

**The Role of Stress Mindset in Shaping Cognitive, Emotional, and
Physiological Responses to Challenging and Threatening Stress**

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Abstract

Background and Objectives: Prior research suggests that altering situation-specific evaluations of stress as challenging versus threatening can improve responses to stress. The aim of the current study was to explore whether cognitive, physiological and affective stress responses can be altered independent of situation-specific evaluations by changing individuals' mindsets about the nature of stress in general. **Design:** Using a 2 x 2 design, we experimentally manipulated stress mindset using multi-media film clips orienting participants to either the enhancing or debilitating nature of stress. We also manipulated challenge and threat evaluations by providing positive or negative feedback to participants during a Trier Social Stress Task. **Results:** Results revealed that under both threat and challenge stress evaluations, a stress-is-enhancing mindset produced sharper increases in anabolic ("growth") hormones relative to a stress-is-debilitating mindset. Furthermore, when the stress was evaluated as a challenge, a stress-is-enhancing mindset produced sharper increases in positive affect, heightened attentional bias towards positive stimuli, and greater cognitive flexibility whereas a stress-is-debilitating mindset produced worse cognitive and affective outcomes. **Conclusions:** These findings advance stress management theory and practice by demonstrating that a short manipulation designed to generate a stress-is-enhancing mindset can improve responses to both challenging and threatening stress.

Keywords: Stress, mindset, appraisal, affect, cognitive performance, neuroendocrinology

Pioneering studies by Lazarus and Folkman (1984) highlighted the importance of cognitive appraisal in determining the stress response. This research proposed that individuals first appraise the degree to which the situation is demanding (primary appraisal) and then appraise whether or not they have adequate resources to cope with the situation (secondary appraisal). More recently, researchers have elaborated on these stages and highlighted that the stress response is determined by the balance of perceived resources (e.g., knowledge, skills) and perceived demands (e.g., danger, uncertainty) and have identified physiological concomitants of these challenge and threat evaluations (Blascovich, Mendes, Tomaka, Salomon, & Seery, 2003; Gaab, Rohleder, Nater, & Ehlert, 2005; Seery, 2011; Tomaka, Blascovich, Kelsey, & Leitten, 1993; Tomaka, Blascovich, Kibler, & Ernst, 1997; Wirtz, von Kamel, Emini, Suter, Fontana, & Ehlert, 2007). Simply put, a situation is deemed *threatening* when the individual evaluates the environmental demands to outweigh their resources or ability to cope. Physiologically, threat evaluations are associated with lower cardiovascular efficiency, heightened hormonal responses, negative affect, and poorer cognitive performance (Kassam, Koslov, & Mendes, 2009; Blascovich & Mendes, 2010; Mendes, Blascovich, Hunter, Lickel, & Jost, 2007). A situation is considered *challenging* when the individual perceives that they have sufficient resources to meet the environmental demands. Challenge evaluations are typically associated with increased cardiac efficiency and hormonal responses related to thriving and growth, preparing the body for action and signaling approach motivation as well as increases in cognitive performance (Mendes, Blascovich, Hunter, Lickel, & Jost, 2007; Kassam, Koslov, & Mendes, 2009; Blascovich & Mendes, 2010).

While the distinction between “threat” and “challenge” evaluations is important, there are a few critical limitations to practically applying threat and challenge theory to improve stress

responses. First, given that the components of demands include danger and uncertainty, there are times in which it may be impossible to reduce the demands of a situation; for example, students facing an unpredictable stressor such as a pop-quiz in a difficult class. Second, since the elements of resources include knowledge and abilities, there are instances where trying to increase resources may be futile, particularly in the short-term; for instance, cramming in new material two minutes before a pop-quiz. Finally, trying to remove the experience of threat by reducing demands and increasing resources does not capitalize on the possibility that the *imbalance itself* can promote psychological and physiological growth.

In light of these limitations, two important questions arise: is it possible to acknowledge a stressor as a “threat,” yet still garner adaptive physiological and behavioral outcomes? Conversely, might it be possible to appraise a stressor as a “challenge,” but nevertheless experience maladaptive physiological and behavioral outcomes? In the current paper, we address these questions by examining the role one’s mindset about stress plays in challenge and threat contexts. Specifically, we examine whether the extent to which one holds an adaptive mindset about stress (e.g., that stress-is-enhancing) or a maladaptive mindset about stress (e.g., that stress-is-debilitating) will dictate one’s physiological, cognitive, and emotional responses in the context of challenge and threat evaluations.

Stress Mindset Theory

Stress mindset is conceptualized as the extent to which an individual holds the mindset that stress has enhancing consequences for various stress-related outcomes (referred to as a “stress-is-enhancing mindset”) or holds the mindset that stress has debilitating consequences for outcomes such as performance and productivity, health and wellbeing, and learning and growth (referred to as a “stress-is-debilitating mindset”) (Crum, Salovey, & Achor, 2013). There is

growing evidence that mindset not only affects outcomes in domains of intelligence (Dweck, 2008) and aging (Levy & Myers, 2004), but also shapes the stress response. Preliminary studies measuring stress mindset suggest that stress mindset is related to perceived health and life satisfaction over and above aggregate measures of amounts of stress, appraisals of stress, and various coping strategies (Crum, Salovey, & Achor, 2013). Additionally, individuals who have a stress-is-enhancing mindset exhibit more adaptive physiological responses and more approach-oriented behavioral responses in the face of stress (Crum, Salovey, & Achor, 2013). Specifically, participants who rated themselves as having a stress-is-enhancing mindset experienced moderate cortisol reactivity and were more receptive to feedback than those with a stress-is-debilitating mindset when exposed to an acutely stressful situation. Stress mindset can also be altered via intervention to produce corresponding changes in self-reported health and work performance (Crum, Salovey, & Achor, 2013). In line with evidence that suggests mindsets can be changed quite readily by simply orienting people to different information (c.f. Blackwell, Trzesniewski, & Crum et al., 2013; Dweck, 2007; Panesku et al., 2015; Tamir et al., 2007; Walton, 2014), mindsets about stress can be changed by having individuals watch a series of three, 3-minute videos orienting them to either the enhancing or debilitating effects of stress (Crum, Salovey, & Achor, 2013). Further, prior research has demonstrated that video interventions can influence performance and well-being; participants exposed to stress-is-enhancing videos not only developed a stress-is-enhancing mindset, but also reported better work performance and improved health conditions (Crum, Salovey, & Achor, 2013). These strong effects of stress mindset video interventions are consistent with research more broadly highlighting the enduring effects of interventions using short articles or videos to alter mindset in other domains including

intelligence (Blackwell, Trzesniewski, & Dweck, 2007), belongingness (Walton, 2011), aging (Levy, 2009) and emotion regulation (Tamir et al., 2007).

