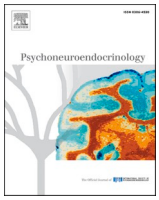
Psychoneuroendocrinology 180 (2025) 107544

Contents lists available at ScienceDirect

Psychoneuroendocrinology

journal homepage: www.elsevier.com/locate/psyneuen



Fueled and focused: A brief intervention integrating stress reappraisal and achievement goals improves exam performance and reduces cortisol

Audrey-Ann Journault [a,*], Marisa E. Marotta [a], Emily J. Hangen [b], Hannah Gravelding [a], Andrew J. Elliot [a], Jeremy P. Jamieson [a]

[a] Department of Psychology, University of Rochester, 500 Wilson Blvd, Rochester, NY 14611, USA
[b] Department of Psychology, Philosophy and Neuroscience, State University of New York, Brockport, 350 New Campus Drive, Brockport, NY 14420, USA

ARTICLE INFO

Keywords:
Stress reappraisal
Achievement goals
Intervention
Performance
Cortisol

ABSTRACT

When taking an exam, experiencing stress is natural, especially for students transitioning to new academic environments. Students who reappraise stress arousal as a functional resource and who adopt approach-oriented achievement goals —focusing on attaining success rather than avoiding failure— may experience healthier biological stress responses and perform better. This study tested whether a short intervention that integrated the stress reappraisal and achievement goal models 1) increased students' exam scores and 2) decreased their stress hormones during their course exams compared to a control condition. Students in an Introduction to Psychology course (N = 308; M_{age} = 18.30 years, SD_{age} = 0.62 years, 59 % Female) were randomly assigned to a short reading-writing intervention or a control condition between their first and second in-class exams. Students provided a saliva sample immediately after each exam to assess the cortisol levels produced while taking the exam, and exam scores were obtained from the course instructor. Results revealed that the intervention increased exam scores and decreased production of salivary cortisol at Exam 2 post-intervention compared to the control intervention. In brief, the short intervention was a successful tool in helping students view their stress responses as additional fuel to focus on the exam and perform.

1. Introduction

Academic examinations allow instructors to assess students' learning progress across every stage of the educational system. While necessary for monitoring learning and identifying areas needing further instruction, exams are inherently stressful given their evaluative nature and consequences for academic success (Koudela-Hamila et al., 2022; McCrindle, 2021; Merz and Wolf, 2015). They are particularly stressful when students face heightened uncertainty during academic transitions, such as the transition from high school to college (Högberg, 2021). Failure or underperformance becomes a potential threat, and the brain and body respond in ways that support or undermine success in such contexts (Blascovich and Mendes, 2010; Lazarus and Folkman, 1984). That is, stress responses are not inherently negative, but rather multifaceted, with some response patterns predicting improved performance and some predicting worse performance (e.g., Jamieson, 2017).

Modern stress theories, such as biopsychosocial (BPS) models, emphasize this multifaceted nature (see Jamieson et al., 2016 for a review). One prominent model particularly relevant for performance contexts like exams is the BPS model of challenge and threat (Blascovich and Mendes, 2010). This model outlines two general stress response patterns in a continuum: challenge and threat. These patterns arise when one encounters performance-based stressors. Each state distributes the mobilized energy of the stress response to either approach or avoid the stressor based on cognitive appraisals of the situation's demands (e.g., difficulty level) and their available resources to face them (e.g., knowledge level). Challenge-states emerge when individuals perceive resources as surpassing demands, as they can view the stressor as an opportunity to grow or succeed. Physiological processes then come into play to promote direct action to engage with the exam. This includes cardiovascular changes to deliver oxygenated blood to the brain and peripheral musculature (Jamieson et al., 2012), production of catecholamines and anabolic hormones (Jamieson et al., 2022), and the release of moderate cortisol to meet energy needs without exceeding

* Correspondence to: Meliora Hall 451, 500 Wilson Blvd, Rochester, NY 14611, USA.
E-mail addresses: ajournau@UR.Rochester.edu (A.-A. Journault), marisamarotta1@gmail.com (M.E. Marotta), ehangen@brockport.edu (E.J. Hangen), hgraveld@u.rochester.edu (H. Gravelding), andrew.elliot@rochester.edu (A.J. Elliot), jeremy.jamieson@rochester.edu (J.P. Jamieson).

https://doi.org/10.1016/j.psyneuen.2025.107544
Received 3 February 2025; Received in revised form 9 May 2025; Accepted 9 July 2025
Available online 10 July 2025

physiological needs (Epel et al., 2018). In contrast, threat-states emerge when the demands surpass the available resources, which triggers avoidance of the stressor to protect the individual from threat of harm, including social harm and loss of status. Increased vascular resistance contributes to increased concentration of blood in the core, and higher cortisol levels are produced, which are often prolonged as the confrontation is expected to last longer (Jamieson et al., 2022; Pulopulos, 2020).

