However, significant associations between individual difference measures of prior knowledge, and math self-efficacy and anxiety showed that both were positively related to endorsement of challenge appraisal scores, meaning that participants who had higher math pretest scores and higher math motivation also had higher challenge appraisal scores. For descriptives on the challenge appraisals, see Figure 12.

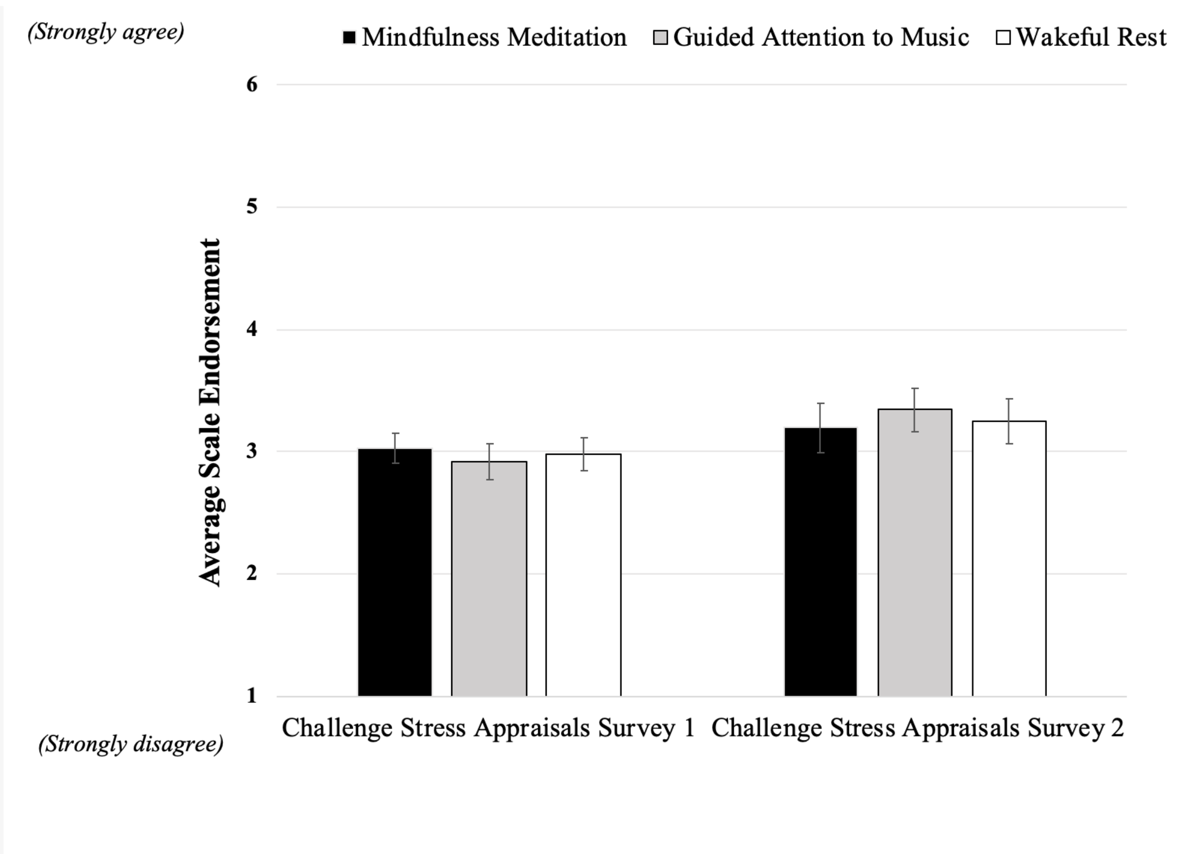


Figure 12. Average endorsement of Likert scores from one (strongly disagree) to six (strongly agree) scores for the challenge stress appraisal items from session 1 (after the pretest) and session 2 (after the statistics invention task). Error bars represent one standard error of the mean.

3.3.2 Threat Appraisals

Toinvestigate the effect of condition on participants self-reported threat stress appraisals I conducted two (2) (timing of the stressor: after the stressful performance feedback vs. the statistics invention task) X three (3) (condition: mindfulness meditation, guided attention to music, and wakeful rest) mixed-design ANCOVA. Analyses for the threat appraisals showed significant results for the mathematics self-efficacy and anxiety covariate, F (1, 100) =.12.2, p =.001, η^2p = .10, showing that participants' reports of math motivation predicted their average endorsement of threat appraisals. I also found a significant main effect for the session as an independent variable, F (1, 100) =5.3, p =.02, η2p =.05, meaning there were significant differences in threat appraisals from the first to the second session.

There were no effects of the following covariates: pretest, mindfulness, emotion regulation, and worry (*F's<1.2, p's>.05*). Additionally, I found no main effects or interactions for session and condition, (*F's<.52, p's>.05*). See Figure 13 for descriptive statistics.

