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Mind over Matter: Reappraising Arousal Improves Cardiovascular and Cognitive Responses to Stress

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Abstract

Researchers have theorized that changing the way we think about our bodily responses can improve our physiological and cognitive reactions to stressful events. However, the underlying processes through which mental states improve downstream outcomes are not well-understood. To this end, we examined whether reappraising stress-induced arousal could improve cardiovascular outcomes and decrease attentional bias for emotionally-negative information. Participants were randomly assigned to either a reappraisal condition in which they were instructed to think about their physiological arousal during a stressful task as functional and adaptive, or to one of two control conditions: attention reorientation and no instructions. Relative to controls, participants instructed to reappraise their arousal exhibited more adaptive cardiovascular stress responses – increased cardiac efficiency and lower vascular resistance – and decreased attentional bias. Thus, reappraising arousal shows physiological and cognitive benefits. Implications for health and potential clinical applications are discussed.

Keywords

Reappraisal; emotion regulation; stress; attentional bias; biopsychosocial model

> "The greatest weapon against stress is our ability to choose one thought over another." – William James

How we respond to stress has important consequences for our biological and cognitive functioning. As the above quote illustrates, for over a century theorists have speculated that stress responses are affected not only by situational factors, but also by perceptions of events. Consistent with the idea that altering perceptions has significant effects downstream, research indicates that appraisals influence emotions (Barrett, 2006; Gross, 1998; 2002; Mauss, Cook, Cheng, & Gross, 2007), clinical outcomes (Hofmann & Smits, 2008), and performance (Jamieson, Mendes, Blackstock, & Schmader, 2010). Building on this previous

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work, the research presented here examines the potential cardiovascular and cognitive benefits of reappraising arousal during a stressful laboratory task.

The Biopsychosocial Model

The Biopsychosocial (BPS) Model of Challenge and Threat provides a theory of how appraisals shape stress responses (e.g., Blascovich, Mendes, Hunter, & Salomon, 1999). More specifically, this model posits that during active, goal-directed tasks, appraisals of situational demands interact with appraisals of available resources (see Blascovich & Mendes, 2010 for a review). When people believe they possess sufficient resources to cope with stressors they experience a *challenge* response, but when situational demands are seen as exceeding resources individuals experience *threat*. Physiologically, challenge is characterized by activation of the sympathetic-adrenal-medullary (SAM) axis, increased cardiac efficiency, and vasodilation; changes that signal an approach orientation and increase peripheral blood flow. Threat also activates the SAM axis, but the specific cardiovascular reactivity differs from challenge and is associated with reduced cardiac efficiency and vasoconstriction; changes that signal an avoidance orientation and prepare the body for damage/defeat (Mendes, Blascovich, Hunter, Lickel, & Jost, 2007). Whereas challenge typically is associated with positive outcomes (e.g., Blascovich et al., 1999; Deinstbier, 1989; Jamieson et al., 2010), threat impairs decision-making in the short-term and in the long-term is associated with accelerated "brain aging," cognitive decline, and cardiovascular disease (Jefferson, Himali, Beiser, Au, Massaro, Seshardri, et al., 2010; Matthews, Gump, Block, & Allen, 1997).

In stressful situations signs of increased arousal (e.g., racing heart) are frequently construed as anxiety, nervousness, or fear. These negative appraisals encourage people to perceive demands as exceeding resources, triggering a maladaptive threat response. Thus, modifying resource appraisals may help improve physiological responses. In fact, the clinical literature suggests such an approach might be efficacious. For instance, panic attacks are characterized by a "fear of fear" – fear in response to somatic sensations (Bouton, Mineka, & Barlow, 2001) – and cognitive-behavioral therapies (CBT) help to improve outcomes by modifying faulty emotional responding to harmless cues of arousal (e.g., Smits, Powers, Cho, & Telch, 2004).