Taken together, the emerging body of research on mindsets suggests that one way to meaningfully influence the stress response is to change an individual's mindset about stress. The concept that stress mindset is not situation-specific and can influence the stress response regardless of challenge and threat evaluations has been argued conceptually and through structural equation modeling (see Crum, Salovey, & Achor, 2013). However, this premise has not been experimentally tested, leaving open the question of exactly how experiences of stress may differ in the context of both challenge and threat evaluations, depending on one's stress mindset.

Distinguishing between Stress Mindset and Threat versus Challenge Theories

One critical distinction between stress mindset theory and theories surrounding challenge and threat evaluations is that stress mindset does not focus on the *amount* of stress one is experiencing or the manner in which one *appraises and copes* with stress. Rather, stress mindset focuses on *the nature of stress itself* (i.e., whether stress is enhancing or debilitating). Stress mindset is distinct from stress evaluations in that it is a meta-cognitive belief about the nature of stress in general, and exists regardless of how an individual assesses demands and resources at any particular moment (Crum, Salovey, & Achor, 2013). For example, one may view a stressor (e.g., job interview) as threatening, but have a stress-is-enhancing mindset, expecting the experience of stress to result in positive outcomes (e.g., motivation to practice interviewing skills, staying cognitively focused, and ultimately improving self-esteem). Conversely, one might view the job interview as a challenge but have a stress-is-debilitating mindset, expecting the experience of stress to result in negative outcomes (e.g., energy depletion, cognitive deficits,

and reduced self-esteem). In addition, mindset differs from evaluations of challenge or threat in its temporal focus: threat or challenge evaluations are an immediate assessment of one's resources to cope with the demands of the stressor while mindset assesses the long-term influence of the stressor in light of one's belief about the nature of stress.

Understanding how stress mindset operates in challenging and threatening contexts provides critical insights into *if* and *how* individuals can improve their responses to stress without relying on changing the demands of a situation (which may be difficult or impossible), or improving their immediate resources (which can be infeasible or taxing). Further, the majority of interventions intended to engender adaptive stress responses rely on altering situation-specific stress evaluations. By showing that the stress response can be altered independent of situation-specific evaluations by changing individuals' general beliefs, we advance existing literature and lay the foundation for an integrated theory that can apply to any type of stressful situation. Practically, understanding how stress mindset operates in the context of threat and challenge evaluations will offer more specific coping strategies, and more flexible options that can aid individuals in improving their stress responses in varied contexts.

Overview of the Current Research

In the current study, we experimentally manipulated stress-is-enhancing and stress-is-debilitating mindsets and then exposed participants to a laboratory social stressor (Trier Social Stress Task; [TSST] Kirschbaum, Pirke, & Hellhammer, 1993) designed to engender threat or challenge stress evaluations. Following the stress manipulation, we assessed participants' mood, cognitive flexibility, and attentional bias, all metrics found to be influenced by stress (Alexander et al., 2007; Bolger et al., 1989; Het & Wolf, 2007; Mogg et al., 1990; Plessow, Fischer, Kirschbaum, & Goschke, 2011). We also measured the catabolic hormone, cortisol, and its

anabolic counterpart, dehydroepiandrosterone-sulfate (DHEAS) to test the degree to which stress-is-enhancing and stress-is-debilitating mindsets differentially promote physiological thriving when evaluating a situation as challenging or threatening (Dienstbier, 1989; Epel, McEwen, & Ickovicks, 1998). We hypothesized that those evaluating the stressor as a threat (engendered through negative feedback during the TSST) would exhibit maladaptive emotional, cognitive, and neuroendocrine responses to stress relative to those evaluating the stressor as a challenge (engendered through positive feedback during the TSST). Specifically, we predicted that threat evaluations would be associated with greater negative emotion, diminished cognitive flexibility, heightened focus on threatening faces, and greater cortisol secretion relative to challenge evaluations. Further, we predicted an interaction between mindset and challenge and threat conditions, such that under threat, having a stress-is-enhancing mindset would be associated with more adaptive emotional, cognitive, and neuroendocrine responses than having a stress-is-debilitating mindset. Conversely, under challenge, we predicted that having a stress-is-debilitating mindset might dampen or even inhibit the cognitive, physiological, or psychological benefits of challenge evaluations.

Method

Participants

We recruited 124 (40.2% White, 32% Asian, 15.3% Black, 9.8% Indian, and 2.5% other) participants (65.6% female; $M_{\text{age}} = 24.1$ years; $SD = 5.1$) from a university study pool.

Participants received \$20 for their participation. A power analysis based on the average effect size ($d = .66$) found in previous stress reappraisal manipulations (e.g., Jamieson et al., 2010; 2012; Tomaka et al., 1993) led to a targeted sample of 30 participants per condition.

Procedure

Participants were scheduled to participate for 90 minutes during afternoon hours (between 2:30pm and 5pm). Participants were instructed to refrain from drinking caffeine or eating yogurt for a minimum of two hours prior to their scheduled time and from engaging in strenuous exercise, drinking alcohol, smoking or taking non-prescription medication immediately before their appointment. During the consent process, the experimenter asked participants if they had complied with these instructions, and collected information on the number of hours participants slept the night prior, if they felt sick, and for females, the date of their last menstrual cycle. Following informed consent procedures, participants completed questionnaires assessing their mood and stress mindset and provided the first saliva sample. Stress mindset was then induced by randomly assigning participants to watch a 3-minute video that either emphasized the enhancing properties of stress (stress-is-enhancing condition) or the deleterious properties of stress (stress-is-debilitating condition). The videos were comprised of words, music, and corresponding images related to the effects of stress on cognitive performance (Crum et al., 2013)¹. Following the videos, participants again completed the stress mindset measure.

Participants then engaged in a modified version of the TSST, which was described as a “mock job interview.” During the interview, participants were instructed to give an 8-minute speech, followed by a 5-minute question and answer period in which they discussed their dream job and described their strengths and weaknesses in front of two interviewers (one white male and one white female) (Akinola & Mendes, 2008). We selected a public speaking/verbal task rather than a math/cognitive task as we wanted to create a motivated performance situation that would allow participants to receive explicit positive and negative verbal feedback on their

¹ The videos used in this study are available upon request from the first author.

performance and consistent with evidence that both public speaking/verbal interaction tasks and math/cognitive tasks can result in heightened HPA activation (Dickerson & Kemeny, 2004).

On the basis of previous research, we manipulated challenge and threat evaluations by randomly assigning participants to receive either positive or negative feedback during the interview (Akinola & Mendes, 2008; Kassam, Koslov, & Mendes, 2009). Approximately 30 seconds into the interview, participants assigned to the positive feedback condition received positive verbal and nonverbal feedback from the interviewers who nodded, smiled, leaned forward, and gave explicit positive feedback (e.g., “You are very clear and manage to put your personality across. You are very self-assured and authentic, really great job”). In the negative feedback condition, interviewers expressed negative nonverbal feedback by furrowing their brows, shaking their heads, and crossing their arms throughout the interview. They also gave explicit negative feedback (e.g., “I felt that you could be much clearer and more articulate. Think about what you are saying before you say it”). The entire interview task, including prep time, speech, and Q & A lasted approximately 20 minutes.

