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FlashReport

Cytokine responses and math performance: The role of stereotype threat and anxiety reappraisals

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HIGHLIGHTS

- Female college students take a math exam described as gender-fair or gender-biased.
- In one condition, participants directed to reappraise physiological arousal.
- Performance on math exam and post-exam levels of the cytokine IL-6 were measured.
- Reappraisal of physiological arousal buffers inflammatory responses to exam across conditions.
- Reappraisal of arousal especially effective buffer of inflammatory responses in stereotype threat condition.

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ABSTRACT

This research independently manipulated two potential attenuators of stereotype threat – reappraisal of anxiety and test framing – to explore their independent and combined effects. Female participants took a difficult math exam that was described as gender-biased or gender-fair and were told that anxious arousal could positively impact performance or were given no information regarding arousal. Levels of the cytokine Interleukin-6 (IL-6), an immune marker of inflammation, were measured in oral mucosal transudate (OMT) both before and after the exam. Our findings indicate that directing reappraisal of physiological arousal attenuated increases in IL-6 across test framing conditions, and was especially effective under stereotype threat (i.e., gender-biased test condition). Reappraisal also mapped onto better test performance in the threat condition. Together, these findings provide insight into the unique and interactive effects of two situational interventions meant to reduce stereotype threat, indexed here by both physiological and performance-based correlates of threat.

Introduction

A widely shared stereotype in our society alleges that women possess weaker mathematical abilities than men (Cheryan, Plaut, Davies, & Steele, 2009; Swim, 1994). Women risk being judged by this stereotype and worry that they will confirm negative stereotypes when performing math tasks; such gender-based stereotype threat has been linked to anxiety, cognitive resource depletion, and underperformance (e.g., Johns, Schmader, & Martens, 2005; Mendoza-Denton, Kahn, & Chan, 2008).

Prior research has shown that reappraising anxious arousal as beneficial to performance yields better performance and more adaptive physiological responses relative to providing no reappraisal instructions (Jamieson, Mendes, Blackstock, & Schmader, 2010; Jamieson, Nock, & Mendes, 2012). Targets of negative stereotypes may be especially likely to benefit from reappraisal, given the heightened state of anxiety and physiological arousal inherent to the experience of stereotype threat (Schmader, Johns, & Forbes, 2008). Indeed, Johns, Inzlicht, and Schmader (2008) observed benefits of reappraising anxiety on test performance among participants under stereotype threat; however, to our knowledge no research has addressed whether reappraisal strategies also reduce the physiological consequences associated with stereotype threat. We fill this gap in the literature by experimentally testing whether reappraisal of anxiety, specifically among women in math contexts, diminishes both performance impairments and increases in a marker of inflammation associated with stereotype threat.

In this research we specifically focused on the effects of reappraisal on the pro-inflammatory cytokine Interleukin-6 (IL-6). Pro-inflammatory cytokines such as IL-6 are critical for orchestrating the body's inflammatory response, which is crucial to fighting injury or infection (Parkin & Cohen, 2001; Segerstrom & Miller, 2004). However, if the inflammatory response becomes persistent or exaggerated it can lead to a host of diseases and health conditions. Inflammation is increasingly recognized as a risk factor for illnesses such as cardiovascular disease, autoimmune

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disorders, and some cancers (Cesari, Penninx, & Newman, 2003; Nathan & Ding, 2010).

Prior research (e.g., Dickerson, Gable, Irwin, Aziz, & Kemeny, 2009; Murali, Hanson, & Chen, 2007) suggests shifts in inflammatory cytokine levels in response to situational stressors (e.g., taking an exam). While IL-6 in particular can exert both inflammatory and anti-inflammatory effects (Scheller, Chalaris, Schmidt-Arras, & Rose-John, 2011), prior research characterizes increases in IL-6 specifically in response to a stressor as signaling an inflammatory response (Dickerson et al., 2009; John-Henderson, Rheinschmidt, Mendoza-Denton, & Francis, 2014; Slavich, Way, Eisenberger, & Taylor, 2010). In this research, we assessed changes in IL-6 in oral mucosal transudate (OMT). While levels of inflammatory cytokines in OMT are not a reflection of systemic inflammation, which is assessed through blood (Fernandez-Botran, Miller, Burns, & Newton, 2011), inflammatory markers in OMT have been shown to be affected by acute situational stressors (Chiang, Eisenberger, Seeman, & Taylor, 2012; John-Henderson et al., 2014; Slavich et al., 2010).

Method

Participants and procedure

Ninety-seven female undergraduates at UC Berkeley participated for partial course credit. Their ages ranged from 18 to 35 years ($M = 20.88$, $SD = 2.77$), and the ethnic composition was 53.6% Asian, 21.6% White, 16.4% Hispanic, .06% other, and .02% African American.

This study crossed previously published manipulations of stereotype threat (Spencer, Steele, & Quinn, 1999) and reappraisal of anxiety (Jamieson et al., 2010). We manipulated stereotype threat by following the exact procedure of Spencer et al. (1999). More specifically, we described the math exam as a test of intellectual ability for solving math problems that had or had not produced gender differences in performance. We also varied whether participants received reappraisal instructions or no information about reappraisal. Using the wording of Jamieson et al. (2010), the reappraisal instructions encouraged participants to view arousal and anxiety as helpful to test performance. Participants were randomly and independently assigned to condition. Participants provided samples of oral mucosal transudate (OMT) at three time points (baseline, post-exam, and recovery) to assess changes in IL-6 in response to the experimental manipulations. The experimenters were blind to participants' condition, as all manipulations occurred via paper-based instructions embedded in the math examination packet. Participants were given 30 min to complete the test.

