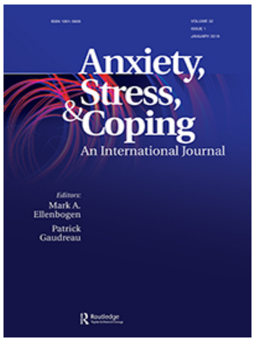

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Stress reappraisal during a mathematics competition: testing effects on cardiovascular approach-oriented states and exploring the moderating role of gender

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ABSTRACT

Background and objectives: Effects of reappraising stress arousal during an interpersonal competition were tested on physiological functioning and performance. Additionally, the moderating role of gender was explored.

Design and method: Participants ($N = 279$) were randomly assigned to a stress reappraisal, stress-is-debilitating, or a neutral control condition. Reappraisal materials educated participants about the adaptive benefits of stress, whereas stress-is-debilitating materials instructed participants to avoid stress. Control materials did not mention stress. Participants then competed against a gender-matched confederate on a 10-minute math performance task while cardiovascular reactivity was assessed. Participants were instructed to complete math problems as quickly and accurately as they could and were informed that a winner and loser would be determined by the resulting math scores.

Results: Reappraising stress arousal led to more adaptive challenge-like cardiovascular responses, but no condition effects were observed on math performance. Exploratory analyses revealed that reappraisal instructions were effective for improving physiological functioning and facilitating performance for men, but women were unaffected by the manipulation.

Conclusions: Reappraising stress arousal can improve physiological functioning during interpersonal competitions, but effects may be limited to men. Implications for future research are discussed.

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Stress reappraisal; competition; challenge; threat; gender

Competition pervades daily life. Athletes compete in sports, students compete for admissions, and potential employees compete for jobs, to name a few domains. In addition to competition being ubiquitous, competitive situations are inherently stressful. Competitors marshal resources to actively address task demands, which activates biological stress systems. However, stress responses to competitive situations are not uniform: individuals may exhibit approach- *or* avoidance-oriented responses (Hangen, Elliot, & Jamieson, 2016; Jamieson, Crum, Goyer, Marotta, & Akinola, 2018; Murayama & Elliot, 2012). Although approach-oriented responses are generally associated with better health and performance, research has yet to test the efficacy of active regulation approaches for promoting approach-oriented stress responses *in vivo* during an interpersonal competitive performance context. Towards this end, the research presented here adapted an intervention approach from the affect regulation literature – *stress reappraisal* (Jamieson et al., 2018; Jamieson,

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Hangen, Lee, & Yeager, 2018) – in an effort to promote approach-oriented stress responses and facilitate performance during competition.

Competition and the biopsychosocial model of challenge and threat

The stress responses that competitors experience depend largely on appraisal processes (Jamieson et al., 2018). According to the biopsychosocial (BPS) model of challenge and threat, appraisals of situational demands and personal resources interact to elicit challenge- and threat-type stress responses in motivated performance contexts (Mendes & Park, 2014). Resulting challenge and threat states are associated with specific physiological response patterns (see Mendes & Park, 2014, for a review) derived from activation of the sympathetic-adrenal-medullary (SAM) and hypothalamic–pituitary–adrenal (HPA) axes. Both challenge and threat responses are accompanied by SAM activation, but the HPA axis is activated only for threat responses. Thus, challenge is characterized by increased cardiac output – the volume of blood pumped by the heart across time – and decreased peripheral vascular resistance. However, HPA activation tempers effects of the SAM in threat responses and results in reduced (or little change in) cardiac output and increased peripheral vasculature resistance (for a review see Blascovich, 2014).

Challenge and threat states are also associated with motivational orientations: Challenge is generally associated with approach and threat with avoidance (e.g., Jamieson, Nock, & Mendes, 2012; Jamieson, Valdesolo, & Peters, 2014). The distinction between approach and avoidance motivation is critical for understanding responses to competition because competition is posited to have positive downstream implications when it evokes approach processes, and negative downstream implications when it evokes avoidance processes (Murayama & Elliot, 2012). Indeed, challenge and threat responses have been used as direct predictors of performance in competitive contexts (Blascovich, Seery, Mugridge, Norris, & Weisbuch, 2004; Meijen, Jones, Sheffield, & McCarthy, 2014; Moore, Wilson, Vine, Coussens, & Freeman, 2013; Turner et al., 2013; Turner, Jones, Sheffield, & Cross, 2012).

Given the general benefits of experiencing challenge relative to threat, developing regulatory methods that promote challenge responses (approach-oriented responses) can have substantial benefits. Towards this end, the current research sought to adapt a BPS-derived intervention approach – stress reappraisal – to promote challenge responses during competition.

