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Reappraising Stress Arousal Improves Performance and Reduces Evaluation Anxiety in Classroom Exam Situations

Jeremy P. Jamieson[1], Brett J. Peters[1], Emily J. Greenwood[1], and Aaron J. Altose[2]

Abstract

For students to thrive in the U.S. educational system, they must successfully cope with omnipresent demands of exams. Nearly all students experience testing situations as stressful, and signs of stress (e.g., racing heart) are typically perceived negatively. This research tested the efficacy of a psychosituational intervention targeting cognitive appraisals of stress to improve classroom exam performance. Ninety-three students (across five semesters) enrolled in a community college developmental mathematics course were randomly assigned to stress reappraisal or placebo control conditions. Reappraisal instructions educated students about the adaptive benefits of stress arousal, whereas placebo materials instructed students to ignore stress. Reappraisal students reported less math evaluation anxiety and exhibited improved math exam performance relative to controls. Mediation analysis indicated reappraisal improved performance by increasing students' perceptions of their ability to cope with the stressful testing situation (resource appraisals). Implications for theory development and policy are discussed.

Keywords

test anxiety, reappraisal, developmental education, emotion regulation

Nearly all students experience testing situations as stressful (Bradley et al., 2010). This is not surprising, considering students must expend cognitive resources solving problems/answering questions, performance is typically under time pressure, and students face evaluative scrutiny from self and others. Exam situations present acute task demands that require active coping.

Contrary to lay beliefs, however, stress is not necessarily harmful for performance (see Jamieson, Mendes, & Nock, 2013a for a review). In acutely demanding situations, such as exams, individuals can exhibit a multitude of acute stress responses that derive from cognitive appraisal processes. That is, appraisals construct responses to acute stressors by integrating bodily changes with external information and knowledge of the situation (e.g., Barrett, 2006). So modifying appraisal processes can promote more adaptive and beneficial stress responses in evaluative contexts. Along these lines, the current research presents data from a double-blind field experiment that manipulated stress appraisals and examined effects on affective responses and academic performance.

The Biopsychosocial Model of Challenge and Threat

A fundamental principle of the biopsychosocial (BPS) model of challenge threat is the idea that appraisals of situational demands and coping resources interact to elicit challenge- and threat-type responses in motivated performance contexts (see Blascovich & Mendes, 2010; Jamieson, 2016; Seery, 2011, for reviews; for a related model see Gross, 2015). Individuals experience challenge states when appraisals of coping resources exceed perceived situational demands. Alternatively, threat manifests when perceived demands exceed resources. To illustrate, two students facing the same exam may experience commensurate levels of sympathetic arousal (i.e., "stress"), but one might feel that he or she has the resources (e.g., knowledge, study time, familiarity, etc.) to meet the demands of the difficult exam, whereas the other might appraise the demands as exceeding his or her resources. A challenge state would be expected in the former, and threat in the latter.

Challenge and threat are conceptualized as anchors along a continuum rather than as dichotomous states: As the ratio of perceived resources to demands shifts, individuals move along

[1] Department of Psychology, University of Rochester, Rochester, NY, USA
[2] Department of Mathematics, Cuyahoga Community College, Cleveland, OH, USA

Corresponding Author:
Jeremy P. Jamieson, Department of Psychology, University of Rochester, Rochester, NY 14627, USA.
Email: jeremy.jamieson@rochester.edu

the continuum. For instance, in the example above, the threatened student could move toward challenge if she perceived she studied sufficiently (increased resources) or believed the exam questions were easy (decreased demands), or both.

Both challenge- and threat-type responses are accompanied by sympathetic arousal. So motivationally tuned physiological measures are needed to differentiate stress responses (Jamieson, Koslov, Nock, & Mendes, 2013). The experience of challenge is characterized by improved cardiac efficiency and vasodilation (Seery, 2011), which facilitates delivery of oxygenated blood to the brain. Thus, challenge states predict improved performance outcomes in achievement domains (Blascovich, Mendes, Hunter, & Salomon, 1999; see also Dienstbier, 1989; Jamieson, Mendes, Blackstock, & Schmader, 2010). The experience of threat, on the other hand, leads to increased vascular resistance in anticipation of social defeat or harm (Mendes, Blascovich, Hunter, Lickel, & Jost, 2007). Moreover, threat responses have been linked to poor cognitive performance outcomes (Blascovich et al., 1999).