Because threat prevents individuals from engaging successfully with pressurized evaluative situations like exams, threat states are less beneficial than challenge states in such performance settings (e.g., Behnke and Kaczmarek, 2018; Hase et al., 2018; Jamieson et al., 2022). Thus, attenuating threat and promoting challenge has the potential to improve outcomes in stressful exam situations (Hase et al., 2024). Towards this end, some individual-level interventions have been developed leveraging BPS models that focus on shifting the ratio of perceived resources to demands (e.g., Jamieson et al., 2012; 2022; Yeager et al., 2022). These stress reappraisal interventions are "wise interventions", which are brief, target specific mechanisms (e.g., stress appraisals), and are self-reinforcing (Walton and Wilson, 2018). This family of interventions aims to shift students' threat appraisals into challenge appraisals by helping students view their physiological stress responses as a functional resource to thrive during exams (Jamieson et al., 2018). Although stress reappraisal interventions have led to small improvements in performance compared to controls for both sexes (for a meta-analysis, see Bosshard and Gomez, 2024), their effect on physiological responses is not always consistent. In their meta-analysis, Singh and Journault (in preparation) found a significant small increase in cardiac output with no heterogeneity for the participants in the stress appraisal/mindset condition when conducting a stressful task (e.g., see Gurera and Isaacowitz, 2022; Jamieson et al., 2012; Oveis et al., 2020 and Sammy et al., 2017), but small decreases in total peripheral resistance and cortisol with high heterogeneity. Jamieson et al., 2012 report an increase in total peripheral resistance, whereas Jamieson et al., (2013); Oveis et al., 2020 and Sammy et al., 2017 report a decrease. Similarly, Crum et al., (2017) and Jamieson et al., 2022 report a decrease in cortisol, whereas Jentsch and Wolf, (2020) report an increase.

One of the potential explanations for the heterogeneity of stress reappraisal effects on physiological responses involves the degree of alignment between individuals' *fuel* (i.e. viewing stress responses as a resource or demand and orienting toward challenge or threat, accordingly) and their *focus* in taking the exam (i.e., the type of goal they adopt that directs their competence-based behavior). According to the achievement goal approach to achievement motivation, students may adopt approach goals that focus on attaining success, or avoidance goals that focus on evading failure (Elliot and Church, 1997). Approach goals include two types, mastery-approach goals (e.g., trying to attain task-based competence or self-improvement) and performance-approach goals (e.g., trying to attain competence relative to others). Likewise, avoidance goals include two types, mastery-avoidance goals (trying to avoid task-based incompetence or doing worse than before) and performance-avoidance goals (trying to avoid incompetence relative to others; Elliot et al., 1999; see also Elliot and McGregor, 2001; Pintrich, 2000). Both mastery-approach and performance-approach goals have been shown to be positively associated with academic achievement, as they facilitate task-absorption, effort, and persistence that promote performance outcomes. In contrast, both mastery-avoidance and performance-avoidance goals have been shown to be negatively associated with academic achievement, as they undermine task engagement, prompt anxiety, and lead to self-protective behaviors that impede performance outcomes (for meta-analyses and narrative reviews, see Chazan et al., 2022; Elliot and Hulleman, 2017; Huang, 2012; Yperen et al., 2014).

Motivation entails the energization and direction of behavior; energization activates and orients individuals, and direction focuses this energization in a specific way (Elliot, 2006). Both energization and direction are important predictors of behavior. Optimal motivation in academic settings typically involves approach energization coupled with approach direction (Liem and Elliot, 2018; Senko and Tropiano, 2016). Applied to the current work, a stress reappraisal intervention that promotes challenge could particularly amplify the well-established benefits for the performance of students pursuing approach-based achievement goals. Although these two frameworks are highly compatible — and have the potential to create synergistic effects when leveraged together, no studies have tested this possibility by integrating the stress reappraisal and achievement goal approaches within the same intervention.

This is a notable shortcoming given that leveraging multiple psychological processes is typically more effective than isolated interventions that focus on a single dimension (e.g., Yeager et al., 2022). To help students transitioning from high school to college, the current study investigated the effects of a novel intervention integrating stress reappraisal and achievement goals in a real-life setting. More specifically, we tested whether a stress reappraisal*achievement goal intervention emphasizing challenge appraisals and approach-based goals 1) increased students' exam scores and 2) decreased their production of cortisol during course exams compared to a control intervention.

2. Method

2.1. Participants and achievement context

College freshmen (M_{age} = 18.30 years, SD_{age} = 0.62 years) were recruited across two consecutive years from an Introduction to Psychology course offered during the fall semester of the University of Rochester, Rochester, NY, USA. To maximize statistical power, it was decided before the start of data collection that students would be recruited across two years from two cohorts of the same course (i.e., identical content taught by the same instructor in 2017 and 2018). An *a priori* power analysis was conducted to estimate the sample size needed to identify a small-medium effect size f^2 = .08 in a multiple regression model with four predictors and a target power level of .80; 153 participants were required. A total of 308 students were recruited, with 59 % identifying as female and 41 % as male. The ethnic/racial breakdown was Caucasian/White (39 %); Asian/Asian-American (39 %), African/African-American/Black (9 %), Hispanic/Latino (8 %), and Other (5 %). Students were compensated with extra course credit. Age, sex, and ethnicity did not differ statistically between the two cohorts ($ps >$ .05).

The course was a large introductory psychology lecture class designed according to the principles of Self-Determination Theory (Ryan and Deci, 2020). For example, the syllabus highlighted student autonomy, exams were scored based on an absolute standard (i.e., percentage correct) instead of a normative standard (i.e., graded on a curve), and exam questions aimed to assess deep understanding rather than memorization.

2.2. Procedure

This study was approved by the University of Rochester's Institutional Review Board; the results presented herein have yet to be presented in prior work. All data were collected before analyses were conducted. Other self-report measures irrelevant to this paper were collected. The dataset is available on OSF at: https://osf.io/dsgkx/.

After providing written consent to participate, students completed several surveys during the semester, including a baseline survey comprising demographic measures administered at the beginning of the semester (early-mid September) on a regular class day. That day, students also provided a saliva sample to measure baseline stress hormone levels (i.e., cortisol) without exams. Using simple randomization assignment within the course each semester, students were randomly administered an intervention or control reading-writing activity between the first (end-of-September) and second exams (end-of-October).