Threat-Related Attentional Bias

Markers of threat responses have also been linked to increased attention for threat-related information, such as angry faces or emotionally-negative words (e.g., Roelofs, Bakvis, Hermans, van Pelt & van Honk, 2007; van Honk, Verbaten, Tuiten, van der Hout, Koppeschaar, et al., 1999). Functionally, a bias for threat-related information facilitates the detection of danger and helps individuals respond effectively to potential threats. However, attentional bias also elicits and maintains feelings of anxiety and has been linked to a host of clinical conditions, including panic disorder (e.g., McNally, Amir, Lourro, Lukach, Riemann, & Calamari, 1994), posttraumatic stress disorder (e.g., Kaspi, McNally, & Amir, 1995), social anxiety (e.g., Mathews & MacLeod, 2002; 2005), and suicidal behavior (Cha, Najmi, Park, Finn, & Nock, 2010). In fact, one treatment for anxiety disorders focuses on reducing attentional bias via retraining attention away from threat-related information by instructing individuals to attend to a cue that predicts the location of a non-threatening target (e.g., Amir, Weber, Beard, Bomyea, & Taylor, 2008).

Overview of the Current Research

Building on emotion regulation research that demonstrates reappraising affective responses improves emotional outcomes and concomitant physiological responses (e.g., Gross, 1998;

2002; Mauss et al., 2007), the current research tested whether altering appraisals of stress arousal was sufficient to promote a more adaptive physiological response and decrease attention to emotionally-negative information.

To test the effects of reappraisal, participants were assigned to one of three conditions: *reappraisal*—in which participants were instructed that arousal is functional and aids performance (e.g., Dienstbier, 1989; Jamieson et al., 2010), *ignore external cues*—an attention reorientation control designed to rule out the possibility that any face-valid attentional intervention is sufficient to improve outcomes, and *no-intervention control*.

Participants then completed a stressful public-speaking task (Kirschbaum, Pirke, & Hellhammer, 1993) while their cardiovascular responses were recorded, followed by a test of attentional bias (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). Because of the efficacy of CBT (e.g., Smits et al., 2004) and emotion regulation techniques (e.g., Gross, 1998), reappraisal participants were hypothesized to demonstrate improved acute cardiovascular functioning and reduced attentional bias for emotionally-negative information relative to ignore and no-intervention participants.

Method

Participants

Fifty participants (25 male, 25 female) were recruited from the Cambridge, MA area and compensated $25 or two-credit hours for participation (*M* age = 21.88 years). Participants were pre-screened for physician-diagnosed hypertension and heart murmur, presence of a pacemaker, cardiac medications, and pregnancy. One participant wished to terminate the experiment and was excluded from the analysis.

Procedure

After application of sensors, participants rested for a 5-minute baseline cardiovascular recording. They were then assigned to an experimental condition. The reappraisal and ignore conditions began with scripted instructions about the benefits of reappraising arousal or ignoring stress, respectively. Participants then read three summaries of journal articles (some real, some made-up to match the message conveyed in each condition) on the computer. After each summary, participants answered two questions that ensured they read the summaries and encouraged them to endorse the information presented.

The reappraisal manipulation educated participants about the functionality of physiological arousal during stress. More specifically, participants assigned to this condition were informed that increased arousal during stressful situations is not harmful. Instead, the instructions explained that our body's responses to stress have evolved to help us successfully address stressors, and that increased arousal actually aids performance in stressful situations. Thus, reappraisal participants were instructed to appraise arousal as functional and adaptive but were not encouraged to perceive the evaluative task as any less demanding or stressful.

The “ignore external cues” condition instructed participants that the best way to reduce nervousness and improve outcomes is to ignore the source of stress. Thus, they were told to look at an “X” placed to the left of the evaluators. This attention reorientation paradigm was based on emotion-suppression techniques (e.g., Gross, 1998). However, rather than suppressing affective reactions, participants were instructed to re-direct their visual attention. Like in the reappraisal condition, participants read through summaries of articles advocating the benefits of such an approach. The ignore manipulation was not expected to improve outcomes, even though it instructed participants or orient attention away from threat-related information.

No-intervention controls were not given any instructions before their speech, but completed a non-demanding task to control for time. Manipulations took 10-15 minutes to complete.