Math Anxiety and Classroom Performance

Experientially, threat responses are tied to myriad avoidance-motivated, negative affective states, such as shame and anxiety (Beltzer, Nock, Peters, & Jamieson, 2014; Jamieson, Nock, & Mendes, 2013b). In mathematics performance contexts—the focus of the current research—negative affect often manifests as feelings of math anxiety (Bradley et al., 2010; see Ma, 1999, for a meta-analytic review). Not surprisingly, math anxiety predicts worse performance in laboratory and classroom measures and reduced enrollment in math courses (Ashcraft, 2002; Ma, 1999) and even activates neural pain networks (Lyons & Beilock, 2012). Moreover, attenuating math anxiety improves academic performance in mathematics (e.g., Ramirez & Beilock, 2011).

Math anxiety loads onto two subcomponents: learning anxiety and evaluation anxiety (Hopko, Mahadevan, Bare, & Hunt, 2003). Learning anxiety assesses feelings of anxiety related to learning math, such as listening to a lecture. Evaluation anxiety indexes feelings of anxiety stemming from the potential for evaluation in math, such as taking an exam. This distinction is important for the current research because evaluation anxiety hones in on the precise evaluative performance contexts (classroom exams) that this study focuses on. Moreover, previous research suggests math anxiety is stable (Ashkraft & Kirk, 2001; Berch & Mazzocco, 2007), and thus little research has sought to attenuate math anxiety by targeting cognitive processes (for a notable exception, see Ramirez & Beilock, 2011). However, the BPS model of challenge and threat posits modifying appraisals of coping resources and situational demands can regulate affective responses, such as math anxiety.

Stress Reappraisal

In the BPS model of challenge and threat when the ratio of perceived resources to demands increases, individuals exhibit more challenge-type responses. Laboratory studies have implemented material specifically designed to increase resource appraisals to promote challenge-type responses (e.g., Beltzer et al., 2014; Jamieson et al., 2013b; Jamieson, Nock, & Mendes, 2012, 2013; John-Henderson, Rheinschmidt, & Mendoza-Denton, 2015). In that line of research, arousal experienced during stressful situations is presented as an adaptive, functional *coping resource* that aids performance. Signs of stress arousal are presented as coping tools (e.g., heart rate increases to increase the delivery of oxygen to your brain).

Notably, stress reappraisal methods are not aimed at eliminating or dampening stress arousal (i.e., it does not encourage calmness) but instead focuses on changing the *type* of stress response (see also, Brooks, 2014; Crum, Salovey, & Achor, 2013). In social stress contexts, such as classroom exams, job interviews, or conflict discussions, individuals encounter acute task demands that require instrumental responding. If individuals do not experience stress, they cannot reap benefits of sympathetic arousal (e.g., Dienstbier, 1989). For example, recent research highlighted the benefits of being excited (a high-arousal stress state) versus calm (a low-arousal state) in performance situations (Brooks, 2014). Participants instructed to ''get excited'' outperformed those instructed to ''remain calm'' on a laboratory mathematics test. Thus, techniques aimed at improving performance under stress—the focus of the current research—should seek to maintain (or even increase) sympathetic arousal.

The focal mechanism of stress reappraisal is *resource appraisals* as defined by the BPS model. This approach does not seek to convince individuals that stressful situations are not demanding. Rather, stress reappraisal focuses on illustrating the adaptive benefits of stress (i.e., how stress responses evolved to increase fitness) and encourages individuals to reconceptualize stress as a coping tool. This is an important mechanistic distinction when individuals encounter acute stress situations that cannot be avoided or mitigated. For example, students frequently must take exams (i.e., engage in effortful responding), and the relevance of exams for grades/placements/applications (i.e., uncertainty processes) cannot be attenuated without changing the structure of the broader educational system.

Current Research

This research presents data from a randomized double-blind field experiment testing the efficacy of stress reappraisal for improving student outcomes. To date, no research has tested this approach in a classroom setting. Thus, this research represents the next step in work on stress reappraisal.

Another novel aspect of this research is the targeted sample. Rather than examining highly achieving students, we instead focused on developmental math students at a community college. To provide open access to postsecondary education, nearly all community colleges offer remedial/developmental courses (Cohen & Brawer, 2003). These courses seek to teach students basic skills and offer underachieving and/or disadvantaged students the opportunity to improve their lives (Boylan, 1999). Unfortunately, graduation rates for developmental

programs are low: Only 27% of students referred to developmental math earn bachelor's degrees (ECS, 2010). Thus, developmental programs are often the "last stop" in the educational system for at-risk students, and facilitating achievement in this sample has the potential to accumulate in substantial individual and societal benefits.