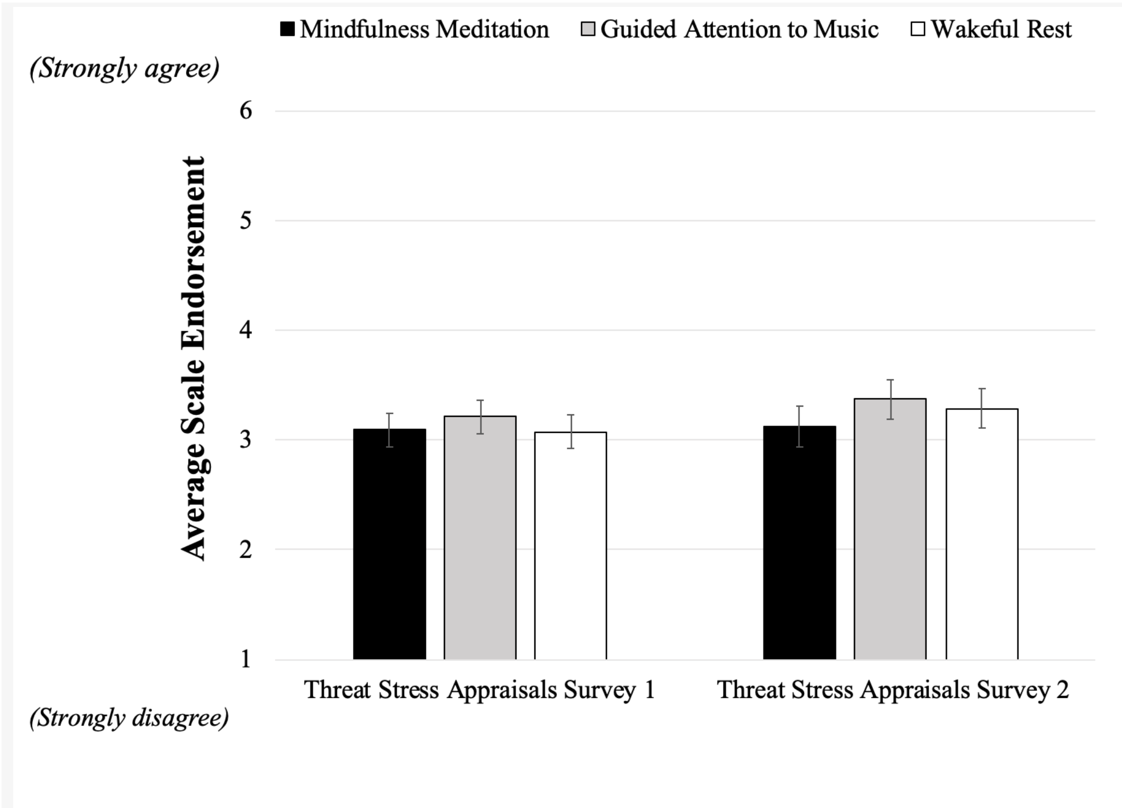


Figure 13. Average endorsement of Likert scores from one (strongly disagree) to six (strongly agree) scores for the threat stress appraisal items from session 1 (after the pretest) and session 2 (after the statistics invention task). Error bars represent one standard error of the mean.

3.4 Differences in Learning

H3.) Participants in the mindfulness meditation group would reveal the greatest differences in procedural and conceptual measures of learning and performance of novel math concepts followed by the guided attention to music group, and then the wakeful rest group.

In the following analyses, I assessed whether the groups differed on learning and performance outcomes. I examined scores from the statistics invention activity, practice problem with direct instruction, and a posttest assessment to determine the degree to which participants differed on their learning from pre to post.

3.4.1 Statistics Invention Task

Perforance on the learning activities was scored for the following correct categories: 1) conceptual features (precision, accuracy, and the number of pitches), 2) mathematical procedure of reliability with correct mean deviation responses. There were two main goals of delivering this secondary learning task: first, to further boost stress from learning of the novel math concepts; second, to determine if there were treatment effects on this secondary learning measure.

To examine whether there was an effect of condition on the statistics invention task performance I used a (two) 2 X (three) 3 mixed-design ANCOVA with a within-subjects factor of problem type (conceptual features vs. reliability) and a between-subjects factor of condition (mindfulness meditation, guided attention to music, and wakeful rest). Analyses showed the following effect of the math self-efficacy and anxiety covariate to predict average score differences on the statistics invention task, $F(1, 100) = 5.7$, $p = .02$, $\eta^2 p = .05$. This showed that differences in participants' math motivation predicted their responses to problem type on the statistics invention task.

Additionally, results showed there were no effects for the following covariates: pretest, trait mindfulness, emotion regulation, and trait worry, ($F's<2.0$, $p's>.05$). For the independent variables and interaction effects, analyses showed there was no effect of condition, problem type, or interaction between problem type and condition, ($F's<.66$, $p's>.05$). This may be indicative that participants' low performance accomplished the first intention of inducing stress. However, the second goal—of determining if there were learning effects for those in the mindfulness group—showed no effects. See Table 6 for descriptive statistics.

3.4.2 Practice Problem

The learning activity consisted of a direct instruction video that explained the mean deviation formula and participants practiced what they learned using a worked example that was scored from zero to three (0–3) points for calculating the correct sub-features of mean deviation. A preliminary analysis for the homogeneity-of-regression assumption showed there were no interactions between condition and any of the five covariates when considered in models with one interaction term of the model and with all five interaction terms. I ran a between-subjects ANCOVA to determine the effects of independent variables and covariates on the practice problem.

Analyses showed there were no significant effects for the following covariates: pretest, mindfulness, emotion regulation, math self-efficacy and anxiety, and worry (*F's<.31, p's>.05*). Additionally, there was no effect of condition on the practice problem, F (2, 100) = .10, p >.05, η^2p = .002. Examination of the means in these findings indicates that students performed with high scores or perfect scores which may indicate ceiling effects. To further test if learning affected by the condition, I examined whether there were improvements in learning from pretest to post-test in the following section. See Table 6 for descriptive statistics.

