Threatening the Heart and Mind of Gender Stereotypes:

Can Imagined Contact Influence the Physiology of Stereotype Threat?

Ben Allen

Dissertation submitted to the faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

In

Psychology

Bruce H. Friedman, Chair

Danny K. Axsom

Martha A. Bell

David W. Harrison

Thomas H. Ollendick

Copyright 2012, Ben Allen

Threatening the Heart and Mind of Gender Stereotypes:

Can Imagined Contact Influence the Physiology of Stereotype Threat?

Ben Allen

Abstract

Research shows that when a gender stereotype is made salient and the target of the stereotype is asked to perform in the stereotyped domain, targets of the stereotype often perform at a lower level compared to situations when the stereotype was not made salient (Spencer, Steele, & Quinn, 1999). Current models of stereotype threat show that increased physiological arousal and reduced working memory capacity partially explain this decrement in performance (Ben-Zeev, Fein, & Inzlicht, 2005; Schmader, Johns, & Forbes, 2008). Furthermore, the noticeable absence of female faculty and students in math and science departments at coed universities throughout the United States may increase the belief in gender stereotypes and discourage women from pursuing careers in these fields (Dasgupta & Asgari, 2004). Contact with counter-stereotypical exemplars, such as female science experts, decreases belief in gender stereotypes and increases women's motivation to pursue careers in science (Stout, Dasgupta, Hunsinger, & McManus, 2011). Thus, the present study examined whether imagining an interpersonal interaction with a counter-stereotypic exemplar removes the physiological and performance effects of stereotype threat. However, the stereotype threat manipulation failed to elicit a strong stereotype threat effect on performance or physiology. Only reaction time and high frequency heart rate variability were sensitive to the stereotype threat induction. The imagination manipulation significantly attenuated the physiological effects of stereotype threat, whereas the reaction time effects were only marginally significant. Limitations and future directions for stereotype threat and imagined contact are discussed.

ACKNOWLEDGEMENTS

I would like to recognize my mentor, Dr. Bruce Friedman.

I would also like to thank Carmen Dove, Katherine Magruder, Anarkali Morrill, and Jessica Worthen who assisted with data collection.

DEDICATION

I dedicate this dissertation to Kristy, Lori, and Mae.

TABLE OF CONTENTS

List of Figures

List of Tables

Introduction

Throughout history, women have been underrepresented in science and engineering. During the last 80 years of the 20^{th} century, men received 79% of the PhD's in science and engineering (Thurgood, Golladay, & Hill, 2006). The gender disparity in science and engineering has decreased in recent years, yet it remains substantial. Between the years 1990 and 1999, men received 68% of the PhD's awarded in science and engineering (Thurgood et al., 2006). Many factors contribute to this inequity; the primary objective of the current study is to examine this disparity from a social neuroscience perspective.

Several social psychologists have proposed that negative stereotypes, such as men having greater mathematical ability compared to women, might partially explain the gender disparity in these fields (e.g., Davies, Spencer, Quinn, & Gerhardstein, 2002). Research shows that when a stereotype is made salient and the target of the stereotype is asked to perform in the stereotyped domain (e.g. asking a woman to complete a "gender-biased" math test), targets of the stereotype often perform at a lower level compared to situations when the stereotype was not made salient (Steele & Aronson, 1995; Spencer, Steele, & Quinn, 1999). Current models of stereotype threat also show that increased physiological arousal and reduced working memory capacity at least partially explain this performance decrement (Ben-Zeev, Fein, & Inzlicht, 2005; Schmader, Johns, & Forbes, 2008). Furthermore, inductions of stereotype threat elicit cardiovascular profiles indicative of threat and neural activity associated with physical and emotional distress (Blascovich, Spencer, Quinn, & Steele, 2001; Eisenberger, Lieberman, & Williams, 2003; Wraga, Helt, Jacobs, & Sullivan, 2007).

In addition to the way in which stereotype threat affects physiology and performance, many researchers have focused on moderators of stereotype threat. One such moderating factor is the amount of positive interpersonal contact the target of a stereotype has with members of the group who have an implied benefit from the stereotype. For example, the more interpersonal contact (i.e. direct contact) elderly people have with grandchildren, the less stereotype threat diminishes their performance on a test of intellectual ability (Abrams et al., 2008). Furthermore, elderly people who were instructed to imagine a positive encounter with a young person (i.e. imagined contact) were subsequently unaffected by stereotype threat as well (Abrams et al., 2008). Mediation analyses show that these findings were partially caused by a reduction in state anxiety, suggesting that physiological stress may have been reduced as well. Thus, a fruitful extension and replication of this research might explore a similar intervention for a different stereotyped group while collecting indices of the physiological stress response.

Women are a likely candidate for an imagined contact intervention because of the abundance of gender stereotypes, such as women being inferior to men in the domains of math, science, and engineering. Recently, a study of more than 30 countries found that the nationwide prevalence of gender stereotypes regarding math and science predicted national differences between 8th grade boys and 8th grade girls on standardized tests of math and science (Nosek et al., 2009). Moreover, the noticeable absence of female faculty and students in science, math, and engineering departments at coed universities throughout the United States increases the belief in these stereotypes and discourages women from pursuing careers in these fields (Dasgupta & Asgari, 2004). Conversely, contact with counter-stereotypical exemplars, such as female science experts, decreases belief in gender stereotypes and increases women’s motivation to pursue careers in science (Stout, Dasgupta, Hunsinger, & McManus, 2011). However, increasing the prevalence of women in university science, math, and engineering departments is a difficult and slow process. Imagined contact with female science, math, or engineering experts may serve as a temporary and inexpensive surrogate for direct contact by reducing the effects of gender stereotypes and motivating women to pursue careers in science, math, and engineering. Thus, the present study examined the effects of an imagined contact procedure on both the physiological and performance effects of stereotype threat.

Stereotypes and Threatened Performance

The word *stereotype* comes from the Greek words *stereos typos* meaning "solid impression" which originally referred to a metallic impression of a typographical element used during the printing process (Harper, 2010; Hodgson, 1820). Walter Lippmann (1922) later used the word stereotype as a metaphor for the mental impressions held by humans that approximate common characteristics of certain social groups. *Stereotype threat* results from an intimidating situation in which a stereotype becomes salient while the target of the stereotype is performing in the stereotyped domain (Steele & Aronson, 1995). One of the results of these threatening situations is impaired performance in the stereotyped domain. For example, Blacks are often stereotyped as having a lower intellectual ability compared to Whites. In a seminal study by Steele et al., (1995), when told they were taking a test diagnostic of their intelligence, Blacks performed poorly on the test relative to Blacks who were told the test was non-diagnostic. Women have exhibited similar performance decrements when told they are taking a "gender-biased" math test (Spencer, Steele, & Quinn, 1999).

Beyond demonstrating the effects of stereotype threat, researchers have tested mediation models of the resulting performance impairment. One probable mediator of the performance decrements during stereotype threat is physiological arousal resulting from activation of the hypothalamic pituitary adrenal (HPA) axis and the sympathetic nervous system (SNS) (Schmader, Johns, & Forbes, 2008). For example, the inverted-U function of arousal and performance suggests that excessive activation of the sympathetic nervous system and release of cortisol from the adrenal cortex serves to impede performance on difficult tests of executive function but improves performance on easier tests (Lupien & McEwen, 1997; Elzinga & Roelofs, 2005). Supporting this curvilinear relationship between HPA / SNS activation and performance, manipulations of stereotype threat actually improve performance on easy tests within a stereotyped domain and hinder performance when the tests are difficult (Ben-Zeev, Fein, & Inzlicht, 2005; O'Brien & Crandall, 2003). These findings support the notion that stereotype threat induces physiological arousal, which interferes with performance in the stereotyped domain resulting in relatively poorer performance. Therefore, a model of how HPA / SNS activation interferes with performance during stereotype threat may provide a biological criterion for interventions intended to reduce stereotype threat.