Students provided one additional saliva sample immediately after the first (i.e., pre-intervention) and second exams (i.e., post-intervention) to assess cortisol levels produced during each exam. The intervention was administered between the first two exams to acquire a better understanding of students' endocrine functioning and performance on an exam pre-intervention, and thus adequately assess intervention effectiveness. Students undertook a third exam in mid-November.

The reappraisal*approach goals intervention provided students with a summary of (ostensible) scientific papers detailing how stress responses can fuel performance when undertaking exams and how trying to master the material content or do well compared to others during the exam can boost performance. An example excerpt is: "Approach goals frame exam situations as positive opportunities for success and growth, and two important approach goals are '*Try to master the exam material*' and '*Try to do well compared to others on the exam*'. These goals help channel general excitement and energy from the 'good stress' toward specific positive outcomes to strive to achieve." After reading the information, students were asked to write how they could integrate the information they just read to better prepare specifically for their next exam in the class. The intervention took approximately 10 minutes to complete. The control intervention was developed to appear as similar to the intervention material as possible, including the completion time, the engagement level, and the boosters. It depicted general brain facts unrelated to stress or motivation; a commonly used control condition in the psychological intervention literature (Yeager et al., 2022). Brief (< 1 page) booster content was delivered to students the night before Exam 2 and Exam 3. Time and delivery setting was standardized between the conditions as the intervention materials were completed in the classroom. All study materials are available on our laboratory website: https://socialstresslab.wixsite.com/urochester/research.

2.3. Measures

Exam scores. Students' Exam 1, 2, and 3 scores were obtained from the course instructor. Each exam was scored out of a maximum of 50 points.

Salivary cortisol. Salivary cortisol was measured at baseline (i.e. during a non-exam class period), and immediately after Exam 1 (end-of-September) and Exam 2 (end-of-October) to assess reactivity in cortisol levels. The baseline measure was included because this study was conducted during a major transition for students between high school and college, which has been found to be naturally stressful and, thus, likely to increase the production of cortisol (Drake et al., 2016; Lupien et al., 2013). Samples were collected between 2 pm and 3:15 pm. Participants were given saliva tubes (SaliCaps IBL tubes, REF. RE69995) and provided 2 mL of pure saliva (no cotton swab) in the tube via passive drooling. Saliva samples were stored in biomedical freezers at −20 °C until assay. No samples were taken after Exam 3.

Extraction and measurement procedures were performed in two different laboratories for the two cohorts. For the 2017 cohort, the saliva samples were determined at the laboratory Kirschbaum, Technical University of Dresden, Germany, whereas the samples for the 2018 cohort were determined at the Centre for Studies on Human Stress (CSHS) in Montreal, Canada. Both procedures were done using a high-sensitivity enzyme immune assay kit (SalimetricsÒ, State College, PA, Catalogue No. 1–3102). Frozen samples were thawed to room temperature before being centrifuged at 1500 x g (3000 rpm) for 15 min. This assay detects within a range of 0.012^{-3} µg/dL. For each sample, we averaged the duplicate assay values received. Because different laboratories analyzed the two cohorts' samples, cortisol levels were standardized for each cohort before analysis.

2.4. Statistical approach

Before conducting the main analyses on SPSS 29, we explored potential cohort effects on all measures and demographics (Age, Sex, and Ethnicity) to control for them in the main analyses if necessary. The same approach was taken to compare the intervention and control groups at baseline. We then conducted mixed-model ANOVAs. The first 2 (Condition: Intervention vs. Control) x 3 (Time: Exam 1 vs. Exam 2 vs. Exam 3) model compared students' exam scores. The second 2 (Condition: Intervention vs. Control) x 3 (Time: Baseline vs. Exam 1 vs. Exam 2) model compared students' salivary cortisol levels (no saliva samples were available after Exam 3). No other cofounding variable was accounted for. We used partial eta squared (η_p^2) to estimate effect sizes, where .01, .06, and .13 benchmarks correspond to small, medium, and large effect sizes, respectively (Richardson, 2011).

3. Results

3.1. Descriptive statistics

Table 1 presents correlations, means, and standard deviations for all measures. No significant differences between cohorts emerged in the focal outcomes or demographics (*ps* > .05; see supplemental), except for Exam 3 scores, which were higher in the 2017 vs. 2018 cohort. Consequently, cohort effects were adjusted for in the ANOVA comparing exam scores between conditions. No significant differences between conditions emerged at baseline (*ps* > .05). A Little's MCAR test was performed on salivary cortisol, and a non-significant result ($\chi^2 = 7.63$, $p = .47$) revealed that data were missing completely at random. Approximately 5 % of the cortisol data was missing, and 0 % for exam scores. Considering the low rate of missing data and that they were MCAR, listwise deletion was unlikely to introduce bias in ANOVAs (Enders, 2020).

3.2. Main analyses

As expected, the stress reappraisal*approach goals intervention improved students' performance when adjusting for cohort effects ($F(2607.10) = 10.91$, $p < .001$, $\eta_p^2 = .035$, Fig. 1); the scores of students were similar at Exam 1 pre-intervention ($\Delta = 0.25$, $p = .695$), but students who received the intervention achieved higher scores at Exam 2 ($\Delta = 1.66$, $p = .004$, 95 %CI [−2.78, −0.54]) and Exam 3 than controls ($\Delta = -1.39$, $p = .010$, 95 %CI [−2.44, −0.33]).

