Journal of Experimental Psychology: General

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Online First Publication, July 22, 2021. http://dx.doi.org/10.1037/xge0000893

CITATION

Jamieson, J. P., Black, A. E., Pelaia, L. E., Gravelding, H., Gordils, J., & Reis, H. T. (2021, July 22). Reappraising Stress Arousal Improves Affective, Neuroendocrine, and Academic Performance Outcomes in Community College Classrooms. *Journal of Experimental Psychology: General*. Advance online publication. http://dx.doi.org/10.1037/xge0000893

AMERICAN PSYCHOLOGICAL ASSOCIATION

Journal of Experimental Psychology: General

ISSN: 0096-3445

https://doi.org/10.1037/xge0000893

Reappraising Stress Arousal Improves Affective, Neuroendocrine, and Academic Performance Outcomes in Community College Classrooms

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The field experiment presented here applied a stress regulation technique to optimize affective and neuroendocrine responses and improve academic and psychological outcomes in an evaluative academic context. Community college students (N = 339) were randomly assigned to stress reappraisal or active control conditions immediately before taking their second in-class exam. Whereas stress is typically perceived as having negative effects, stress reappraisal informs individuals about the functional benefits of stress and is hypothesized to reduce threat appraisals, and subsequently, improve downstream outcomes. Multilevel models indicated that compared with controls, reappraising stress led to less math evaluation anxiety, lower threat appraisals, more adaptive neuroendocrine responses (lower cortisol and higher testosterone levels on testing days relative to baseline), and higher scores on Exam 2 and on a subsequent Exam 3. Reappraisal students also persisted in their courses at a higher rate than controls. Targeted mediation models suggested stress appraisals partially mediated effects of reappraisal. Notably, procrastination and performance approach goals (measured between exams) partially mediated lagged effects of reappraisal on subsequent performance. Implications for the stress, emotion regulation, and mindsets literatures are discussed. Moreover, alleviating negative effects of acute stress in community college students, a substantial but understudied population, has potentially important applied implications.

Keywords: stress, reappraisal, challenge and threat, psychophysiology, community college

Supplemental materials: https://doi.org/10.1037/xge0000893.supp

Whether you think you can, or you can't—either way, you're right.—Henry Ford

Supporting proficiency in science, technology, engineering, and mathematics (STEM) is important for addressing 21st century demands. STEM vocations are growing at faster rates with lower unemployment and greater earning potential than non-STEM vocations (Carnevale et al., 2013; Fayer et al., 2017). Employment in STEM vocations, though, requires STEM training, especially at the postsecondary level. Postsecondary STEM education, however, has traditionally underrepresented individuals from low-income and/or stigmatized groups, creating a "skills gap" in American society (White & Shakibnia, 2019). Community college systems, which are affordable 2-year programs in the United States that provide open access to postsecondary education, offer a promising and powerful mechanism for reducing skills gaps by preparing students for 4-year university programs and providing workforce development—that is, helping people maintain/upgrade professional skills and meet/maintain licensure requirements (Lowry & Thomas-Anderson, 2017).

Supporting STEM achievement is particularly important for underserved populations in the educational pipeline, such as community college students. Although community college students comprise a large proportion (42%) of U.S. postsecondary students (Ma & Baum, 2016) there remains a lack of research on this group, which is especially notable because community college students are disproportionately members of underrepresented groups (Carnevale et al., 2018). Moreover, community colleges often serve as the "last stop" in the educational system for students. If students do not pass community college courses and matriculate to 4-year programs, their vocational options and lifetime earnings potential are hamstrung (Autor et al., 2008; Webber, 2016). Thus,

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Data for this research were collected as part of a larger project funded by the U.S. Department of Education (R305A150036) awarded to Jeremy P. Jamieson and Harry T. Reis. We thank Tracy Boykins for her invaluable help recruiting classrooms and overseeing data collection procedures at one of the campuses, Aaron Altose for recruiting classrooms and his help developing manipulation materials, the Carnegie Foundation for the Advancement of Teaching for their help developing materials, as well as the many research assistants in the Social Stress Lab at Rochester for their help organizing data into electronic summary files.

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facilitating STEM achievement in community colleges has the potential to bear tangible benefits downstream and even provide an avenue through which inequalities in America might be addressed. Toward this end, the current research applied a stress regulation technique to attenuate the negative effects of academic stressors in this sensitive population. More specifically, we sought to test whether leading individuals to endorse the idea that stress responses can facilitate thriving (i.e., reappraise stress) would improve psychological, biological, and performance outcomes.

Regulating stress via optimization approaches is a promising avenue for intervention because Americans overwhelmingly adopt the view that stress is "bad" (Brooks, 2014). Indeed, a large corpus of research indicates that negative (i.e., avoidance-oriented) stress responses promote poor decision making (Jamieson & Mendes, 2016), harm cognitive functioning (Jefferson et al., 2010), and contribute to cardiovascular disease (Juster et al., 2010) and psychopathology (Aldao et al., 2010), to name a few harmful consequences of negative stress responses. Nonetheless, it is no surprise that regulatory efforts aimed at alleviating negative effects of stress have focused on stress reduction and avoiding stressors (e.g., Bränström et al., 2010; Hembree, 1988; see Somerfield & McCrae, 2000, for a review). For instance, meta-analytic data highlights the efficacy of stress reduction for decreasing feelings of anxiety in academic settings (e.g., Regehr et al., 2013; Yusufov et al., 2019).

Although stress is typically experienced and perceived as negative and maladaptive, experiencing stress can also have positive effects (see Crum et al., 2020, for a review). In fact, approach-oriented stress responses, in which individuals actively engage with and address demands, can attenuate feelings of anxiety, facilitate cognitive performance, and protect the body from damaging effects of catabolic hormones (e.g., Dienstbier, 1989; Epel et al., 1998; Jamieson et al., 2016; Mendes et al., 2007). Thus, the right kind of stress response can help people thrive in demanding situations (Crum et al., 2013). Indeed, people may underachieve, miss growth opportunities, or even suffer negative health outcomes if they allocate substantial resources to avoiding or reducing stress in acute settings. Accordingly, regulatory efforts that help individuals optimize their stress responses can lead to positive benefits, not just the avoidance of negative outcomes. Regulating stress via optimization may be particularly efficacious when individuals encounter stressful situations that cannot be mitigated or avoided. For example, educational systems around the world require students to take evaluative exams, which are inherently stressful because students are presented with acute demands (i.e., the test) they must address (i.e., provide answers). Exams have consequences for grades, advancement, and vocational opportunities. Providing students, particularly those at-risk like community college students, with regulatory tools that support active coping can help them realize their aspirations.

Biopsychosocial Model of Challenge and Threat

The biopsychosocial (BPS) model of challenge and threat provides a framework for understanding the processes underpinning stress responses in situations that require individuals to enact instrumental responses to acute demands (e.g., Blascovich & Mendes, 2010; Mendes & Park, 2014). More specifically, when individuals actively engage with stressful situations, appraisals of demands (e.g., uncertainty, potential danger, and expected effort) and resources (e.g., familiarity, knowledge, and ability) interact to inform challenge- and threat-type psychological states and physiological responses (see Mendes & Park, 2014, for a review). Challenge manifests when appraisals of resources are perceived as exceeding situational demands, whereas threat stems from demands exceeding resources.

Physiologically, challenge and threat states differentially activate the sympathetic-adrenal-medullary (SAM) and hypothalamic-pituitary-adrenal (HPA) axes. Both challenge and threat responses elicit SAM activation—stimulating a rise in catecholamines, which increases ventricular contractility and dilates blood vessels (e.g., via beta-2 receptor systems; Brownley et al., 2000). The experience of threat also stimulates the HPA axis, activation of which is typically assessed by measuring its end product: the catabolic adrenal hormone, cortisol. Approach-oriented challenge responses, however, counteract catabolic effects of cortisol by increasing growth-promoting anabolic hormones. Elevations in anabolic hormones are indicative of active, approach-oriented coping, as well as associated with resilience and thriving in acute stress contexts (e.g., Crum et al., 2017; Epel et al., 1998; Russo et al., 2012).

The BPS literature also demonstrates that challenge and threat have consequences for motivational and affective responses. For example, whereas challenge predicts appetitive approach motivation, threat leads to aversive avoidance motivation (e.g., Hangen et al., 2016; Jamieson & Mendes, 2016; Jamieson et al., 2014). Approach motivated states predict a host of positive outcomes, including, but not limited to, greater wellbeing, positive relationship outcomes, and improved cognitive and motor performance (e.g., Elliot & Reis, 2003; Heimpel et al., 2006; Yeatts & Lochbaum, 2013). Accordingly, it is not surprising that, in the stress literature, challenge-type responses lead to positive behavioral and performance outcomes (e.g., Blascovich et al., 1999; Jamieson et al., 2012; Turner et al., 2012). Threat, on the other hand, can impair decision-making and is associated with cognitive decline with age (Jefferson et al., 2010; Matthews et al., 1997). More specifically relevant for this research, threat responses predict anxiety about being evaluated in mathematics (Jamieson et al., 2016). Thus, developing tools to help students regulate their stress responses has the potential to help improve affective, physiological, and academic outcomes.