Contrary to the many hurdles facing developmental education students, little research has sought to identify means to promote achievement in this sample. Toward these ends, we tested the efficacy of a stress reappraisal intervention. To do so, math anxiety, stress appraisals, and academic performance were measured at Exam 1. Students were then randomly assigned to receive arousal reappraisal or placebo control instruction materials prior to Exam 2. After students completed intervention materials, but before beginning Exam 2, we again measured math anxiety and stress appraisals. Finally, terminal grades and course retention rates were recorded.

The core hypothesis was that the reappraisal manipulation would increase appraisals of coping resources, reduce feelings of math evaluation anxiety, and improve exam performance relative to controls. Moreover, we predicted that the change in resource appraisals would predict performance improvements (see Beltzer et al., 2014, for a similar argument).

Method

Targeted Sample Size

An a priori power analysis was used to estimate the number of participants needed to test the effects. Effect sizes were culled from laboratory studies on stress reappraisal that included performance measures (Beltzer et al., 2014; Brooks, 2014; Jamieson et al., 2010; Jamieson, Nock, & Mendes, 2013a; John-Henderson et al., 2015). Using an average of these effect sizes ($d = .60$) and a target power level of .80, we required a minimum of 45 participants per condition ($N = 90$) to examine effects. Data collection was terminated when the total N from participating classrooms exceeded 90.

Participants

Ninety-three developmental mathematics students (64 female, 29 male; $M_{age} = 29.40$, range: 18–58; 64 Black/African American, 29 White/Caucasian) from an urban Midwestern community college participated in this research. Students were sampled from five classes (course material and instructor was identical across classes). Students were randomly assigned to condition within classrooms. No monetary compensation was provided, as study materials were integrated with curriculum materials.

Procedure

Students were informed of the study, provided consent, and asked to complete demographic measures on the third day of class. No students opted out of participating. The study was completed across two class sessions. Session 1 was completed on the day of Exam 1, and Session 2—during which intervention materials were delivered—occurred on the date of Exam 2.

Prior to beginning exams, students completed assessments of math anxiety and stress appraisals (pretested to take ~5 min to complete). After students handed in questionnaires, they were given exams. Exams were designed to allow students sufficient time to complete study materials. If needed, students were given extra time corresponding to time spent on study materials beyond the expected duration.

Before Session 2, students were randomly assigned to condition with the constraint that intervention and placebo groups could not significantly differ in Exam 1 scores (reappraisal $n = 46$; placebo $n = 47$; post add/drop period: reappraisal $n = 40$, placebo $n = 41$). To ensure the instructor was blind to condition assignment, reappraisal and placebo instruction materials used the same cover page. Instructor was blind to hypotheses. Procedures for Sessions 1 and 2 were identical with the exception that intervention materials were implemented before students completed questionnaires in Session 2.

Intervention materials were adapted from laboratory studies (Beltzer et al., 2014; Jamieson et al., 2012, 2013a). Students assigned to the arousal reappraisal intervention condition read summaries of scientific articles (which were modified to match the message conveyed in each condition). After each summary, participants answered two multiple-choice questions to ensure they read the summaries and to encourage them to endorse the information. Materials took ~5–8 min to complete. The reappraisal manipulation educated participants about the adaptive functions of stress. 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).

Participants assigned to the placebo condition read summaries that suggested the best way to improve outcomes during stressful testing situations is to ignore stress. Thus, students were told to ignore negative thoughts associated with stress during exams. Instructions were based on emotion-suppression techniques (e.g., Peters, Overall, & Jamieson, 2014), but, rather than suppressing affective displays, participants ignored (suppressed) negative cognitions. The "ignore" instructions were not expected to negatively impact performance based on previous research using identical instructions (Jamieson et al., 2012). Including a placebo control, as opposed to a no instruction control, was necessary to keep the instructor blind and to account for time spent on materials.

Course retention and final grades were recorded at the end of the semester. After final exams, students were debriefed as to the purpose and design of the study, and placebo students were provided with the arousal reappraisal materials.