A Comprehensive Psychophysiological Model of Stereotype Threat

The biopsychosocial model (BPS) argues that task performance in situations evaluated as challenging vs. threatening produce distinct cardiovascular profiles of motivation (Blascovich & Mendes, 2010). People who evaluate their situations as *threatening* exhibit increased vascular resistance and decreased cardiac efficiency, whereas people who evaluate their situations as *challenging* exhibit increased cardiac efficiency and decreased vascular resistance. The BPS model is based upon Dienstbier's (1989) model of psychophysiological toughness, which states that situations evaluated as threatening elicit increases in both cortisol and catecholamines by the hypothalamus, whereas challenging situations only lead to an increase in catecholamines and sympathetic nervous system activity. For example, women under stereotype threat during performance on a difficult math test exhibited cardiovascular profiles of threat, whereas women in a non-threatening control condition exhibited cardiovascular profiles of challenge (Vick, Seery, Blascovich, & Weisbuch, 2008). These findings support the notion that cardiovascular psychophysiology is a viable approach to studying the arousal component of stereotype threat.

However, the BPS model has focused primarily on indices of alpha and beta-adrenergic sympathetic activity and has neglected the valuable contribution parasympathetic vagal withdrawal may offer when distinguishing cardiovascular profiles of threat. Recent research shows activation of both alpha and beta-adrenergic receptors in the brain stem during states of stress and arousal also increases inhibition of cholinergic cardiac vagal neurons in the nucleus ambiguus via GABAergic and glycinergic neuromodulation (Bateman, Boychuk, Philbin, & Mendelowitz, in press; Boychuk, Bateman, Philbin, & Mendelowitz, 2011). Reduced cardiac vagal outflow functionally removes the parasympathetic brake from the heart and allows inherently faster cardiac pacemaker rhythms to increase heart rate (Porges, 2007). Support for the notion that vagal modulation of the heart decreases during stressors such as stereotype threat comes from research looking at high frequency heart rate variability (HRV) which approximates the functional result of cardiac vagal efferents upon the heart (Grossman & Taylor, 2007). One prior study has demonstrated reduced HRV under stereotype threat, and that increased vagal withdrawal during stereotype threat statistically mediated impaired performance on a test of cognitive ability (Croizet et al., 2004). Furthermore, HRV is a sensitive marker of perceived threat (Elliot, Payen, Brisswalter, Cury, & Thayer, 2011), variation in mental workload (Thayer, Hansen, Saus-Rose, & Johnsen, 2009), and performance on tests of executive function (Hansen, Johnsen, & Thayer, 2003). Together, these findings suggest that measures of both cholinergic cardiac vagal activity and traditional measures of beta and alpha-adrenergic sympathoexcitation might complement one another and form a more complete psychophysiological model of stereotype threat.

Imagined Contact with Counter-Stereotypical Group Members

In addition to contributing a biological metric of arousal during stereotype threat, a comprehensive psychophysiological model also enables an objective, real-time assessment of whether moderators of stereotype threat affect physiological arousal during performance in a stereotyped domain. One interesting moderator of stereotype accessibility, and therefore stereotype threat, is exposure to counter-stereotypical exemplars. For example, women who attend predominantly female colleges and frequently encounter women in leadership positions also exhibit lower levels of gender stereotypes (i.e., men are more apt than women for leadership positions; Dasgupta & Asgari, 2004). Furthermore, women who read biographies of famous women in leadership positions subsequently reported lower levels gender stereotypes compared to women who read facts about flowers (Dagsupta et al., 2004). These findings suggest that those stereotyped individuals who have frequent contact with counter-stereotypical exemplars might not be as affected by stereotype threat compared to individuals who have infrequent contact with counter-stereotypical exemplars.

There are several ways to test the notion that contact with counter-stereotypical exemplars can ameliorate the physiological arousal and/ or performance decrements associated with stereotype threat. One indirect method might include passive exposure to vignettes of biographies describing counter-stereotypical exemplars (Dasgupta & Asgari, 2004). However, a more active approach toward manipulating contact with counter-stereotypical exemplars is a procedure known as *imagined contact*. Imagined contact entails having an imagined interpersonal interaction with a member of an infrequently encountered group (Crisp, Stathi, Turner, & Husnu, 2009). Imagined contact often results in temporary effects similar to actual contact, such as reduced intergroup anxiety and reduced intergroup bias (Turner, Crisp, & Lambert, 2007).

Preliminary evidence supports the notion that imagined contact is capable of *inoculating* the elderly from the stereotype that intellectual performance declines with age. In a study by Abrams et al., (2008), the effects of stereotype threat were diminished in elderly people who had frequent contact with grandchildren. The effects of stereotype threat were also reduced in elderly people who imagined having a social interaction with a young person, relative to elderly people who imagined a nature scene. Furthermore, reduced self-reported anxiety mediated the improved performance that resulted from the imagined contact procedure. The notion that imagined contact can reduce anxiety suggests physiological stress responses may also be attenuated in situations relevant to the imagined scene. Thus, the present study examined the utility of a similar imagined contact procedure to inoculate women from the performance *and* physiological effects of stereotype threat.

Hypotheses

The central goal this experiment was to test the ability of imagined contact with a counter-stereotypical exemplar to inoculate women from the threat of gender stereotypes. Research has shown contact with counter-stereotypical exemplars (e.g. female math professors) reduces women's reports of gender stereotypes (Blair, 2002; Dagsupta & Asgari, 2004). Thus, the imagined contact scenario used to inoculate a gender stereotype (e.g., women are less apt at science, math, & engineering) will entail an interpersonal interaction with a woman described as a math professor.

Hypothesis #1 & 2: Women who briefly imagine interacting with a counter-stereotypical exemplar can reduce the performance impairments and physiological arousal associated with stereotype threat:

1. Imagining a counter-stereotypical exemplar would increase accuracy, decrease reaction time, and increase working memory capacity relative to imagining a nature scene
2. Imagining a counter-stereotypical exemplar would increase cardiac output with no change in total peripheral resistance relative to imagining a nature scene

The first hypothesis was based upon the notion that decreased working memory capacity is one of the proposed mechanisms through which stereotype threat impairs performance in the stereotyped domain (Schmader, Johns, & Forbes, 2008). This hypothesis was tested by measuring performance within an n-back paradigm, which is a type of working memory task that taxes executive function (Carpenter, Just, Reichle, 2000). The second hypothesis was tested by concurrently measuring impedance cardiography (ICG) and blood pressure (BP). ICG allows the estimation of cardiac output and pre-ejection period, metrics of cardiac efficiency and beta-adrenergic influences at the heart. The combination of metrics derived from ECG, ICG, and BP contributed to the assessment of cardiovascular profiles indicative of threat (Blascovich, Spencer, Quinn, & Steele, 2001).

The second aim of the current study was to develop a more comprehensive psychophysiological model of stereotype threat through the examination of cardiac vagal control.