Stress Reappraisal

Research on stress reappraisal grew directly out of challenge and threat theory (e.g., Blascovich, 1992) and the positive emotion literature (Tugade & Fredrickson, 2004). This regulatory approach is predicated on the idea that manipulating or modifying cognitive appraisals has the potential to improve stress responses and downstream outcomes. Indeed, a growing body of literature supports the notion that in motivated-performance contexts, stress responses, affective processes, and behavioral and performance outcomes can benefit from modifying stress appraisals (e.g., Beltzer et al., 2014; Brady et al., 2018; Hangen et al., 2019; Jacquart et al., 2020; Jamieson et al., 2010; Jamieson, Mendes, & Nock, 2013; Jamieson, Nock, & Mendes, 2013; Jamieson et al., 2012, 2016; John-Henderson et al., 2015; Moore et al., 2015; Oveis et al., 2020; Rozek et al., 2019; Sammy et al., 2017). Optimization approaches like stress reappraisal emphasize individual agency in the construction of acute stress responses (cf. Barrett, 2017). That is, individuals actively regulate by engaging upstream appraisal processes to shape downstream stress responses (e.g., Blascovich, 2008; Carver et al., 1989; Folkman & Lazarus, 1984).

The aim of stress reappraisal is to increase the ratio of perceived resources to perceived demands by presenting the stress response itself as a coping tool (for reviews, see Jamieson, 2017; Jamieson et al., 2018). More specifically, these techniques provide individuals with information that encourages them to endorse the perspective that the arousal experienced during stressful situations can be a functional resource that facilitates performance and resilience (cf., Crum et al., 2013; Dienstbier, 1989). If individuals allocate less effort toward ignoring, eliminating, or dampening their stress responses and instead appraise their body's stress responses as resources, this shift in cognitive processing increases the ratio of resource to demand appraisals, making it more likely individuals will experience challenge instead of threat.

However, extant research has typically focused on effects of stress reappraisal in laboratory settings (e.g., Jamieson et al., 2012) or in highly achieving students (e.g., Brady et al., 2018; Jamieson et al., 2010; for an exception, see Jamieson et al., 2016). The research presented here sought to build upon prior work demonstrating that stress reappraisal manipulations might be effective in promoting positive psychological and performance outcomes in community college students (Jamieson et al., 2016). That is, we were interested in testing whether helping at-risk students regulate their stress responses in an evaluative exam setting could produce immediate and sustained benefits across multiple levels of analysis: psychological processes, physiological responses, and academic outcomes. To date, no stress reappraisal research has elucidated the processes underlying temporal dynamics. Reappraising stress arousal was primarily tested *within* the contexts in which the manipulations were delivered and the processes driving potential sustained and/or lagged effects are unclear. That is, although initial work observed that standardized test scores were higher months after a reappraisal manipulation (Jamieson et al., 2010), there is no evidence for how this effect emerged. Exploring potential lagged effects using a process-focused approach can advance this literature because promoting more adaptive stress responses in one situation has the potential to feed-forward to impact stress processes in subsequent similar (or even dissimilar) stressful situations (Gross, 2015).

Emotion Regulation Dynamics

The idea that affective responses—as well as stress responses—are dynamic is central to Gross's generative process model of emotion regulation (Gross, 2015). An update to the model—the extended process model of emotion regulation (EPM)—theorizes that recurrent interactions occur among the "World" (situational factors), "Perceptions" (attentional processes), "Valuations" (appraisal and mindset processes), and "Actions" (responses), creating a "W-PVA" cycle across first- and second-level valuation systems (Gross, 2015). First-level valuation systems are affect (or stress) generation systems (i.e., the W-PVA cycle that constructs emotional experiences). Second-level valuation systems target and modify first-level processes when current affective states do not match desired states. The regulatory action outputs of second-level systems can modify attributes of the "world" such as situation selection (e.g., Livingstone & Isaacowitz, 2015), perceptual processes such as distraction (e.g., Knight et al., 2007), valuation processes such as reappraisal (e.g., Goldin et al., 2008), and/or action outputs such as expressive suppression (e.g., Peters & Jamieson, 2016).

An innovation of the EPM was to provide a framework to map how affect regulation can persist over time. If second-level regulatory outputs become internalized within first-level systems, the regulated output becomes "the new normal." Going forward, this new (i.e., previously regulated) first-level W-PVA cycle impacts the construction of future affective responses without actively engaging second-level regulation systems. For example, stress reappraisal manipulations that seek to help community college students endorse the idea that their stress responses are functional may promote resilience in an exam setting. The new appraisal pattern, explicitly enacted previously with help from the manipulation materials, can potentially become integrated into the first-level system if reappraisal efforts were successful. Therefore, when students encounter subsequent stressful exams, they may not need to engage a second-level system to regulate stress responses because the first-level system has already incorporated that valuation.

To speculate on how such a process could operate, a mindsets-based manipulation delivered to teenagers at the start of the school year fed-forward and improved stress responses and performance outcomes via alterations in stress appraisals on subsequent days in which those teens encountered stressful social situations (Yeager et al., 2016). This notion coheres well with other work illustrating that brief manipulations delivered at sensitive times can exert positive effects months, or even years, down the road (e.g., Yeager et al., 2016). In fact, intervention scientists emphasize that internalization and recursive processes are critical for sustaining benefits over time (Yeager & Walton, 2011).

Building on this perspective, the research presented here explored how stress reappraisal instructions might feed-forward to impact responses in future stressful situations decoupled from manipulation delivery. To do so, the design of the current research measured two preparation processes between exam contexts when the manipulation was administered and the subsequent exam: Procrastination tendencies and performance goals. Overwhelming stressors (i.e., demands > resources) may lead students to procrastinate to avoid negative affective experiences (Kandemir et al., 2014) and procrastinating when preparing for stressful assessments negatively predicts outcomes (Steel, 2007). Performance goals play an important role in how students engage with and perform in evaluative settings (Elliot & MacGregor, 2001). Performance avoidance goals—seeking to avoid a negative possibility—are associated with avoidance-oriented negative affective states like anxiety (e.g., Hannon, 2012), whereas performance approach goals can predict positive affective responses and facilitate coping in stressful evaluative contexts (e.g., Nicholls et al., 2014). This research hypothesized that reappraising stress arousal would help increase the ratio of students' coping resources relative to situational demands, which could then alter how students prepare for and aim to do on future exams. This would provide evidence that adaptive stress appraisal processes in one situation can become internalized and subsequently aid outcomes in future (albeit similar) contexts.

Current Research

This field experiment was planned with two core aims: First, we sought to test the efficacy of reappraising stress arousal on affective processes, neuroendocrine responses, and exam performance in a naturalistic setting with an understudied population: community college students. Research suggests feelings of overwhelming stress are more likely to impede learning and achievement in community college students relative to students at 4-year colleges (Eisenberg et al., 2016). To better understand students' affective experiences, we measured math anxiety—operationalized as avoidance oriented negative affect that manifests when engaging with math (Jamieson et al., 2020). Anxiety about math taps into negative affect in two ways: engaging with math (*learning anxiety*) and/or being evaluated in math (*evaluation anxiety*; e.g., Hopko et al., 2003). This distinction is important for the stressful context studied here (i.e., classroom exams). That is, because we sought to optimize stress responses in an evaluative context, math evaluation anxiety was the focal affective process (see also, Jamieson et al., 2016).

While we posit that helping students view their stress responses as a resource should support more adaptive affective responses and promote achievement in performance settings, it is possible that stress reappraisal may not be effective for students from this population. For instance, if demands are too high, students may "check out" and disengage. To test whether reappraising stress as adaptive and subsequent stress responses might help guard against student disengagement, we examined course retention rates after the manipulation was delivered. If reappraising stress as functional lessens anxiety, improves stress responses, and facilitates performance, this process has the potential to help students persevere rather than exiting the course before completion.

Second, we sought to explore the processes through which effects of stress reappraisal might generalize beyond a single stress context. To date, no research on stress reappraisal has clearly mapped sustained effects of the manipulation. The little research that has examined outcomes beyond the time at which the manipulation was delivered relied on single metrics, such as a score on a standardized test or a grade (Brady et al., 2018; Jamieson et al., 2010) and did not elucidate processes. Thus, mechanisms undergirding effects remain murky. The lack of process-focused data are a sizable gap because without this knowledge there is little idea *how* stress optimization approaches might work, identifying boundary conditions or samples for which the manipulation may be more or less effective is difficult to achieve.