Table 6. Average Scores for Learning Performance on the Conceptual Features and Reliability of the Statistics Invention Task (0–7 points) and the Practice Problem (0–3 points)

	Mindfulness Meditation			Guided Attention to Music			Wakeful Rest		
	n	M (SD)	95% CI	n	M (SD)	95% CI	n	M (SD)	95% CI
Statistics Invention Task: Conceptual Features	33	.40(.30)	[.29,.50]	35	.38 (.22)	[.30,.44]	36	.33 (.30)	[.23,.43]
Statistics Invention Task: Reliability	33	.00 (.04)	[-.00,.02]	35	.02 (.13)	[.00, .75]	36	.03 (.13)	[.01, 08]
Practice Problem	33	2.7 (.50)	[2.57, 2.93]	35	2.8 (.45)	[2.7, 3.0]	36	2.8 (.72)	[2.5,3 .0]

3.4.3 Post-test Performance

For the post-test, questions were examined by problem type: mean deviation and standardization for a total of 12 points. I focused on problems 1 and 3 for mean deviation, and problem 4 for the standardization problem, which was an isomorphic problem to the pretest. To investigate whether the effect of the condition affected participants post-test scores, I conducted a 2 X 3 mixed-design ANCOVA with a within-subjects factor of problem type (mean deviation vs. standardization) and a between-subjects factor of condition (mindfulness meditation, guided attention to music, and wakeful rest). The results showed that the trait mindfulness covariate was significant, F (1, 96) = 5.8, p =.02, $\eta^2 p$ = .06, meaning participants' math self-efficacy and anxiety scores were related to the endorsement of ruminative feelings. The following covariates did not show significant main effects: pretest, emotion regulation, math self-efficacy and anxiety, and worry (*F's<2.5, p's>.05*).

The following independent variables did not show significant main effects and interaction: condition, problem type, the interaction between problem type, and conceptual features (*F's<1.3,* *p's>.05*). Further, results did not show significant effects for an interaction. See Figure 14 for the descriptive statistics.

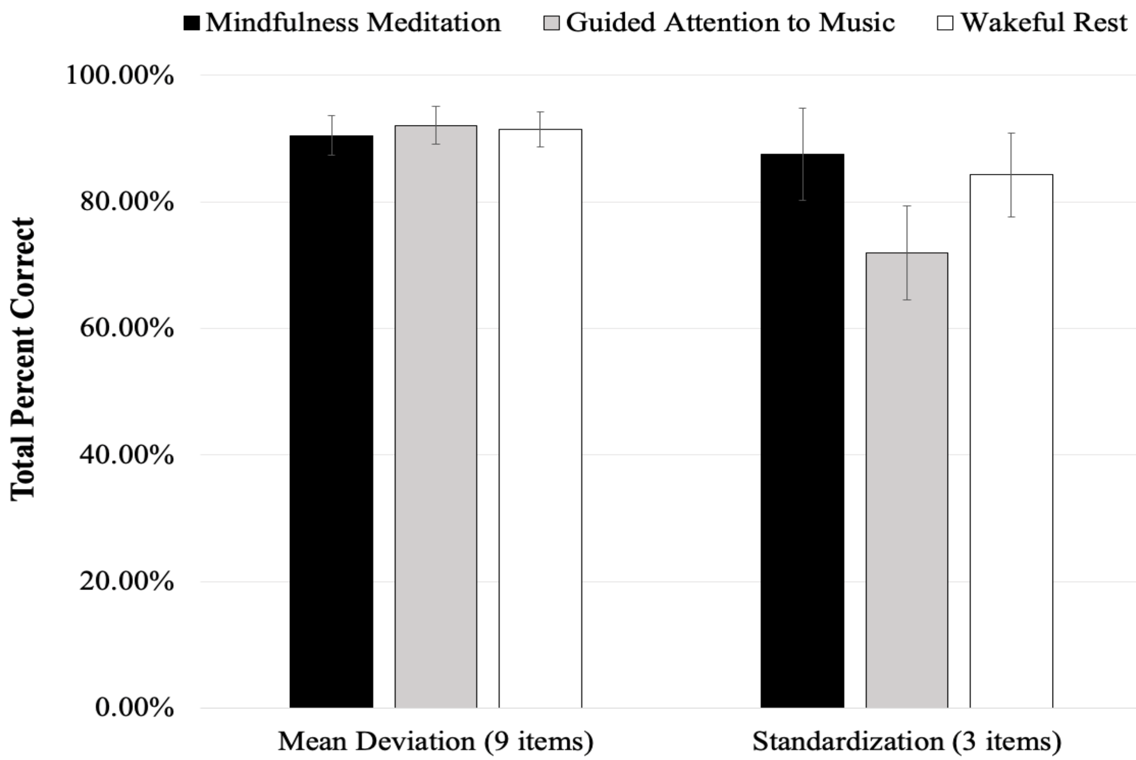


Figure 14. Total percent correct scores for post-test by problem type for each group. Mean deviation items were scored as incorrect or correct for a total of nine (9) possible points. Standardization items were scored as incorrect or correct for a total of three (3) possible points. Error bars represent one standard error of the mean.

4.0 Discussion

The purpose of this investigation was to test the effects of mindfulness meditation training on regulating academic stress (i.e., a high-stakes pressure to achieve in academic contexts) and improvements in mathematics learning with undergraduate students. I found null results for the effects of mindfulness meditation training on emotion regulation (i.e., rumination and stress appraisals) and learning. In the following sections, I discuss the results relative to each of the examined outcomes and then identify the strengths and weaknesses of the training, as well as the study's implications, limitations, and future directions.

4.1 Rumination

Rumination, or negative and repetitive self-referential thinking, manifests for some students as an inefficient emotion regulation response to academic stress (Lyubomirsky et al., 2003). For example, studying for a math exam may prompt a student to be cognitively and emotionally preoccupied with changing a past failure and prompt worrying about its future consequences. In this study, I assessed rumination following an academic stress induction of evaluative and social comparison feedback about students' performance on a math test, followed by a learning math task that most students typically fail. Rumination was measured via four self-report measures: the emotional valence of thoughts, ruminative feelings, the frequency of math thoughts, and the frequency of worries about math performance.