Materials

Stress appraisals. A validated measure from the social stress literature was adapted to index stress appraisals (Beltzer et al., 2014; Mendes, Gray, Mendoza-Denton, Major, & Epel, 2007;

Table 1. Raw Means, Standard Deviations, and 95% Confidence Intervals for Exam Scores and Psychological Variables as a Function of Reappraisal Condition.[a]

		Exam 1			Exam 2		
Measure		*M*	*SD*	95% CI	*M*	*SD*	95% CI
Exam score (scale: 1–100)	Placebo	73.95	16.01	[68.83, 79.06]	71.93	17.06	[66.47, 77.38]
	Reappraisal	73.48	15.33	[68.57, 78.38]	76.03	13.01	[71.86, 80.19]
Math learning anxiety (scale: 1–5)	Placebo	1.80	.81	[1.54, 2.06]	1.74	.74	[1.50, 1.97]
	Reappraisal	1.65	.74	[1.42, 1.89]	1.67	.90	[1.38, 1.96]
Math evaluation anxiety (scale: 1–5)	Placebo	2.65	1.01	[2.32, 2.98]	2.64	1.00	[2.32, 2.96]
	Reappraisal	2.60	.84	[2.33, 2.87]	2.19	.85	[1.92, 2.47]
Resource appraisals (scale: 1–7)	Placebo	4.88	1.95	[4.25, 5.50]	4.60	1.92	[3.99, 5.21]
	Reappraisal	4.49	1.72	[3.92, 5.03]	4.78	1.64	[4.25, 5.30]
Demand appraisals (scale: 1–7)	Placebo	2.55	1.71	[2.00, 3.10]	2.78	1.79	[2.20, 3.35]
	Reappraisal	2.55	1.68	[2.01, 3.09]	2.30	1.47	[1.83, 2.77]

[a]Exploratory analyses of raw means indicate that reappraisal participants reported less math evaluation anxiety at time 2 compared to controls, $t(79) = 2.12$, $p = .037$, $d = .48$.

see Appendix for the full scale). The scale is composed of *coping resources* and *task demands* subscales ($\alpha_{resource} = .78$, $\alpha_{demand} = .86$). Task demand appraisals index perceptions of danger, uncertainty, and required effort (e.g., Blascovich, Mendes, Tomaka, Salomon, & Seery, 2003), whereas appraisals of coping resources assess perceptions of the safety and familiarity of the situation and skills, knowledge, and abilities (e.g., Seery, 2011). Resource and demand appraisals were analyzed separately. One control participant did not complete all demand appraisal items at Time 2.

Math anxiety. Math anxiety was assessed using the Abbreviated Math Anxiety Scale, which was constructed, validated, and replicated with a large student sample ($\alpha = .83$; Hopko et al., 2003). This scale loads onto two factors: learning anxiety and evaluation anxiety (Hopko et al., 2003). Hypotheses focused primarily on evaluation anxiety. Thus, we constructed separate composites for each subscale ($\alpha_{\text{learning}} = .79$; $\alpha_{\text{evaluation}} = .84$) and analyzed composites separately.

Academic performance. Performance variables included scores on the first and second in-class exams. Exam performance was analyzed as standardized *z* scores to assess performance relative to class averages and account for differences in raw scores between Exams 1 and 2. End-of-year course grades, controlling for scores on Exams 1 and 2, were recorded as a longer term index of academic performance. We also recorded course retention rates.

Results

Data Analysis Plan

Students were randomly assigned to condition *within* classroom. To account for the nesting of students in classrooms, we built a two-level Hierarchical linear model (HLM) using HLM6 software (Version 6), with students within class cohort at Level 1 and class cohorts at Level 2. These models failed to identify significant variance at the level of class cohort, *exam change* $\chi^2(4) = .35$, $p = .986$; variance < .001; *final grade* $\chi^2(4) = 1.37$, $p = .851$; variance = .036; *resource appraisals* $\chi^2(4) = 4.01$, $p = .404$ variance = .002; *demand appraisals* $\chi^2(4) = .86$, $p = .930$; variance < .001; *learning anxiety* $\chi^2(4) = 5.20$, $p = .266$; variance = .007; and *evaluation anxiety* $\chi^2(4) = 4.04$, $p = .401$; variance = .002, suggesting no need to model that nesting—this may not be surprising considering all classrooms sampled were from the same community college, used the same curriculum materials, and were led by the same instructor. Thus, results presented below do not include class cohort.