Effects of stress reappraisal were tested in comparison to an active control condition structured to be similar to traditional advice regarding stress regulation. More specifically, control materials advised students to ignore the sources of the stress they might be experiencing and to "try not to think about it" and "put it out of your mind" (e.g., Jamieson et al., 2012). Although it would appear on the surface that advising someone to ignore stressors and negative affect is reasonable, ironic processes research suggests that efforts to ignore target stimuli actually make targets more, not less, salient (Wegner, 1994). Furthermore, existing research shows that suppression often enhances rather than reduces negative emotions, especially activated negative emotions like anxiety (Ruan et al., 2020). Thus, the control helped establish an expectation that the instructions would be beneficial, but we did not expect control materials to promote adaptive stress responding or aid performance. Because students were randomized *within* classrooms and in a group setting, the organization and presentation of the content mirrored the reappraisal condition, so it appeared all students were completing similar materials, regardless of condition.

These aims were tested in a community college sample. Testing effects in community college students is notable because of the limited research on way to support achievement in this large, but at-risk, group of postsecondary students. Additionally, the reappraisal manipulation took a "person centered" approach aimed at encouraging students to internalize the new appraisal pattern rather than relying on external "ought to" coaching or reminders. This is important considering the high turnover of instructors at community colleges.

Sample sizes and data collection termination rules were determined a priori (see below). Instructors were blind to condition assignment and specific hypotheses. All data were collected before analyses were conducted, and all analyses, including multilevel models (MLMs), were planned a priori. All manipulations, data exclusions, and variables analyzed are reported, and the data and stress reappraisal manipulation materials are publicly available at: https://socialstresslab.wixsite.com/urochester/research. We confirm that no analyses were conducted for the current experimental tests until the termination of data collection at the end of the project.

Method

Targeted Sample Size and Data Collection Termination Rule

To maximize power, data were collected throughout the duration of the funded project (see Author Note). Data collection was terminated when funding was exhausted. To ensure that the sample size was sufficiently powered, we calculated the targeted sample size for basic tests of the manipulation on outcomes (i.e., main effects of stress reappraisal). Given a low-medium effect size (Cohen's d = .40), 100 participants per condition would be needed to achieve .80 power. Thus, as indicated below, the sample size recruited N = 339 was sufficiently powered (reappraisal n = 167, control n = 172). Because we anticipated correlated responses among members of the same cohort and participants were randomized *within* cohort, this power analysis is conservative in that an MLM analysis accounts for nesting.

Participants

Students (N = 339) were recruited from mathematics courses at an urban Midwestern community college system (M_{age} = 24.94, SD_{age} = 9.00, range = 14–60; 211 female, 128 male; 166 Black/African American, 139 White/Caucasian, 16 Latinx, 16 Asian, 2 Mixed/Other). The observed demographic characteristics of the sample recruited here (i.e., high proportion of minority students and a wide age range) broadly correspond to the broader population of community college students in the United States. That is, community colleges typically (but not exclusively) serve postsecondary students who are enrolled in licensure/certificate programs, terminal 2-year programs, and/or matriculate to 4-year college programs. We note that the system studied here serves a large urban area with a 39% minority student enrollment and a .55 diversity index score, both of which exceeded college enrollment averages for the state. Moreover, the median income of students/students' families was ~$50,000 and 65% of students were considered low-income based on Federal Pell grant Aid receipts. Students were recruited from 30 mathematics courses across 10 semesters and two campuses (campus 1 n = 18 classes, campus 2 n = 12 classes). Courses included diverse topics, including prealgebra, algebra, prestatistics, probability and statistics, trigonometry, and precalculus. Participants were prescreened and excluded for physician-diagnosed conditions that impact endocrine functioning, current medications with endocrine effects, and BMI > 30 (Body Mass Index).

Three research staff collected data from each of the college's two campuses. No monetary compensation was provided, as manipulation materials and measures were integrated with curriculum materials. To facilitate recruitment of classrooms and compensate for instructors' time spent integrating study materials, instructors were provided with a $500 honorarium. Parental consent was obtained for three participants who were under 18 years of age.

Procedure

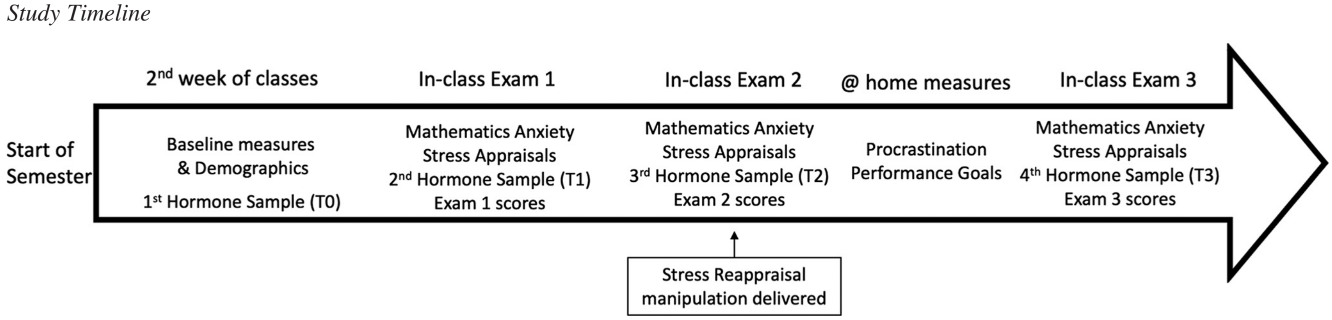
All procedures, materials, and measures were approved by institutional review boards at both community college that was the site of data collection and the authors' home university where data was analyzed. After instructors provided access to their classes, research staff visited classrooms during the first week of the semesters to explain the study. During this visit students provided consent and completed demographic measures in class, including a baseline saliva sample (T0) to be assayed for hormones. After the baseline sessions, measures of math anxiety and stress appraisals were collected on the day of students' first in-class exam. Students completed assessments (pretested to take < 5 min to complete) before beginning their exams. After students handed in questionnaires, they were given test tubes to collect saliva samples (T1). Once students completed saliva samples, they were given their exams. Students received their exams after completing all study materials to allow for psychological and neuroendocrine measures to serve as predictors

As shown in Figure 1, the reappraisal manipulation was implemented at students' second in-class exam. This sequence afforded comparisons to a prior exam when assessing the effects of the manipulation. That is, this procedure minimizes the possibility that any differences between stress regulation groups might stem from random assignment artefacts. Students were randomly assigned to stress appraisal and active control groups by off-site personnel who had no prior contact with the students. Both reappraise stress and ignore stress manipulation materials took ~12 min to complete. Exams were planned to account for time spent on study materials. Moreover, students were afforded time to assimilate the manipulation content has they completed questionnaires (see below) and provided saliva samples after completing manipulation materials.

The aim of the stress reappraisal materials was to encourage individuals to endorse the idea that their stress responses are functional and help facilitate their performance on the exam that day. More specifically, participants assigned to this condition were informed that increased arousal felt during testing is not harmful. Instead, the instructions explained how stress responses evolved to help us address acute demands and that increased arousal aids performance (Jamieson et al., 2012). Materials were adapted from laboratory studies (Beltzer et al., 2014; Jamieson et al., 2012) and a prior field test (Jamieson et al., 2016). All materials are freely available at https://socialstresslab.wixsite.com/urochester/research. In the stress reappraisal condition students first read two summaries of scientific articles, which were modified to match the message conveyed in each condition. Consistent with a values alignment approach to changing psychological processes (Bryan et al., 2019); students completed a brief writing exercise after each summary with the prompt: *In your own words please briefly describe how this information can help you perform well on your exam today*. Then, students were shown an illustrative diagram highlighting biological responses to stress throughout the body and how those response can be helpful (e.g., *Stress increases your heart rate so it can deliver fuel to your brain to help you think. Your heart sends oxygen to fuel your brain*) followed by a self-reflection on what the body's stress responses means to them and how it can help aid their performance.

The format of the active control condition was identical to the stress reappraisal condition: summaries of research articles followed by an illustrative diagram with brief writing exercises after each. However, the materials in the control condition conveyed the idea that the best way to improve outcomes during stressful testing situations is to ignore stress and "put it out of your mind" to remain calm. Thus, students were told to ignore negative thoughts associated with stress during exams. The notion that

Figure 1
Study Timeline



stress is negative and attenuating stress responses is the optimal coping strategy aligns well with people's lay theories of stress (Brooks, 2014). Materials were based on expressive suppression from the emotion regulation literature (e.g., Peters & Jamieson, 2016), but, rather than suppressing affective displays (i.e., outputs), participants were told to ignore and try not to experience stress (i.e., suppress the affective experience rather than the output). Using this active control, as opposed to a no-instruction control, kept instructors and students blind to conditions, and also accounted for time/effort spent on materials.