For the first assessment of rumination, I explored the emotional tone of self-reported thoughts and did not find the mindfulness meditation condition to have reported more positive thoughts across activity sessions. Interestingly, I found a significant decrease in positive thoughts for the guided attention to music conditions compared to the mindfulness and wakeful rest conditions. In addition, contrary to the tested prediction on rumination differences I found no significant effects of ruminative feelings for the frequency of math thoughts, nor worries about math performance across all three conditions. Taken together, these results suggest our brief mindfulness training did not reduce rumination in this context. However, overall evidence suggests that rumination was generally low.

There are two possible alternative explanations for the null findings on these rumination measures. First, participants were not sufficiently stressed by the math test and feedback or the learning task to induce rumination. Although math tasks and tests have been successful stress inductions in past studies (Beilock & DeCaro, 2007; Johns, Inzlicht, & Schmader, 2008; Park, Ramirez, & Beilock, 2014), targeting math-anxious students in the lab or alternative high-stakes learning scenarios in the classroom (e.g. exam or class performance) may lead to greater amounts of stress for some students and is likely to prompt higher levels of reported rumination.

Second, these data may suggest participants in the guided attention to music and wakeful rest conditions were using other productive strategies to deal with their stress such as distraction (Broderick, 2005b). For example, after the stress-induced feedback participants in the guided attention to music group may have been distracted and immersed by the music exhibiting positive emotions, which reoriented them away from rumination as a strategy during the experiment.

One way to further assess rumination is to examine the open-ended data, similar to analyses conducted in Ramirez and Beilock's (2011) study on expressive writing as an intervention for rumination about stress and math performance. The researchers used a more fine-grained measure that examined the types of thoughts participants had, specifically, worrying about a math test categorizing stressful, anxious, or negative words or phrases and grouped those who had the highest scores in stress and rumination. Individual difference measures could also reveal group differences for those who are dispositionally high in rumination tendencies. These individual differences and qualitative open-ended responses to such thought content questions not reported here (i.e., “What are you thinking about right now”) suggest that research into these predictions could be quite promising. These open-ended data and potential group differences may suggest mindfulness has improved outcomes for rumination reduction, but only for highly math-anxious or stressed students.

4.2 Stress Appraisals

Productive and positive stress appraisals of an academic stressor is another emotion regulation mechanism that leads students to better cope with stress and adequately learn. Two types of stress appraisals shown to affect behavioral and academic outcomes are challenge and threat appraisals. I measured both challenge and threat—as separate constructs—immediately after the stress-induced feedback and the math learning task. These results did not support the tested hypothesis for the promotion of positive appraisals. I concluded that there were no significant differences between the three conditions on self-reported levels of challenge. Further, there were no significant differences between conditions on self-reported levels of threat. Based on these results, I can conclude that this instantiation of mindfulness training was not effective for affecting stress appraisals in this experiment. Perhaps it was too low of a dose of the mindfulness training intervention. More experiments are needed to further test the potential impact of higher doses of mindfulness on stress appraisals.

The alternative explanations for the findings on stress appraisals may be threefold: participants were not stressed enough, participants in all conditions found other productive ways to regulate stress that mitigated against appraisals of the stressor, and reconceptualizing stress appraisals could potentially capture important dimensions that I did not consider in this analysis. Although stress appraisals have been shown to be linked to academic performance on tests (Jamieson et al., 2016a; Yeager, Lee, et al., 2016), similar to the explanation of rumination null findings, this study may not have induced the appropriate amount of stress participants needed to substantiate the use of stress appraisals. Additionally, participants may have used other ways to productively cope with the academic stressor. For example, the guided attention to music and wakeful rest conditions may have used distraction and mind wandering to orient them away from the stress inhibiting the use of more positive or less negative stress appraisals. Lastly, this study showed important challenges with the measurement of stress appraisals. In future studies, stress appraisals could be reconceptualized and assessed via the measurement of participants' perceptions of resources and demands; reconstructing challenge and threat using one's perception of coping resources and stress level with the academic demand at hand. The current conceptualization takes a one-dimensional approach to examine perceptions of stress; however, an additional dimension could allow for an understanding of coping perceptions, theorized to embody one's views of the resources and skills needed to successfully perform the task in relation to the demands of the stress it ensues. Coping perceptions of resources and skills to perform the task are critical features for one's assessment of their ability to successfully meet the stressful demands. From this new conceptualization, a difference score can develop consisting of self-report (e.g., by way of survey items and open-ended responses) or behavioral measures (e.g., problem types on the math tasks, the math activity, and math test assessments) that would capture perceived psychological threat compared to challenge. This conceptualization can be directly tested and measured via the effects of mindfulness on academic stress appraisals. For example, the delivered mindfulness training would prompt a participant's focused attention on the academic stressor and their emotion regulation skills to constructively identify their resources and skills to cope with the stressful demands. Bringing one's awareness of resources and skills to light may undermine the stressful demands by training the use of nonjudgmental acceptance that is free of elaboration, emotional value, and negative evaluation. Researchers could explore two interesting questions that emerged from this study: 1) How quickly can changes in stress appraisals for students happen following a training in an ecologically valid environment (e.g., stressful academic experiences in the classroom), compared to a controlled lab environment? 2) Are there less intense effects for when students become directly aware of challenge and threat appraisals specifically targeted in a mindfulness training compared to a different assessment of their stress appraisals (i.e., by way of their perception of coping resources and demands)? Based on the results of this study, I predict re-operationalizing stress appraisals based on a difference score would capture a different aspect of stress appraisals. Participants might indicate greater effects for decreasing psychological threat and subsequently identifying the needed resources to cope and meet the demands, thus enhancing the use of challenge appraisals.