While the second aim was exploratory, cardiac vagal activity withdrawal associated with a stereotype threat induction was hypothesized to be reduced when preceded by imagining a counter-stereotypical exemplar relative to imagining a nature scene

Method

Subjects

Non-smoking, right handed women (N=130; *M* = 19.53 years old, S.E. = .20) were recruited using SONA at Virginia Tech and awarded extra credit in an undergraduate psychology course. Handedness was confirmed via self-report on a laboratory questionnaire. Only right handed subjects were recruited to control for any possible differences between handedness and performance on the imagination or n-back task. Subjects were asked via email to abstain from alcohol at least twenty-four hours and refrain from caffeine at least twelve hours prior to the experiment; and to avoid eating and rigorous exercise at least one hour before the experiment. All experimental methods were approved by the local institutional review board.

Questionnaires

All subjects provided written informed consent before the study began. A mental and physical health questionnaire was administered on a computer at the beginning of the study. Self-reported height and weight were used to calculate body mass index (BMI), which was computed as weight (kg) ÷ [height (m)^2]. The average BMI for the sample was within the normal range (*M* = 22.30, S.E. = .25). Following the experiment, all subjects were full debriefed.

Apparatus

Task instructions, questionnaires, and stimulus presentation for each task was displayed using DMDX presentation software (Forster & Forster, 2003). Impedance cardiography, electrocardiography, and blood pressure were recorded using a BIOPAC MP150 system (BIOPAC Systems Inc, Goleta, CA). All raw signals were digitized at 1,000 Hz and analyzed with BIOPAC AcqKnowledge software 4.1 (BIOPAC Systems Inc, Goleta, CA).

ECG measures the electrical activity of the heart from the surface of the skin. ECG was recorded using two thoracic electrodes placed in a modified II lead configuration. ECG is necessary to derive inter-beat intervals and subsequent spectral analysis for estimation of heart rate (HR) and heart rate variability (HRV), respectively.

ICG was collected using a four spot impedance electrode array. ICG quantifies blood flow through the thorax, from which cardiac output (CO), stroke volume (SV), and pre-ejection period (PEP) can be derived (Sherwood et al., 1990).

Data Reduction

Inter-beat intervals (IBI) were defined as the time in milliseconds between consecutive R spikes derived from the ECG. The time-series of inter-beat intervals was band-pass filtered within the normative respiratory frequency range (0.15 – 0.40 Hz) and the natural log of the variance was extracted to estimate cardiac vagal control (Allen, Chambers, & Towers, 2007). The time-series of inter-beat intervals was also band-pass filtered within what is known as the frequency range (0.04 – 0.12 Hz) and the natural log of the variance was extracted. Stroke volume (SV) was quantified from the dZ/dT waveform from the ICG following Kubicek's formula (Kubicek, et al, 1974). Cardiac output (CO) was quantified as the product of HR and SV. PEP was calculated from the time between the onset of the Q wave and the B point of the dZ/dt (Lozano et al., 2007; Sherwood et al., 1990). Mean arterial pressure (MAP) was calculated as = 2/3 DBP + 1/3 SBP (Nyklicek, Thayer, & Van Doornen, 1997), which is mathematically equivalent to other formulas used to calculate MAP (e.g., DBP + [(.333)*(SBP-DBP)]. Total peripheral resistance (TPR) was quantified as MAP / CO.

To assess the effects of the current study's manipulations within the framework of the biopsychosocial model of challenge and threat appraisal (Blascovich & Mendes, 2010), a unitary metric of challenge and threat was calculated. This metric was computed as the difference between normalized reactivity scores for total peripheral resistance and normalized cardiac output (zCO – zTPR). Reactivity scores were calculated as the average values for the first two minutes of the n-back task minus the average of the last two minutes of the baseline period. The resulting metric is thought to differentiate physiological profiles of challenge and threat, with positive scores representing challenge states and negative scores representing threat states.

Procedure

Upon arrival to the laboratory, subjects were greeted by a female experimenter, seated in a sound and light attenuated room, and provided a written informed consent document. The experimenter then connected the subject to the physiological recording equipment. Following completion of the questionnaires, the subject engaged in five tasks in a fixed sequence (see Figure 1): 10-minute vanilla baseline, imagination task (≈ 3-minutes), stereotype threat manipulation (≈ 1-minute), working memory task (≈ 7-minutes; see Fig. 2), and 10-minute recovery (tasks described in detail below; some of the durations are approximate because task instructions were paced by the subjects). Subjects were randomly assigned without replacement to a control (n = 41) or stereotype threat condition (n = 89). Subjects in the control condition all completed the imagined nature scene task. Subjects in the stereotype threat condition were randomly assigned without replacement to either the imagined nature scene condition (n = 44) or the condition in which they imagined an interpersonal interaction with a female math professor (n = 45). Physiological signals were collected continuously throughout the experiment and analyzed offline.

Acclimation to the experimental environment was achieved using a 10-minute vanilla baseline to capture a stable and controlled physiological state for later calculation of physiological reactivity (Jennings, Kamarck, Stewart, Eddy, & Johnson, 1992). The vanilla baseline stimuli consisted of a 10 x 12 cm rectangle displayed on a computer screen that changed color every 10 seconds. Six different colors were presented randomly with equal probability (red, green, yellow, blue, purple, and white). Subjects were asked to count the number of times a randomly selected color appears and to report this number at the end of the 10-minutes.

The imagined contact instructions included two between-subjects levels: imagined nature scene (i.e., control condition) and imagined contact (Crisp, Stathi, Turner, & Husnu, 2009). The imagined nature scene condition included instructions to imagine a pleasant outdoor scene: “We would like you to take a minute to imagine an outdoor scene. Try to imagine aspects of the scene (e.g., is it a beach, a forest, are there trees, hills, what’s on the horizon).” Following the imagined task, subjects were be asked to “list the different things that you saw in the scene you just imagined.” The imagined contact condition with a female math professor included instructions to imagine a positive social interaction: “We would like you to take a minute to imagine yourself meeting a female math professor for the first time. Imagine that the interaction is positive, relaxed and comfortable.” Following the imagined task, subjects were asked to “list the different ways in which you could classify the female math professor following the conversation you imagined.”

The stereotype threat manipulation included two between-subjects levels: stereotype-relevant and stereotype-irrelevant (i.e., control condition; Spencer, Steele, & Quinn, 1999). The first portion of the task instructions was the same across conditions: “As you may be aware, there has been some controversy surrounding the issue of whether there are gender differences in math ability. Previous research has sometimes shown gender differences and sometimes shown no gender differences. We are developing some new tests that we are evaluating across a large group of Virginia Tech students. The task you are about to complete is a memory test related to mathematical and cognitive ability." Subjects in the stereotype-relevant condition were instructed further as follows: "In the past, this task has been shown to produce gender differences. Please indicate your gender by pressing 'M' for male or 'F' for female." Subjects in the stereotype-irrelevant condition were instructed further as follows: "In the past, this task has not been shown to produce gender differences."

Performance on a visuospatial n-back task was used to quantify the effects of the stereotype threat and imagined contact manipulations upon performance. Each trial of the n-back task began with the presentation of cross hairs located in the center of a computer screen for 500ms followed by the presentation of a green square in one of eight different locations on a black computer screen (500 ms stimulus presentation, 2,500 ms inter-stimulus interval; see Figure 2). Subjects were required to respond via a button press whether the presented square matches or does not match the stimulus presented *n* presentations ago. Subjects used their right middle and index fingers to make "match" and "no-match" responses on a 1000 Hz ultra-polling keyboard. To increase the difficulty of the task, the value of *n* was adapted according to performance within each block of 20 trials. The level of *n* increased by 1 when performance is 70% or greater and *n* decreased by 1 when performance is less than 70%.