After completing reappraisal/control materials and subsequent questionnaires, students were given a sanitary straw, test tube, and self-report measures. Students were asked to expectorate 1 ml of saliva into test tubes after which they completed the self-report measures. Saliva samples (T2) were timed to begin ∼15–20 min from the start of manipulation materials, and sample collection ended ∼20–30 min from start of manipulation materials. This timing was implemented because research indicates that it takes 15 min to observe anticipatory responses in salivary cortisol and ∼30 min to observe peak responses (Aschbacher et al., 2013; for similar methods see Jamieson & Mendes, 2016).

After the second in-class exam, instructors from a subset of classrooms (k = 14) consented for researchers to contact their students with requests to complete questionnaires outside of class between their second and third classroom exams. Questionnaires asked students to report on stress appraisals about their upcoming third exam, their performance goals for the exam (e.g., Elliot et al., 1999) and procrastination behaviors (e.g., Steel, 2007). Out of a possible 229 students from participating classrooms (i.e., the classrooms that consented to at-home questionnaires), 147 students (64%) returned questionnaires before their third exam—however, one participant did not complete all performance goal items.

Research staff returned to classrooms for students' third in-class exam and assessed stress appraisals and math anxiety followed by a saliva sample (T3). Procedures during Exam 3 were identical to those implemented at Exam 1 (i.e., no manipulation boosters were provided). This design was intentional as we sought to track potential sustained effects of the manipulation across exam times.

Measures

Math Anxiety

Math anxiety was assessed using the Abbreviated Math Anxiety Scale (AMAS), which was constructed, validated, and replicated with a large student sample (Hopko et al., 2003). Consistent with previous research using the AMAS, a factor analysis conducted on the nine-item scale on the dataset here provided a two-factor solution that accounted for 68% of the variance, determined using Cattell's "scree" test and eigenvalues greater than one. The two factors were best interpreted using the subscale designations of learning anxiety (Cronbach's α = .79) and evaluation anxiety (Cronbach's α = .86) identified in previous research (Hopko et al., 2003). Thus, composites were constructed for each subscale and analyzed separately (for a similar approach, see Jamieson et al., 2016).

Stress Appraisals

A measure from the social stress literature was used to index stress appraisals (Beltzer et al., 2014; Jamieson et al., 2016; Yeager et al., 2016; adapted from Mendes et al., 2007). This short-form four-item appraisal measure included two demand appraisal and two resource appraisal items. As is common practice with research using this scale, composites of situational demands (e.g., "*this situation is demanding*") and personal resources (e.g., "*I have the abilities to perform well*") were computed at each time point (αs > .80).

In the context of the BPS model, threat states stem from appraisals of coping resources relative to perceived task demands. Thus, we created a threat appraisal score by subtracting resources from demands, such that values greater than 0 corresponded to threat appraisals (demands > resources), and values less than 0 corresponded to challenges (perceived resources exceed demands). For a similar approach, see Yeager et al. (2016).

Performance Goals

Students' goals for their performance on their upcoming exam were measured using Elliot and Murayama's (2008) six-item achievement goal measure, which yielded performance-approach (α = .84) and performance-avoidance (α = .81) goal indexes. Given observed positive correlations between approach and avoidance goals (Hangen et al., 2019), approach and avoidance goals were analyzed separately.

Procrastination Tendencies

Meta-analytic data indicate that procrastination negatively predicts academic achievement and performance (Kim & Seo, 2015). Procrastination tendencies were assessed in the current research with the validated Pure Procrastination Scale, which conceptualizes procrastination behaviors as irrational delays (α = .77; Steel, 2010).

Neuroendocrine Responses

Neuroendocrine functioning was measured by assessing cortisol and testosterone reactivity. To do so, two 1-ml saliva samples were collected using passive drool procedures, in which participants expectorated saliva through a small straw into an IBL SaliCap collection device (Hamburg, Germany; test tubes were marked with a line indicating 1 ml). Participants were allowed a maximum of 7-min to provide samples. (for similar procedures, see Lee et al., 2019; Peters et al., 2016; Yeager et al., 2016).

After collection, research staff transferred samples to a −30 °C biomedical freezer where they were stored until shipment for assay. At the conclusion of the study, samples were packed on dry ice and shipped to Brandeis University (Waltham, MA) where they were assayed for salivary free testosterone and cortisol using commercial immunoassays kits (Testosterone Saliva ELISA, Tecan; chemiluminescence assay, IBL, Toronto, Canada, respectively). Samples were assayed in duplicate and outliers checked by reassay. Inter- and intraassay coefficients of variance were < 10%. Due to an insufficient sample neuroendocrine reactivity for 20 participants could not be analyzed.

As mentioned above, baseline samples were collected in class on a day without an assessment, whereas exam day samples were collected before exams. It was important that baseline samples were collected in class on a day without an assessment to control for time of day and classroom environment—that is, we were interested in students' neuroendocrine responses to stressful evaluative situations above and beyond typical functioning in a classroom environment.

To measure reactivity—or changes from baseline levels—we first standardized cortisol and testosterone levels within sex using the levels recorded at baseline. Because of pronounced sex differences in testosterone reactivity and some sex differences in associations between testosterone and cortisol (e.g., Juster et al., 2016), cortisol and testosterone were standardized separately for males and females. Then, we subtracted standardized cortisol and testosterone levels collected on exam days from those collected at baseline (T1-T0; T2-T0; T3-T0).

To reduce undue influence from extreme values, it was decided a priori that any cases of standardized hormone variables exceeding 3 would be winsorized to a value of 3. Across the four hormone variables (baseline to Exam 3) for 24 cases were winsorized for testosterone and 49 for cortisol. Results for the hormone variables presented below use the winsorized versions of these variables, however, results are essentially identical (i.e., no significant effects dropped to nonsignificance, and no nonsignificant effects were then significant) if raw scores are used for all hormone analyses.

Results

Data Analysis Plan and Descriptive Statistics

Analyses include results from all participants who provided data for that analysis. When more than one variable is involved in an analysis (e.g., analyses including all three exams), analyses include all participants for whom *all* of the included variables were provided. Basic correlations among predictor and outcome variables are reported in online supplemental material. Demand and resource appraisals were negatively and moderately correlated at Exam 1 ($r = -.37$, $p < .001$), again at Exam 2 ($r = -.35$, $p < .001$), and Exam 3 ($r = -.37$, $p < .001$), and, consistent with the literature reviewed earlier, were combined into a composite by subtracting demands from resources. Predictor variables were grand-mean centered in the multilevel analyses.

Multilevel Analyses

To examine classroom performance, we first analyzed exam scores. Given that data were collected from 30 classrooms, students completed exams at different schedules, and courses covered multiple mathematics topics (e.g., algebra, statistics, etc.), nesting data within class cohorts was necessary. Indeed, a repeated measures analysis of variance (ANOVA) examining the effect of class cohort across the three exams exhibited a significant effect of class cohort, $F(29, 309) = 2.74$, $p < .001$, and exam scores across time, $F(2, 618) = 5.27$, $p = .005$, which were both qualified by an Exam × Class Cohort interaction, $F(58, 618) = 2.21$, $p < .001$. Because of these differences and the fact that the data structure involved repeated measurements nested within students nested within classrooms, a three-level multilevel model was constructed to test hypotheses (Raudenbush & Bryk, 2002). Predictors were measured at the repeated-time level (Level 1), which were nested within students (Level 2), which were nested within cohorts (classrooms) at Level 3. Each predictor was included as a fixed effect, with random intercepts for each model.

Main Effects of Stress Reappraisal

Exam Performance

We first examined how the reappraisal manipulation predicted exam performance. In this and all subsequent analyses, time was represented by two contrasts, the first compared T1 exam scores (premanipulation) with T2 and T3 scores (contrast 1), and the second compared T2 and T3 scores (contrast 2). The predicted interaction between manipulation condition and contrast 1 was significant, $B = 1.17$, $SE = .20$, $t(511.865) = 5.73$, $p < .001$, $r = .25$ (see Figure 2).[1] Simple effects tests revealed no difference between conditions at Exam 1 (that was expected as students had not been randomized into conditions at that point), $M_{reapp} = 76.13$, $SD_{reapp} = 14.20$, $M_{cont} = 77.59$, $SD_{cont} = 13.92$, $B = -.61$, $SE = .78$, $t(548.923) = -.78$, $p = .437$, $r = .03$.[2] However, the difference between conditions was significant at Exam 2, $M_{reapp} = 77.55$, $SD_{reapp} = 15.34$, $M_{cont} = 71.72$, $SD_{cont} = 17.09$, $B = 3.03$, $SE = .78$, $t(548.923) = 3.87$, $p < .001$, $r = .17$, and at Exam 3, $M_{reapp} = 79.01$, $SD_{reapp} = 14.42$, $M_{cont} = 73.77$, $SD_{cont} = 15.90$, $B = 2.74$, $SE = .78$, $t(548.923) = 3.50$, $p = .001$, $r = .15$. No Manipulation × Contrast 2 interaction emerged, $B = .15$, $SE = .34$, $t(576.588) = .43$, $p = .670$, $r = .02$, suggesting effects of the manipulation did not significantly vary from Exam 2 to Exam 3.