Stress reappraisal

Given that challenge and threat states stem from appraisals, altering those appraisals has the potential to influence affective responses and subsequent motivational, behavioral, and health outcomes. Indeed, research on stress reappraisal has successfully optimized stress responses by presenting stress responses as a coping resource (e.g., Beltzer, Nock, Peters, & Jamieson, 2014; Jamieson et al., 2012; Jamieson, Mendes, Blackstock, & Schmader, 2010; Jamieson, Peters, Greenwood, & Altose, 2016; John-Henderson, Rheinschmidt, & Mendoza-Denton, 2015; Moore, Vine, Wilson, & Freeman, 2015; Sammy et al., 2017). Presenting stress as a coping resource stands in stark contrast to how people typically perceive stress. People frequently equate experiences of stress with negative affect. For instance, when individuals perceive increases in arousal they often construct negative emotions like anxiety (Barrett, 2017). The result is that people believe that to cope with stress, one should relax and reduce stress rather than utilize the stress response.

Notably, increased sympathetic arousal can be functional for performance in acutely stressful competitive situations. Thus, stress reappraisal is a well-suited method for regulating affective responses in stressful competitive situations because it seeks not to dampen stress arousal (i.e., it does not encourage relaxation), but instead focuses on changing appraisals of arousal in order to change the *type* of stress response experienced (for related approaches see Brooks, 2014; Crum, Akinola, Martin, & Fath, 2017).

Current research

The current research sought to promote approach-motivated responses in an interpersonal, competitive mathematics situation and advances the extant literature in several ways. First, it tested the efficacy of stress reappraisal in an interpersonal context. To date, the effects of stress reappraisal on cognitive performance have been limited to solo social evaluative situations (e.g., Jamieson et al., 2010; Jamieson et al., 2016; John-Henderson et al., 2015). Second, physiological responses to competition were measured *in vivo* during competitive performance, whereas previous research assessed physiological responses *prior* to competitive events (Moore et al., 2013; Moore et al., 2015; Sammy et al., 2017). Measuring responses online is important because how individuals orient to a task can vary substantially from how they respond during tasks (e.g., Jamieson & Harkins, 2011). Third, physiological responses and performance were examined during a mathematics competition. The extant research to date on stress reappraisal in competition has focused on motor tasks (Moore et al., 2013; Moore et al., 2015; Sammy et al., 2017). Mathematics also has real-world relevance as students compete for admissions, high scores on quantitative standardized tests, or in competitions as "mathletes." Fourth, the design included an avoidance-expectancy control. These materials were presented as a method to help competitors avoid performing poorly, equated stress with anxiety, and allow for tests of potentially divergent effects of approach- and avoidance-oriented instructions (e.g., Murayama & Elliot, 2012).

To test the effects of reappraisal instructions during competition, individuals were randomly assigned to one of three conditions: *stress reappraisal, stress-is-debilitating,* or *control*. Participants in the stress reappraisal condition were instructed that stress is functional and adaptive for performance during competition. Participants were encouraged to appraise their stress arousal as a functional coping tool that could help them do well compared to others. In contrast, participants in the stress-is-debilitating condition read modified materials that presented stress as maladaptive for performance during competition. Participants were encouraged to avoid performing poorly relative to others. In a "no instruction" control condition, participants read materials about the structure and function of the brain. This has been used previously as a no-instruction control and took participants approximately the same amount of time to complete as the other instructions (e.g., Blackwell, Trzesniewski, & Dweck, 2007).

We hypothesized *a priori* that participants assigned to the stress reappraisal condition would exhibit more adaptive, challenge-like physiological responses during competition and outperform participants assigned to the stress-is-debilitating and control conditions. Follow-up comparisons between conditions were used to identify the source and direction of effects. Given notable gender differences in preference for competition (Croson & Gneezy, 2009; Niederle & Vesterlund, 2007), math anxiety (Hembree, 1990; Maloney, Waechter, Risko, & Fugelsang, 2012), and math performance (Hedges & Nowell, 1995; Reis & Park, 2001), we followed up *a priori* analyses with a series of exploratory analyses to examine effects of competitor gender.

Method

All work was conducted with the formal approval of University of Rochester's research subjects review board.