Immediately following the interview, participants completed demand and resource evaluations and reported their emotions. They then provided a second saliva sample (timed approximately 30 minutes after the onset of the TSST) after which they engaged in two² cognitive performance tasks assessing attentional bias (timed approximately 40 minutes after the onset of the TSST) and cognitive flexibility (timed approximately 45 minutes after the onset of the TSST). Finally, participants provided a third and final saliva sample (timed approximately 60 minutes after the onset of the TSST). At the end of the study, participants were debriefed, paid, and thanked.

² Participants also completed a third cognitive interference task, however we do not report on this measure as it not the theoretical focus of the current research.

Measures

Stress Mindset. Stress mindset was assessed prior to and following the video manipulation using the Stress Mindset Measure (SMM; Crum, Salovey, & Achor, 2013). Participants rated how strongly they agreed with eight statements (e.g., the effects of stress are positive and should be utilized, the effects of stress are negative and should be avoided) on a 0 (*strongly disagree*) to 4 (*strongly agree*) scale with numbers equal to or above two reflecting a stress-is-enhancing mindset ($\alpha_{\text{baseline}} = .85$, $\alpha_{\text{post-video}} = .94$).

Threat vs. Challenge Evaluations. After the speech task, participants evaluated the demands of the situation (e.g., the task was very demanding) and their resources (e.g., I had the abilities to perform well on the task) on a 1 (strongly disagree) to 7 (strongly agree) scale (Akinola & Mendes, 2013). Demand ($\alpha = .80$) and resource ($\alpha = .75$) evaluations were averaged separately and a “threat ratio” (demands/resources) was created. In line with previous research (Akinola & Mendes, 2008; Kassam, Koslov, & Mendes, 2009), ratios above 1 indicated threat evaluations and below 1 indicated challenge evaluations.

Positive and Negative Affect. We assessed self-reported emotions at five time-points: upon arrival (baseline), after watching the stress mindset videos, after receiving speech task instructions, after the speech task (during the TSST), and after the question and answer component of TSST, using the Positive and Negative Affect Schedule (Watson, Clark, & Tellegen, 1988). Participants rated their feelings on 20 emotional states (10 positive; 10 negative) on a 1 (not at all) to 5 (a great deal) scale. Positive (α s range from .89 to .92) and negative (α s range from .80 to .85) emotion scales were calculated. Because we were primarily interested in examining changes in positive affect and negative affect in anticipation of and during the TSST, we focused our analyses the three key time-points: (1) baseline, (2) pre-speech,

and (3) post-speech. For ease of interpretation, report results from only these three time-periods, however, analyses using all five times periods followed similar linear and quadratic trends.

Attentional Bias. To assess visual attention to positive and negative stimuli, participants engaged in a computerized dot-probe task (Macleod et al., 1986). Black and white pictures of white male faces identical to those used in Bradley, Mogg, Falla, and Hamilton (1998) served as stimuli. The emotions displayed in the pictures varied such that there were 16 angry faces, 16 happy faces, and eight neutral faces. Each trial began with a fixation cross in the middle of the screen for 500ms, followed by 200ms of blank screen. Stimulus pairs were then presented, consisting of angry/neutral, happy/neutral, or neutral/neutral face pairings, displayed horizontally, side by side on the screen. Face pairs were presented for 1500ms after which one of the pictures was replaced by the visual probe (a small dot). Participants were instructed to press one of two keys indicating the side, right or left, of the probe's appearance. Reaction time to the probe was used to assess participants' attentional bias. Facial expression of the stimuli (happy, angry, or neutral) and dot position (right or left of fixation) were randomized across all 80 trials presented and the computer recorded latencies. Response latencies above 2000 milliseconds and below 200 milliseconds were removed from the data, as were all incorrect responses (less than 5% of total responses) (Koster, Crombez, Verschuere, de Houwer, 2004). Attentional bias scores were calculated separately for happy and angry faces by subtracting participants' mean log-transformed dot-detection latency for the happy or angry-face location trials from their mean log-transformed dot-detection latency for the neutral-face location trials (c.f. Richeson & Trawalter, 2008). Greater bias scores indicate greater attention to the happy (or angry) faces.

Cognitive Flexibility. Participants engaged in the Alternative Uses task (Guilford, 1967) in which they were asked to generate as many creative uses for a newspaper as possible within

two minutes. Because of the time constraints on this task, participants must utilize cognitive flexibility to avoid perseveration and come up with multiple uses for the newspaper before the time for the task expires. Uses were coded for fluency (total number of responses), elaboration (amount of detail for each response), flexibility (number of different categories used), and originality (uniqueness of the responses). Two independent judges, unaware of condition, scored the four categories. Final scores were computed by taking the average of the two coders' scores (inter-coder reliability ranged from .80 to .90).

Neuroendocrine Measures: DHEAS and Cortisol. Saliva samples were obtained at three time periods: 1) before the TSST (T1), 2) approximately 30 minutes after the onset of the TSST but before the cognitive tasks (T2), and 3) approximately 60 minutes after the onset of the TSST, immediately following the cognitive tasks (T3). At each time point, 1mL of saliva was collected using the passive drool method. Because hormone levels are known to vary depending on flow rate, the time it took for participants to complete each 1mL sample was recorded by the experimenter. Upon completion of the study, saliva samples were immediately frozen until they were shipped overnight on dry ice to a laboratory in College Park, PA. Saliva samples were assayed for cortisol and DHEAS using a highly sensitive enzyme immunoassay (Salimetrics, PA). Intra- and inter-assay coefficients were less than 10%. Flow rates for each time period were calculated as 1mL divided by the time it took for each sample to be collected and DHEAS and cortisol levels multiplied by the flow rate so as to express the results as a function of time ($\mu\text{g}/\text{min}$). Finally, because flow rate corrected levels were positively skewed, they were log-transformed prior to analysis.

Data Analysis Strategy

To test our prediction that stress mindset would differentially influence affective, cognitive, and neuroendocrine responses depending on the type of stress (i.e., challenge or threat) experienced, we conducted 2 (mindset: stress-is-enhancing vs. stress-is-debilitating) x 2 (feedback: negative/threat vs. positive/challenge) ANOVAs for all dependent variables. For positive affect, negative affect, DHEAS, and cortisol (all of which were collected at multiple time-points) we conducted repeated measures ANOVAs with time as a within subjects variable and mindset and feedback conditions as between subjects variables. Gender and stress mindset at baseline were included as covariates in all analyses. Hours of sleep and menstrual cycle phase were also included as covariates for the neuroendocrine measures. In cases where Mauchly's test of sphericity was violated, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity.

Results

Participant attrition

Eleven participants were excluded from the analyses, five due to recognition of the evaluators (confederates), four to equipment malfunction, and two because they did not complete the entire study. Data from the remaining 113 participants were used in all analyses. Varying degrees of freedom reflect the data loss across variables. Means and standard deviations are reported for all key outcome variables in Table 1.