Data Analytic Plan

Performance on the n-back was investigated by running separate repeat-measures ANOVA's on the three metrics of performance: average number of trials correct per block (accuracy), average reaction time on correct trials (reaction time), and level achieved during the n-back (working memory capacity). Performance was compared within-subjects across the 0-back trials (low working memory load) and the average of the last three blocks of the n-back trials (high working memory load). The last three blocks of the n-back were chosen because with the adaptive nature of the n-back task used, working memory load should be maximized for each individual during these later blocks. Between-subjects comparisons were inspected for differences between experimental group (i.e., nature-irrelevant vs. nature-relevant, nature-relevant vs. interpersonal-relevant) in the way the different experimental groups performed on the n-back.

Similar analyses were conducted for all physiological variables. Differences in baseline physiology were first tested by comparing the three experimental groups across the 10-minute baseline trials. No significant differences between groups were found for any physiological variables. Thus, raw physiological values during the 0-back trials (low working memory load) and the average of the last three blocks of the n-back trials (high working memory load) were used in the separate repeated measures ANOVA's.

Exploratory analyses were also conducted to determine whether any of the experimental effects varied as a function of perceived influence of task instructions. This binary variable was entered as an additional between-subjects factor in the repeated-measures ANOVA's for performance and physiology.

Results

Perceived Influence of Stereotype Threat Manipulation

The effect of the stereotype threat manipulation upon perception was estimated by examining the subject's verbal responses during the debriefing process. Each subject was asked if the stereotype-relevant (or stereotype-irrelevant) instructions influenced their performance on the task. The three experimental groups significantly differed, χ^2 (2) = 6.558, *p* = .038, in the extent to which they believed the task instructions to have influenced their performance (see Table 1). Roughly half of each group that received the stereotype-relevant instructions reported the task instructions as having an influence on their performance (nature-relevant: Yes = 23, No = 21; interpersonal-relevant: Yes = 21, No = 24). The significant difference between the three groups was driven by the nature-irrelevant group, who reported significantly less influence of the task instructions (Yes = 11, No = 30). Each subject was also asked during the debriefing process how well they thought they had performed on the task, overall, on a scale of 0 to 100% correct. Regression analyses indicated no significant differences between the three groups in terms of their perceived task performance (R^2 =.01, F (1,128) = .960, *p* = .33).

Overall Performance During the N-back

Examination of the whole sample showed significant differences in accuracy, working memory capacity, and reaction time over the course of the n-back. Accuracy was significantly lower, $F(1, 129) = 611.44$, $p < .001$, during the average of the last three blocks n-back trials (*M* = 14.36, S.E. = 0.16) compared to the 0-back block of n-back trials (*M* = 18.88, S.E. = 0.10). Working memory capacity significantly increased, $F(1, 129) = 878.36$, $p < .001$, during the average of the last three n-back blocks (*M* = 3.1, S.E. = .105) compared to the initial 0-back block where the working memory capacity was fixed at zero. Reaction time was significantly longer, $F(1, 129) = 295.12$, $p < .001$, during the average of the last three n-back blocks (M = 752.23, S.E. = 15.60) compared to the 0-back block (M = 503.15, S.E. = 9.49). Together, these results affirm that the n-back task increased in difficulty over time (i.e., higher working memory capacity), and that this increase in difficulty was reflected in the reduced accuracy, as well as the increased reaction time.

Stereotype Threat and Performance During the N-back

Subsequent group analyses (i.e., nature-irrelevant vs. nature-relevant) were conducted to determine the effects of the stereotype threat manipulation on performance. Accuracy did not vary as a function of the stereotype threat manipulation, $F(1, 83) = .38$, $p = .539$. The nature-relevant group performed at a similar level of accuracy (M = 16.67, S.E. = .174) compared to the nature-irrelevant group (M = 16.60, S.E. = .176). Working memory capacity did not vary as a function of the stereotype threat manipulation either, $F(1, 83) = .003$, $p = .954$. The nature-relevant group displayed a similar working memory capacity (M = 3.02, S.E. = .19) compared to the nature-irrelevant group (M = 3.01, S.E. = .19).

The change in reaction time from the 0-back to the average of the last three n-back blocks trended toward significant differences between the two stereotype threat manipulations, $F(1, 83) = 2.88$, $p = .093$. This trend was being driven by an overall significant difference between groups in reaction time during both sections of the n-back, $F(1, 83) = 5.850$, $p = .018$. The nature-relevant group had a longer average reaction time during the n-back (M = 653.91, S.E. = 17.53) compared to the nature-irrelevant group (M = 593.58, S.E. = 17.74). These findings indicate that reaction time was the only metric of performance sensitive to the stereotype threat manipulation, with stereotype threat being associated with longer reaction times.

Imagination and Performance During the N-back

Group analyses (i.e., nature-relevant vs. interpersonal-relevant) were also conducted to determine the effects of the imagination manipulation on performance. Accuracy during the n-back was unaffected by the imagined manipulation, $F(1, 86) = .924$, $p = .339$. The nature-relevant group performed at a similar level of accuracy ($M = 16.67$, S.E. = .174) compared to the interpersonal-relevant group ($M = 16.60$, S.E. = .171). Working memory capacity was also unaffected by the imagined manipulation, $F(1, 86) = .852$, $p = .359$. The nature-relevant group displayed a similar working memory capacity ($M = 3.02$, S.E. = .19) compared to the interpersonal-relevant group ($M = 3.26$, S.E. = .17). Finally, group differences in reaction time only trended toward significance, $F(1, 86) = 2.83$, $p = .096$. The nature-relevant group ($M = 653.91$, S.E. = 18.41) displayed marginally longer reaction times compared to the interpersonal-relevant group ($M = 634.48$, S.E. = 18.00).

Overall Physiological Change During the N-back

Examination of the whole sample showed significant changes during the n-back in IBI, LF-HRV, and HF-HRV, but no changes in cardiac output, mean arterial pressure, total peripheral resistance, or pre-ejection period. IBI significantly decreased, $F(1, 98) = 11.08$, $p = .001$, during the average of the last three blocks n-back trials ($M = 808.43$, S.E. = 12.14) compared to the 0-back block of n-back trials ($M = 824.10$, S.E. = 13.03). LF-HRV significantly decreased, $F(1, 102) = 9.70$, $p = .002$, during the average of the last three blocks n-back trials ($M = 6.03$, S.E. = 0.09) compared to the 0-back block of n-back trials ($M = 6.26$, S.E. = 0.10). HF-HRV also significantly decreased, $F(1, 102) = 57.01$, $p < .001$, during the average of the last three blocks n-back trials ($M = 6.44$, S.E. = 0.10) compared to the 0-back block of n-back trials ($M = 6.83$, S.E. = 0.11). Changes in cardiac output, $F(1, 98) = .008$, $p = .930$, mean arterial pressure, $F(1, 90) =$

.205, *p* = .652, total peripheral resistance, *F*(1, 79) = .725, *p* = .397, and pre-ejection period, *F*(1, 98) = .018, *p* = .895, did not significantly change during the n-back.

