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Learning to relax: Evaluating four brief interventions for overcoming the negative emotions accompanying math anxiety

Tad T. Brunyé [a,b,*], Caroline R. Mahoney [a,b], Grace E. Giles [a,b], David N. Rapp [c], Holly A. Taylor [a], Robin B. Kanarek [a]

[a] Tufts University, Department of Psychology, Medford, MA, United States
[b] U.S. Army NSRDEC, Cognitive Science, Natick, MA, United States
[c] Northwestern University, School of Education and Social Policy & Department of Psychology, Evanston, IL, United States

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ABSTRACT

We examined the potential effectiveness of four brief interventions, three behavioral and one nutritional, for helping high math-anxious college students regulate negative emotions immediately prior to a time-pressured arithmetic test. Participants with low versus high math anxiety performed a timed arithmetic task after practicing one of three short-term breathing exercises promoting focused attention, unfocused attention, or worry, and after consuming either 0 or 200 mg L-theanine. Overall, participants with high math anxiety underperformed relative to those with low math anxiety. This effect, however, was largely alleviated by a focused breathing exercise, which increased rated calmness and enhanced performance on the arithmetic test amongst those with high math anxiety. L-theanine supplementation showed only minimal effects. These results provide insights into the attentional mechanisms involved in regulating the negative emotions that lead to testing underperformance, and suggest that focused breathing exercises can be a useful, practical tool for helping address the negative impacts of math anxiety.

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1. Introduction

Individual differences in math anxiety cause many intellectually capable students to opt out of higher mathematics education, ultimately decreasing enrollment in mathematics courses and reducing work force competencies (for a review, see Ashcraft, 2002). Identifying reliable and tractable therapeutic methods for reducing the negative emotions accompanying math anxiety is critical to increasing student participation in higher mathematics education, increasing mathematics competencies, and supporting math-related career decisions in science, technology, engineering, and mathematics (STEM) disciplines (Ashcraft & Krause, 2007). To this end, we examined the effects of four brief interventions, three behavioral mindfulness interventions (focused breathing, unfocused breathing, versus a worry exercise) and one nutritional intervention (L-theanine supplementation), on reducing negative emotions and boosting math testing performance in individuals with low versus high levels of math anxiety.

1.1. Math anxiety

An estimated majority (Perry, 2004) of college students exhibit math anxiety, characterized by feelings of fear and tension in anticipation of situations demanding the application of mathematics knowledge (Ashcraft, 2002). Students with high math anxiety avoid math exposure in both daily life (e.g., calculating a tip at a restaurant) and formal educational coursework (e.g., calculus), ultimately resulting in lower exposure to math, reduced practice using mathematics principles, and reduced workforce math competence. Because time-pressured testing situations characterize many college mathematics courses, math anxiety becomes a primary impediment to students' academic success.

Individual differences in the ability to effectively control attention during testing (often measured via working memory capacity; Engle, 2002) predict speed and accuracy during arithmetic problem solving (Geary & Widaman, 1992). Behavioral and cognitive neuroscience results suggest that regulating emotions, and specifically regulating feelings of anxiety, demands resources in the very same brain networks critical to effectively controlling attention (for a review, see Ochsner & Gross, 2005). Together, this work predicts that high math-anxious students devote a considerable amount of cognitive and attentional resources towards intrusive thoughts and worries, rather than the processing demands of the arithmetic task, resulting in underperformance (Ashcraft, 2002; Beilock & Carr, 2005). Evidence for this relationship comes from studies demonstrating high math-anxious students begin to underperform only when, 1) tests are given in time-pressured circumstances (Faust, Ashcraft, & Fleck, 1996), and 2) arithmetic problems become more complex and demand increasingly high working memory resources for processes such as carrying, borrowing, and monitoring and updating sequences of operations (Ashcraft & Krause, 2007).

* Corresponding author at: Tufts University, Department of Psychology, 490 Boston Ave, Medford, MA 02155, United States. Tel.: +1 617 627 4075.
E-mail address: tbruny01@tufts.edu (T.T. Brunyé).

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If math anxious college students generally have the knowledge and ability to perform mathematics operations but are limited in their ability to effortfully control attention during anxiety-inducing situations, then treatments targeted at reducing anxiety and training attentional control might prove beneficial in supporting their math test performance. Unfortunately many contemporary treatments for math anxiety tend to be costly, rare, instructor-driven, and can require long-term (e.g., 2–14 weeks) commitments by students (often resulting in attrition). Recent work has identified one successful short-term intervention, asking students to briefly write about their testing worries immediately prior to a math exam. This activity provides temporary relief of the "burden that worry places on working memory," ultimately boosting math test scores by 5–10% (Ramirez & Beilock, 2011, p. 211). With the goal of building a resource toolkit of short-term interventions which students and instructors alike can easily implement, we investigated mindfulness-based and nutrition-based approaches that might prove valuable in reducing math anxiety and freeing up the mental resources necessary for performance during high pressure tests.