The model testing for intervention effects on students' stress response during the exams also yielded a significant interaction term ($F(2546) = 4.33$, $p = .017$, $\eta_p^2 = .016$, Fig. 2). As expected, salivary cortisol levels were similar at baseline ($\Delta = 0.18$, $p = .13$, 95 %CI [−0.54, 0.41]) and at the end of Exam 1 pre-intervention ($\Delta = 0.20$, $p = .10$, 95 %CI [−0.40, 0.44]), but students who received the intervention produced significantly less cortisol at the end of Exam 2 compared to those who received the control intervention ($\Delta = 0.48$, $p < .001$, 95 %CI [−0.71, −0.24]).[1]

3.3. Exploratory analyses

To further explore the effects of the intervention on students' stress responses during the exams, we additionally tested whether stress appraisals were associated with cortisol production in the intervention condition. Using linear regression, we tested whether Exam 2 scores predicted students' salivary cortisol production at the end of the exam. Although an expected negative correlation was found, it did not reach statistical significance ($B = -.23$, $p = .12$, 95 % CI [−0.27, .03]), suggesting that cortisol production was not significantly associated with how well students were doing during the exam.

[1] Although interventions targeting students' appraisals in prior work have shown similar results in both sexes, we still explored for sex effects by conducting additional ANOVAs for the exam scores and salivary cortisol levels in which we added Sex to the interaction term. All of the main results did not significantly vary across sex (*ps* > .05).

Table 1
Means, standard deviations, and correlations of study variables.

Measures	*Mean*	*SD*	Correlations						
			1	2	3	4	5	6	7
1. Sex	0.59	0.49	–						
2. Baseline salivary cortisol	3.65	3.01	.014	–					
3. Exam 1 salivary cortisol (pre)	4.30	3.00	−.04	**.52**	–				
4. Exam 2 salivary cortisol (post)	4.26	3.48	.05	**.50**	**.70**	–			
5. Exam 1 score (pre)	41.18	5.55	.01	.02	−.12	−.05	–		
6. Exam 2 score (post)	41.71	5.05	−.07	.02	−.06	**−.14**	**.72**	–	
7. Exam 3 score (post)	41.57	5.27	−.07	.01	−.08	−.11	**.62**	**.64**	–

Note. Significant (*ps* <.05) correlation coefficients are in bold. Mean and SD are for raw cortisol levels. Salivary cortisol unit is ug/dL. Sex was coded 0 for male and 1 for female.

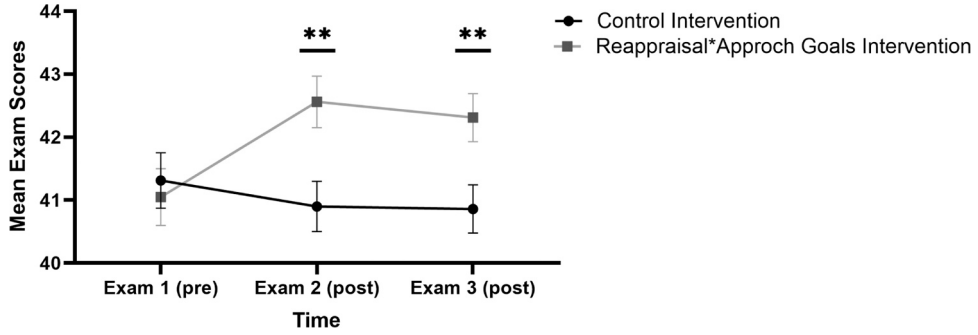


Fig. 1. Exam scores by time and condition adjusting for cohorts effects. Error bars are SDs. ** $p < .01$.

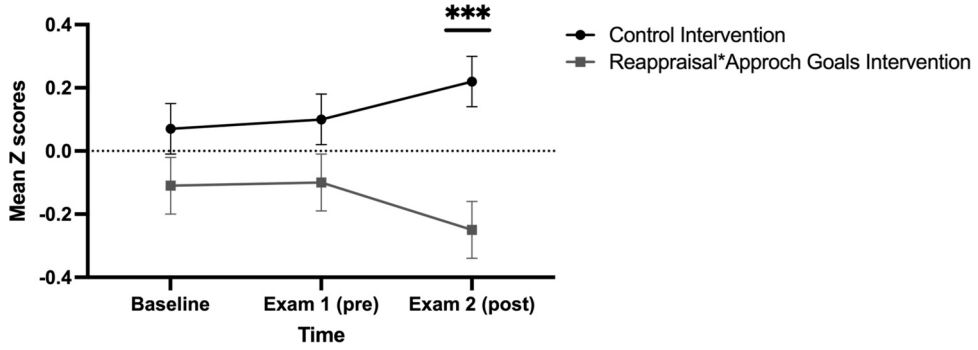


Fig. 2. Salivary cortisol levels (ug/dL) by time and by condition. Error bars are SDs, *** $p < .001$.