Stereotype Threat and Physiology During the N-back

Subsequent group analyses (i.e., nature-irrelevant vs. nature-relevant) were conducted to determine the effects of the stereotype threat manipulation on physiological change during the n-back. Change in IBI did not vary as a function of the stereotype threat manipulation, *F*(1, 62) = 1.67, *p* = .201. The nature-relevant group exhibited similar IBI's (*M* = 814.63, S.E. = 23.01) during the average of the last three blocks n-back trials compared to the nature-irrelevant group (*M* = 818.82, S.E. = 20.81). Change in LF-HRV did not vary as a function of the stereotype threat manipulation either, *F*(1, 58) = 1.33, *p* = .253. The nature-relevant group exhibited similar LF-HRV (*M* = 5.97, S.E. = 0.13) during the average of the last three blocks n-back trials compared to the nature-irrelevant group (*M* = 6.09, S.E. = 0.14). Change in HF-HRV, however, did vary as a function of the stereotype threat manipulation, *F*(1, 58) = 7.25, *p* = .009. The nature-relevant group exhibited lower levels of HF-HRV (*M* = 6.27, S.E. = 0.16) during the average of the last three blocks n-back trials compared to the nature-irrelevant group (*M* = 6.51, S.E. = 0.15).

The absence of change during the n-back in cardiac output, mean arterial pressure, total peripheral resistance, or pre-ejection period for the entire sample was paralleled by no effect of the stereotype threat manipulation on these same variables. Cardiac output, *F*(1, 62) = 0.00, *p* = .999, mean arterial pressure, *F*(1, 50) = .534, *p* = .468, total peripheral resistance, *F*(1, 50) = .736, *p* = .395, and pre-ejection period, *F*(1, 62) = 1.03, *p* = .314, all failed to vary as a function of the stereotype threat manipulation. These findings indicate that HF-HRV was the only physiological measure sensitive to the stereotype threat manipulation, with stereotype threat being associated with a greater reduction in HF-HRV.

Imagination and Physiology During the N-back

Group analyses (i.e., nature-relevant vs. interpersonal-relevant) were also conducted to determine the effects of the imagination manipulation on physiological change during the n-back. Change in IBI did not vary as a function of the imagination manipulation, $F(1, 58) = 1.11$, $p = .297$. The nature-relevant group exhibited similar IBI's ($M = 814.63$, S.E. = 23.01) during the average of the last three blocks n-back trials compared to the interpersonal-relevant group ($M = 792.96$, S.E. = 20.97). Change in LF-HRV did not vary as a function of the imagination manipulation either, $F(1, 54) = .037$, $p = .848$. The nature-relevant group exhibited similar LF-HRV ($M = 5.97$, S.E. = 0.13) during the average of the last three blocks n-back trials compared to the interpersonal-relevant group ($M = 5.97$, S.E. = 0.21). Change in HF-HRV, however, did vary as a function of the imagination manipulation, $F(1, 54) = 4.755$, $p = .034$. The nature-relevant group exhibited lower levels of HF-HRV ($M = 6.27$, S.E. = 0.16) during the average of the last three blocks n-back trials compared to the interpersonal-relevant group ($M = 6.46$, S.E. = 0.23).

Once again, the lack of change during the n-back in cardiac output, mean arterial pressure, total peripheral resistance, or pre-ejection period for the entire sample was paralleled by no effect of the imagination manipulation on these same variables. Cardiac output, $F(1, 58) = 0.04$, $p = .834$, mean arterial pressure, $F(1, 46) = .081$, $p = .777$, total peripheral resistance, $F(1, 46) = .655$, $p = .\ 423$, and pre-ejection period, $F(1, 58) = .060$, $p = .807$, all failed to vary as a function of the imagination manipulation. These findings indicate that HF-HRV was the only physiological measure sensitive to the imagination manipulation, with nature imagination condition being associated with a greater reduction in HF-HRV.

Challenge / Threat Analysis

Physiological responses during n-back performance were analyzed using the unitary metric of challenge and threat (Blascovich & Mendes, 2010). However, in the absence of significant task effects in cardiac output and total peripheral resistance, comparison of the three experimental groups using this challenge/threat metric yielded no significant differences, $F(2, 74) = .963$, $p = .39$.

Experimental Group and Perceived Influence of Task Instructions

Exploratory analyses were conducted to determine if perceived influence of task instructions affected the relationship between the stereotype threat manipulation and task performance. No significant group (nature-irrelevant vs. nature-relevant) by perception (Yes vs. No) interaction was found for accuracy, $F(1, 80) = .049$, $p = .86$, working memory capacity, $F(1, 80) = .052$, $p = .82$, or reaction time, $F(1, 80) = 1.504$, $p = .22$. Further exploratory analyses were also conducted to determine if perceived influence of task instructions affected the relationship between the imagination manipulation and task performance. No significant group (nature-relevant vs. interpersonal-relevant) by perception (Yes vs. No) interaction was found for working memory capacity, $F(1, 83) = .207$, $p = .65$, or reaction time, $F(1, 83) = .320$, $p = .57$.

However, the imagination manipulation did interact with perceived influence of task instructions in predicting accuracy, $F(1, 83) = 3.986$, $p = .049$. Subjects who imagined a nature scene exhibited lower accuracy levels ($M = 13.94$, S.E. = .36) if they reported having been influenced by the task instructions compared to subjects in the same group who reported the task instructions had no influence on their performance ($M = 14.82$, S.E. = .44). This pattern was reversed for subjects who imagined an interpersonal interaction with a female math professor, with subjects exhibiting lower accuracy levels (*M* = 14.03, S.E. = .39) if they reported having not been influenced by the task instructions compared to subjects in the same group who reported the task instructions did influence their performance (*M* = 14.77, S.E. = .39).

Exploratory analyses were also conducted to determine if perceived influence of task instructions affected the relationship between the stereotype threat manipulation and physiology during the n-back. No significant group (nature-irrelevant vs. nature-relevant) by perception (Yes vs. No) interaction was found for IBI, $F(1, 60) = 2.376$, $p = .128$, LF-HRV, $F(1, 56) = 1.780$, $p = .187$, HF-HRV, $F(1, 56) = .052$, $p = .82$, cardiac output, $F(1, 60) = .027$, $p = .87$, mean arterial pressure, $F(1, 48) = .002$, $p = .96$, total-peripheral resistance, $F(1, 48) = 0.000$, $p = .98$, or pre-ejection period, $F(1, 60) = .004$, $p = .95$. Further exploratory analyses were conducted to determine if perceived influence of task instructions affected the relationship between the imagination manipulation and physiology during the n-back. No significant group (nature-relevant vs. interpersonal-relevant) by perception (Yes vs. No) interaction was found for IBI, $F(1, 55) = .293$, $p = .590$, LF-HRV, $F(1, 51) = .041$, $p = .839$, HF-HRV, $F(1, 51) = .107$, $p = .76$, cardiac output, $F(1, 55) = 2.75$, $p = .10$, mean arterial pressure, $F(1, 43) = .000$, $p = .98$, total-peripheral resistance, $F(1, 43) = .125$, $p = .73$, or pre-ejection period, $F(1, 55) = 1.01$, $p = .32$.

Discussion

The main goal of the current study was to test the ability of imagined contact with a counter-stereotypical exemplar to influence the effects of stereotype threat. Performance and physiological activity during a spatial working memory task were examined to test the effects of a stereotype threat manipulation, and how these effects were influenced by imagining a counter-stereotypical exemplar. Performance and physiological results are discussed below. Limitations of the experimental design, as well as implications for future investigations of imagined contact are also discussed.

Can Imagined Contact Influence the Performance Decrements of Stereotype Threat?