In subsequent analyses, sex (male = 0, female = 1), race (Black = 1, White = 0) and age (centered) were added as potential moderators of exam score. Race was associated with exam scores (across time), $B = -4.57$, $SE = 1.44$, $t(333.346) = -3.16$, $p = .002$, $r = .17$, with Black students scoring lower on the exams relative to White students. Race, though, did not interact with the manipulation and contrast 1, $B = .09$, $SE = .50$, $t(752.979) = .19$, $p = .853$, $r = .01$, nor with the manipulation and contrast 2, $B = .89$, $SE = .72$, $t(607.808) = 1.24$, $p = .217$, $r = .05$. Sex and age were not significantly associated with exam scores, $ps = .053$ and $.593$, respectively, nor did either variable interact with the manipulation and contrast 1, $ps = .905$ and $.950$, respectively, or the manipulation and contrast 2, $ps = .123$ and $.251$, respectively.[3]

Course Retention

Postmanipulation retention (i.e., retention rates *after* the reappraisal and control materials were delivered at Exam 2) was tested with a generalized linear mixed model using a binomial probability distribution for the outcome—whether or not participants completed the course—with robust estimation. Intercepts were allowed to vary randomly, and fixed effects were used to estimate the condition effect. The condition effect was significant, $t = 4.28$, $p =$

[1] B coefficients reported in the text are unstandardized.

[2] We conducted simple effects tests only following a significant interaction, which ensures an acceptable family-wise error rate (Cohen et al., 2013), per the Fisher's protected-t procedure.

[3] The marginal effect of sex on exam scores, $B = 2.72$, $t(323.793) = 1.94$, $p = .053$, $r = .11$, implied that, contrary to gender-math stereotypes, females slightly outperformed males overall.

.002, odds ratio (*OR*) = 2.48 95% confidence interval (CI) [1.63, 3.77]. In the control condition, 78.8% of the students who were enrolled at the time the reappraisal manipulation was delivered (i.e., the students who remained enrolled up through their second exam) completed the course; in the reappraisal condition, 90.2% of students completed the course.[4]

In subsequent analyses, we added sex, race, and age as potential moderators of retention. Age was associated with retention rates, such that older students were more likely to complete the course, $t = 2.029$, $p = .043$, $OR = 1.04$ 95% CI [1.00, 1.09]. Age did not interact with the reappraisal manipulation, though, $t = .114$, $p = .909$. Sex and race did not influence retention, *ps* = .864 and .599, respectively, nor did either variable interact with condition, *ps* = .117 and .286, respectively.

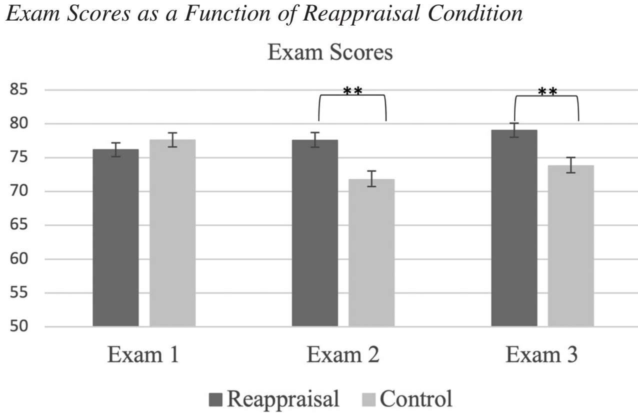
Math Anxiety

As shown in Table 1, Math learning anxiety and math evaluation anxiety were analyzed separately. Tests of the effect of reappraisal on math learning anxiety yielded no significant interactions between condition and contrast 1, $B = -.00$, $SE = .01$, $t(474.477) = -.23$, $p = .821$, $r = .01$, or between condition and contrast 2, $B = -.02$, $SE = .02$, $t(577.390) = -1.35$, $p = .177$, $r = .06$.

For math evaluation anxiety, however, the predicted interaction between condition and contrast 1 emerged, $B = -.06$, $SE = .01$, $t(451.877) = -4.35$, $p < .001$, $r = .20$. Simple effects tests revealed no significant difference in math evaluation anxiety between conditions at Exam 1 (before manipulation delivery), $M_{reapp} = 3.28$, $M_{cont} = 3.19$, $B = .04$, $SE = .05$, $t(509.764) = .73$, $p = .467$, $r = .03$. However, consistent with predictions, condition differences emerged at Exam 2, $M_{reapp} = 3.06$, $M_{cont} = 3.30$, $B = -.13$, $SE = .05$, $t(512.665) = -2.49$, $p = .013$, $r = .11$, and Exam 3, $M_{reapp} = 3.02$, $M_{cont} = 3.33$, $B = -.14$, $SE = .05$, $t(546.492) = -2.69$, $p = .007$, $r = .11$. The Contrast 2 × Condition interaction was not significant $B = .01$, $SE = .02$, $t(614.066) = .32$, $p = .752$, $r = .01$.

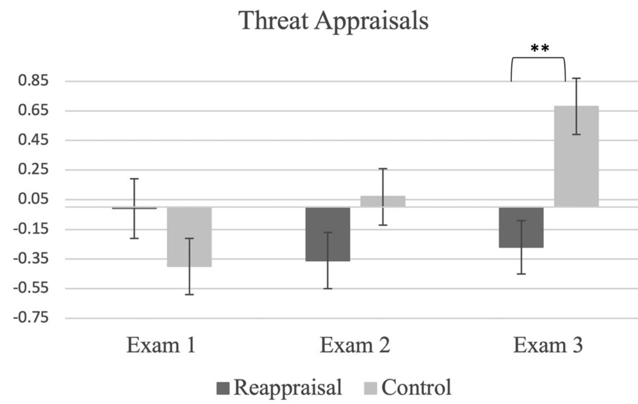
In subsequent analyses, sex, race, and age were added to the model as potential moderators of math evaluation anxiety. None significantly influenced evaluation anxiety, *ps* = .081, .766, and .567, respectively, nor did any of these variables interact with condition and contrast 1, *ps* = .560, .051, and .829, respectively, or with the manipulation and contrast 2, *ps* = .355, .453, .620, respectively.

Figure 2
Exam Scores as a Function of Reappraisal Condition



Note. ** Indicates conditions differed at $p < .01$.

Figure 3
Change in Threat Appraisals From Baseline for Each Exam Time as a Function of Reappraisal Condition



Note. ** Indicates conditions differed at $p < .01$.

Threat Appraisals

The next model assessed the effect of the manipulation on stress appraisals. First, as hypothesized, we observed a Contrast 1 × Manipulation interaction, $B = -.17$, $SE = .03$, $t(465.540) = -4.86$, $p < .001$, $r = .22$ (see Figure 3). As expected, simple effects tests revealed no significant difference by condition at Exam 1, $M_{reapp} = -.01$, $SD_{reapp} = 2.56$, $M_{cont} = -.40$, $SD_{cont} = 2.50$, $B = .18$, $SE = .12$, $t(559.112) = 1.50$, $p = .136$, $r = .06$. Then, contrary to predictions, threat appraisals did not differ between conditions at Exam 2, $M_{reapp} = -.36$, $SD_{reapp} = 2.49$, $M_{cont} = .07$, $SD_{cont} = 2.42$, $B = -.22$, $SE = .12$, $t(562.583) = -1.80$, $p = .072$, $r = .08$, though the condition effect did emerge at Exam 3, $M_{reapp} = -.27$, $SD_{reapp} = 2.17$, $M_{cont} = .68$, $SD_{cont} = 2.23$, $B = -.42$, $SE = .12$, $t(600.104) = -3.36$, $p = .001$, $r = .14$. The Contrast 2 × Condition interaction was not significant, $B = .10$, $SE = .05$, $t(616.125) = 1.85$, $p = .065$, $r = .07$.

Sex, race, and age were added as potential moderators, but none influenced threat appraisals, *ps* = .279, .370, and .567, respectively, nor did any of these variables significantly interact with condition and contrast 1, *ps* = .218, .770, and .922, respectively, or with condition and contrast 2, *ps* = .787, .980, .492, respectively.