1.2. Focused breathing and attentional control

Attentional control theory (Eysenck, Santos, Derekeshan, & Calvo, 2007) suggests that when individuals experience anxiety about upcoming events they show impairments in effortfully controlling attention in a goal-directed manner. Under this theory, states of anxiety cause cognitive resources to be diverted away from task-relevant stimuli (e.g., math test performance) towards worry and rumination. A result of this resource shift is impairment of cognitive processes necessary for maintaining performance on difficult tasks, for instance controlling and shifting attentional resources, and updating and monitoring the contents of working memory (cf., Miyake et al., 2000). Attentional control theory provides a solid foundation for understanding why the math anxious show reduced test performance in spite of having the requisite knowledge to solve a task. Indeed as arithmetic problems become more demanding of carrying and borrowing operations, they recruit executive resources towards updating and monitoring (Hitch, 1978; Logie, Gilhooly, & Wynn, 1994). If these resources are otherwise consumed by anxious worry, cognitive performance suffers. The theory also makes the strong suggestion that some practices, such as mindfulness-based exercises aimed at reducing anxiety, hold potential in freeing up the mental resources necessary for controlling attention during demanding arithmetic tasks.

Mindfulness describes a mental state that allows individuals to maintain full attention to the sensations of present, ongoing experience. Long-term mindfulness training, such as mindfulness-based stress reduction (MBSR), has proven beneficial in promoting regulatory mental functioning such as controlling attention and regulating emotions (Lutz, Brefczynski-Lewis, Johnstone, & Davidson, 2008). Beneficial effects of mindfulness practices have also been found following relatively short-term bouts of focused breathing. For instance, 20 min of focused breathing enhances focused attention on the Stroop task (Wenk-Sormaz, 2005) and performance on a visuospatial task requiring attentional control (Kozhevnikov, Louchakova, Josipovic, & Motes, 2009). Behavioral evidence for the effects of mindfulness training on the control of attention is complemented by emerging findings in cognitive neuroscience (for a review, see Lutz et al., 2008). Brief bouts of mindfulness exercises (such as focused breathing) may hold promise for reducing anxious worry and enhancing test performance immediately following a short-term exercise; if this is the case, this type of exercise might prove advantageous in classroom settings involving high-stakes testing.

1.3. L-theanine and attentional control

The consumption of teas containing the amino acid L-theanine is historically associated with relaxing properties and may hold promise as a mild anxiolytic (Juneja, Chu, Okubo, Nagato, & Yokogoshi, 1999). Gomez-Ramirez et al. (2007) measured electroencephalographic (EEG) response during rest and after 250 mg of L-theanine, and found L-theanine related increased anticipatory alpha band activity over parietal and occipital scalp regions, suggesting reduced arousal states and potentially enhanced effortful control of attention.

To our knowledge very few studies have investigated L-theanine effects on acute stress response in humans, and results are equivocal. Kimura, Ozeki, Juneja, and Ohira (2007) suggest that 200 mg L-theanine supplementation can reduce both psychological and physiological stress responses to a mental arithmetic task (see also, Haskell, Kennedy, Milne, Wesnes, & Scholey, 2008). In contrast, Rogers, Smith, Heatherley, & Pleydell-Pearce, 2008 showed 200 mg of L-theanine reduced blood pressure relative to placebo, but did not reduce anxiety or arousal ratings. Similar results were found by Lu et al. (2004), who found that L-theanine did not reduce anxiety levels relative to placebo under stressful conditions. Thus, current results are mixed with regard to L-theanine's effects on human affective state and performance under anxiety-provoking circumstances.

1.4. The present study & hypotheses

To examine the effects of mindfulness exercises and L-theanine supplementation, we administered either 0 or 200 mg of L-theanine in capsule form, crossed with one of three breathing exercises (focused, unfocused, worry), in a repeated-measures design. Participants then completed a timed arithmetic task designed to elicit acute stress. We hypothesized that: 1) Students with high versus low math anxiety would show lower math subtest performance on standardized achievement tests, and relatively poor performance on the timed arithmetic task, 2) Students with high versus low math anxiety would show lower working memory capacity, indicating reduced capacity to effortfully control attention during complex timed tasks, 3) Focused breathing (versus unfocused or worry), and L-theanine supplementation (versus placebo), would increase self-reported calmness and decrease nervousness, particularly among those with high math anxiety, 4) The worry condition would induce the lowest overall arithmetic test performance (versus unfocused or focused), particularly among those with high math anxiety, and 5) If focused breathing and/or L-theanine supplementation increase self-reported calmness, these effects would translate to enhanced testing performance in math-anxious students.

2. Method

2.1. Participants

Thirty-six Tufts University undergraduates (18 males, 18 females) participated for monetary compensation. Demographics are detailed in Table 1. All participants were non-tobacco users and were not taking any prescription medications (other than oral contraceptives). Participants were excluded if they: reported being pregnant or nursing, have trouble swallowing pills, or have a history of diabetes, depression, anxiety disorders, panic attacks, cardiac disease, hepatic function impairment, hypertension, peptic ulcer disease, severe reflux or insomnia.

2.2. Design

We used a within-participants design with two independent variables, L-theanine (double-blind; 0 mg, 200 mg), and Breathing (Focused, Unfocused, Worry). These two factors were fully counterbalanced across participants. The two treatment levels were administered in identical capsule form with water; placebo contained microcrystalline cellulose powder.