Stereotype threat was induced in the current study by modifying the instructions that preceded the n-back task. The stereotype-relevant condition included information that in the past the task had produced gender differences, whereas in the stereotype-irrelevant condition, the task was described as having previously not produced gender differences. The stereotype-relevant instructions were hypothesized to induce stereotype threat, and ultimately reduce performance on the n-back task. Performance was quantified as accuracy, reaction time, and working memory capacity.

Analysis of the performance data, however, suggests there may have been problems in effectively inducing stereotype threat. Performance was largely unaffected by the stereotype threat manipulation. Accuracy and working memory capacity were not significantly affected by the stereotype threat manipulation. Both the nature-irrelevant and nature-relevant groups exhibited a decrease in accuracy and increase in working memory capacity over the course of the task. However, these task effects did not vary as a function of the stereotype threat manipulation. These results are incongruent with past stereotype threat research that has demonstrated performance decrements on tests of intelligence, mathematical ability, and working memory capacity (e.g., Blascovich et al.,, 2001; Schmader et al., 2008; Spencer et al., 1999).

One possible explanation of these findings may lie in the stereotype threat manipulation. The stereotype-irrelevant and stereotype-relevant groups were both primed to some degree a mentioning of the broad topic of gender differences. Only the stereotype-relevant condition was informed that the task they were about to complete had produced gender differences, but this difference may not have been potent enough to elicit a strong stereotype threat effect. Conversely, the stereotype threat manipulation was nearly identical to manipulations used in prior work (i.e., Spencer et al., 1999).

An additional explanation for the lack of effect of the stereotype threat manipulation on performance might be the specific n-back task itself, rather than the stereotype threat manipulation. Prior research on working memory and stereotype threat have used a delayed-recall paradigm in which a collection of words are presented, a mathematical reasoning test is conducted to cause working memory interference, and finally recollection of the previously presented words is assessed (Schmader et al., 2008). The working memory task used in the present study, the n-back, included memorization and updating visuospatial sequences, with relatively no linguistic or mathematical reasoning component. A visuospatial working memory task was used because prior research shows that accuracy on visuospatial working memory tasks, but not verbal working memory task, is specifically impaired by threatening situations (Shackman et al., 2006). It is possible that stereotype threat primarily reduces accuracy on verbal and but not spatial working memory tasks.

One similarity between the present findings and prior stereotype threat research is the significant lengthening of reaction times under stereotype threat (Schmader & Johns, 2003). This aspect of performance suggests that the stereotype induction may have increased mental stress and functionally reduced processing speed. Prior work has shown that mental stressors, such as the Trier Social Stress Test (Kirschbaum et al., 1993), can increase reaction times during working memory tests, but that this effect is transient and may only last five minutes (Schoofs, Preuß, & Wolf, 2008).

The short time-course of the effects of mental stress on working memory performance (i.e., accuracy, reaction time) is important and may be related to the findings of the present study. The n-back task used in the current study was adaptive, meaning that the level of the n-back task was determined by prior performance. However, the task began with a practice block of 0-back trials and was followed by a block of 1-back trials. The difficulty of the task was likely not sufficient until the 3rd or 4th block of trials in the n-back, and this latency may have attenuated the effect of the stereotype threat on performance.

The time-course of the n-back task may also help explain the effects of the imagination manipulation on the stereotype threat manipulation. As the stereotype threat manipulation only seemed to affect reaction time, it is not surprising that the imagination manipulation had no influence on accuracy or working memory capacity. However, reaction time was significantly lengthened by the stereotype threat manipulation; yet imagining a counter-stereotypical exemplar only had marginal effects on this pattern. Imagining a counter-stereotypical exemplar was related to somewhat faster reaction times, but the petite size of this effect speaks to strength of the imagined manipulation. It is possible that by the time the n-back reached sufficient difficulty, the effects of the imagined manipulation had attenuated. These findings speak to the necessity for future studies to examine the effects of repeated imagined contact over long time periods (e.g., several weeks).

Can Imagined Contact Influence the Physiology of Stereotype Threat?

The current study also examined the physiological effects of imagining a counter-stereotypical exemplar preceding a stereotype threat manipulation. Cardiovascular measures were recorded to quantify complex patterns of physiological responding indicative of psychosocial stress, such as stereotype threat (Blascovich & Mendes, 2010; Croizet et al., 2004). Some of the hypotheses were based upon the biopsychosocial (BPS) model, which includes differential patterns of cardiovascular responding that are thought to represent subjective appraisal of task demands. However, the task used in the current study failed to elicit substantial alpha or beta-adrenergic activation of the sympathetic nervous system (SNS). SNS activation is a key component of the BPS model, and in its absence, a true test of the effects of imagined contact on stereotype threat within the BPS framework is impossible.

The single physiological metric that was sensitive to the stereotype threat manipulation was high frequency heart rate variability, a measure of cardiac vagal control. Stereotype threat was associated with reduced cardiac vagal control during the n-back task, which is consistent with prior research that suggests cardiac vagal control is a sensitive marker of threat appraisals (Elliot et al., 2011) and variation in mental workload (Thayer et al., 2009). One prior study has also shown that cardiac vagal control was reduced under stereotype threat, and that increased vagal withdrawal during stereotype threat statistically mediated impaired performance on a test of cognitive ability (Croizet et al., 2004).

In addition to being a sensitive biological marker of the stereotype threat induction, cardiac vagal control was also sensitive to the imagination manipulation. Comparison of the two groups who received a stereotype threat induction but imagined different scenarios displayed different patterns of cardiac vagal control during the n-back. Imagining an outdoor nature scene before the stereotype threat induction was related to greater vagal suppression during the n-back, compared to imagining an interpersonal interaction with a female math professor. These findings suggest the imagined interpersonal interaction may have reduced the mental effort or psychological stress related to the stereotype threat induction, as greater mental workloads are associated with greater vagal suppression (Thayer et al., 2009).

Limitations & Future Directions

As noted above, a major limitation to the present investigation was the meager stereotype threat effects. The stereotype threat induction was similar to inductions used in prior stereotype threat research (Spencer et al., 1999). However, roughly 27% of the stereotype-irrelevant group reported that the task instructions had indeed influenced their performance. Some subjects reported that they didn't want to let their gender down by doing poorly on the task. Thus, the stereotype-irrelevant instructions may have served a performance motivator, rather than a pure control condition. These differences in perception largely had no effect on the relations between the experimental manipulations and task performance / physiology. However, the intricacies of differences in the perception of task instructions may not have been fully captured by the binary Yes-No response. A future study should examine subtle differences in stereotype threat manipulations by comparing control conditions that do and do not include mentioning of the topic of "gender differences."

In addition to the stereotype threat manipulation, and possibly of greater relevance, was the n-back task itself. Results from the present study suggest stereotype threat may impair the capacity for specific forms of information in working memory, such as words, rather than sequences of spatial locations. Furthermore, the time course and low initial difficulty of the n-back may have reduced the threatening influence on performance. Future research on working memory and psychosocial stressors, such as stereotype threat, should be mindful of the type of working memory being assessed and that the performance task is high in difficulty early on to ensure that working memory performance is maximally influenced by the stressor. Specifically, a future study could compare verbal and spatial working memory tasks that systematically vary in difficulty across time.