Insert Table 1 About Here

Manipulation checks

Changes in stress mindset from baseline were measured to assess whether the videos engendered stress-is-enhancing and stress-is-debilitating mindsets. Participants in the stress-is-enhancing condition experienced increases on the stress mindset measure reflecting a more enhancing stress mindset ($M=2.48$); $t(53)=7.99$, $p<.001$, while those in the stress-is-debilitating condition experienced decreases on the stress mindset measure reflecting a more debilitating stress mindset ($M=1.13$); $t(53)=-7.63$, $p<.001$ (Figure 1a).

We then examined the threat ratio created from the cognitive evaluations following the speech task. As intended, the negative feedback condition resulted in a higher threat ratio ($M=1.44$) than the positive feedback condition ($M=.95$), $t(111)=4.82$, $p<.001$ (Figure 1b), indicating that we successfully manipulated threat and challenge evaluations.

 Insert Figure 1 About Here

Importantly, the stress mindset manipulation did not significantly alter evaluations of the speech task in either the positive ($F(1,55)=.29$, $p=.593$, $\eta^2=.005$) or negative ($F(1,56)=.09$, $p=.763$, $\eta^2=.007$) feedback conditions. This finding supports the theory that mindsets and threat versus challenge evaluations are distinct constructs and therefore could be examined independently.

Positive and Negative Affect

For positive affect, we observed a significant time x feedback condition effect $F(2,202)=18.29$, $p<.001$, $\eta^2=.153$ such that participants in the positive feedback (challenge evaluation) condition experienced increases in positive affect over time relative to those in the negative feedback (threat evaluation) condition, who experienced decreases in positive affect

over time. We also found a significant time x mindset condition effect $F(2,202)=3.63, p=.020, \eta^2=.035$ such that participants in the stress-is-enhancing condition experienced increases in positive affect over time relative to those in the stress-is-debilitating condition, who experienced decreases in positive affect over time. The three-way interaction between mindset, feedback, and time was not statistically significant $F(2,202)=.73, p>.482, \eta^2=.007$. However, simple-effects tests (illustrated in Figure 2) demonstrated that while there were no differences between the four conditions in positive affect at baseline $F(3,112)=.322, p=.810, \eta^2=.009$ or prior to the speech $F(3,110)=1.35, p=.262, \eta^2=.037$, there was a significant difference between conditions following the speech $F(3,112)=5.47, p=.002, \eta^2=.131$, such that participants who had a stress-is-enhancing mindset and were in the positive feedback (challenge evaluation) condition had significantly more positive affect after the speech task than participants in the other three conditions.

 Insert Figure 2 About Here

For negative affect, we observed a significant time x feedback condition effect, $F(1.84,186)=19.63, p<.001, \eta^2=.163$. Simple-effects tests within each time period (Figure 2) indicated that there were no differences in negative affect between the positive feedback (challenge evaluation) condition and the negative feedback (threat evaluation) condition at baseline $F(1,106)=2.37, p=.126, \eta^2=.023$ or pre-speech $F(1,107)=.90, p=.345, \eta^2=.007$. However, there were significant differences between conditions following the speech $F(1,107)=37.99, p<.001, \eta^2=.271$, such that negative affect remained higher for participants in the negative feedback (threat evaluation) condition compared to participants in the positive feedback (challenge evaluation) condition. Neither the time x mindset condition effect nor the

three-way interaction between mindset, feedback, and time were significant [$F(1.84,186)=.02$, $p=.978$, $\eta^2=.000$ and $F(1.84,186)=.036$, $p=.965$, $\eta^2=.000$, respectively].

Attentional Bias

Results for the attentional bias for happy faces showed a similar pattern as our positive affect findings in the positive feedback condition. There were no main effects of mindset or feedback condition on attentional bias, however there was a significant mindset x feedback condition interaction, $F(1,95)=4.48$, $p=.037$, $\eta^2=.047$. Simple effects tests showed that, in the positive feedback (challenge evaluation) condition, bias towards happy faces was significantly higher for those with a stress-is-enhancing mindset relative to those with a stress-is-debilitating mindset, $F(1,46)=4.40$, $p=.042$, $\eta^2=.091$, again suggesting that a stress-is-enhancing mindset only boosted attentional bias towards happy faces when participants were in the positive feedback (challenge stress evaluation) condition. In contrast, in the negative feedback (threat evaluation) condition, there was no difference in bias toward happy faces between mindset conditions, $F(1,48)=.88$, $p=.354$, $\eta^2=.019$ (Figure 3a). With respect to attentional bias toward angry faces on the Dot Probe task, we observed a marginally significant effect of feedback condition, $F(1,95)=3.46$, $p=.066$, $\eta^2=.037$, such that those in the negative feedback (threat evaluation) condition showed greater attentional bias away from angry faces than those in the positive feedback (challenge evaluation) condition (Figure 3b).

Insert Figure 3 About Here

Cognitive Flexibility

For flexibility, while there was no main effect of mindset, we observed a significant main effect of feedback condition $F(1,105)=4.64, p=.033, \eta^2=.044$, such that participants in the positive feedback (challenge evaluation) condition received higher cognitive flexibility scores than those in the negative feedback (threat evaluation) condition. This main effect was qualified by a marginally significant interaction, $F(1,105)=3.63, p=.060, \eta^2=.035$. Consistent with our attentional bias findings, participants who were in the positive feedback (challenge evaluation) condition and held a stress-is-enhancing mindset received higher flexibility scores than those who held a stress-is-debilitating mindset, $F(1,52)=4.22, p=.045, \eta^2 = .079$ (Figure 3c). Aligned with the aforementioned effects, this suggests that a stress-is-enhancing mindset only generated creative flexibility when participants were in the positive feedback (challenge evaluation) condition. In contrast, in the negative feedback (threat evaluation) condition, there was no difference in flexibility between mindset conditions, $F(1,52)=.21, p=.648, \eta^2 = .004$. In other words, whereas stress-is-enhancing and stress-is-debilitating mindsets significantly differed from each other in cognitive flexibility in the positive feedback condition, they did not differ in the negative feedback condition.

In summary, for each of the cognitive performance categories, we observed differential performance for participants with a stress-is-enhancing mindset relative to those with a stress-is-debilitating mindset, but mainly in the positive feedback (challenge evaluation) condition.