Neuroendocrine Responses

Before examining effects of reappraisal on neuroendocrine reactivity (i.e., changes from baseline) on exam days, we first tested for baseline differences between conditions that could mask (or amplify) reactivity effects. As expected, simple effects tests revealed no condition effects for either cortisol, $B = .00$, $SE = .05$, $t(513.030) = .00$, $p = .998$, $r = .00$, or testosterone, $B = .05$,

[4] A follow-up analysis predicted retention from the reappraisal manipulation and Exam 2 scores. Both effects were significant: condition, $B = .686$, $t(388) = 2.85$, $p < .05$; Exam 2 scores, $B = .033$, $t(388) = 5.47$, $p < .001$. This pattern of data indicates the reappraisal manipulation facilitated retention over and above Exam 2 performance.

Table 1

Math Anxiety Means and Standard Deviations (in Parentheses) for Reappraisal and Control Conditions

Variable	Exam 1	Exam 2	Exam 3
Math learning anxiety, reappraisal	1.78 (0.81)	1.79 (0.80)	1.80 (0.78)
Math learning anxiety, control	1.76 (0.70)	1.83 (0.72)	1.76 (0.70)
Math evaluation anxiety, reappraisal	3.28 (1.00)	**3.06 (1.06)**	**3.02 (0.98)**
Math evaluation anxiety, control	3.19 (1.01)	**3.30 (0.99)**	**3.33 (0.91)**

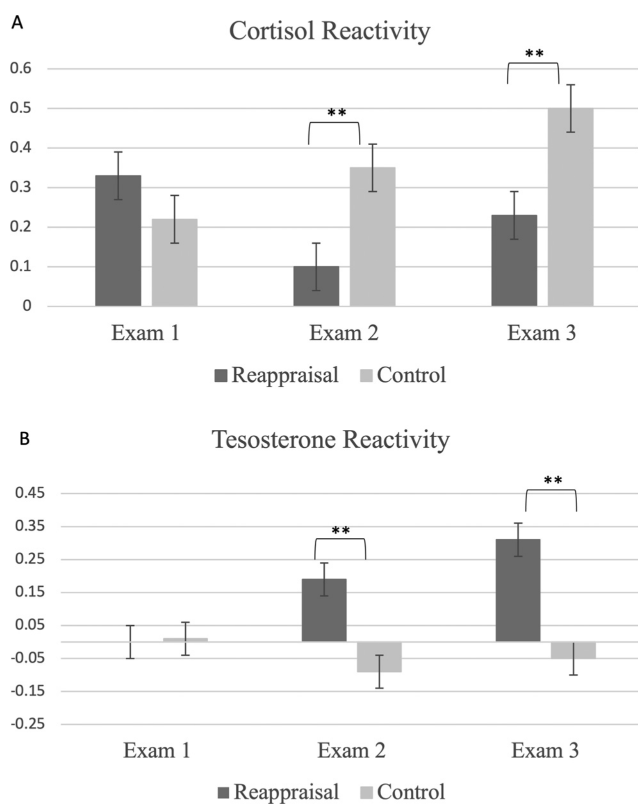
Note. Bolded means signify a statistically significant difference as a function of condition.

SE = .05, t(418.653) = .98, p = .328, r = .05. Then, condition effects were analyzed using the same approach as described previously for the self-report variables.

Consistent with hypotheses, the Contrast 1 × Condition interaction emerged for cortisol reactivity, B = −.06, SE = .01, t(497.179) = −4.71, $p < .001$, r = .21, and the Contrast 2 × Condition interaction was not significant, B = −.00, SE = .02, t(498.899) = −.03, p = .976, r = .00 (see Figure 4). Simple effects analyses revealed no condition differences in cortisol reactivity at exam prior to the manipulation delivery, M_{reapp} = .33, SD_{reapp} = .68, M_{cont} = .22, SD_{cont} = .81, B = .05, SE = .04, t(601.719) = 1.16, p = .245, r = .05, but there was a significant difference between conditions at Exam 2, M_{reapp} = .10, SD_{reapp} = .70, M_{cont} = .35, SD_{cont} = .80, B = −.13, SE = .04, t(608.799) = −3.01, p = .003, r = .12, and Exam 3, M_{reapp} = .23, SD_{reapp} = .78, M_{cont} = .50, SD_{cont} = .97, B = −.13, SE = .05, t(669.212) = −2.84, p = .005, r = .11. Reappraisal participants exhibited blunted cortisol reactivity at Exams 2 and 3 relative to controls.

Figure 4

Panel (A): Cortisol Reactivity as a Function of Reappraisal Condition; (B) Testosterone Reactivity as a Function of Reappraisal Condition



Note. ** Indicates conditions differed at $p < .01$.

Predicting testosterone reactivity, the Contrast 1 × Condition interaction emerged, B = .06, SE = .01, t(448.440) = 5.77, $p <$ .001, r = .26, but not the Contrast 2 × Condition interaction, B = −.02, SE = .02, t(535.879) = −1.48, p = .140, r = .06 (see Figure 4). Again, simple effects analyses revealed no difference between conditions at Exam 1, M_{reapp} = −.00, SD_{reapp} = .55, M_{cont} = .01, SD_{cont} = .56, B = −.00, SE = .04, t(517.144) = −.12, p = .902, r = .01, but reappraisal participants demonstrated a greater increase in testosterone than controls at Exam 2, M_{reapp} = .19, SD_{reapp} = .65, M_{cont} = −.09, SD_{cont} = .54, B = .15, SE = .04, t(522.274) = 4.14, $p < .001$, r = .18, and Exam 3, M_{reapp} = .31, SD_{reapp} = .80, M_{cont} = −.05, SD_{cont} = .69, B = .20, SE = .04, t(581.695) = 5.26, $p < .001$, r = .21.

We then added sex, race, and age as potential moderators. None had an effect on cortisol reactivity, ps = .533, .434, and .884, respectively, nor did any of these variables interact with the manipulation and contrast 1, ps = .765, .688, and .973, respectively, or with the manipulation and contrast 2, ps = .408, .165, .264, respectively. Sex, however, did predict testosterone reactivity, B = .17, SE = .06, t(306.891) = 2.70, p = .007, r = .15, with females having greater testosterone reactivity using standardized scores. However, sex did not significantly interact with the manipulation and contrast 1, B = .00, SE = .02, t(448.498) = .05, p = .960, r = .00, nor with the manipulation and contrast 2, B = .03, SE = .03, t(533.757) = .88, p = .381, r = .04. Race and age did not predict testosterone reactivity, ps = .770 and .573, respectively, nor did they interact with the manipulation and contrast 1, ps = .247 and .362, respectively, or with the manipulation and contrast 2, ps = .719 and .192, respectively.

Procrastination and Performance Goals

To examine the impact of the reappraisal manipulation on the at-home procrastination and performance goal measures, we used two-level multilevel models because these measures were only collected at a single timepoint (between Exams 2 and 3). Supporting the hypotheses, students in the reappraisal condition reported procrastinating less than controls, B = −.43, SE = .17, t(137.031) = −2.51, p = .013, r = .21 (see Table 2). Moreover, students instructed to reappraise their stress arousal

Table 2
Means and Standard Deviations for Procrastination and Performance Goals

Variable	M_{reapp}	SD_{reapp}	$M_{control}$	$SD_{control}$
Procrastination	**2.61**	0.96	**3.03**	1.17
Performance approach goals	**5.06**	1.28	**4.58**	1.35
Performance avoidance goals	4.63	1.24	4.51	1.36

Note. Bolded means signify a statistically significant difference between reappraisal and control conditions.

reported more performance approach goals relative to controls, $B = .46$, $SE = .21$, $t(137.534) = 2.22$, $p = .028$, $r = .19$. However, the reappraisal manipulation did not have an effect on performance avoidance goals, $B = .12$, $SE = .20$, $t(136.582) = .59$, $p = .554$, $r = .05$.

As before, sex, race, and age were examined as potential moderators. None of sex, race, or age significantly influenced procrastination, *p*s = .526, .322, and .131, respectively, nor did any of these variables interact with the manipulation, *p*s = .778, .923, and .074, respectively. Similarly, none of sex, race, and age influenced performance approach goals, *p*s = .336, .459, and .729, respectively, nor did any of these variables significantly interact with the manipulation, *p*s = .810, .401, and .801, respectively.

Targeted Mediation

We conducted two sets of multilevel mediation analyses informed by the BPS model of challenge and threat and planned a priori. The first examined the reappraisal manipulation as the predictor, threat appraisals as the mediator, and exam performance as the outcome—at both Exam 2 and Exam 3. For the Exam 2 mediation model, we used threat appraisals assessed on the day of Exam 2 and included all participants who took Exam 2 ($n = 393$). For the mediation analysis examining Exam 3, we used threat appraisals assessed on the day Exam 3 and included all participants who took that exam ($n = 339$).