Because this study took place in the context of an Introduction to Psychology course for first-year college students, individuals likely entered the class with different levels of prior knowledge, which could have shaped stress appraisals. If students with similar cortisol levels between baseline and Exam 2 (i.e. those who were not experiencing strong stress responses during Exam 2) performed better than those with increased cortisol levels at Exam 2, it could suggest that those students perceived the exam as less threatening. Thus, we first computed a delta variable representing students' salivary cortisol levels at the end of Exam 2 minus baseline, and then binned students into groups based on their salivary cortisol trajectories since baseline (for a similar approach, see Hangen et al., 2016). Students with ≤ -1 SD in cortisol reactivity were classified into the "decrease" group (N = 63). Conversely, those $\geq +1$ SD in cortisol reactivity were classified into the "increase" group (N = 110). Lastly, students who exhibited less than $+/-1$ SD change in cortisol levels from baseline were classified into the "non-responder" group (N = 135). A one-way ANOVA compared students' Exam 2 scores based on their cortisol reactivity groups. Results showed that students in the non-responder group performed better than those in the "increased" group (F (2305) = 6.05, $p = .003$, 95 %CI [.13, .74], $\eta_p^2 = .04$, Fig. 3). This could suggest that students whose salivary cortisol changes were

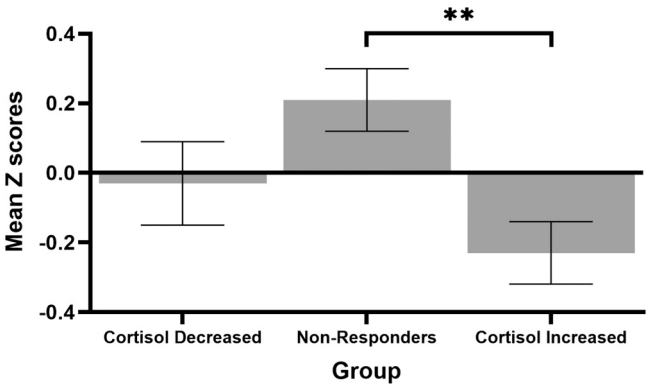


Fig. 3. Exam scores as a function of students' change in cortisol salivary levels between baseline and Exam 2. Error bars are SDs, ** $p < .01$.

comparatively minimal between baseline and Exam 2 were less threatened. It is possible that these students' knowledge base or exam preparation rendered the evaluative exam non-stressful and did not even

require the marshaling of stress resources to succeed.

4. Discussion and conclusion

The promising results from our study align with previous work, suggesting that integrating multiple psychological frameworks within stress interventions can benefit students (Bosshard and Gomez, 2024; Crum et al., 2020; Yeager et al., 2016; 2022). Manipulating stress appraisals and achievement goals in an integrated intervention improved students' performance and reduced their production of cortisol during the exam, although the effects were small. The findings from this study suggest that adopting approach-based goals may direct students' arousal and orientation going into exams away from avoiding performing poorly and toward seeking to perform well, which aligns well with the messaging that stress responses can be functional "fuel" for performance in stress reappraisal approaches (Crum et al., 2013; Jamieson et al., 2012; Yeager et al., 2022).

It remains unclear, however, whether students' performance was enhanced because they exhibited greater challenge states, in particular. First, this study only analyzed salivary cortisol. While larger increases in cortisol when facing a stressor indicate threat appraisals (Jamieson et al., 2018), cortisol alone cannot confirm that threat was attenuated (and by proxy challenge promoted). More nuanced understandings of challenge and threat stress responses during pressurized exams are possible through recording autonomic physiology (e.g., cardiac output and total peripheral resistance) in combination with endocrine measures. As wearable technology improves with possibilities for recording impedance cardiography in naturalistic settings, future studies could more precisely integrate different levels of physiological measurement to better understand stress in academic settings. Alternatively, it is not possible to establish whether enhancements in performance could also be explained by a reduction in cortisol levels that is unrelated to a shift in stress appraisals caused by the intervention. The results of exploratory analyses indeed suggested that students whose salivary cortisol changes were comparatively minimal between baseline and Exam 2 were less threatened. It is possible that these students' knowledge base or exam preparation rendered the evaluative exam less stressful and did not even require the marshaling of stress resources to succeed.

Moreover, conclusions regarding the process through which the intervention produced effects on cortisol should be understood in the context of the design. In this study, cortisol was assessed via one saliva sample when finishing the exam. Thus, this is not as "pure" of an indicator of challenge and threat responses compared to sampling cortisol immediately prior to exams (e.g., Jamieson et al., 2022). There is great heterogeneity in acute stress reactivity between individuals, where cortisol peaks are expected from ~15–20 min (Jamieson and Mendes, 2016; Juster et al., 2012) to 38 min (Goodman, 2017) after the onset of a stressor. As the exams lasted upwards of 70 min, some of the reactivity observed in our measure could be tied to students' perception of performing well/poorly during the exams rather than pure acute responses to the stressor. Additional samples of cortisol levels when entering the exam are needed for a more robust assessment of the pattern of reactivity during the exam and how it is impacted by the intervention. Importantly, anabolic hormones (e.g., testosterone, DHEA), which counteract the catabolic effects of cortisol, would be valuable to assess to clarify the mechanisms of the intervention on cortisol levels.

The achievement goal approach is a highly generative and robust approach to achievement motivation, but there has been surprisingly little intervention work conducted from this perspective (for reviews, see Chazan et al., 2022; Elliot and Hulleman, 2017). In addition, most of the work that has been conducted has focused on promoting the establishment of approach-based classrooms, not on encouraging individuals to adopt approach-based goals per se. Ideally, the promising results yielded herein will serve as an impetus for more individually-focused empirical work on achievement goal interventions. With regard to the present results, it is important to note that our design did not allow a test of achievement goals independent of reappraisal, of mastery-approach and performance-approach goals separately, nor of avoidance-based goals. Follow-up work would do well to address these more granular questions, as well as delve more deeply into the reasons why the integrated intervention is effective. One intriguing possibility is that there is a perceived fit between the appetitive appraisal and appetitive goals that "feels right" (Higgins, 2000) and thus promotes positive engagement, effort, and persistence.