4.3 Learning and Performance

For the final analysis, I examined whether brief mindfulness training would promote better learning for participants after direct instruction followed by subsequent performance. I developed a stressful learning paradigm to induce students psychological and behavioral responses to academic stress following feedback about failure. To assess learning and performance, I used three behavioral measures to examine knowledge acquisition for the target concepts of mean deviation and standardization: the statistics invention task, a direct-instruction activity, and post-test outcomes, respectively.

These results did not support the tested predictions that participants in the mindfulness meditation condition would significantly improve on the learning task, practice problem, and post-test. Contrary to the hypothesis, this suggests mindfulness training does not affect learning in this experiment. Although there were no significant differences in learning for the selected mean deviation and standardization problems across the conditions, the results did reveal that most participants in the experiment increased in average learning scores of the target and transfer problems pre-to-post-test. This suggests the instructional learning tasks and activities during the experiment may have impacted these improvements, although more analyses are needed.

One possible explanation for the lack of an effect of mindfulness for learning may be that all participants were not sufficiently stressed enough. These results may be indicative of a trait strengths-based approach to examining students learning and performance in stressful contexts, suggesting that many students already have the skills it takes to handle a degree of academic stress and subsequently learn and perform well. Interestingly, in line with studies on stress and performance, these results may also suggest individuals function with optimal levels of stress when facing performance pressures meaning that there is a degree to which stress serves a useful purpose for performance (Crum & Lyddy, 2014). However, this alternative explanation does not address why mindfulness training was ineffective in this experiment. I argue detriments occur at the point in which one's perception of stress, which may not accurately depict the demands of the stressor, exceeds their ability to cope that consequently affects their learning. There is still more research needed to examine the levels at which stress is ineffective, when mindfulness training is the most impactful for cognitive and emotion regulation outcomes, and how it is connected to learning by way of other affective processes under stress, such as different types of motivation (e.g., self-efficacy, belonging, and different facets of academic identity). Questions for researchers to ask include: What are the self-regulatory strategies and motivational strengths that enhance learning and academic performance under stress? How may we better help students enhance these strengths with mindfulness training? Mindfulness training may provide students with focused attention and an open awareness to identify these strategies and strengths, and allow them to implement changes as the reception to stressful feedback disarms.

4.4 Implications and Strengths

The results of this study have implications for three strands of the literature: mindfulness, emotion regulation, and learning. Although much past work has shown the benefits of mindfulness meditation on emotion regulation and academic performance, little work has examined whether the features of mindfulness benefit learning. Results were inconsistent with all three hypotheses as mindfulness training did not predict significant rumination reduction, use of productive and positive stress appraisals, or promote better learning and academic performance.

Although I did not find results to support the hypotheses, three important implications for this study are mentioned. First, this work attempts to bridge the measurement of dispositional and state measures of the examined constructs. Prior studies have assessed dispositional measures of mindfulness (via self-reports) and found significant links between stress, cognition, and academic performance outcomes (Bellinger et al., 2015; Flett, Haghbin, & Pychyl, 2016; Hanley, Palejwala, Hanley, Canto, & Garland, 2015; Sirois & Tosti, 2012); however, there remain limitations for drawing inferences about the relationship between state differences. To address these limitations, this study measures both trait and state-like measures of prior math knowledge, mindfulness, emotion regulation, rumination, math self-efficacy and anxiety to examine the relationship they may have with one another, and the tested outcomes. These results allow for a better theoretical understanding of individual differences and the state effects of mindfulness training on cognitive and affective responses to learning.

Second, this study includes the use of novel and well-matched comparison conditions for mindfulness training in an experimental design. Meaning, these groups were designed to control for the tested mechanisms of mindfulness (i.e., self-regulation of attention and emotions) and use of traditional implementation practices (e.g., individuals alone at rest listening to guided instruction with training vs. guided instruction without training) in the lab. More specifically, I developed the guided attention to music training condition to control for the verbal sensory information and instructional training of focused attention. Additionally, I adapted the wakeful rest condition instructions from prior studies on memory and learning because it did not train focused attention nor nonjudgmental awareness (Dewar et al., 2012). Many studies using control conditions (e.g., audiobooks) with guided verbal sensory information have fewer theoretical links to mindfulness and cognition. This condition has been shown to deliver effects for memory and learning and was used in this study to control for free-form contemplative thoughts without training through verbal instructional information (i.e., “Think about whatever comes to mind”). This was done to mirror the sensory input of verbal instruction and transition cues participants received in the other two conditions.

Third, I created a unique lab-based academic stress induction. I designed it to resemble an average student's academic experience of evaluative and social comparison performance feedback greatly prevalent during undergraduate training. Following this, I reinforced the feeling of failure with a difficult learning task of the target concept to measure what students learn from subsequent instruction. Although my work didn't validate the effects in the manner predicted, this work brings to light important limitations and questions for future research that should be considered.

4.5 Limitations and Future Research

The first set of limitations concerns the examination of a specific stressful student STEM group and various contextual factors that influence students' varying experiences of stress. It would be informative to deliver mindfulness training to "at-risk" undergraduate students who have an aversion to STEM (Science, Technology, Engineering, and Mathematics) learning and demonstrate poor performance because of adverse academic experiences. A chosen subgroup would potentially allow for a greater detection of effects among the groups on stress outcomes as these students may be more prone to rumination and negative stress appraisals when faced with the pressure to learn difficult and novel math concepts successfully. Although this could be tested in the lab, it would also be useful to deliver this study through long-term training and screen those participants who only report high stress for an academic subject, evaluating their identities.

Another important limitation concerns the measurement of the emotion regulation constructs of rumination and worry in relation to mindfulness training. Clinical researchers suggest features of mindfulness training may serve more beneficially to target rumination and worry, separately, including individuals in nonclinical samples who face acute stressors (Hallion, Wright, Coutanche, & Joormann, 2019).