The second set of mediation models was similar: condition was entered as the predictor and Exam 3 scores as the outcome, but we examined procrastination and performance goals at mediators to assess whether those variables could help explain lagged manipulation effects. The model that examined goals as mediators included both approach and avoidance goals as simultaneous mediations due to their correlated nature. We used multilevel mediation to conduct analyses, so that the nested structure would continue to be controlled, as in prior analyses (Hayes & Rockwood, 2020).

Threat Appraisals as the Mediator

First, stress appraisals partially mediated the effect of condition on Exam 2 performance, $B = 2.33$, $SE = .79$, $p = .003$, 95% CI [.86, 3.94] (see Figure 5A). Similarly, the indirect effect of the manipulation through stress appraisals on Exam 3 performance was also significant, $B = 2.44$, $SE = .71$, $p = .001$, 95% CI [1.17, 3.92] (see Figure 5B). Note that in both cases, the significant direct effect of the manipulation remained, indicating that the mediation was partial.

Performance Goals and Procrastination as Mediators

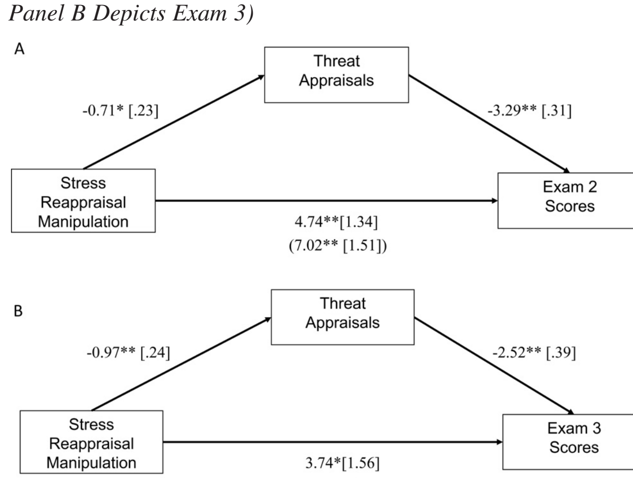
First performance approach and avoidance goals were examined in a simultaneous mediation model. We observed a marginally significant (i.e., not reliable) indirect effect from the manipulation through performance approach goals on Exam 3 scores, $B = 2.01$, $SE = 1.06$, $p = .058$, 95% CI [.18, 4.34], but the indirect effect through performance avoidance goals was not significant, $B = -.15$, $SE = .35$, $p = .667$, 95% CI [−1.01, .47] (see Figure 6).

Notably, we observed a significant indirect effect from the manipulation through procrastination on Exam 3 scores, $B = 2.76$, $SE = 1.20$, $p = .022$, 95% CI [.57, 5.36] (see Figure 6). In mediation analyses of both procrastination and performance goals, the direct effect of the manipulation on Exam 3 scores remained significant, indicating partial mediation.

Discussion

This research examined the effects of manipulating appraisals of stress arousal on affective responses, neuroendocrine functioning, and performance outcomes in an understudied, but substantial, academic population—community college students—during a stressful academic assessment. Overall, results supported hypotheses. Stress reappraisal led to less math evaluation anxiety, lower threat appraisals, more adaptive neuroendocrine responses, and higher scores on exams compared with the active, "ignore stress," control condition. Reappraisal students also persisted in their courses at a higher rate than controls. Then, compared with control participants, the reappraisal group reported more performance approach goals and less procrastination between their second and third exams. Finally, on students' subsequent exam (the third exam), the reappraisal group again outperformed controls, and also exhibited less evaluation anxiety, improved stress appraisals, and a more adaptive neuroendocrine response pattern.

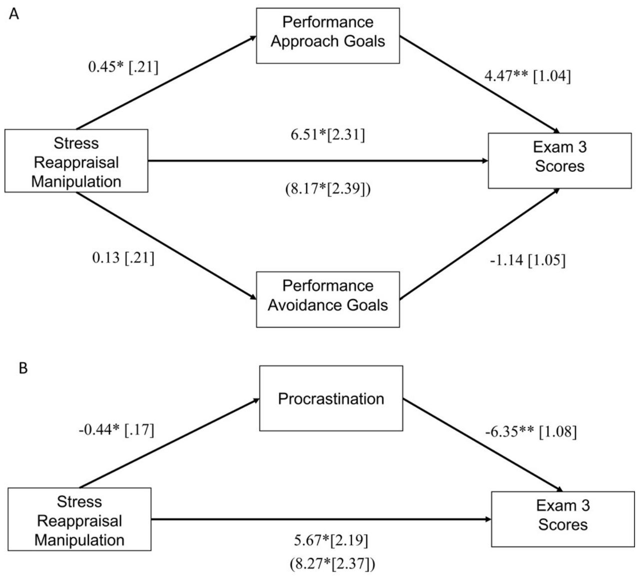
Figure 5
Threat Appraisals as Mediators of the Effect of the Reappraisal Manipulation on Exam Performance (Panel A Depicts Exam 2; Panel B Depicts Exam 3)



Note. Each coefficient is presented first, with standard errors in bracketed text. The total effect in parentheses represents the effect from the manipulation to exam scores, excluding the mediator.
* $p < .05$. ** $p < .001$.

Figure 6

Performance Goals (A) and Procrastination (B) as Mediators of the Effect of Reappraisal Condition on Exam 3 Performance



Note. Each coefficient is presented first, with standard errors in bracketed text. The total effect in parentheses represents the effect from the manipulation to exam scores, excluding the mediators.
* $p < .05$. ** $p < .001$.

Targeted mediation indicated that stress appraisals emerged as partial mediators of effects of the manipulation on Exams 2 and 3; when the manipulation led students to increase appraisals of resources relative to demands, their exam performance improved. Notably, a mediation model linking the manipulation delivered at Exam 2, to procrastination and goals measured between Exams 2 and 3, and then to scores on Exam 3 observed that less procrastination and more performance approach goals helped to explain the effects of the lagged effect of reappraisal on Exam 3 scores. Taken together, these findings provide some evidence that reappraising stress responses as functional in naturalistic academic contexts can improve outcomes with direct and indirect consequences for health and achievement.

The focus on improving outcomes in mathematics courses, specifically, was intentional. Proficiency in mathematics, and other STEM domains, is imperative for enabling individuals to address 21st century challenges (Carnevale et al., 2013; Fayer et al., 2017). Because of the importance of STEM training at the societal level, the U.S. educational system has emphasized STEM learning goals, and policies have focused on STEM education for decades (Bybee, 2010). U.S. students, however, continue to lag those from other developed nations in STEM achievement and vocational attainment (e.g., DeSilver, 2017). Thus, building methods to help students maximize their potential and seek out challenges in STEM can have a profound societal impact. Toward this end, the data presented here provide initial evidence that helping students regulate stress responses in evaluative math settings via optimization methods can be one approach to attenuate math anxiety, facilitate achievement, and foster resilience.

The student population studied here also suggests applied implications. Community college students are understudied even though they comprise almost half of U.S. postsecondary students (Shapiro et al., 2014). Community colleges are an integral access point for low socioeconomic status (SES) students and students from disadvantaged backgrounds to receive postsecondary education. Community colleges also frequently serve as academic endpoints. Students cannot matriculate to a 4-year programs without passing community college course work. The overrepresentation of underrepresented students in community college systems can contribute to educational and income gaps that are major sources of income and health disparities (e.g., Gordils et al., 2020). Therefore, helping community college students persist and achieve has the potential to help combat pernicious and persistent societal problems. The findings reported here provide evidence that it is possible to develop regulatory approaches to bolster students' capacity to actively cope with the demands of academic stressors and become more resilient as they pursue their goals (cf., Yeager et al., 2016).

The stress regulation findings reported here also have relevance for the broader stress and stress regulation literatures. First, these data are relevant for research on stress and resilience by highlighting possible benefits of dissociating "stress" from "distress" in naturalistic settings. The overarching perspective that "stress is bad" conflates the concept of stress with the experience of distress. For instance, people overwhelmingly believe that remaining calm and trying to relax (i.e., reducing or eliminating stress) is the optimal stress regulation approach, even in performance settings (Brooks, 2014). Indeed, widely used self-report scales that measure stress are overwhelmingly constructed of negative items (e.g., Cohen et al., 1983), and actually tap into feelings of distress rather than stress more broadly. The result is that traditional stress regulation approaches emphasize stress reduction rather than stress optimization (Jamieson et al., 2018). Alternatively, the research presented here demonstrates that stress can have benefits for functioning in acute evaluative situations, and that optimization is a viable regulatory approach in such settings.