Neuroendocrine Responses: DHEAS and Cortisol

For DHEAS, we observed a significant time x mindset condition effect, $F(2,108)=6.62, p=.002, \eta^2=.109$. Within-subjects contrasts revealed that this effect was quadratic in nature, $F(1,54)=12.32, p=.001, \eta^2=.186$, such that that relative to participants in the stress-is debilitating condition, participants in the stress-is-enhancing condition experienced significantly sharper

increases in DHEAS between baseline (T1) and the end of the TSST (T2), $F(1,54)=10.65$, $p=.002$, $\eta^2=.165$, followed by significantly sharper decreases in DHEAS between the end of the TSST (T2) and the end of the cognitive tasks (T3), $F(1,55)=7.73$, $p=.007$, $\eta^2=.123$. Simple-effects tests within each time period (illustrated in Figure 4a) indicated that there were no differences in DHEAS between the stress-is-enhancing and stress-is-debilitating mindset conditions at baseline (T1), $F(1,60)=.29$, $p=.595$, $\eta^2=.005$ or following the cognitive tasks (T3), $F(1,61)=.04$, $p=.845$, $\eta^2=.001$, but that DHEAS was higher for participants in the stress-is-enhancing mindset condition compared to participants in the stress-is-debilitating mindset condition following the speech task (T2), $F(1,61)=4.07$, $p=.048$, $\eta^2=.068$. Neither the time x feedback condition effect nor the mindset x feedback x time effects were significant for DHEAS [$F(2,108)=1.17$, $p=.316$, $\eta^2=.021$ and $F(2,108)=.27$, $p=.764$, $\eta^2=.005$, respectively].

 Insert Figure 4 About Here

For cortisol, the time x mindset condition was not significant, $F(1.20,45.33)=.304$, $p=.305$, $\eta^2=.004$. Further, aligned with our DHEAS findings, neither the time x feedback condition effect nor the mindset x feedback x time effects were significant for cortisol [$F(1.73,93.24)=.24$, $p=.754$, $\eta^2=.004$ and $F(2,93.24)=.09$, $p=.884$, $\eta^2=.025$, respectively].

Exploratory Analyses

In line with research suggesting that both DHEAS (e.g., Morgan et al., 2004, Shields, Lam, Trainor, & Yonelinas, 2016, Sripatha et al., 2013, Neuropsychopharmacology) and cortisol (e.g., Gagnon & Wagner, 2016; Het, Ramlow, & Wolf, 2005; Shields, Bonner, & Moons, 2015) can influence cognitive functioning, we examined the relationship between our neuroendocrine

measures and cognitive performance scores using the AUC increase measure for both DHEAS and cortisol. In order to analyze these correlations we conducted area under the curve increase analysis (AUC; Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003) using the following formula: $((\text{HormoneTime1} + \text{HormoneTime2}) * 60)/2 + (((\text{HormoneTime2} + \text{HormoneTime3}) * 20)/2) - (\text{HormoneTime1} * 80)$, with 60 representing the time between the first and second saliva samples, 20 representing the time between the second and third saliva samples, and 80 representing the time from saliva sample one to saliva sample three. These results indicated no significant correlations between our neuroendocrine measures and our cognitive performance measures (all $ps > .510$).

Additionally, although our time x mindset condition effects were not significant for cortisol, given the significant quadratic within-subjects contrasts effects we observed with DHEAS and a trending within-subjects contrast effect for cortisol $F(1,54)=2.54, p=.117, \eta^2=.045$, we wanted to analyze our cortisol data with greater granularity by examining the differences between the stress-is-enhancing and stress-is-debilitating conditions within each time period. Between baseline (T1) and the end of the TSST (T2), stress-is-enhancing participants demonstrate a slightly stronger, though not significant, increase in cortisol relative to stress-is-debilitating participants, $F(1,54)=.92, p=.341, \eta^2=.017$. However, between the end of the TSST (T2) and the end of the cognitive tasks (T3), stress-is-enhancing participants exhibited a significantly sharper decline in cortisol than stress-is-debilitating participants, $F(1,55)=4.63, p=.036, \eta^2=.078$. In other words, simple-effects tests at each time period (illustrated in Figure 4b) indicated that there were no differences in cortisol levels between the stress-is-enhancing and stress-is-debilitating mindset conditions at baseline (T1), $F(1,60)=1.236, p=.271, \eta^2=.022$ or following the cognitive tasks (T3), $F(1,61)=.33, p=.570, \eta^2=.006$, but cortisol levels were

significantly higher for participants in the stress-is-enhancing mindset condition compared to participants in the stress-is-debilitating mindset condition following the TSST (T2),

$F(1,61)=4.38, p=.041, \eta^2=.073$.

Discussion

The goal of this study was to examine how stress mindset would moderate emotional, cognitive, and neuroendocrine responses in the context of challenge and threat evaluations. Consistent with extant theory, we predicted that threat evaluations would produce poorer emotional, cognitive and neuroendocrine outcomes relative to challenge evaluations. However, we also predicted that threat and challenge evaluations would be moderated by stress mindset such that having a stress-is-enhancing mindset would improve responses in the context of threat evaluations and having a stress-is-debilitating mindset would worsen responses in the context of challenge evaluations.

Consistent with our predictions, we found that adopting a stress-is-enhancing mindset was indeed beneficial as it relates to positive emotion and DHEAS secretion; participants with a stress-is-enhancing mindset experienced greater increases in DHEAS and greater increases in positive emotions relative to those with a stress-is-debilitating mindset in both the positive feedback (challenge) and negative feedback (threat) conditions. The boost to positive emotions and DHEAS-amplifying effect of a stress-is-enhancing mindset is particularly noteworthy as it contributes to stress management theory and practice by showing that adaptive outcomes don't solely ensue from acknowledging a stressor as challenging, but can also ensue from acknowledging a stressor as threatening if accompanied by an enhancing mindset. Importantly, having a stress-is-enhancing mindset may not make stressful situations feel any less emotionally difficult (as negative affect was still high) or any less physiologically taxing (as cortisol levels

were still high). However, having a stress-is-enhancing mindset can promote physiological thriving as evidenced by the heightened DHEAS we observed under both challenge and threat evaluations. The anabolic and antiglucocorticoid effects of DHEAS (Morgan et al., 2004), particularly when combined with its ability to promote psychological resilience (Charney, 2004) and positive mood (Frye & Lacey, 1999), may foster resilience under stress, facilitating one's ability to endure future stressors. Taken together, this finding affirms the value of adopting a stress-is-enhancing mindset, regardless of how one evaluates the stressor.

With respect to cognitive responses, we found that a stress-is-enhancing mindset produced greater attentional bias towards happy faces, and more cognitive flexibility, than a stress-is-debilitating mindset for participants receiving positive feedback (challenge evaluation). In other words, although mindset did moderate the effects of stress differentially depending on whether challenge or threat evaluations were evoked, the majority of the cognitive benefits of a stress-is-enhancing mindset occurred primarily under challenge evaluations. In contrast, those with a stress-is-debilitating mindset experienced worse cognitive flexibility and less bias to happy faces despite facing a seemingly manageable stressor (i.e., positive feedback). The finding that adopting a stress-is-debilitating mindset under challenge evaluations produced similar outcomes as those under threat may help explain why even small everyday stressors can have negative effects (McIntyre, Korn, & Matsuo, 2008), sometimes evoking worse somatic outcomes than more threatening life events (Almeida, 2005; DeLongis, Coyne, Dakof, Folkman, & Lazarus, 1982). Moreover, the amplifying cognitive flexibility effect we observed of having a stress-is-enhancing mindset under challenge evaluations is particularly interesting as it is consistent with literature showing that the experience of positive emotions can broaden individuals' thought-action repertoires, building enduring physical, intellectual, social, and

psychological resources and producing flexible, creative, and novel thinking (Amabile et al., 2005; Fredrickson, 2001; Tugade & Fredrickson, 2004).