More specifically, rumination is a negative self-referential state that can serve as a catalyst for students' negative beliefs and attributions about their knowledge and skills that typically involve thinking about one's past with negative affect (e.g., hopelessness) about not having been in control of one's experience. Worry is defined as more future-oriented thinking with negative affect (e.g., anxiety) around the desire to control an experience. This distinction is important to consider in the design of future training as the features of mindfulness may be tailored to each have different impacts. In this study, one of the mindfulness features tested—nonjudgmental awareness—involves acceptance without emotional value or an evaluation of one's thoughts and feelings. Such an evaluation might otherwise lead to self-judgment, diminishing the effects of rumination. *Nonreactivity* involves the observation of emotions and thoughts without reaction and was assessed only indirectly in our measure of state mindfulness. Both, nonreactivity and nonjudgmental awareness may guide students preoccupied with worries about future consequences to use fewer reactions without elaboration of negative affective thoughts. Students who experience worry may use focused attention—a conscious mental mode of attending to one's present moment-to-moment experience—a catalyst to nonreactivity and nonjudgment that allows people to focus on the task at hand without negative judgment of past outcomes and elaboration on future consequences. This study represents an important contribution to a better understanding of the constructs of rumination and worry—well-established in the clinical literature—with observed educational outcomes and application to non-clinical students learning in stressful academic contexts.

Future research should investigate three important directions: individual differences, target samples, and various academic stress contexts; especially because mindfulness continues to gain popularity in educational interventions. This is important to consider so that researchers can assess how and for whom mindfulness training may work, what cognitive or affective dispositional differences exist among students to promote or inhibit their learning, also under what contexts and the degree to which stress manifests in students differently.

To elaborate on these factors, first, researchers could assess individual differences such as mindfulness, emotion regulation, as well as math motivation and anxiety, with learning and academic performance outcomes. This study indicates several significant correlational effects between individual differences and also patterned associations with the examined outcomes of rumination, stress appraisals, and learning. I draw potential inferences about the relationships noted as a strength for this study, and also a possible limitation to detect effects for the examined outcomes. This examination could better inform an understanding of how trait differences may influence the regulation of stressful learning and performance outcomes across different individuals. To support these claims, evidence shows trait differences in mindfulness and motivation impact students' performance and learning outcomes (Howell & Buro, 2011). Other research suggests trait mindfulness is linked with decreased levels of rumination and worry for individuals (Desrosiers, Vine, Curtiss, & Klemanski, 2014). A series of studies from a large data set of psychological and mental health outcomes examined the links of the five facets of trait mindfulness (nonjudgement, nonreactivity, acting with awareness, describing, and observing)—a widely supported conceptualization of trait mindfulness (i.e., Five Facet Mindfulness Questionnaire (FFMQ): Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). Among the samples (i.e., clinical vs. non-clinical), self-report levels of rumination and worry (assessed separately and together) showed significant correlations with the nonjudgement and nonreactive facets. This suggests important relationships between the facets of trait mindfulness with emotion regulation (Thompson, Jamal-Orozco, & Hallion, in press).

A future direction for this work will be to examine a sample of students in an ecologically valid context (e.g., STEM classroom) who report greater levels of academic stress. For example, minoritized students have to manage school and societal-based structural challenges surrounding inequities and prejudices that may influence how they view their knowledge and skills in relation to their identified racial or ethnic group (e.g., stereotype threat and race-based rejection sensitivity). In academic contexts where these students are underrepresented compared to white and male students, minoritized students may experience heightened rumination about their identity and confidence. Prior research suggests women and students of color experience lower self-confidence and lack of identity in STEM-related academic experiences (Else-Quest & Mineo, 2013; Good et al., 2003; Good, Rattan, & Dweck, 2012; Yeager et al., 2012) Mathematics anxiety is also higher for minoritized students—a well-established detrimental affective state for high-pressure academic performance situations caused by exposure to learning or performing math (Aronson et al., 2002). Similarly, for the tested mechanisms of emotion regulation, these students may experience greater negative thoughts of fewer skills or resources to cope with the stressor driving negative stress appraisals because of the information they receive from their environment. Therefore, students facing structural challenges may be better served by training that targets cognitive and affective responses to manage rumination and stress appraisals. Cultivating attention and awareness to one's resilience by way of coping skills and resources to manage adversity may buffer against the potential information the environment may inflict.

More research needs to be conducted on learning effects to delineate between them and performance outcomes. One way to examine this is by measuring knowledge transfer, or the application of knowledge and skills of a concept in one context to a new one. Future research should continue to ask what are the effects of mindfulness training for learning and subsequent transfer?

Taken together, these future directions are recommendations for researchers to bring to the forefront and ask who the student is, how and under what contexts they learn best, and whether cognitive and affective training or interventions such as, mindfulness meditation, impacts educational experiences and opportunities for students.

4.6 Conclusion

In sum, this study tested features of mindfulness using well-matched and designed control groups. This research uniquely attempted to bridge different, yet related, bodies of literature to create a theoretically robust understanding of the psychological mechanisms and processes at play in students' experience of academic stress, emotion regulation, learning, and academic performance outcomes.

Appendix A Pretest

Please solve the following problems. Show all your calculations and rough work.

1. Find the mean (average) and mean deviation of the following numbers:
{5, 10, 6, 9, 10} **(2 points)**

2. Find the mean and mean deviation of the following numbers.
{55, 63, 47} **(2 points)**

3. Twenty students took a midterm in their science class, and they had an average score of 75. Five of them scored 70, five students scored 65, five students scored 80, and five students scored 85. What is the mean deviation? **(3 points)**

4. Two people were arguing whether Joe Smith or Luke Johnson had more power for hitting home runs. Joe Smith's longest homerun was 540 ft. That year, the mean homerun among all players was 420-ft long, and the mean deviation was 70 ft. The mean deviation indicates how close all the homeruns were to the average. Luke Johnson's longest homerun was 590 ft. That year, the mean homerun was 450 ft, and the mean deviation was 90 ft. Who do you think showed more power for his biggest homerun, Joe Smith or Luke Johnson? Use math to help back up your opinion.
(3 points)

Appendix B Pretest Feedback

Your score on the test is _______out of 10 points.