This research focused on examining effects of stress reappraisal on appraisals, math anxiety, and exam performance. To assess change as a function of the intervention, change scores were computed. For analyses of exam performance, we first standardized scores within each time point because exams included different material. Then, we computed change scores by subtracting standardized scores at Time 1 from Time 2.[1] For analyses of stress appraisals and math anxiety, change scores were computed by subtracting raw scores at Time 1 from Time 2 because the scale was identical across time points.

Raw means and *SD*s for all measures are presented in Table 1. No condition differences were observed at Time 1 for any measure analyzed in this research (*p*s > .26), thus random assignment was successful. We report all variables and analyses conducted as part of this research.

Stress Appraisals

Stress reappraisal instructions targeted resource appraisals to a greater extent than demand appraisals (see Jamieson et al., 2013b for a review). That is, instructing participants that stress is functional and adaptive is not expected to decrease perceived effort or attenuate situational uncertainty (i.e., demand appraisals) but increase perceptions of safety, skills, and/or abilities (Blascovich et al., 2003; Jamieson et al., 2012; Seery, 2011).

Supporting a priori hypotheses, participants assigned to the reappraisal group reported increased coping resources from Exam 1 to Exam 2 ($M\Delta = .30$, $SD = 1.68$) compared to controls ($M\Delta = -.34$, $SD = 1.11$), $t(79) = 2.03$, $p = .046$, $d = .46$. However, we observed no significant effect of reappraisal condition on demand appraisals, $p = .18$ (see Table 1 for raw means and *SD*s).

To increase generalizability of this research to previous BPS studies, appraisals were also analyzed as a ratio of resources to demands (e.g., Beltzer et al., 2014). To do so, we first subtracted perceived demands from resources (higher scores correspond to challenge-type appraisals) at each time point (see Table 1). Then, we computed a change score by subtracting the ratio at Time 1 from Time 2. Consistent with the analyses above, reappraisal participants reported a greater increase in the ratio of resources to demands ($M\Delta = .55$, $SD = 2.30$) compared to controls ($M\Delta = -.50$, $SD = 1.84$), $t(78) = 2.26$, $p = .027$, $d = .51$.

Math Anxiety

No significant effect of reappraisal condition emerged for math learning anxiety, $p = .59$. As predicted, however, students assigned to reappraise stress as functional and adaptive reported a decrease in math evaluation anxiety from Exam 1 to Exam 2 ($M\Delta = -.41$, $SD = .81$) compared to placebo control students ($M\Delta = .02$, $SD = .81$), $t(79) = 2.36$, $p = .021$, $d = .53$ (see Table 1).[2]

Observing an effect for only evaluation, and not learning, anxiety here may not be surprising given the context: Measures were taken on days of exams, and the reappraisal manipulation focuses on promoting adaptive responses to evaluative stress.

Academic Performance

Consistent with hypotheses, students assigned to reappraise stress arousal as a coping tool performed better on Exam 2 than on Exam 1 ($M_z\Delta = .19$, $SD = .72$) compared to placebo controls ($M_z\Delta = -.21$, $SD = .78$), $t(79) = 2.42$, $p = .018$, $d = .55$ (see Table 1).

To assess longer term effects of stress reappraisal on academic outcomes, we analyzed end-of-semester grades with assignments completed before the manipulation (i.e., Exams 1 and 2) was removed. This allowed us to examine whether reappraisal impacted performance in testing situations *after* delivery of the manipulation. Reappraisal students exhibited marginally higher grades ($M = 83.14$, $SD = 15.79$, CI [68.38, 81.40]) than controls ($M = 74.89$, $SD = 24.10$, CI [76.55, 89.73]), $t(79) = 1.78$, $p = .079$, $d = .40$.

Mediation

To test the hypothesis that the reappraisal manipulation improved performance by increasing resource appraisals, we conducted a bootstrapping mediation analysis (Preacher & Hayes, 2004; 20,000 resamples). Consistent with the hypothesized model, improvements in resource appraisals partially mediated the association between reappraisal condition and performance improvement (unstandardized 95% CI = [.043, .387]; standardized 95% CI = [.062, .285]). See Figure 1 for path coefficients.[3]

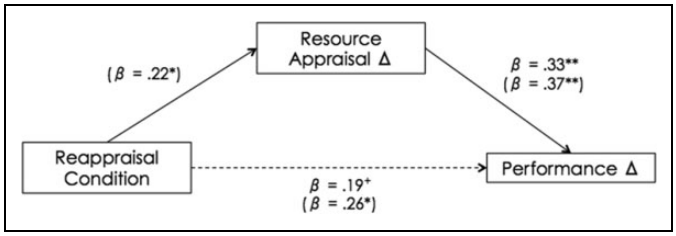

Figure 1. Betas are standardized, $^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$. Zero-order relationships are shown in parentheses. Reappraisal condition is dummy coded: 0 = *placebo control*, 1 = *arousal reappraisal*.