The notion that stress can have positive outcomes corresponds well with recent work on stress mindsets, or beliefs about the nature of stress (e.g., Crum et al., 2013, 2017; Smith et al., 2020). Individuals holding a "*stress-is-enhancing*" mindset believe that experiences of stress can have enhancing effects, whereas those holding a "*stress-is-debilitating*" mindset believe that stress has debilitating effects. Stress mindsets act as lenses through which individuals broadly view and engage with stressful situations, while the stress reappraisal techniques studied here encourage individuals to alter contextually grounded appraisals to enact positive change. Individuals with a stress-is-enhancing mindset may not benefit as much from stress reappraisal materials compared with those with a stress-is-debilitating mindset because they already believe that their stress responses can be helpful for optimizing performance.

Although empirical work formally integrating stress mindsets with stress reappraisal methods has yet to appear in the literature, researchers have theorized that helping individuals regulate their stress responses via situation-general mindsets and situation-specific reappraisal processes can have synergistic effects (Crum et al., 2020; Jamieson et al., 2018). That is, promoting an enhancing stress mindset has the potential to help individuals apply reappraisal tools across various situations and interpersonal contexts, and reappraisal instructions can serve as the tools (i.e., contextualized mechanisms) through which general beliefs can regulate responses in vivo. Informed by the null effects of stress reappraisal on learning anxiety observed here, integrating concepts from stress reappraisal with broader mindsets about stress may be especially important for understanding challenge-seeking behaviors, such as enrolling in difficult courses. That is, although students were less anxious about being evaluated in math, the situational-specific regulation manipulation used here did not impact anxieties related to learning math concepts. Anxiety about learning math, however, can dampen enrollments in future courses and challenge-seeking behaviors in STEM. Future longitudinal work integrating stress reappraisal and stress mindsets could help elucidate such processes.

This research also interfaces with research on emotion regulation. Encouraging community college students to endorse ideas that stress responses can be functional and adaptive reduced threat appraisals in exam settings, which then improved neuroendocrine functioning and supported academic achievement. From the perspective of emotion regulation theory—and the EPM in particular—perceiving one's stress responses as functional coping resources can change the underlying *valuation* of what stressful emotional experiences entail. That is, instead of stress responses being valued as "bad for me" and "to be avoided," stress can be appraised as potentially "good for me" and "to be embraced." As reviewed by Crum and colleagues (2020), changing valuations of stress may first remove the "stress about being stressed" that stems from worries about experiencing stress (Brady et al., 2018), which has the potential to then alter subsequent stress regulation goals. If stress is perceived as bad or negative, the regulatory goal is to avoid or reduce stress. However, if stress can be valued as helpful, the regulatory goal is to utilize stress to thrive. Thus, the in vivo regulatory reappraisal materials presented to students in an exam context have the potential to alter how students engage with future stressful evaluative academic contexts.

Limitations and Future Directions

Limitations need to be considered when considering these findings. First, although efforts were made to test for lagged effects, the lag was brief and the lagged context highly similar to the context in which the manipulation was delivered (math exams). Thus, caution should be exercised when generalizing these findings to longer timeframes, such as across semesters, and/or across educational domains (e.g., exams in a history course rather than a mathematics course). As touched on above, future research is needed to more thoroughly examine dynamical effects of reappraising stress or stress mindsets on student functioning and achievement.

Engagement processes are also important for understanding stress reappraisal effects because without sympathetic arousal, there is no stress to reappraise. That is, consider students taking important, difficult exams at the frontier of their abilities. Those experiencing threat can reappraise the stress they experience, and, in turn, potentially improve their performance (e.g., Brady et al., 2018; Jamieson et al., 2010, 2016). However, disengaged students might "check out" and not seriously work on the exam. This lack of engagement in acute stress contexts could result from learned helplessness processes (e.g., Neves de Jesus & Lens, 2005), whereby an individual believes that it is not worth even trying in a given context because failure will result regardless. Stress reappraisal and other *active* stress optimization techniques would likely be ineffective for such students and contexts. Instead, approaches that focus on self-efficacy and belonging may be particularly beneficial for disengaged students (Brady et al., 2020; see Fredricks et al., 2019, for a review).

It is necessary to emphasize that stress reappraisal, like any stress regulation method, is not a "silver bullet" nor should it be expected to improve acute stress outcomes for all people across all situations. For instance, in some clinical samples, challenge type stress responses may be experienced in settings in which *no* stress response is appropriate or functional. For example, an individual with posttraumatic stress disorder may experience a stress response in a nondemanding situation that includes trauma-inducing cues, such as a veteran responding to hearing a car backfire because it resembles the sound of a gunshot. Reappraising stress as functional in these situations would not help the individual cope because sympathetic arousal is not needed to address demands. Future research that delves into important moderators and boundary conditions of stress optimization approaches will help best tailor the regulatory approach to individual needs (e.g., Hangen et al., 2019).

Academic performance and resilience in this study were conceptualized as exam scores and course retention. This limited diagnostic approach calls for additional research to test for effects on broader outcomes, such as challenge-seeking behaviors (i.e., enrolling in difficult courses), degree attainment, and/or performance on other assignments completed inside and outside of class. Furthermore, although no effects of reappraisal emerged for learning anxiety, it was encouraging to observe effects on exam performance and retention, controlling for cohort, given that students from different cohorts completed exams constructed of different questions/topics and on different time schedules. Future research may probe how stress reappraisal (and related) regulatory approaches impact performance outside of mathematics domains (for an example, see Brady et al., 2018) or across semesters/years in conjunction with stress mindsets. It will also be important to study effects of stress optimization on other academic factors, such as organizational skills and peer/teacher relationship factors.

It also bears noting that the mediation tests indicated partial mediation. This means that the manipulation influenced exam scores and retention through (likely many) other mechanisms in addition to stress appraisals, approach goals, and procrastination. Indeed, it is rare for single psychological or neuroendocrine variables to completely explain an effect of an experimental manipulation, such as stress reappraisal, on downstream outcomes. First, stress appraisal processes are not always consciously accessible, and able to be measured precisely with self-reports (Jamieson, 2017). Second, myriad third variables such as chronic stress processes, interpersonal daily events, sleep, or even diet and exercise, to name some factors, have substantial effects on neuroendocrine responses independent of the reappraisal manipulation or math exam context studied here. Future research is needed to examine how stress reappraisal interfaces with other psychological processes to gain a deeper understanding of how altering the way people think about stress can benefit outcomes.

Finally, studying stress processes and stress regulation in community college students provided much needed data on this understudied population, but this sample also limits generalizability.

Relative to 4-year college students, community college students are more likely to have performed poorly in their secondary education (e.g., Ma & Baum, 2016). Moreover, adult learners, who comprise a substantial proportion of community college students, exhibit lower math efficacy and more anxiety compared with "traditional" students at 4-year colleges and universities. Thus, effects of the reappraisal manipulation could have been boosted by regression to the mean processes. Future work testing stress optimization in educational contexts across multiple student populations will help educators tailor programs to the needs of specific groups of students, although some work suggests stress reappraisal approaches can promote achievement in elite private university samples (Brady et al., 2018; Jamieson et al., 2010).

Conclusions

The manipulation presented here grew directly out of the BPS model of challenge and threat (Blascovich & Mendes, 2010), and was also strongly influenced by work on positive emotions (Tugade & Fredrickson, 2004), the EPM (Gross, 2015), and theory of constructed emotion (Barrett, 2017). Alleviating the negative effects of stress in evaluative situations has potential to promote student health and achievement, and downstream, potentially facilitate educational attainment and reduce health and income disparities. This research provides promising evidence for the effectiveness of a stress regulation approach aimed at helping students reappraise and optimize their stress responses in evaluative settings. Promoting STEM achievement and competency is a core area of emphasis for the U.S. educational system. Data such as these, as well as research on other stress optimization approaches (e.g., Crum et al., 2013; Yeager et al., 2019), posit that strides in education and health can be achieved by targeting the stress and negative affective responses people experience in evaluative settings.

Context

The research presented here was informed by the authors' program of research on the effects of stress appraisals on affective processes, physiological responses, and performance/behavioral outcomes, and more specifically, research examining how stress responses can be regulated and optimized. More broadly, the ideas underlying the stress reappraisal regulatory approach grew out the literatures on the BPS model of challenge and threat (Mendes & Park, 2014), emotion regulation (Gross, 2015), emotion construction (Barrett, 2017), and positive emotions (Tugade & Fredrickson, 2004). This research builds on prior findings by demonstrating that leading students to endorse the perspective that their stress responses are functional and adaptive can have direct, "real world" benefits in a field setting with an understudied population (community college) students. Although this and other stress reappraisal research have observed benefits as a function of the manipulation, future work in this area should seek to integrate stress appraisal processes with broader mindsets about stress to best maximize the efficacy of stress optimization interventions via a synergistic approach (Crum et al., 2020).

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Received May 11, 2020
Revision received January 12, 2021
Accepted March 1, 2021 ■