Participants

An *a priori* power analysis was used to estimate the number of participants needed to test for differences as a function of stress reappraisal. Given a medium effect size ($d = 0.50$) and a targeted power level of .80, a minimum of 64 participants per condition was needed to test hypotheses. To account for attrition and missing data, data collection was terminated at the end of the academic semester where each condition included at least 70 participants. Data collection spanned four consecutive academic semesters. A total of 279 participants were recruited via a psychology subject pool (SONA). Fifteen were excluded from analyses *a priori*: 3 did not complete the study; 10 identified the confederate as a fake participant; 1 reported during debriefing that she did not understand that she was competing, and 1 participant assigned to the stress-is-debilitating condition received stress reappraisal instructions via a course lecture immediately before participating. The final sample included 264 participants with demographics reflecting the available subject pool (200 female, 64 male; 177 White/Caucasian, 73 Asian/Asian-American, 6 Hispanic, 8 Other; $M_{age} = 19.9$ years, $SD_{age} = 1.2$ years).

Procedure

Upon arrival at the lab, participants met another same-gender, same-race student (actually a confederate) waiting to complete the same study. The following description refers to both the actual participant and the confederate as "participants;" the actual participant directly experienced the procedure, whereas the confederate played the role of participant for appearance sake. An experimenter greeted the participants and brought each to a separate testing room. Study procedures were thoroughly explained and participants provided written informed consent. After completing intake questionnaires, autonomic sensors were affixed, and participants sat for a 5-minute baseline recording. Following baseline, participants were brought together and informed that the study was about competition, and that they would compete against each other on a test of "general cognitive abilities." They were then given two practice problems. Upon completion of the practice problems, the pair was told that a computer program would randomly choose 20 problems (all problems were selected from the same set of 20, but presented in random order).

Before beginning, participants read one of three sets of instructions: *stress reappraisal* ($n = 88$; 76% female), *stress-is-debilitating* ($n = 84$; 71% female), or *control* ($n = 92$; 79% female). The *stress reappraisal* condition was adapted from previous materials that highlighted the functionality of stress (see Jamieson et al., 2012; 2016). The *stress-is-debilitating* condition modified reappraisal materials to present stress as maladaptive. In both conditions, participants read three summaries of journal articles (some based on actual articles, others fictitious articles; see supplemental materials for full manipulation materials).

The *stress reappraisal* condition informed participants that the materials were developed to help them perform well, and they read summaries that presented stress as adaptive for performance (similar to reappraisal materials used previously; Jamieson et al., 2012; 2016). The materials educated the participants about the functionality of stress arousal and the performance benefits therein. Participants assigned to the *stress-is-debilitating* condition were told materials were developed to help them avoid performing poorly, and they read summaries that presented stress as maladaptive (a "stress-is-debilitating" mindset; Crum, Salovey, & Achor, 2013). After each summary, participants answered two questions to ensure that they read the summaries and to encourage them to endorse the information (full scripts are presented in the supplemental material). Control materials were modeled after a no-treatment control used previously (e.g., Blackwell et al., 2007). Participants assigned to the control condition were asked to proofread materials on the structure and function of the brain. As in the *stress reappraisal* and *stress-is-debilitating* conditions, the participants in the *control* condition answered two questions after each summary designed to ensure that they read the material. Following manipulation materials, participants completed questionnaires (see supplemental material).

Participants were then informed that they would be competing with each other (i.e. participant versus confederate) on the math task and that a winner and loser would be declared on the basis of who earned the higher (or lower) score. For their scores, participants were told they would have 10 minutes to solve as many problems as they could, and that they would earn 1-point for every problem answered correctly and would be penalized ¼ point for every problem answered incorrectly. Participants were told that they could skip problems without penalty (except for the opportunity cost of not answering a problem). Paper and pencil were provided for working problems and the participant and confederate were seated at their computers so that they were facing each other. After the competition, the participant and the confederate were separated and the participant completed brief post-task measures (see supplemental material) and a demographics questionnaire. Once all measures were completed, sensors were removed and the participant was debriefed.

Measures

Physiological measures. The following signals were collected during baseline and the competition: electrocardiography (ECG), impedance cardiography (ICG) with band sensors, and blood pressure (BP). ECG and ICG signals were collected at 1000 Hz, and integrated with an MP150 system (Biopac Systems Inc., Goleta, CA). BP readings were obtained from the brachial artery on the non-dominant arm using an ambulatory system (Colin Medical Instruments, San Antonio, TX) and were taken at 2-min intervals during each recording period (i.e. baseline and the competition). ECG and ICG signals were ensembled into one-minute averages using Mindware software (IMP v3.0.21; Mindware Technologies, Gahanna, OH). Trained coders visually examined all B, Q, and R points for artifacts and corrected erroneous placements.