Participants then completed the Trier Social Stress Test (TSST) (Kirschbaum, Pirke, & Hellhammer, 1993), which required them to deliver a 5-minute videotaped speech in front of two evaluators. Throughout the speech, the evaluators provided negative feedback (furrowed brow, crossed arms, frowning, etc.). Following the speech, participants performed an impromptu 5-minute mental arithmetic task: Counting backwards in steps of 7 from 996 while the evaluators provided negative feedback.

An emotional Stroop task (MacLeod et al., 2002) was administered after the TSST to assess attentional bias. Participants were asked to name the colors (red, green, or blue) words were printed in as quickly and accurately as possible. Words were presented in two 100 word lists. The “threat” list consisted entirely of emotionally-negative words, whereas the “neutral” list consisted of emotionally-neutral words. Words were sampled from the Stimulus Pairs list from MacLeod et al. (2002, Appendix A). This enabled us to match words for length and frequency of usage. List order was counterbalanced and participants completed a practice list (10 threat and 10 neutral words) before beginning. An experimenter unaware of condition assignment recorded errors and how long it took participants to read each list. Interference scores were computed by subtracting the time it took participants to read the neutral list from their time on the threat list.

Physiological measures

The following measures were collected during baseline and the TSST: electrocardiography (ECG, Biopac, Goleta, CA), impedance cardiography (NICO, Biopac, Goleta, CA), and blood pressure (Colin Prodigy II, Colin Medical Instruments, San Antonio, TX). Signals were integrated with Biopac MP100 hardware. Electrocardiograph and impedance cardiograph signals were scored off-line by trained personnel. Signals were visually examined and the ensembled averages were analyzed using Mindware software (Mindware Technologies, Gahanna, OH). Reactivity scores were computed by subtracting scores taken during the final minute of baseline (the “most relaxed” portion) from those collected during the first minute of the speech (the “most reactive” portion). We focused on two measures that provide the best distinction between challenge and threat states: cardiac output (CO) and total peripheral resistance (TPR). CO is the amount of blood ejected from the heart during one minute and is calculated by first estimating stroke volume (the amount of blood ejected during each beat) and multiplying that by heart rate. Increases in CO index improved cardiac efficiency. TPR is a measure of overall vasoconstriction/vasodilation. During threat states, the peripheral vasculature constricts so as to limit blood flow to the periphery. TPR was calculated with the following formula: (mean arterial pressure / CO) × 80 (Sherwood, Allen, Fahrenberg, Kelsey, Lovallo, & van Dooren et al., 1990).

Questionnaires

Participants completed a resource/demand appraisal questionnaire (e.g., Mendes, Gray, Mendoza-Denton, Major, & Epel, 2007) pre- (but after manipulations) and post-TSST. In addition to the resource and demand items, the questionnaire included ratings of subjective stress and effort. Items were scored on a 1 (strongly disagree) to 7 (strongly agree) scale. Participants also completed the Positive and Negative Affect Schedule (PANAS) at both time points.

Results

Questionnaires

Self-reports were analyzed in 3 (Condition) × 2 (Time: pre- vs. post-TSST) mixed ANOVAs.

Analysis of resource appraisals revealed a main effect for condition, $F(2,46) = 3.26$, $p = .047$. Consistent with predictions, planned contrasts (Kirk, 1995) showed that reappraisal participants reported higher levels of perceived resources ($M = 5.88$, $SD = 1.05$) than the no-intervention ($M = 5.11$, $SD = 1.17$), $F(1,47) = 4.27$, $p = .044$, $d = .60$, and ignore participants ($M = 5.00$, $SD = 1.03$), $F(1,47) = 5.58$, $p = .022$, $d = .69$.

After completing the TSST, participants reported that they expended more effort ($M = 4.67$, $SD = 1.42$) than they expected to prior to beginning ($M = 3.43$, $SD = 1.31$), $F(1,46) = 37.08$, $p < .001$, $d = 1.79$. No other effort effects were significant.

Analyses of task demands, subjective stress, and positive and negative emotions produced no significant effects, *F*s < 1.