This research demonstrates that a novel stress reappraisal*achievement goal intervention can lead to small improvements in real-world classroom performance and slightly attenuate cortisol production during exams. A unique feature of this study is the specificity level of both intervention components. Indeed, this intervention is shaped to manipulate students' cognitions at a specific level (i.e., the specific appraisals and achievement goals they could have about their upcoming exam in the Introduction to Psychology class). In contrast, previous work targeted broader or more general cognitions related to stress and motivation, such as general attributions at school and the idea that stress can be enhancing or debilitating (i.e., stress mindsets). The intervention is, therefore, a novel and interesting tool for future examination since it is brief, easy to implement, and psychologically precise (Walton and Wilson, 2018). However, the fact that the Introduction to Psychology class that was the focus of this research was designed in accordance with Self-Determination Theory principles could be considered a classroom-level manipulation that all students received, and this may have weakened the effects of our individual-level intervention (Wang et al., 2024). One could hypothesize that the effects may be greater in a more standard class not initially designed to improve students' motivation, as there would be more room for stress reappraisal and a shift from avoidance- to approach-based achievement goals. On the other hand, one could argue that an autonomy supportive classroom environment lays the groundwork for other appetitive encouragements to take root and have their impact (Walton and Yeager, 2020). Future research is needed to better examine how contextual affordances influence the effectiveness of individual-level wise interventions, a dynamic described by the concept of "seed and soil effects". For instance, testing the intervention used in this study in a regular introduction to psychology class vs an SDT-oriented class could help explain the heterogeneity observed in students' outcomes. In addition, while research from intervention science has demonstrated that appraisal-based synergistic interventions provide added, emergent value compared to their unique contribution (Yeager et al., 2022), future research is needed to test and compare the effects of each component of our intervention. Finally, it is important to acknowledge that alternative theoretical frameworks to the BPS model of challenge and threat are relevant to investigate the link between academic stress and neuroendocrine functioning (e.g., Špiljak et al., 2022).

This field-based experimental study represents a theoretical innovation by integrating the stress reappraisal and achievement goal approaches to help improve students' academic outcomes in stressful situations during their first semester of college. Our findings suggest that promoting approach-based achievement goals can support stress reappraisal in improving students' hormonal stress responses and performance during exams. As such, the stress reappraisal*approach goals intervention provides both the fuel and focus that students need to perform better in the classroom.

CRediT authorship contribution statement

Audrey-Ann Journault: Writing – review & editing, Writing – original draft, Visualization, Validation, Formal analysis. **Marisa E. Marotta:** Writing – review & editing, Project administration, Investigation, Conceptualization, Methodology. **Emily J. Hangen:** Writing – review & editing, Writing – original draft, Investigation. **Hannah Gravelding:** Writing – review & editing, Project administration, Methodology. **Andrew J. Elliot:** Writing – review & editing, Writing –

original draft, Validation, Supervision, Resources, Methodology, Investigation, Conceptualization. **Jeremy P. Jamieson:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization.

Funding

This research was supported by Google, Inc. (Research Grant: Understanding in vivo Responses to Daily Stressors & Optimizing Stress to Facilitate Coping) and the U.S. Department of Education, Institute of Education Sciences (IES) [Research grant #R305A150036).

Declaration of Competing Interest

None.

Acknowledgements

The authors are grateful to Professor Chris Niemiec for providing access to his classes and for cooperating with assessing exam scores, as well as to the many great research assistants from the Social Stress Lab at the University of Rochester.

References

Behnke, M., Kaczmarek, L.D., 2018. Successful performance and cardiovascular markers of challenge and threat: a meta-analysis. Int. J. Psychophysiol. 130, 73–79. https://doi.org/10.1016/j.ijpsycho.2018.04.007.

Blascovich, J., Mendes, W.B., 2010. Social psychophysiology and embodiment. In: Handbook of Social Psychology, 1. John Wiley & Sons Inc, pp. 194–227.

Bosshard, M., Gomez, P., 2024. Effectiveness of stress arousal reappraisal and stress-is-enhancing mindset interventions on task performance outcomes: A meta-analysis of randomized controlled trials. Sci. Rep. 14 (1), 7923. https://doi.org/10.1038/s41598-024-58408-w.

Chazan, D.J., Pelletier, G.N., Daniels, L.M., 2022. Achievement goal theory review: an application to school psychology. Can. J. Sch. Psychol. 37 (1), 40–56. https://doi.org/10.1177/08295735211058319.

Crum, A.J., Akinola, M., Martin, A., Fath, S., 2017. The role of stress mindset in shaping cognitive, emotional, and physiological responses to challenging and threatening stress. Anxiety Stress Coping 30 (4), 379–395. https://doi.org/10.1080/10615806.2016.1275585.

Crum, A.J., Jamieson, J.P., Akinola, M., 2020. Optimizing stress: an integrated intervention for regulating stress responses. Emotion 20 (1), 120. https://doi.org/10.1037/emo0000670.

Crum, A.J., Salovey, P., Achor, S., 2013. Rethinking stress: the role of mindsets in determining the stress response. J. Personal. Soc. Psychol. 104 (4), 716. https://doi.org/10.1037/a0031201.

Drake, E.C., Sladek, M.R., Doane, L.D., 2016. Daily cortisol activity, loneliness, and coping efficacy in late adolescence: a longitudinal study of the transition to college. Int. J. Behav. Dev. 40 (4), 334–345. https://doi.org/10.1177/0165025415581914.