Attrition

We tracked attrition after Exam 1, the first date data were collected for this project. Prior to the reappraisal manipulation 12 (12.90%) students dropped the course. Then, eight additional students (two reappraisal and six control; 8.60%) dropped the course *after* intervention materials were delivered. The overall attrition rate was 22.58%.

We tested whether stress reappraisal might have improved retention. To explore this possibility, we analyzed attrition after the manipulation. No significant effect of condition emerged, $p = .16$. However, we note that this null finding may have stemmed from a ceiling effect (see Table 1).

Exploratory Analyses

In addition to testing core hypotheses, we explored associations among appraisals, math anxiety, and performance at Exam 1 before we administered the reappraisal manipulation to provide insights into basic relationships. That is, although no a priori predictions were made regarding associations among variables, we suspected that such associations might manifest and, if so, can potentially inform future, confirmatory research.

Higher levels of math anxiety (both learning anxiety and evaluation anxiety) were correlated with resource and demand appraisals, all ps $< .01$. Moreover, math anxiety and stress appraisal measures exhibited significant zero-order correlations with exam performances, ps $< .05$ (see Table 2).

In a follow-up multiple regression analysis, when Exam 1 performance was regressed on stress appraisals and math anxiety measures in a multiple regression model, only demand appraisals emerged as a predictor of performance (see Figure 2). This suggests that demand appraisals and math anxiety may tap similar processes that can be more fully elucidated in future research.

Discussion

This classroom experiment suggests teaching students to reappraise stress arousal as functional and adaptive can facilitate

Table 2. Zero-Order Correlations Among Math Anxiety, Stress Appraisals, and Exam Performance on Exam 1.

	Math Learning Anxiety	Math Evaluation Anxiety	Resource Appraisals	Demand Appraisals	Exam Performance
Math learning anxiety	1	.474**	−.159	.337**	−.344**
Math evaluation anxiety	-	1	−.239*	.465**	−.380**
Resource appraisals	-	-	1	−.242*	.248*
Demand appraisals	-	-	-	1	−.431**
Exam performance	-	-	-	-	1

*$p < .05$. **$p < .01$.

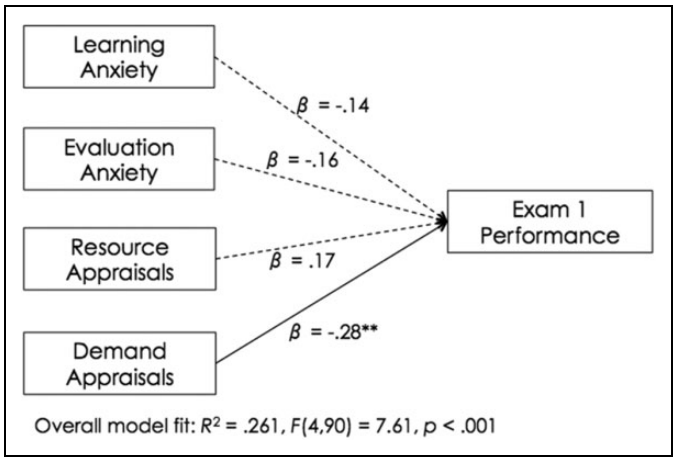

Figure 2. Associations between psychological variables and Exam 1 scores. Betas are standardized, **$p < .01$.

classroom exam performance. Furthermore, consistent with theorizing, a mediation analysis suggested the reappraisal intervention improved performance by increasing students' resource appraisals. Effects of the reappraisal intervention also tended to have longer term effects such that reappraisal students achieved marginally higher end-of-semester grades than controls when controlling for scores on Exams 1 and 2. This pattern is potentially interesting, given that the intervention materials were delivered *only* prior to Exam 2 without any boosters. Taken together, the effects reported here extend previous research on stress reappraisal to applied classroom settings.