Physiological reactivity

Planned contrasts revealed that participants instructed to reappraise arousal exhibited lower TPR reactivity than participants assigned to the no-intervention, $F(1,47) = 7.83$, $p = .007$, $d = .81$, and ignore conditions, $F(1,47) = 4.82$, $p = .033$, $d = .63$, omnibus $F(2,46) = 4.40$, $p = .018$ (Figure 1a). Reappraising arousal led to lower peripheral resistance versus the control conditions. Reappraisal participants also exhibited elevated CO compared to those in the no-intervention, $F(1,47) = 6.86$, $p = .012$, $d = .76$, and ignore conditions, $F(1,47) = 4.62$, $p = .037$, $d = .62$, omnibus $F(2,46) = 3.97$, $p = .026$ (Figure 1b). Taken together, the reappraisal condition was associated with lower TPR and greater CO, which indicates a more adaptive physiological response while engaged in a motivated performance task like the one used here (e.g., Blascovich et al., 1999).[1]

Attentional Bias

Two colorblind participants did not complete the Stroop task. Planned contrasts revealed that participants instructed to reappraise arousal demonstrated less attentional bias for emotionally-negative information versus the ignore condition, $F(1,45) = 6.75$, $p = .013$, $d = .77$, and with marginal significance compared to no-intervention controls, $F(1,45) = 3.88$, $p = .055$, $d = .58$, omnibus $F(2,44) = 3.44$, $p = .040$ (Figure 2).

The effect of reappraisal on interference scores cannot be attributed to a speed-accuracy tradeoff because reappraisal participants made fewer errors on the threat list ($M = .46$, $SD = .74$) than ignore participants ($M = 1.12$, $SD = 1.09$), $F(1,45) = 4.10$, $p = .049$, $d = .59$, and did not differ from no-intervention controls ($M = .63$, $SD = .81$), $F < 1$, omnibus $F(2,44) = 2.31$, $p = .111$. Additionally, the manipulation had no influence on neutral list errors (overall $M = .42$), $F < 1$.[2]

We also examined the association between physiological reactivity and attentional bias. To do so, we first created a physiological index by taking a composite of *Z*-scored CO and reverse *Z*-scored TPR reactivity scores such that higher values corresponded to a more

[1]Reactivity was also analyzed in 3 (Intervention) × 2 (Time: baseline vs. speech) mixed ANOVAs. This analysis did not alter the pattern of results.

[2]Errors and reaction times were also analyzed in 3 (Intervention) × 2 (List: threat vs. neutral) mixed ANOVAs. This analysis did not alter the pattern of results.

adaptive physiological profile. Then, we examined the association between interference scores and the physiological index. The analysis indicates that improvements in cardiovascular functioning were associated with reduced threat-related attentional bias, $\beta = -.282$, $p = .036$.

Discussion

Theorists have speculated for years that humans can cognitively control their responses to stress (i.e. show "mind over matter"), and current models of emotion (Barrett, 2006; Gross, 1998) afford a proximal role for appraisal processes in the generation and regulation of psychological states. To illustrate, individuals better able to reappraise situations so as to decrease the emotional impact exhibit more adaptive emotional and physiological responses to anger provocation (Mauss et al., 2007). Along these lines, the study presented here examined the physiological and cognitive benefits of reappraising arousal during acute evaluative stress. Data supported predictions: Participants instructed to reappraise or "rethink" arousal as functional exhibited increased perceptions of available resources, improved cardiovascular functioning, and less threat-related attentional bias. Thus, consistent with research on emotion regulation (Gross, 2002) and CBT (Hofmann & Smits, 2008), interpretations of bodily signals impact how the body and mind respond to acute stress.

It may seem surprising that altering arousal appraisals is sufficient to change biological and cognitive responses to stress; however, the evidence from the clinical literature is consistent with this idea. More specifically, like the reappraisal intervention used in this research, cognitive restructuring components of CBT are hypothesized to improve clinical outcomes by altering appraisals of bodily signals (Gould, Otto, & Pollack, 1995). Additionally, clinical research indicates that retraining attention for threat-related stimuli can reduce anxiety symptoms (e.g., Amir et al., 2008). Thus, the data presented here may help advance our understanding of CBT by potentially elucidating the physiological and attentional mechanisms underlying specific components of CBT treatments.