Analyses were conducted on the following measures: pre-ejection period (PEP), cardiac output (CO), and total peripheral resistance (TPR). These responses were used to distinguish challenge and threat states. PEP is an index of sympathetic arousal and measures the time from the start of left ventricle contraction to the opening of the aortic valve. Shorter PEP intervals indicate the greater contractile force of the heart and greater sympathetic activation. CO is the amount of blood ejected from the heart during one minute. An increase in CO indicates improved cardiac efficiency and is typically observed in approach-oriented challenge states. TPR is a measure of overall vascular resistance (calculated here as follows: TPR = (mean arterial pressure/CO) * 80; Sherwood et al., 1990). An increase of TPR suggests a reduction of blood flow to the periphery, and accompanies threat states, whereas vasodilation (i.e., reduced TPR) facilitates delivery of oxygenated blood to the brain and periphery, and is suggestive of challenge states.

Mathematics performance task. The participants were given 20 Graduate Record Exam (GRE) quantitative problems adapted from problem sets used in previous research (Jamieson & Harkins, 2009). The problem set used herein included 5 “low difficulty” problems (~ 75% solution rate in the population) and 15 “moderate difficulty” problems (~ 50% solution rate; see supplemental material for full materials). Problems were presented in randomized order. The participants were given 10 minutes to correctly answer as many problems as they could.

Two performance metrics were analyzed: adjusted score and percent correct[1]. Adjusted score is a modified number correct measure and was calculated by adding problems answered correctly and subtracting ¼ point for each problem answered incorrectly (skipped problems counted as zero). Percent correct was calculated based on the number of problems answered correctly out of the total number of problems answered (problems skipped were not included).

Results

All data exclusions, manipulations, and measures analyzed are reported.

Physiological responses

As is common in the stress literature, reactivity scores were computed to assess physiological responses (for examples see, Hangen et al., 2016; Jamieson et al., 2012; Jamieson et al., 2014) by subtracting scores taken during the final minute of baseline (i.e., the most relaxed period) from those collected during the first minute of the competition (i.e., the most reactive period). Prior to analyzing reactivity scores, differences in raw baseline measures were tested (PEP, CO, and TPR) and none emerged as a function of condition: $Fs < 1.9$, $ps > .15$.

Engagement. Sympathetic arousal was indexed with PEP reactivity. First, we ensured that the sample as a whole was sufficiently engaged during competition by testing whether PEP decreased from baseline to performance, which, indeed, it did, $t(253) = -13.42$, $p < .001$, $d = 0.84$.

Follow-up, exploratory analyses indicated PEP reactivity differences emerged as a function of condition, $F(2, 251) = 3.43$, $p = .034$, $\eta_p^2 = .03$. To test whether experimental materials (both of which participants were told were designed to help them) encouraged greater engagement than control materials, combined experimental conditions were contrasted to the control condition (reappraisal = 1, control = −2, stress-is-debilitating = 1) along with its orthogonal contrast (stress-is-debilitating = −1, control = 0, reappraisal = 1). Differences were non-significant, although individuals assigned to experimental conditions ($M = -7.96$, $SD = 8.61$) trended towards greater engagement than controls ($M = -5.78$, $SD = 8.24$), $t(251) = -1.93$, $p = .055$, $d = 0.26$[2].

Challenge-threat responses. The main focus of this research was on challenge and threat responses elicited during competition. As is common in the challenge and threat literature, a continuous challenge-threat index was computed to test for effects of condition on challenge-threat responses: CO and TPR reactivity scores were standardized, and TPR was subtracted from CO. The continuous index was created following standard procedures (Blascovich et al., 2004; Seery, Blascovich, Weisbuch, & Vick, 2004; Shimizu, Seery, Weisbuch, & Lupien, 2011), and has been used previously to delineate responses in a competition context (Hangen et al., 2016): Higher scores indexed more challenge-like states.

A one-way (condition: stress-is-debilitating vs. control vs. stress reappraisal) ANOVA accompanied by *a priori* planned contrasts was used to compare effects between conditions (stress reappraisal = 1, control = 0, stress-is-debilitating = −1), along with its orthogonal contrast (stress reappraisal = 1, control = −2, stress-is-debilitating = 1) on physiological responses. For the overall model a small effect of condition was trending but was non-significant, $F(2, 251) = 2.56$, $p = .080$, $\eta_p^2 = .02$.