Elliot, A.J., 2006. The Hierarchical Model of Approach-Avoidance Motivation. Motivation and Emotion 30 (2), 111–116. https://doi.org/10.1007/s11031-006-9028-7.

Elliot, A.J., Church, M.A., 1997. A hierarchical model of approach and avoidance achievement motivation. Ournal Personal. Soc. Psychol. 72 (1), 218–232. https://doi.org/10.1037/0022-3514.72.1.218.

Elliot, A.J., Hulleman, C.S., 2017. Achievement goals. in handbook of competence and motivation. Theory and Application, Second Edition. Guilford Publications.

Elliot, A.J., McGregor, H.A., 2001. A 2 × 2 achievement goal framework. J. Personal. Soc. Psychol. 80 (3), 501–519. https://doi.org/10.1037/0022-3514.80.3.501.

Elliot, A.J., McGregor, H.A., Gable, S., 1999. Achievement goals, study strategies, and exam performance: a mediational analysis. J. Educ. Psychol. 91 (3), 549–563. https://doi.org/10.1037/0022-0663.91.3.549.

Enders, C.K., 2020. Applied Missing Data Analysis, Second Edition. The Guilford Press.

Epel, E.S., Crosswell, A.D., Mayer, S.E., Prather, A.A., Slavich, G.M., Puterman, E., Mendes, W.B., 2018. More than a feeling: a unified view of stress measurement for population science. Front. Neuroendocrinol. 49, 146–169. https://doi.org/10.1016/j.yfrne.2018.03.001.

Goodman, W.K. (2017). Meta-Analytical Assessment of the Effects of Protocol Variations on Cortisol Responses to the Trier Social Stress Test.

Gurera, J.W., Isaacowitz, D.M., 2022. Arousal reappraisal in younger and older adults. Psychol. Aging 37 (3), 350–356. https://doi.org/10.1037/pag0000674.

Hangen, E.J., Elliot, A.J., Jamieson, J.P., 2016. The opposing processes model of competition: Elucidating the effects of competition on risk-taking. Motivation. Science 2 (3), 157–170. https://doi.org/10.1037/mot0000038.

Hase, A., Moore, L.J., O'Brien, J., & Freeman, P. (2018). The Relationship Between Challenge and Threat States and Performance: A Systematic Review.

Hase, A., Nietschke, M., Kłoskowski, M., Szymański, K., Moore, L., Jamieson, J., Behnke, M., 2024. The effects of challenge and threat states on performance outcomes: an updated review and meta-analysis of recent findings. EXCLI J. https://doi.org/10.17179/excli2024-7995.

Higgins, E.T., 2000. Making a good decision: value from fit. Am. Psychol. 55 (11), 1217–1230. https://doi.org/10.1037/0003-066X.55.11.1217.

Högberg, B., 2021. Educational stressors and secular trends in school stress and mental health problems in adolescents. Soc. Sci. Med. 270, 113616. https://doi.org/10.1016/j.socscimed.2020.113616.

Huang, C., 2012. Discriminant and criterion-related validity of achievement goals in predicting academic achievement: a meta-analysis. J. Educ. Psychol. 104 (1), 48–73. https://doi.org/10.1037/a0026223.

Jamieson, J.P., 2017. Challenge and threat appraisals. In Handbook of competence and motivation: Theory and application, Second ed. The Guilford Press, pp. 175–191.

Jamieson, J.P., Black, A.E., Pelaia, L.E., Gravelding, H., Gordils, J., Reis, H.T., 2022. Reappraising stress arousal improves affective, neuroendocrine, and academic performance outcomes in community college classrooms. J. Exp. Psychol. Gen. 151 (1), 197–212. https://doi.org/10.1037/xge0000893.

Jamieson, J.P., Hangen, E.J., Lee, H.Y., Yeager, D.S., 2018. Capitalizing on appraisal processes to improve affective responses to social stress. Emot. Rev. J. Int. Soc. Res. Emot. 10 (1), 30–39. ⟨https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6550483/⟩.

Jamieson, J.P., Mendes, W.B., Nock, M.K., 2013. Improving acute stress responses: the power of reappraisal. Curr. Dir. Psychol. Sci. 22 (1), 51–56. https://doi.org/10.1177/0963721412461500.

Jamieson, J.P., Mendes, W.B., 2016. Social stress facilitates risk in youths. J. Exp. Psychol. Gen. 145 (4), 467–485. https://doi.org/10.1037/xge0000147.

Jamieson, J.P., Nock, M.K., Mendes, W.B., 2012. Mind over matter: reappraising arousal improves cardiovascular and cognitive responses to stress. J. Exp. Psychol. Gen. 141 (3), 417–422. https://doi.org/10.1037/a0025719.

Jamieson, J.P., Peters, B.J., Greenwood, E.J., Altose, A.J., 2016. Reappraising stress arousal improves performance and reduces evaluation anxiety in classroom exam situations. Soc. Psychol. Personal. Sci. 7 (6), 579–587. https://doi.org/10.1177/1948550616644656.

Jentsch, V.L., Wolf, O.T., 2020. The impact of emotion regulation on cardiovascular, neuroendocrine and psychological stress responses. Biol. Psychol. 154, 107893. https://doi.org/10.1016/j.biopsycho.2020.107893.

Juster, R.-P., Perna, A., Marin, M.-F., Sindi, S., Lupien, S.J., 2012. Timing is everything: Anticipatory stress dynamics among cortisol and blood pressure reactivity and recovery in healthy adults. Stress 15 (6), 569–577. https://doi.org/10.3109/10253890.2012.661494.