Although the reappraisal manipulation in this research builds on past work and shares similarities with cognitive restructuring, it differs in important ways from some other components of CBT such as mindfulness mediation (e.g., Rubia, 2009) and breathing retraining (e.g., Beck, Stanley, Baldwin, Deagle, & Averill, 1994). Unlike these approaches, reappraisal is not aimed at decreasing or dampening arousal, but rather at reshaping how that arousal is construed. For example, the experimental manipulation did not impact pre-ejection period (PEP) reactivity, $F(2,46) = 1.42$, $p = .252$, which indexes the contractile force of the heart and is related to sympathetic nervous system activation.

In this study physiological and attentional outcomes were not independent. Participants who demonstrated more adaptive physiological responses also exhibited reduced threat-related attentional bias. However, caution must be exercised when making conclusions regarding the causality of this relationship from the data presented here. For instance, reappraisal could have altered physiological responding, which via feedback and/or embodiment processes may have reduced attentional bias. Or reductions in attentional bias could have produced the improvements in physiological outcomes (e.g., Dandeneau, Baldwin, Baccus, Sakellaropoulo, & Pruessner, 2007). There also exists the possibility that a third variable could have affected both. Future work is needed to disentangle the association between physiological reactivity and attentional bias.

Another interesting avenue for future research is the exploration of the physiological and cognitive benefits of reappraising arousal for the treatment of disorders involving acute stress. This avenue of research is especially promising given the work on panic disorder. For example, repeatedly exposing individuals to panic-inducing sensations (e.g., dizziness) and teaching them to accept (rather than suppress) their affective responses improves outcomes (Craske, Rowe, Lewin, & Noriega-Dimitri, 1997). However, research has not observed concurrent changes in physiological reactivity with this interoceptive exposure (Levitt, Brown, Orsiollo, & Barlow, 2004). It is our hope that disorders directly tied to the experience of acute social stress may benefit from reappraisal interventions. Also, although one must always exercise caution when comparing results across experiments, it is interesting to note that the effect of reappraisal on attentional bias observed here (reappraisal vs. attention reorientation, $d = .59$) is in-line with effects from studies with clinically anxious individuals (e.g., attention retraining vs. attention control, $d = .42$; Amir et al. 2008, Experiment 1). Moreover, the experimental procedures such as those used here may help clinical researchers test the cognitive and physiological mechanisms of change in psychological interventions (Kazdin & Nock, 2003).

Finally, future work should examine the translational implications of this research. The medical literature suggests that preventative methods are more effective than curative treatments (Leaf, 1993). That is, forestalling the development of disease is preferred, both in terms of resources and outcomes, to treatments that focus on alleviating symptoms. In this research simple reappraisal instructions were sufficient to impact both physiological and cognitive responses. Given that adaptive responses to acute stress improve our ability to cope with future stressors (Dienstbier, 1989) health education programs might seek to educate students about the functionality of stress in an effort to break the link between physiological arousal and negative appraisals.

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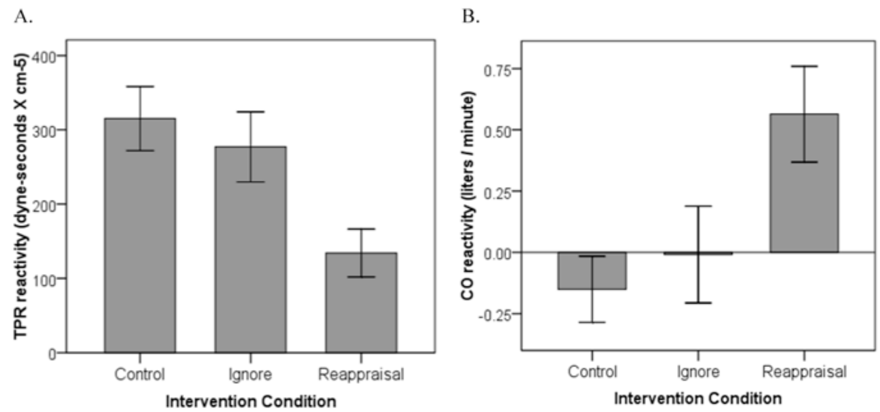