It is important to note that the interpretation of our attentional bias findings remains unclear as there is significant debate regarding whether the dot-probe measures a heightened vigilance *toward information* or an inability to *disengage from information* (e.g., Fox, Russo, Bowels & Dutton, 2001, 2002; Koster, Crombez, Verscheure & DeHouwer, 2004; Salemink, van den Hout, Kindt, 2007). In light of this debate, our finding that under challenge evaluations, bias towards happy faces was significantly higher for those with a stress-is-enhancing mindset relative to those with a stress-is-debilitating mindset could suggest that either those in the stress-is-enhancing condition had heightened vigilance to happy faces or couldn't disengage from happy faces. Regardless of the interpretation, our finding nonetheless represents the concept that participants who believe stress is enhancing spend more time attending to happy faces than those who believe stress is debilitating.

Interestingly, the current results suggest that while having a stress-is-enhancing mindset increased positive mood, cognitive flexibility, attention to happy faces, and DHEAS responses, it did not seem to reduce negative emotional reactions to the stress in either the challenging or threatening conditions. This suggests that adopting a stress-is-enhancing mindset in the face of both challenging and threatening situations may be beneficial, not necessarily because of its ability to make the stress *feel* less negative or threatening, but rather, by recruiting and magnifying cognitive, emotional and physiological attributes that may contribute to adaptive responses over the long-run.

Accordingly, our exploratory analyses of the effects of adopting a stress-is-enhancing mindset on cortisol responses deserves some attention. Although the omnibus time x mind effect

was not statistically significant, limiting our ability to draw strong conclusions, our exploratory finding that there was a significantly sharper decrease in cortisol levels for stress-is-enhancing relative to stress-is-debilitating participants between the end of the TSST and the end of the cognitive tasks, suggests that adopting a stress-is-enhancing mindset may have led participants to engage with but more rapidly recover from the stressful task. Past studies have observed similar findings, particularly among individuals with high cortisol reactivity to stress when compared to non-stressful days (Crum et al., 2013). Therefore future studies examining the effects of mindsets on cortisol reactivity that employ research designs capturing individual differences and varying levels of stress are needed to further our understanding of how cortisol responses may be differentially altered depending the person, their mindset, and the context.

Several limitations should be acknowledged and explored in future research. First, our stress task was constrained as we focused on the relative effects of mindset only under threat and challenge evaluations. Future research should explore the effect of mindset in more ambiguous and naturally-occurring stressful situations to better tease apart the processes through which stress mindsets exert psychological, physiological, and behavioral effects. Second, we explored mindset effects as they relate to acute short-term stressors. Of considerable interest are the duration of stress mindset effects and the longitudinal sequence of emotional, cognitive, and neuroendocrine outcomes triggered by approaching stress in a stress-is-enhancing mindset relative to a stress-is-debilitating mindset under situations of chronic stress. Third, there is evidence that both DHEAS and cortisol have cognitive effects (Gagnon & Wagner, 2016; Het, Ramlow, & Wolf, 2005; Shields, Bonner, & Moons, 2015; Shields, Lam, Trainor, & Yonelinas, 2016; Sripada et al., 2013), however, these cognitive effects were not observed in our study. It is possible that the type of cognitive tasks we used in this study (alternative uses and dot probe)

may not be representative of the types of tasks that are influenced by neuroendocrine changes, such as episodic recall tasks or measures of decision-making competence. Future studies should consider broadening the range of cognitive tasks used to further our understanding of the types of cognitive tasks for which stress mindset manipulations may be particularly beneficial. Finally, as is common with laboratory research, our sample consisted of young and healthy undergraduate and graduate students living in the United States, and did not include a no-stress control group as we were primarily interested in the relative benefit of stress mindset in challenging and threatening contexts. Additional research is needed to examine whether the benefits of adopting a stress-is-enhancing mindset extend to different populations and settings, such as among individuals with anxiety disorders, in contexts with no stress or more extreme levels of stress, and in cultures where mindsets about stress and anxiety are different from those in the United States (Tweed, White, & Lehman, 2004).

Stress is an undeniable part of everyday reality for most individuals. Our findings advance stress theory by highlighting the relative benefit of stress mindset in the context of both threat and challenge evaluations. Taken together, these results do not refute or question the powerful role of threat and challenge evaluations in shaping the stress response. Rather, they enrich the literature by capturing an important nuance: that even stress considered threatening can be beneficial when approached with a stress-is-enhancing mindset, and that even stress considered challenging may not be experienced in an adaptive manner when approached through the stress-is-debilitating mindset. These results lay the foundation for an integrated theory demonstrating that altering general beliefs about stress can change situation-specific stress evaluations. In doing so, this research provides a hopeful possibility that individuals can improve their responses to stress—both in the face of manageable stressors as well as in the face of

threatening stressors—by adopting more enhancing mindsets about stress that are not specific to the stressor at hand, but can generally apply to any stressful situation.

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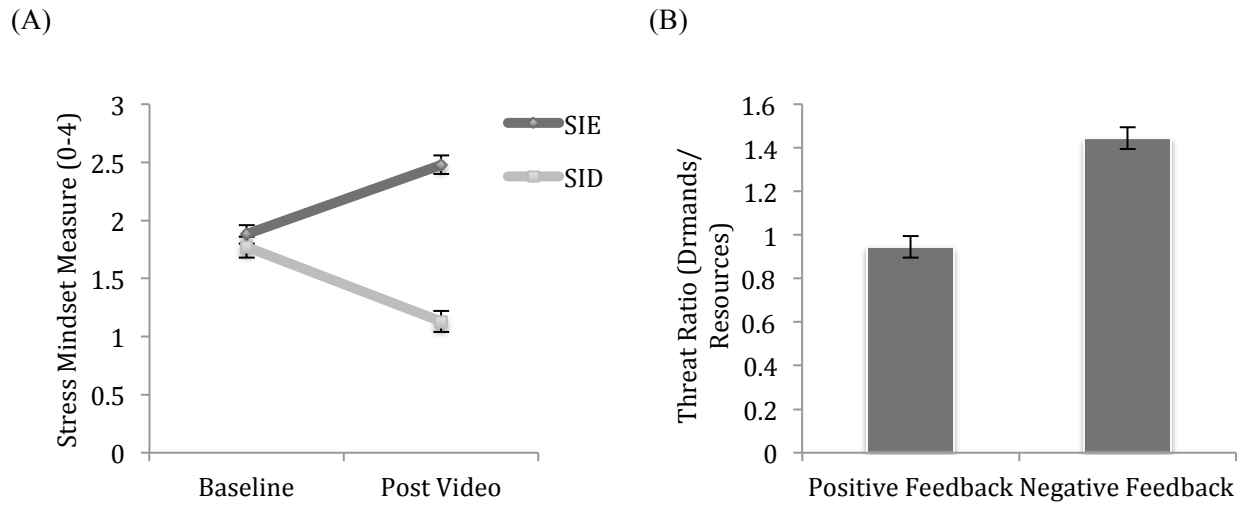
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Table 1. Means and Standard Deviations (in Parentheses) for Key Outcome Variables as a function of mindset and feedback conditions