Koudela-Hamila, S., Smyth, J., Santangelo, P., Ebner-Priemer, U., 2022. Examination stress in academic students: A multimodal, real-time, real-life investigation of reported stress, social contact, blood pressure, and cortisol. J. Am. Coll. Health 70 (4), 1047–1058. https://doi.org/10.1080/07448481.2020.1784906.

Lazarus, R.S., Folkman, S., 1984. Stress, Appraisal, and Coping. Springer Publishing Company.

Liem, G.A.D., Elliot, A.J., 2018. Sociocultural influences on achievement goal adoption and regulation: a goal complex perspective. In: Liem, G., McInerney, D. (Eds.), Research on Sociocultural Influences on Learning and Motivation—Big Theories Revisited, 12. Information Age Publishing, pp. 41–67.

Lupien, S.J., Ouellet-Morin, I., Trépanier, L., Juster, R.P., Marin, M.F., Francois, N., Sindi, S., Wan, N., Findlay, H., Durand, N., Cooper, L., Schramek, T., Andrews, J., Corbo, V., Dedovic, K., Lai, B., Plusquellec, P., 2013. The DeStress for Success Program: Effects of a stress education program on cortisol levels and depressive symptomatology in adolescents making the transition to high school. Neuroscience 249, 74–87. https://doi.org/10.1016/j.neuroscience.2013.01.057.

McCrindle. (2021). MyStrengths 2021 Youth Wellbeing Report. ⟨https://mystrengths-parenting.mykajabi.com/mccrindle-report-opt-in⟩.

Merz, C.J., Wolf, O.T., 2015. Examination of cortisol and state anxiety at an academic setting with and without oral presentation. Stress 18 (1), 138–142. https://doi.org/10.3109/10253890.2014.989206.

Oveis, C., Gu, Y., Ocampo, J.M., Hangen, E.J., Jamieson, J.P., 2020. Emotion regulation contagion: stress reappraisal promotes challenge responses in teammates. J. Exp. Psychol. Gen. 149 (11), 2187–2205. https://doi.org/10.1037/xge0000757.

Pintrich, P.R., 2000. The role of goal orientation in self-regulated learning. Handbook of self-regulation. Academic Press, pp. 451–502. https://doi.org/10.1016/B978-012109890-2/50043-3.

Pulopulos, M.M., 2020. Cortisol response to stress_ the role of expectancy and anticipatory stress regulation. Horm. Behav. 10.

Richardson, J.T.E., 2011. Eta squared and partial eta squared as measures of effect size in educational research. Educ. Res. Rev. 6 (2), 135–147. https://doi.org/10.1016/j.edurev.2010.12.001.

Ryan, R.M., Deci, E.L., 2020. Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. Contemp. Educ. Psychol. 61, 101860. https://doi.org/10.1016/j.cedpsych.2020.101860.

Sammy, N., Anstiss, P.A., Moore, L.J., Freeman, P., Wilson, M.R., Vine, S.J., 2017. The effects of arousal reappraisal on stress responses, performance and attention. Anxiety Stress Coping 30 (6), 619–629. https://doi.org/10.1080/10615806.2017.1330952.

Senko, C., Tropiano, K.L., 2016. Comparing three models of achievement goals: goal orientations, goal standards, and goal complexes. J. Educ. Psychol. 108 (8), 1178–1192. https://doi.org/10.1037/edu0000114.

Singh, K.K., Journault, A.-A. (in preparation). The Impact of Stress Reappraisal and Mindset Interventions on Physiological and Endocrine Stress Outcomes: A Meta-Analysis.

Špiljak, B., Vilibić, M., Glavina, A., Crnković, M., Šešerko, A., Lugović-Mihić, L., 2022. A review of psychological stress among students and its assessment using salivary biomarkers. Behav. Sci. 12 (10), 400. https://doi.org/10.3390/bs12100400.

Walton, G.M., Wilson, T.D., 2018. Wise interventions: psychological remedies for social and personal problems. Psychol. Rev. 125 (5), 617–655. https://doi.org/10.1037/rev0000115.

Walton, G.M., Yeager, D.S., 2020. Seed and soil: psychological affordances in contexts help to explain where wise interventions succeed or fail. Curr. Dir. Psychol. Sci. 29 (3), 219–226. https://doi.org/10.1177/0963721420904453.

Wang, Y., Wang, H., Wang, S., Wind, S.A., Gill, C., 2024. A systematic review and meta-analysis of self-determination-theory-based interventions in the education context. Learn. Motiv. 87, 102015. https://doi.org/10.1016/j.lmot.2024.102015.

Yeager, D.S., Bryan, C.J., Gross, J.J., Murray, J.S., Krettek Cobb, D., Santos, H.F., Gravelding, P., Johnson, H., M, Jamieson, J.P., 2022. A synergistic mindsets intervention protects adolescents from stress. Nature. https://doi.org/10.1038/s41586-022-04907-7.

Yeager, D.S., Lee, H.Y., Jamieson, J.P., 2016. How to improve adolescent stress responses: insights from integrating implicit theories of personality and biopsychosocial models. Psychol. Sci. 27 (8), 1078–1091. https://doi.org/10.1177/0956797616649604.

Yperen, N.W.V., Blaga, M., Postmes, T., 2014. A meta-analysis of self-reported achievement goals and nonself-report performance across three achievement domains (work, sports, and education). PLOS ONE 9 (4), e93594. https://doi.org/10.1371/journal.pone.0093594.