Figure 1.
(A) Total Peripheral Resistance (TPR) reactivity as a function of intervention condition. (B) Cardiac Output (CO) reactivity as a function of intervention condition. Higher values indicate increases from baseline to TSST. Error bars represent +/− standard error of the mean.

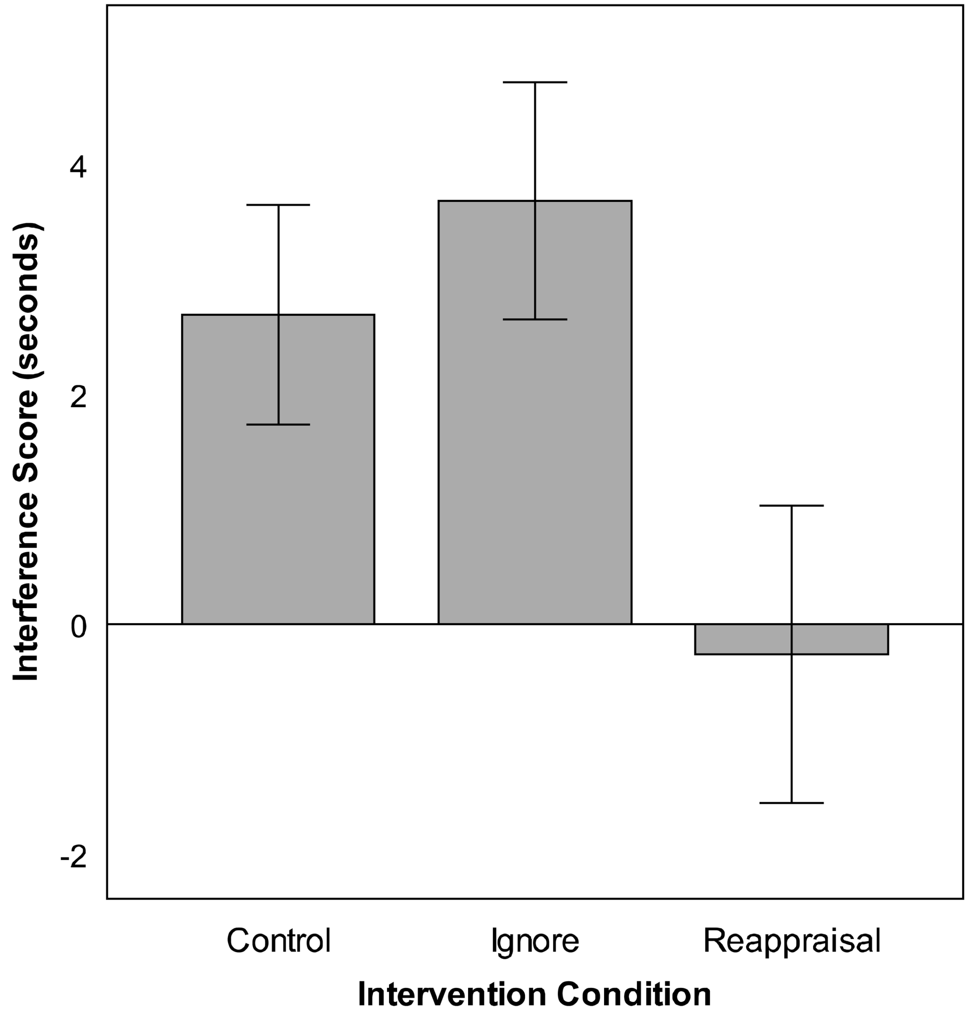

Figure 2.
Interference scores as a function of intervention condition. Higher values indicate greater attentional bias for emotionally-negative information. Error bars represent +/− standard error of the mean.