Variable	Positive Feedback (Challenge Appraisal)		Negative Feedback (Threat Appraisal)	
	Stress-is- Enhancing	Stress-is- Debilitating	Stress-is- Enhancing	Stress-is- Debilitating
Positive Affect (1-5)				
Baseline	2.99(.81)	2.91(.75)	3.10(.66)	3.04(.80)
Pre Speech	3.11(.66)	2.69(.83)	2.96(.87)	2.80(.96)
Post Speech	3.51(.81)	2.99(.86)	2.80(.77)	2.58(.91)
Negative Affect (1-5)				
Baseline	1.42(.37)	1.55(.57)	1.52(.47)	1.58(.56)
Pre Speech	1.86(.57)	1.97(.70)	2.02(.59)	2.10(.75)
Post Speech	1.35(.35)	1.48(.41)	2.06(.67)	2.14(.76)
Attentional Bias				
Happy Faces	19.08(33)	-0.84(45)	-1.81(45)	5.17(45)
Angry Faces	0.78(33)	3.09(50)	-11.34(50)	-21.16(37)
Cognitive Flexibility	6.34(2.03)	5.12(2.21)	4.63(2.19)	5.06(2.30)
Cortisol ($\mu\text{g}/\text{min}$)				
Baseline	8.25(12.88)	6.06(4.68)	8.07(8.06)	4.96(3.40)
Post TSST	12.44(9.59)	12.00(13.97)	15.94(11.84)	9.25(9.12)
Post Cognitive Tasks	7.33(5.03)	8.92(7.61)	10.77(7.18)	8.13(7.31)
DHEAS ($\mu\text{g}/\text{min}$)				
Baseline	2550.74(2219)	2752.41(2108)	2633.98(1972)	2992.33(3674)
Post TSST	3804.08(3750)	2479.32 (2045)	6541.92(9487)	2686.07(2291)
Post Cognitive Tasks	1952.50(1175)	2459.07(2192)	2671.21(1736)	3032.96(2084)

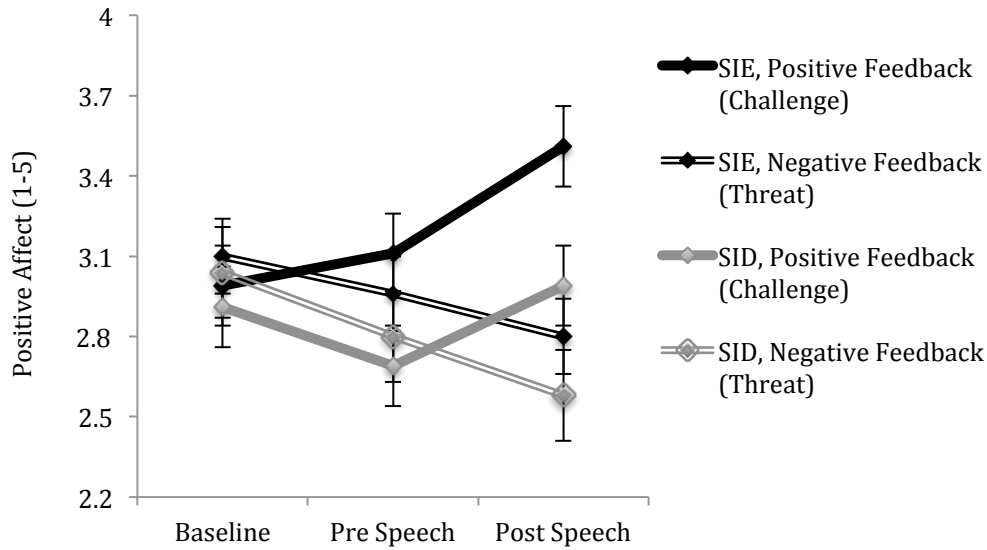
Figure 1. Means and standard errors for Stress Mindset Measure pre and post mindset video (A) and Threat ratio post speech (B)



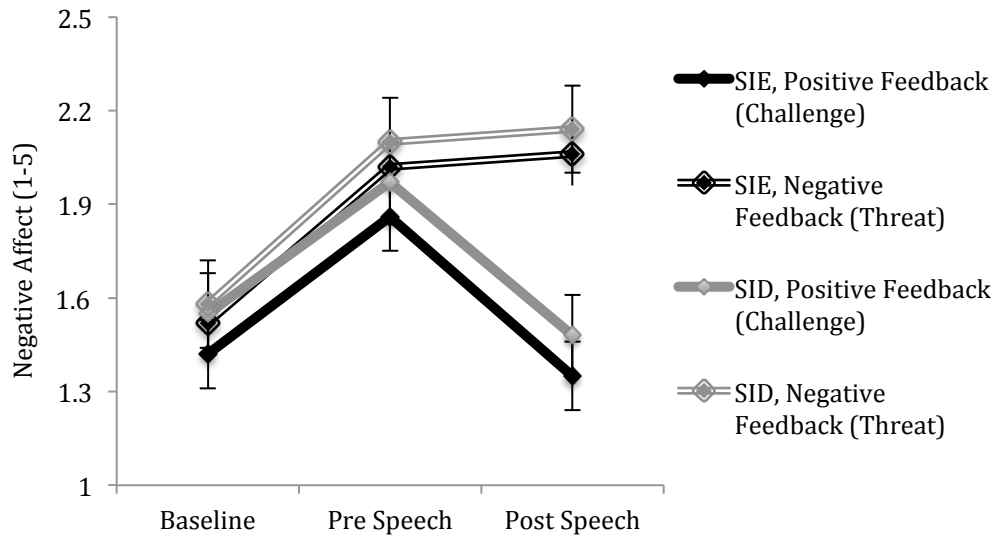
Note: SIE= Stress-is-Enhancing and SID= Stress-is-Debilitating

Figure 2. Mean Positive Affect (A) and Negative Affect (B) ratings as a function of mindset and feedback condition over three time periods.