However as hypothesized, contrasts revealed that stress reappraisal participants exhibited significantly greater challenge responses ($M = 0.35$, $SD = 2.07$) than stress-is-debilitating participants ($M = -0.22$, $SD = 1.49$), $t(251) = 2.07$, $p = .039$, $d = 0.32$. Stress reappraisal participants did not significantly differ in challenge responses from controls (M = −0.14; $SD = 1.72$), but a small effect was trending $t(251) = 1.82$, $p = .070$, $d = 0.26$ (see Figure 1). Stress-is-debilitating and control participants did not differ from each other, $t(251) = 0.32$, $p = .751$, $d = .05$.

Note. Error bars represent 95% confidence intervals.
* $p < .05$
Ŧ $p < .10$

Figure 1. Physiological responses during competition by condition.

Performance effects

To control for family-wise error, a multivariate analysis of variance (MANOVA) was used to test for effects of condition on the two performance metrics (adjusted score and percentage correct). *A priori* planned contrasts compared the performance of participants in the stress reappraisal condition to the other conditions. No significant effects emerged, $F\text{s} < 0.98$, $p\text{s} > .42$. The stress reappraisal condition did not differ in score ($M = 4.73$, $SD = 3.53$) nor accuracy ($M = 52.7\%$, $SD = .23$) from stress-is-debilitating condition ($M = 5.11$, $SD = 3.69$; $M = 52.7\%$, $SD = .20$), nor control condition ($M = 5.15$, $SD = 3.70$; $M = 52.6\%$, $SD = .22$).

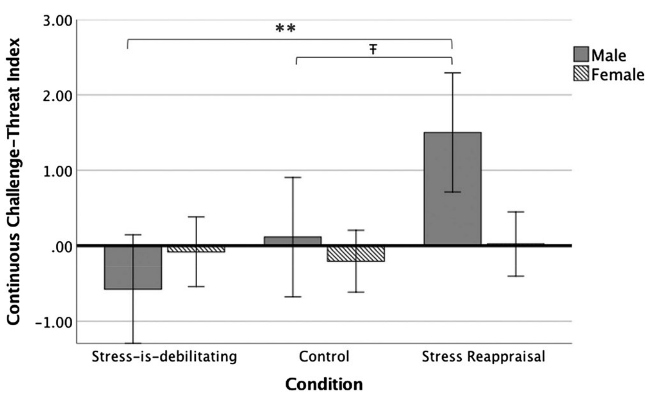
Exploratory analyses of gender differences

Analyses were conducted to test for possible moderation of condition effects by competitor gender. To do so, gender was added as a factor to planned *a priori* analyses to create 3 (condition) × 2 (participant gender: male vs. female) ANOVA (challenge-threat responses) and MANOVA (performance) models.

Challenge-threat responses. The main effect of condition, $F(2, 248) = 6.37$, $p = .002$, $\eta_p^2 = .05$, was qualified by a condition x gender interaction, $F(2, 248) = 4.95$, $p = .008$, $\eta_p^2 = .04$ (see Figure 2). (An effect of gender on challenge-threat responses was not significant but trending, $F(1, 248) = 2.83$, $p = .094$, $\eta_p^2 = .01$)

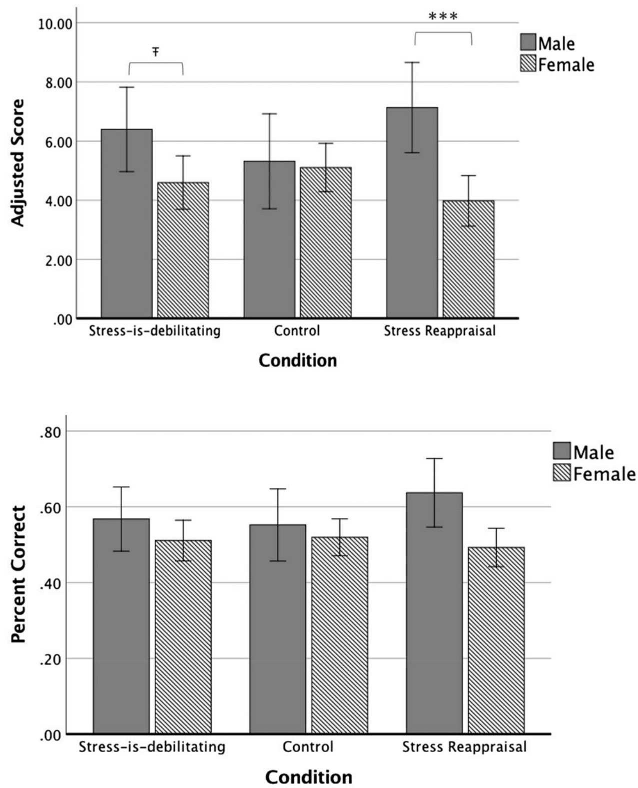
Effects on challenge-threat responses were explored separately for males and females. A significant effect of condition emerged for men, $F(2, 58) = 4.69$, $p = .013$, $\eta_p^2 = .14$, but not for women, $F(2, 190) = 0.35$, $p = .71$. Contrasts (identical to those described in *a priori* analysis section) revealed that men responded in line with hypotheses: a large effect emerged with men in the reappraisal condition exhibiting significantly stronger challenge responses ($M = 1.50$, $SD = 3.04$) relative to men in the stress-is-debilitating condition ($M = -0.57$, $SD = 1.57$), $t(58) = 3.03$, $p = .004$, $d = 0.85$. And although men in the stress reappraisal condition did not significantly differ from men in the control condition ($M = 0.11$, $SD = 1.84$), a medium-sized effect was emerging $t(58) = 1.94$, $p = .058$, $d = 0.55$. The stress-is-debilitating and control conditions did not differ from each other, $t(58) = 1.01$, $p = .319$.