The criterion for passing this test was 9 points, and many students who take this test pass this criterion.

Later in the study you will have a learning opportunity about these problems and another test on the material you learn.

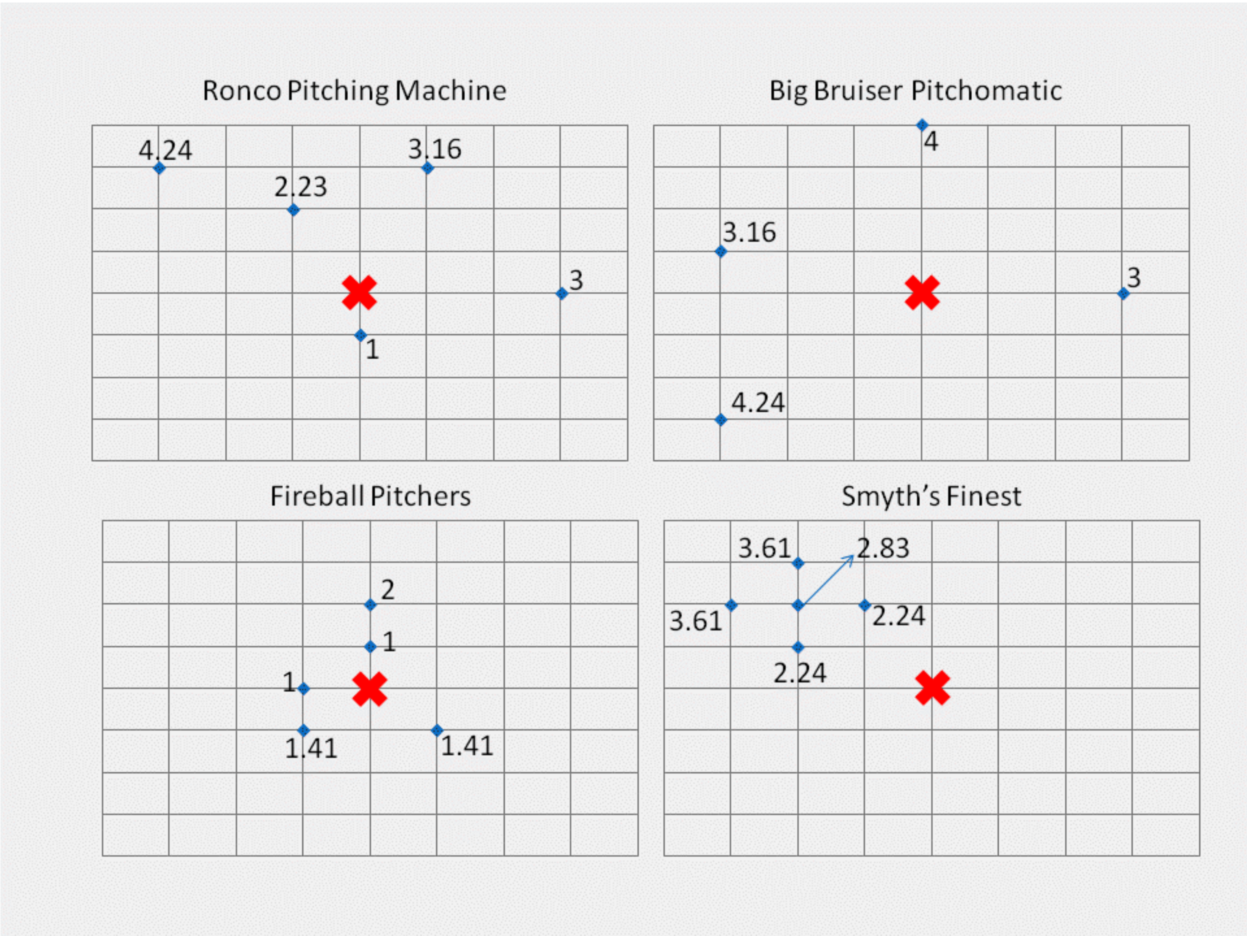
We will now proceed to the next part of the experiment. You will take a brief survey. After the survey you will engage in another cognitive training task followed by more statistics problem solving and instruction.

Appendix C Statistics Invention Task

Problem 1:

Statistics Invention Activity

The four grids below show pitching results from four different pitching machines. The X represents the target, and the black diamonds represent where different pitches landed. Which machine is most reliable? Your task is to invent a procedure for computing a reliability index for each pitching machine. There is no single way to do this, but, to ensure a fair comparison among the machines, you must use the same procedure for each. Using the grids below, compute a reliability index for each pitching machine. Write your procedure and the index value you compute for each.



Based on your initial analysis, which pitching machine do you think is most reliable?

What types of information do you think will be important to include in the procedure?

Write your procedure ideas and calculations below.

Ronco Pitching Machine: ____________________________

Big Bruiser Pitchomatic: _____________________________

Fireball Pitchers: ___________________________________

Smyth's Finest: ____________________________________

Which of these is the most reliable? ______________________________

Appendix D Notes Page

Notes:

You can use this paper if you would like to take notes while watching the video.

Appendix E Mean Deviation Practice Problem

Mean Deviation Practice

In the video, you just watched which computer, the Acme or Computro, is more reliable? ___________________

Here is a new problem. Your goal is to use the mean deviation formula to determine which of the two computers below is more reliable?