(A)

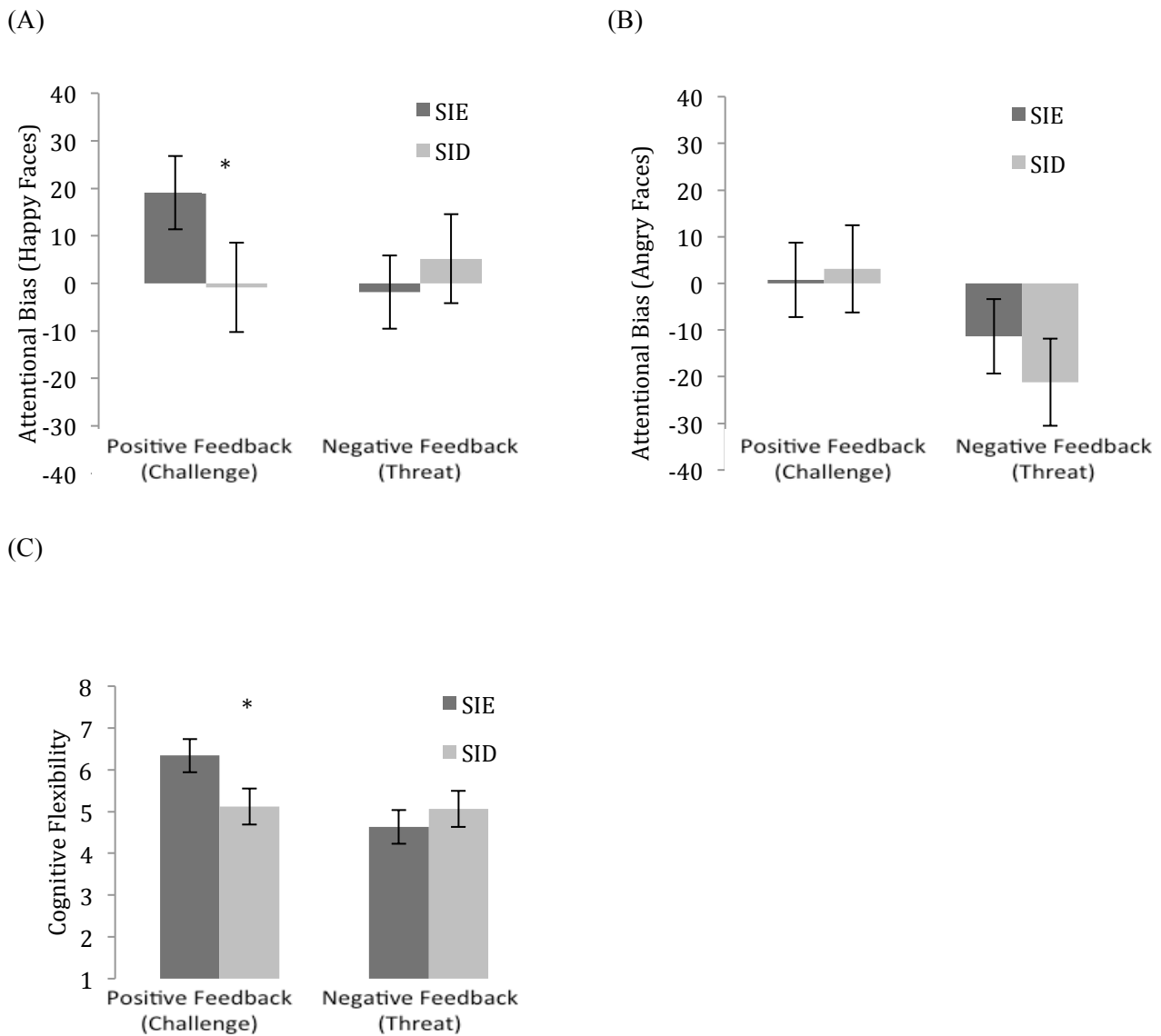


(B)



Note: SIE= Stress-is-Enhancing and SID= Stress-is-Debilitating; Error bars show standard errors.

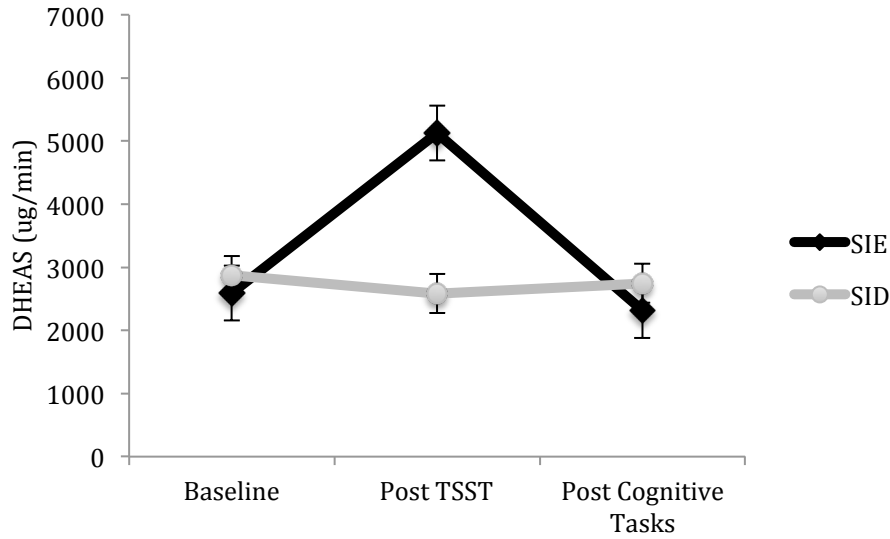
Figure 3. Attentional bias scores for happy faces (A), Attentional bias scores for angry faces (B), and Creativity Scores (C) as a function of mindset and feedback conditions.



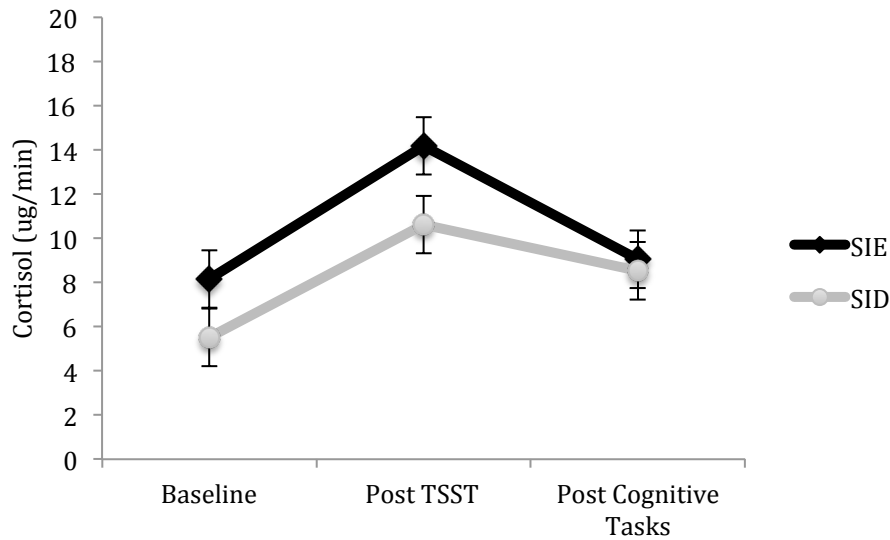
Note: SIE= Stress-is-Enhancing and SID= Stress-is-Debilitating; Error bars show standard errors; *p<.05

Figure 4. Changes in DHEAS (A) and Cortisol (B) over time as a function of mindset.

(A)



(B)



Note: SIE= Stress-is-Enhancing and SID= Stress-is-Debilitating; Error bars show standard errors at each time period.