A third limitation was the lack of a strong alpha and beta-adrenergic response during the n-back. This pattern of responding allowed for a careful examination of cardiac vagal control and stereotype threat, but a test of the effects of imagined contact within the BPS model was rendered impossible. The lack of sympathetic activation is also likely related to the small performance effects of the stereotype threat manipulation. Sympathetic activation is related to activity of the locus coeruleus–norepinephrine system, a neuromodulatory system known to influence prefrontal cortex activity and working memory processes (Nieuwenhuis, Ashton-Jones, & Cohen, 2005; Ramos & Arnsten, 2007). Stressful situations can produce an excessive increase in norepinephrine in the prefrontal cortex, leading to activation of low affinity α1 adrenergic receptors, and subsequent impairment of prefrontal cortex function (Birnbaum et al., 1999; Goldstein, Rasmusson, Bunney, & Roth, 1996). The n-back paradigm is a type of working memory task that taxes executive function (Carpenter et al., 2000); but in the absence sympathetic activation, executive function was not sufficiently impaired to result in differences in accuracy or working memory capacity. Future research on psychosocial stressors and executive function should only use tasks and experimental designs that have resulted in strong sympathetic activation.

A fourth limitation was the potency of the imagined contact manipulation. The physiological effects of the stereotype threat manipulation were attenuated by the imagined contact manipulation; however, the stereotype threat effects on reaction time were only marginally affected by the imagination manipulation. Inspection of the self-reported scenes about the imagination task included many physical characteristics of the female math professor, rather than admirable academic or professional qualities, such as having an inspiring intellect. Future studies should compare different focal points of imagined contact with counter-stereotypical exemplars (e.g., physical appearance vs. intellectual capabilities) to determine their influence on stereotype threat manipulations.

CONCLUSION

The current study examined the effects of an imagined interpersonal interaction with a counter-stereotypical exemplar on a stereotype threat induction. However, the stereotype threat manipulation failed to elicit a strong stereotype threat effect on performance or physiology. A second experiment should be conducted that uses the exact stereotype threat and working memory task that has shown the expected effects in the past (Schmader & Johns, 2003). Examining the power of imagined contact within such conditions would yield a more valid test of the hypotheses examined herein.

References

Abrams, D., Crisp, R. J., Marques, S., Fagg, E., Bedford, L., & Provias, D. (2008). Threat inoculation: Experienced and imagined intergenerational contact prevents stereotype threat effects on older people's math performance. *Psychology and Aging, 23*(4), 934-939. doi: 10.1037/a0014293

Allen, J. J. B., Chambers, A. S., & Towers, D. N. (2007). The many metrics of cardiac chronotropy: A pragmatic primer and a brief comparison of metrics. *Biological Psychology, 74*, 243–262. doi:10.1016/j.biopsycho.2006.08.005

Ax, A. F. (1953). The physiological differentiation between fear and anger in humans. *Psychosomatic Medicine, 15*(5), 433-442.

Bateman, R. J., Boychuk, C. R., Philbin, K. E., & Mendelowitz, D. β adrenergic receptor modulation of neurotransmission to cardiac vagal neurons in the nucleus ambiguus. *Neuroscience*(0). doi: 10.1016/j.neuroscience.2012.02.033

Bem, S. L. (1974). The measurement of psychological androgyny. *Journal of Consulting and Clinical Psychology, 42*(2), 155-162. doi: 10.1037/h0036215

Ben-Zeev, T., Fein, S., & Inzlicht, M. (2005). Arousal and stereotype threat. *Journal of Experimental Social Psychology, 41*(2), 174-181. doi: 10.1016/j.jesp.2003.11.007

Birnbaum, S., Gobeske, K. T., Auerbach, J., Taylor, J. R., & Arnsten, A. F. T. (1999). A role for norepinephrine in stress-induced cognitive deficits: alpha-1-adrenoceptor mediation in the prefrontal cortex. *Biological Psychiatry, 46*(9), 1266-1274.

Blair, I. V. (2002). The malleability of automatic stereotypes and prejudice. *Personality and Social Psychology Review, 6*(3), 242-261. doi: 10.1207/s15327957pspr0603_8

Blascovich, J., Spencer, S. J., Quinn, D., & Steele, C. (2001). African Americans and high blood pressure: The role of stereotype threat. *Psychological Science, 12*(3), 225-229.

Blascovich, J., & Mendes, W. B. (2010). Social Psychophysiology and Embodiment *Handbook of Social Psychology*: John Wiley & Sons, Inc.

Blix, A. S., Stromme, S. B., & Ursin, H. (1974). Additional heart rate--an indicator of psychological activation. *Aerospace Medicine, 45*(11), 1219-1222.

Boychuk, C. R., Bateman, R. J., Philbin, K. E., & Mendelowitz, D. (2011). α1-adrenergic receptors facilitate inhibitory neurotransmission to cardiac vagal neurons in the nucleus ambiguus. *Neuroscience, 193*(0), 154-161. doi: 10.1016/j.neuroscience.2011.07.024

Brown, R. P., & Josephs, R. A. (2000). The importance of importance: The mathematics identification questionnaire. Unpublished manuscript: The University of Texas at Austin.

Brown, R. P., & Pinel, E. C. (2003). Stigma on my mind: Individual differences in the experience of stereotype threat. *Journal of Experimental Social Psychology, 39*(6), 626-633. doi: 10.1016/s0022-1031(03)00039-8

Carpenter, P. A., Just, M. A., & Reichle, E. D. (2000). Working memory and executive function: evidence from neuroimaging. *Current Opinion in Neurobiology, 10*(2), 195-199. doi: 10.1016/s0959-4388(00)00074-x

Carroll, D., Phillips, A. C., & Balanos, G. M. (2009). Metabolically exaggerated cardiac reactions to acute psychological stress revisited. *Psychophysiology, 46*(2), 270-275. doi: 10.1111/j.1469-8986.2008.00762.x

Crisp, R. J., Stathi, S., Turner, R. N., & Husnu, S. (2009). Imagined intergroup contact: Theory, paradigm and practice. *Social and Personality Psychology Compass, 3*(1), 1-18. doi: 10.1111/j.1751-9004.2008.00155.x

Croizet, J.-C. (2004). Stereotype threat undermines intellectual performance by triggering a disruptive mental load. *Personality & social psychology bulletin, 30*(6), 721-731. doi: 10.1177/0146167204263961

Dasgupta, N., & Asgari, S. (2004). Seeing is believing: Exposure to counterstereotypic women leaders and its effect on the malleability of automatic gender stereotyping. *Journal of Experimental Social Psychology, 40*(5), 642-658. doi: 10.1016/j.jesp.2004.02.003

Davies, P. G. (2002). Consuming images: How television commercials that elicit stereotype threat can restrain women academically and professionally. *Personality & Social Psychology Bulletin, 28*(12), 1615-1628. doi: 10.1177/014616702237644

Dienstbier, R. A. (1989). Arousal and physiological toughness: Implications for mental and physical health. *Psychological Review, 96*(1), 84-100. doi: 10.1037/0033-295x.96.1.84

Eisenberger, N. I., Lieberman, M. D., & Williams, K. D. (2003). Does rejection hurt? An fmri study of social exclusion. *Science, 302*(5643), 290-292. doi: 10.1126/science.1089134

Elliot, A. J., Payen, V., Brisswalter, J., Cury, F., & Thayer, J. F. (2011). A subtle threat cue, heart rate variability, and cognitive performance. *Psychophysiology, 48*(10), 1340-1345. doi: 10.1111/j.1469-8986.2011.01216.x