Performance effects. A significant multivariate effect of gender, Wilk's $\lambda = .95$, $F(2, 257) = 6.17$, $p = .002$, $\eta_p^2 = .05$, was qualified by a trending gender × condition multivariate interaction, Wilk's $\lambda = .97$, $F(4, 514) = 2.24$, $p = .064$, $\eta_p^2 = .02$.[3]



Note. Error bars represent 95% confidence intervals.
** $p < .01$
Ŧ $p < .10$

Figure 2. Condition effects on challenge-threat physiological index during competition moderated by gender.



Note. Error bars represent 95% confidence intervals.
*** $p < .001$, Ŧ $p < .05$ but not meeting Bonferroni adjusted alpha level ($p = .043$)

Figure 3. Condition effects on performance as a function of participant gender.

Follow-up univariate analyses revealed that men significantly outperformed women on both performance measures: adjusted score, $F(1, 258) = 11.29$, $p = .001$, $\eta_p^2 = .04$, and percentage correct, $F(1, 258) = 6.56$, $p = .011$, $\eta_p^2 = .03$ (see Figure 3). Gender did not interact with condition for percentage correct, $F(2, 258) = 1.23$, $p = .293$, $\eta_p^2 = .01$, but a gender x condition interaction was trending for adjusted score, $F(2, 258) = 2.67$, $p = .071$, $\eta_p^2 = .02$[4].

To decompose the marginal gender × condition interaction on adjusted score, effects of condition were tested separately for each gender. Univariate ANOVAs revealed no significant effect of condition on adjusted score for men, $F(2, 61) = 1.07$, $p = .350$, $\eta_p^2 = .03$, nor women, $F(2, 197) = 1.90$, $p = .153$, $\eta_p 2 = .02$. Next, a series of *t*-tests examined gender differences in adjusted score within condition and were conducted with a Bonferroni adjusted alpha levels ($p < .017$). Results indicated that men earned higher scores ($M = 7.13$, $SD = 3.00$), than women in the reappraisal condition ($M = 3.98$, $SD = 3.37$), $t(86) = 3.83$, $p < .001$, $d = 0.99$. No significant gender differences emerged for Bonferroni adjusted alpha levels in either the stress-is-debilitating, nor control conditions, *ps* > .04, *d*s < .50 (see Figure 3).

Discussion

This research tested the effects of stress reappraisal *during* an interpersonal competition. Moreover, we explored potential gender differences of stress reappraisal in competitive contexts. Supporting predictions, individuals who were educated about the adaptive benefits of stress (reappraisal condition) exhibited more adaptive, challenge-type cardiovascular responses during the competition compared to individuals who received materials that focused on the detrimental nature of stress (stress-is-debilitating condition). Comparisons to no instruction controls suggested differences were driven by more adaptive responses in the reappraisal condition.

Interestingly, the stress-is-debilitating instructions did not elicit more threat-type responses compared to controls. Although caution should be exercised when interpreting any null result, this pattern may suggest that during competitive math tasks, threat may be highly prevalent. This might not be surprising given the prevalence of math anxiety (Ramirez, Shaw, & Maloney, 2018). Moreover, if competitors "default" to threat responses in these situations, interventions to attenuate threat have the potential to benefit a large number of students who frequently must perform in competitive mathematics contexts (for a meta-analytic review, see Ma, 1999). Null effects for the stress-is-debilitating instructions may also have been due to expectancy effects (Tamir, Bigman, Rhodes, et al., 2015). Participants assigned to the stress-is-debilitating instructions were told that the materials were designed to help them avoid performing poorly. Thus, although avoidance-oriented, materials were presented as beneficial, potentially eliciting expectancy effects that may have attenuated negative effects of the avoidance content.