From a theory-development perspective, these data suggest math anxiety may be more malleable than previously believed. Prior research conceptualizes math anxiety as linked to trait anxiety (e.g., Ferguson, Maloney, Fugelsang, & Risko, 2015). In this research, however, students' reports of math evaluation anxiety were attenuated by the reappraisal manipulation. Given the association between math anxiety and stress appraisals observed here, future studies may seek to specify the cognitive and physiological (i.e., threat type) processes that underlie feelings of math anxiety.

Although prior research provides evidence that arousal reappraisal can improve academic performance (though not in classroom settings), previous studies have focused on high-achievement students. However, students at the other end of the academic performance spectrum (i.e., poorly performing students) stand to gain more from interventions that could improve performance. This was our focus in the current research. More specifically, the findings reported here offer hope for improving student outcomes by integrating psychological theory with educational practice. Developmental math students at community colleges face major hurdles. The rate of failure for such programs is high, and without obtaining a college degree, the opportunities for these at-risk students to succeed later in life are limited. To illustrate, Americans with bachelor's degrees earn over $1.2 million more in lifetime income than those without degrees. The current research shows that a brief, easily administered set of instructions designed to optimize students' stress responses can help improve classroom exam performance, which has the potential to increase the passing rates of developmental students. Psychological interventions, such as the one presented here, have an added "cost to treat" benefit. That is, materials can be easily disseminated to large numbers of students at little or no cost to schools and students.

Limitations and Future Directions

Important limitations should be considered when interpreting this research. First, we focused on *appraisals* here. We did not obtain physiological indexes of stress. The lack of direct physiological evidence opens up the possibility that the effects of the reappraisal intervention could have been due to factors other than stress reactivity. For instance, improving stress appraisals could have improved self-confidence or self-efficacy, and the performance effects may be the result of confidence (e.g., Pajares, 1996; Zimmerman, 2000). However, we do not believe the effects observed here were simply due to positive expectations because of use of the placebo control (e.g., Jamieson et al., 2012).

Future projects may seek to directly measure physiological responses to gain additional insight into mechanism(s) (e.g., Mendes & Jamieson, 2011). For example, saliva samples can be taken in classroom settings and analyzed for neuroendocrine markers of stress. To illustrate, one direct consequence of threat is high levels of the catabolic adrenal steroid hormone cortisol, the end product of hypothalamic–pituitary–adrenal activation (see Dickerson & Kemeny, 2004, for a review). Prolonged exposure to high cortisol levels takes a toll on regulatory systems and the brain (Dubrovsky, 1997). We suspect that the stress reappraisal manipulation operates by instantiating a more adaptive acute stress response, possibly decreasing cortisol (e.g., Beltzer et al., 2014; Jamieson et al, 2013a; John-Henderson et al., 2015).

One could argue the effects observed here were due to the placebo instructions harming students rather than the reappraisal instructions helping. We believe this possibility is unlikely. First, placebo materials were based on empirical research, which indicated these instructions did not impair cognitive performance relative to "no instructions" (Jamieson et al., 2012). Second, none of the appraisal or math anxiety measures demonstrated a significant change from Exam 1 to Exam 2 within the placebo group, ps > .34. Third, at a more general level, the performance of the placebo group resembled that of students ($n = 9$) from a prior course that used the same instructor, course materials, and exams but did not deliver any instruction materials (i.e., a "no instruction" control). Although this post hoc comparison is highly tenuous and exploratory, especially given the very small sample, there is no evidence that placebo materials caused harm.

Another shortcoming of the current study is the lack of mechanistic data for *how* reappraising stress arousal tended to improve end-of-semester grades. Measures of math anxiety and stress appraisals were collected when the manipulation was delivered but not after. The absence of longitudinal data raises the possibility for multiple explanations. For instance, the manipulation may have "stuck" with students, and they implemented the reappraisal strategies during subsequent exams. It is also possible the reappraisal manipulation could have altered *engagement* with the material and improved test *preparation* processes (e.g., reduced procrastination). To more fully explore longer term effects of the intervention, future research may seek to utilize daily diary methods delivered to students outside the classroom (e.g., Almeida, 2005; Bolger, Davis, & Rafaeli, 2003; Iida, Shrout, Laurenceau, & Bolger, 2012).