Measures

Test performance

We measured the number of correct responses on a 17-item math exam modeled after the Graduate Record Examination ($M = 11.6$, $SD = 4.3$).

Inflammation measures

We assessed IL-6 levels in OMT. Participants provided a baseline OMT sample for IL-6 measurement upon arrival to the lab ($M = .45$ pg/mL, $SD = .30$). An OraSure collection device (Epitope, Beaverton, OR) was placed between the lower cheek and gum for 2 min. The exam lasted for 30 min, after which a second sample of OMT was taken using the same method to assess changes in IL-6 ($M = 1.98$ pg/mL, $SD = 2.52$). A third, final sample was taken 30 min after the second sample to gauge recovery ($M = 1.82$ pg/mL, $SD = 2.44$).

All OMT samples were immediately frozen and stored at −80°°C. IL-6 concentrations were determined by an enzyme-linked immunosorbent assay using commercially available kits (R&D systems, Minneapolis, MN). The intra-assay coefficient of variation (CV) was 6.5% and the inter-assay CV was 8.7%. Shapiro–Wilk tests (Shapiro & Wilk, 1965) revealed that IL-6 values at each time point were not normally distributed (baseline: $W = .91$, $p < .001$, post-exam: $W = .67$, $p < .001$, recovery: $W = .65$, $p < .001$). Thus, following prior research (John-Henderson, Jacobs, Mendoza-Denton, & Francis, 2013) we added a constant of one to all raw values (see Osborne, 2002) before applying a log-transformation to IL-6 values. In addition to measuring IL-6 levels, we measured levels of total protein in each OMT sample using the BCA protein assay with bovine serum albumin as the standard (Thermoscientific, Rockford, IL) to control for individual differences in salivary flow rate (Dickerson, Kemeney, Aziz, Kim, & Fahey, 2004). Salivary flow rate was specific to each sample timepoint, given documented fluctuations in these rates under acute stress (Bakke et al., 2004). All total protein samples were run in triplicate following kit instructions.

Body mass index (BMI)

Given its relationship with levels of IL-6 in previous research (Khaodhiar, Ling, Blackburn, & Bistrian, 2004), we calculated participants' BMI ($M = 21.96$, $SD = 3.10$) from their self-reported height and weight for use as a covariate in the IL-6 analyses.

Results

IL-6 reactivity

We conducted a general linear model analysis predicting IL-6 levels as a function of the sample timepoint (3 within-participant levels: baseline, post-exam, recovery) and our between-participant factors of test framing (2 levels: gender-biased, gender-fair) and reappraisal instructions (2 levels: instructions, no instructions). We contrast-coded condition assignments prior to analyses (for reappraisal instructions: −.5 = no mention of arousal, .5 = arousal helps performance; for test framing: −.5 = gender-fair, .5 = gender-biased). We included total protein levels at each timepoint and BMI as covariates; all were mean-centered. Based on Mauchly's test of sphericity, $\chi^2(2) = 42.79$, $p < .001$, we applied a Greenhouse–Geisser correction ($\varepsilon = .72$) to estimate our overall effect more conservatively. We report adjusted degrees of freedom below.

Our analysis revealed the predicted 3-way interaction of time, test framing, and reappraisal instructions, $F(1.43, 121.50) = 10.25$, $p < .001$ $\eta_p^2 = .11$.[1] BMI accounted for a significant amount of variance between participants, $F(1, 85) = 4.39$, $p = .04$, $\eta_p^2 = .05$, but total protein levels at baseline, post-exam, and recovery did not, p's > .34, all $\eta_p^2 < 01$. We broke down the 3-way interaction by looking at the effects of reappraisal instructions within test framing condition. Specifically, we examined whether changes in IL-6 could be characterized by linear and/or quadratic trends over time as a function of reappraisal condition.

In the gender-biased test condition, we observed a significant simple interaction between time and reappraisal instruction condition $F(1, 85) = 59.75$, $p < .001$, $\eta_p^2 = .41$, for the linear effect of time, and $F(1, 85) = 65.32$, $p < .001$, $\eta_p^2 = .44$, for the quadratic effect of time. We conducted simple comparisons at each timepoint to identify significant differences in IL-6 levels by reappraisal condition, applying a Bonferroni correction to reduce Type 1 error. As illustrated in Panel A of Fig. 1, these comparisons indicate no IL-6 differences at baseline, $F(1, 85) = 1.17$, $p = .28$, $\eta_p^2 = .01$. However, women in the reappraisal instruction condition (vs. no instructions condition) had significantly lower levels of IL-6 during the post-exam, $F(1, 85) = 61.30$, $p < .001$, $\eta_p^2 = .42$, and recovery periods, $F(1, 85) = 54.15$, $p < .001$, $\eta_p^2 = .39$.

In the gender-fair test condition, we observed a significant simple interaction between time and the reappraisal instruction manipulation, $F(1, 85) = 6.85$, $p = .01$, $\eta_p^2 = .08$, for the linear effect of time, and $F(1, 85) = 6.32$, $p = .01$, $\eta_p^2 = .07$, for the quadratic effect of time.

[1] We confirmed that our models hold when using age, subjective general health, current illness (1 = yes; 0 = no), and chronic health conditions (1 = yes; 0 = no) as covariates. Further, we repeated the analyses while excluding anyone with a physical illness and/or chronic health condition, and our results hold.