Primary analyses of performance, however, did not support hypotheses. No condition differences were observed. Several factors could have contributed to this null pattern. First, the competition manipulation was minimal, and the context was devoid of explicit evaluation (unlike a Trier-type task, Kirschbaum, Pirke, & Hellhammer, 1993). Although differences were observed in physiological responses by condition, changes from baseline were relatively small compared to laboratory-based social stress research on stress reappraisal (e.g., Jamieson et al., 2012). Thus, observing physiological effects in this minimal paradigm speaks to the robustness of the reappraisal instructions. Second, the randomization of the GRE items was suboptimal to test for condition effects. For instance, randomization restricted our ability to explore performance as a function of problem difficulty. Problems differed in average difficulty (25% of problems were relatively easy: population solution rate >75%). Thus, some participants received easier/harder problem sets than others, which introduced additional variability. Finally, as elucidated by exploratory gender analyses, important moderators should be considered. In fact, this experiment has the potential to stimulate future work on potential moderation effects of competitor gender.

Exploratory effects of competitor gender

Exploratory analyses of gender, albeit underpowered, yielded interesting findings that may provide a springboard for future research on this topic. Notably, for both physiological reactivity and performance, effects of condition only manifested for male competitors. Males assigned to the reappraisal condition exhibited more adaptive physiological profiles than males and females in the other conditions, and had higher adjusted scores than females in the reappraisal condition. Moreover, the performance effects for males as a function of condition were even stronger when analyses were restricted to epochs when participants were engaged (i.e. PEP reactivity < 0) (see Footnotes 3 and 4). There are several potentially interesting reasons for why effects of the stress reappraisal manipulation manifested for males, but not females.

One consideration is that this study focused on interpersonal competition in a mathematics domain, which may have elicited stereotype threat in some female competitors (Spencer, Steele, & Quinn, 1999). However, the likelihood of this possibility may be low for several reasons, First, competitors were matched on gender (i.e. the competition was within-gender). Second, no gender differences as a function of stress reappraisal have been observed in previous research using math tasks (e.g., Jamieson et al., 2010; 2016). Finally, and most notably, stress reappraisal has specifically been shown to alleviate stereotype threat effects (John-Henderson et al., 2015).

More likely possible explanations for the null pattern of findings for female competitions, are rooted in gender differences in trait competitiveness and biobehavioral responses to stress. Women are more reluctant to engage in competitive interpersonal interactions than men and men tend to outperform women in competitive interpersonal contexts (Croson & Gneezy, 2009). Similarly, women are less confident than men regarding their abilities to compete in interpersonal contexts (Niederle & Vesterlund, 2007). What might be the root cause(es) of these observed gender differences? We highlight the possibility of differences in biobehavioral responses to stress as a potential moderator in need of future examination.

Social stress research frequently conceptualizes biobehavioral responses to stress as variants of "fight or flight." However, humans can also seek to affiliate in stressful social situations by forming group bonds so as to jointly address stressors. This response pattern has been labeled as "tend-and-befriend" (see Taylor, 2006 for a review), and women exhibit consistently stronger affiliative, tend-and-befriend responses to social stress than men (Tamres, Janicki, & Helgeson, 2002; Taylor et al., 2002). Interpersonal competitive contexts, such as the one studied here, are particularly ripe for gender differences in biobehavioral responses shaping cardiovascular functioning and performance, because of the inherently social nature of interpersonal competitions, and different possible relational responses available. Future work seeking to map biobehavioral responses to competition should seek to not only measure sympathetic-drive stress processes, such as the challenge and threat states, but also to incorporate measures sensitive to affiliative orientations, such as the peptide hormone oxytocin (e.g., Kubzansky, Mendes, Appleton, Block, & Adler, 2012; Taylor et al., 2000).

Limitations and future directions

Limitations should be considered when interpreting this research. First, the current study used a low-stakes, minimal competition manipulation. Performance was not subject to explicit evaluation, nor could participants gain resources by winning. This led to weaker sympathetic activation patterns compared to other social stress paradigms, such as public speeches (Jamieson et al., 2012), noncorrespondant situations (Peters, Reis, & Jamieson, 2018), or interracial interactions (Page-Gould, Mendes, & Major, 2010) to name a few. Future research may seek to increase the evaluative pressure of competitive situations by providing online feedback, or by increasing the stakes with rewards (Barreto, Wright, Krubinski, Molzof, & Hur, 2015).