Please evaluate the data from these two computers. The scores describe the time, in seconds, it takes for the computer to load a program. Which is more reliable?

Pal-tron	Ace-Paq
X	X
12	8
4	2
4	2
12	8

Which is the most reliable? ___________________________

Appendix F Posttest

TEST

1. The owners of two cinemas, A and B, argue that their respective cinema enjoys a more consistent attendance. They collected the daily attendance of their cinemas for 11 random days. The results of their data collection are shown below:

	Cinema A	Cinema B
Mean, M	*72*	*75*
Mean Deviation, MD	*10*	*14*

Which cinema do you think enjoys a more consistent attendance?

A.Cinema A
B.Cinema B
C.Both enjoy equally consistent attendance.
D.None of the above.

2. A standardized score helps us compare different things. For example, in a swim meet, Cheryl's best high-dive score was an 8.3 and her best low dive was a 6.4. She wants to know if she did better at the high dive or the low dive. To find this out, we can look at the scores of the other divers and calculate a standardized score (see Table C1).

To calculate a standardized score, we find the average and the mean deviation of the scores. The average tells us what the typical score is, and the mean deviation tells us how much the scores varied across the divers. Table C2 presents the average and mean deviation values.

The formula for finding Cheryl's standardized score is her score minus the average, divided by the mean deviation. We can write:

$$\frac{\textbf{Cheryl's Score – average score}}{\textbf{Mean deviation}} \textbf{ or } \frac{\textbf{X – M of } \boldsymbol{x}}{\textbf{M deviation of } \boldsymbol{x}}$$

Table C1

Diver	High Dive	Low Dive
Cheryl	8.3	6.4
Julie	6.3	7.9
Celina	5.8	8.8
Rose	9	5.1
Sarah	7.2	4.3
Jessica	2.5	2.2
Eva	9.6	9.6
Lisa	8	6.1
Teniqua	7.1	5.3
Aisha	3.2	3.4

Table C2

	High Dive	Low Dive
Average	6.7	5.9
M deviation	1.8	1.9

To calculate a standardized score for Cheryl's high dive of 8.3, we plug in the values:

$$\frac{(8.3 - 6.7)}{1.8} = .85$$

Here is the calculation that finds the standardized score for Cheryl's low dive of 6.4:

$$\frac{(6.4 - 5.9)}{1.9} = .26$$

Cheryl did better on the high dive because she got a higher standardized score for the high dive than the low dive.

Cheryl told Jack about standardized scores. Jack competes in the decathlon. He wants to know if he did better at the high jump or the javelin throw in his last meet. He jumped 2.2 m high and he threw the javelin 31 m. For all the athletes at the meet, Table C3 shows the averages and mean deviations. Calculate standardized scores for Jack's high jump and javelin and decide which he did better at. Please show your work.

Table C3

	High Jump	Javelin
Average	2	25
M deviation	0.1	6

Standardized score for the high jump:

Standardized score for the Javelin:

Which did he do better at?

3. Consider the following five datasets:

A: {1, 5, 6, 10}
B: {4, 4, 4, 4}
C: {101, 102, 103, 104}
D: {7, 8, 9, 10}
E: {1, 2, 9, 10}

a. Which dataset has the smallest Mean Deviation? ______________________

b. Which dataset has the largest Mean Deviation? ______________________

c. Which datasets have the same Mean Deviation? ______________________

4. Susan and Robin are two teenagers who both just took their state driver's license road test. They are arguing about who got a better score on their test, which is scored out of 100 possible points. Susan got an 88 taking the driving test with Mr. Wheelie. The mean score Mr. Wheelie gave out that day was a 74, and the mean deviation was 12 points. The mean deviation indicates how close all the people taking the test were to the average. Robin earned an 82 on Mrs. Axel's driving test. On that day, the mean score Mrs. Axel gave out was a 76, and the mean deviation was 4 points. Both Mr. Wheelie and Mrs. Axel tested one hundred teenagers that day. Who do you think did better, Susan or Robin? Use math to help back up your opinion. Please use scratch paper if you need additional space for your calculations or graphs.

5.A data set consisting of five numbers has mean M = 7, and mean deviation, MD = 2.4. Use this information to answer Questions **5(a)** to **5(e)**.

a.If each of the five numbers is increased by 2, what are the new mean and MD?

A.M = 7, MD = 2.4
B.M = 9, MD = 2.4
C.M = 7, MD = 4.4
D.M = 9, MD = 4.4

b.If each of the five numbers is multiplied by 5, what are the new mean and MD?

A.M = 7, MD = 2.4
B.M = 35, MD = 2.4
C.M = 7, MD = 12
D.M = 35, MD = 12

c.If the numbers 4.6 and 9.4 are added to the data set to make it a data set with seven numbers, how will the mean and MD change?

i.M: unchanged / increases / decreases (circle one of these three answers)

ii.MD: unchanged / increases / decreases (circle one of these three answers)

d.If the numbers 1 and 13 are added to the dataset to make it a data set with seven numbers, how will the mean and MD change?

i.M: unchanged / increases / decreases (circle one of these three answers)

ii.MD: unchanged / increases / decreases (circle one of these three answers)

e.If the numbers 3 and 11 are added to the dataset to make it a dataset with seven numbers, how will the mean and MD change?

i.M: unchanged / increases / decreases (circle one of these three answers)

ii.MD: unchanged / increases / decreases (circle one of these three answers)

6.David's scores for Mathematics, Physics and Chemistry in the final examinations are given below. His class's performance for the three subjects is also given below:

	Mathematics	Physics	Chemistry
David's Score	95	90	85
Class Average, M	80	80	80
Class MD	15	5	4

a.Relative to his class, in which subject did David perform best?

b.Relative to his class, in which subject did David perform worst?

End of Test

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