Along similar lines, the reappraisal manipulation reduced evaluation anxiety but exhibited no significant effect on learning anxiety. This discrepancy could have been due to the conceptual alignment of evaluation anxiety and the manipulation. That is, both focus on acutely stressful scenarios/responses when task demands are high. Or, it is possible that effects of evaluation anxiety manifested because of the setting in which the measures were administered: All study materials were completed immediately before an exam (i.e., an evaluative context). Future research incorporating measures outside the classroom would help specify whether reappraising stress arousal only impacts math evaluation anxiety or whether it might also impact learning anxiety.

This research also calls for future research on the moderating role of math anxiety. Given the relatively low (in an absolute sense) math anxiety group means (see Table 1), it is possible that the reappraisal manipulation examined here is only effective for individuals exhibiting moderate levels of anxiety. For example, a nonanxious student may not benefit from stress reappraisal. Alternatively, a student with extremely high levels of math anxiety may be less likely to believe stress can facilitate performance. This possibility, however, may be unlikely. For example, research indicates that individuals with social anxiety disorder (i.e., those exhibiting extreme levels of social anxiety) benefit from stress reappraisal in social evaluative situations (Jamieson et al., 2013a).

Conclusion

The research reported here demonstrated that instructions delineating adaptive benefits of stress reduced math anxiety and improved classroom performance. These data contribute to a growing body of evidence demonstrating the efficacy of brief, social–psychological interventions for improving educational outcomes (see Yeager & Walton, 2011 for a review). As emphasized by Yeager and Walton, these interventions are not "magic" panaceas. Rather, social–psychological interventions target specific processes to enact positive change in educational settings. Here, we sought to improve students' performance in testing situations by targeting stress appraisals. Ultimately, it is our hope that this and other intervention approaches (e.g., Yeager & Dweck, 2012) can be distilled, scaled, and disseminated to potentially improve students' lives at near zero cost.

Appendix

Adapted Stress Appraisal Questionnaire

Please circle the number after each statement that corresponds to how you are feeling right now regarding the math test you are about to begin.

	Strongly Disagree			Neutral			Strongly Agree
1. The upcoming math test is very demanding.	1	2	3	4	5	6	7
2. I am uncertain about how I will perform on the test.	1	2	3	4	5	6	7
3. The math test will take a lot of effort to complete.	1	2	3	4	5	6	7
4. The math test will be very stressful.	1	2	3	4	5	6	7
5. I feel that I have the abilities to succeed on the test.	1	2	3	4	5	6	7
6. It is very important to me that I perform well on this test.	1	2	3	4	5	6	7
7. I'm the kind of person that does well on these types of tests.	1	2	3	4	5	6	7
8. Poor performance on this test would be very distressing for me.	1	2	3	4	5	6	7
9. I expect to perform well on the math test.	1	2	3	4	5	6	7
10. I view this math test as a positive challenge.	1	2	3	4	5	6	7
11. I think this math test represents a threat to me.	1	2	3	4	5	6	7

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Notes

1. We also analyzed raw exam scores with time (Exam 1 vs. Exam 2) included as a within-subjects factor. Analyses of raw scores were identical to the "standardize change score" analyses.
2. Math anxiety was also analyzed in a 2 (time: Exam 1 vs. Exam 2) × 2 (condition) mixed analysis of variance. This produced the expected Time × Condition interaction for evaluation anxiety: $F(1, 79) = 5.57$, $p = .021$, $d = .53$. As can be seen in Table 1, no difference between conditions was observed at Time 1 (preintervention), but reappraisal participants reported less evaluation anxiety postintervention compared to controls.
3. We also tested raw resource appraisals measured at Exam 2 as the mediator of the association between condition and raw Exam 2 scores. This model was consistent with the change score analysis: Resource appraisals partially explained the condition–performance relationship (95% confidence interval = [1.28, 4.44]).

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Author Biographies

Jeremy P. Jamieson is an assistant professor of psychology at the University of Rochester. To better understand how social stress impacts our lives, Jamieson studies the psychological and biological processes that impact emotions, decisions, and performance.

Brett J. Peters is a PhD candidate in social psychology at the University of Rochester. His research focuses on understanding stress processes in relationships, and he is an expert in multilevel analyses.

Emily J. Greenwood is a PhD candidate in social psychology at the University of Rochester. Her research elucidates motivational processes in classroom and competitive contexts with focus on optimizing outcomes.

Aaron J. Altose is an assistant professor of mathematics at Cuyahoga Community College. In conjunction with the Carnegie Foundation, Altose has helped lead the pathways to improvement initiative that seeks to use psychological strategies to help college students master mathematics.