This research used quantitative GRE problems to assess performance, but did not consider the potentially differential impacts of challenge/threat responses on subtypes of problems. That is, the quantitative GRE is constructed of *comparison*- and *solve*-type problems (Jamieson & Harkins, 2009). Whereas *solve* problems tend to be most efficiently solved by applying an equation/algorithm and computing answers, the most efficient approach to complete *comparison* problems tends to be simplifying terms or using logic, estimation, and/or intuition. Given that challenge responses tend to improve cognitive processing efficiency (e.g., Dienstbier, 1989; Jamieson et al., 2010), it is possible that reappraisal participants might have experienced a boost in performance only on *solve* problems that required more cognitive processing. However, because problems were randomized, we were unable to explore performance as a function of problem type (comparison vs. solve) due to restricted samples per problem. Future research may seek to more clearly isolate the mechanisms underlying potential performance effects in interpersonal competitive settings.

Furthermore, challenge and threat responses can be impacted by interaction partners in dyadic contexts (e.g., Peters et al., 2018; Thorson & West, 2018; West, Koslov, Page-Gould, Major, & Mendes, 2017). In the current work, participants competed with a confederate from whom no physiological data were collected, thus limiting analysis of actor/partner effects or physiological linkage. Moreover, although the current research examined competition between individuals, competitions frequently occur between teams or groups. To date, little is known about how emotion regulation processes, such as stress reappraisal, impact teammates. Future research utilizing dyadic or team designs should seek to elucidate the interpersonal dynamics of stress processes in competitive contexts.

Similarly, confederates and participants were matched on race and gender here, limiting conclusions to same-race, same-gender competitions. Interesting effects may emerge as a function of competitor attributes (e.g., interracial or cross-gender competitions). Finally, not all individuals should be expected to benefit similarly from stress reappraisal interventions. Although research has yet to accumulate on moderators of stress reappraisal effects, there are myriad interesting avenues for exploration. For instance, causal attributions (Mendes, Major, McCoy, & Blascovich, 2008), stress mindsets (Crum et al., 2013); interoceptive awareness (Khalsa et al., 2008), and mindfulness mediation processes (Miller, Fletcher, & Kabat-Zinn, 1995) are promising individual-level moderators to consider in future work.

Conclusions

The present research shows that stress reappraisal can promote adaptive physiological responses during an interpersonal competition. These data contribute to a growing body of evidence demonstrating that brief, social–psychological interventions have the potential to improve active coping (see Yeager & Walton, 2011, for a review). As emphasized by Yeager and Walton, however, intervention approaches such as the one presented here are not "magic bullets" for solving problems associated with stress. Rather, social–psychological interventions target specific processes to enact some degree of positive change. Here, we sought to improve affective responses in an interpersonal competition context, but substantial future work is needed to better specify how responses to competition might be optimized, isolate mechanisms of potential effects in competitive situations, and incorporate important moderators, perhaps most notably in competition settings, gender.

Data availability

The data that support the findings of this study are openly available for download at http://socialstresslab.wixsite.com/urochester/papers-publications.

Notes

1. To gain insight into effort participants expended on the task, the number of problems attempted was also analyzed. No differences emerged as a function of condition. Full results can be found in the supplemental material.
2. No significant differences emerged between experimental conditions, but stress reappraisal participants ($M = -9.06$, $SD - 9.43$) were trending towards greater engagement than stress-is-debilitating participants ($M = -6.77$, $SD = 7.51$), $t(251) = -1.73$, $p = .085$, $d = 0.27$.
3. MANOVAs were also run using performance metrics calculated during the first five minutes of the competition because participants, on average, returned to baseline (PEP reactivity = 0) by minute 5 (see supplemental analyses). The 5-min performance data yielded a significant gender × condition multivariate interaction, Wilk's $\lambda = .94$, $F(6, 512) = 2.61$, $p = .017$, $\eta_p^2 = .03$.
4. When analyzing 5-min performance measures, the gender × condition interaction was significant for both indices: adjusted score, $F(2, 258) = 4.99$, $p = .007$, $\eta_p^2 = .04$, and percentage correct, $F(2, 258) = 3.36$, $p = .036$, $\eta_p^2 = .03$. For women, no condition effects emerged on either performance index, $ps > .15$. But for men, marginal condition effects emerged for both performance indices, $ps < .10$, with men in the stress reappraisal condition outperforming men in the control condition, $ps < .05$.

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