Elzinga, B. M., & Roelofs, K. (2005). Cortisol-induced impairments of working memory require acute sympathetic activation. *Behavioral Neuroscience, 119*(1), 98-103. doi: 10.1037/0735-7044.119.1.98

Forster, K., & Forster, J. (2003). DMDX: A Windows display program with millisecond accuracy. *Behavior Research Methods, 35*(1), 116-124. doi: 10.3758/bf03195503

Grossman, P., & Taylor, E. W. (2007). Toward understanding respiratory sinus arrhythmia: Relations to cardiac vagal tone, evolution and biobehavioral functions. *Biological Psychology, 74*(2), 263-285. doi: 10.1016/j.biopsycho.2005.11.014

Hansen, A. L., Johnsen, B. H., & Thayer, J. F. (2003). Vagal influence on working memory and attention. *International Journal of Psychophysiology, 48*(3), 263-274. doi: 10.1016/s0167-8760(03)00073-4

Harper, D. (2010) In *Online Etymology Dictionary*. Retrieved from http://www.etymonline.com/index.php?term=stereotype

Hodgson, T. (1820). *An essay on the origin and progress of stereotype printing; including a description of the various processes*. Newcastle,: S. Hodgson.

Homma, I., & Masaoka, Y. (2008). Breathing rhythms and emotions. *Experimental Physiology, 93*(9), 1011-1021. doi: 10.1113/expphysiol.2008.042424

Jennings, J. R., Kamarck, T., Stewart, C., Eddy, M., & Johnson, P. (1992). Alternate cardiovascular baseline assessment techniques: vanilla or resting baseline. *Psychophysiology, 29*(6), 742-750. doi: 10.1111/j.1469-8986.1992.tb02052.x

Krieger, N., Smith, K., Naishadham, D., Hartman, C., & Barbeau, E. M. (2005). Experiences of discrimination: Validity and reliability of a self-report measure for population health research on racism and health. *Social Science & Medicine, 61*(7), 1576-1596. doi: 10.1016/j.socscimed.2005.03.006

Kubicek, W. G. (1974). The Minnesota impedance cardiograph- theory and applications. *Biomedical Engineering (London, England), 9*(9), 410-416.

Lippmann, W. (1922). *Public opinion*. New York,: Harcourt.

Lozano, D. L., Norman, G., Knox, D., Wood, B. L., Miller, B. D., Emery, C. F., et al. (2007). Where to B in dZ/dt. *Psychophysiology, 44*(1), 113-119. doi: 10.1111/j.1469-8986.2006.00468.x

Lupien, S. J., & McEwen, B. S. (1997). The acute effects of corticosteroids on cognition:

integration of animal and human model studies. *Brain Research Reviews, 24*(1), 1-27. doi: 10.1016/s0165-0173(97)00004-0

Masaoka, Y., & Homma, I. (1997). Anxiety and respiratory patterns: their relationship during mental stress and physical load. *International Journal of Psychophysiology, 27*(2), 153-159. doi: 10.1016/s0167-8760(97)00052-4

Nieuwenhuis, S., Aston-Jones, G., & Cohen, J. D. (2005). Decision making, the P3, and the locus coeruleus--norepinephrine system. *Psychological Bulletin, 131*(4), 510-532. doi: 10.1037/0033-2909.131.4.510

Nosek, B. A., Smyth, F. L., Sriram, N., Lindner, N. M., Devos, T., Ayala, A., et al. (2009). National differences in gender-science stereotypes predict national sex differences in science and math achievement. *Proceedings of the National Academy of Sciences of the United States of America, 106*(26), 10593-10597. doi: DOI 10.1073/pnas.0809921106

Nyklíček, I., Thayer, J. F., & Van Doornen, L. J. P. (1997). Cardiorespiratory differentiation of musically-induced emotions. *Journal of Psychophysiology, 11*(4), 304-321.

O'Brien, L. T. (2003). Stereotype threat and arousal: effects on women's math performance. *Personality & social psychology bulletin, 29*(6), 782-789. doi: 10.1177/0146167203029006010

Pinel, E. C. (1999). Stigma consciousness: The psychological legacy of social stereotypes. *Journal of Personality and Social Psychology, 76*(1), 114-128. doi: 10.1037/0022-3514.76.1.114

Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology, 74*(2), 116-143. doi: 10.1016/j.biopsycho.2006.06.009

Ramos, B. P., & Arnsten, A. F. T. (2007). Adrenergic pharmacology and cognition: Focus on the prefrontal cortex. *Pharmacology & Therapeutics, 113*(3), 523-536. doi: 10.1016/j.pharmthera.2006.11.006

Rossy, L. A., & Thayer, J. F. (1998). Fitness and gender-related differences in heart period variability. *Psychosomatic Medicine, 60*(6), 773-781.

Schmader, T. (2002). Gender identification moderates stereotype threat effects on women's math performance. *Journal of Experimental Social Psychology, 38*(2), 194-201. doi: 10.1006/jesp.2001.1500

Schmader, T., & Johns, M. (2003). Converging Evidence That Stereotype Threat Reduces Working Memory Capacity. *Journal of Personality and Social Psychology, 85*(3), 440-452. doi: 10.1037/0022-3514.85.3.440

Schmader, T., Johns, M., & Forbes, C. (2008). An integrated process model of stereotype threat effects on performance. *Psychological Review, 115*(2), 336-356. doi: 10.1037/0033-295x.115.2.336

Schoofs, D., Preuß, D., & Wolf, O. T. (2008). Psychosocial stress induces working memory impairments in an n-back paradigm. *Psychoneuroendocrinology, 33*(5), 643-653. doi: 10.1016/j.psyneuen.2008.02.004

Sherwood, A. (1990). Methodological guidelines for impedance cardiography. *Psychophysiology, 27*(1), 1-23.

Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype threat and women's math performance. *Journal of Experimental Social Psychology, 35*(1), 4-28.

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology, 69*(5), 797-811. doi:

10.1037/0022-3514.69.5.797

Stout, J. G., Dasgupta, N., Hunsinger, M., & McManus, M. A. (2011). STEMing the tide: Using ingroup experts to inoculate women's self-concept in science, technology, engineering, and mathematics (STEM). *Journal of Personality and Social Psychology, 100*(2), 255-270. doi: 10.1037/a0021385

Thayer, J., Hansen, A., Saus-Rose, E., & Johnsen, B. (2009). Heart rate variability, prefrontal neural function, and cognitive performance: the neurovisceral integration perspective on self-regulation, adaptation, and health. *Annals of Behavioral Medicine, 37*(2), 141-153. doi: 10.1007/s12160-009-9101-z

Thayer, J. F., Friedman, B. H., & Borkovec, T. D. (1996). Autonomic characteristics of generalized anxiety disorder and worry. *Biological Psychiatry, 39*(4), 255-266. doi: 10.1016/0006-3223(95)00136-0

Thurgood, L., Golladay,M.J., and Hill, S.T. (2006). US doctorates in the 20th century. *NSF 06-319*, 06-319.

Turner, R. N., Crisp, R. J., & Lambert, E. (2007). Imagining intergroup contact can improve intergroup attitudes. *Group Processes & Intergroup Relations, 10*(4), 427-441. doi: 10.1177/1368430207081533

Vick, S. B., Seery, M. D., Blascovich, J., & Weisbuch, M. (2008). The effect of gender stereotype activation on challenge and threat motivational states. *Journal of Experimental Social Psychology, 44*(3), 624-630. doi: 10.1016/j.jesp.2007.02.007

Wraga, M., Helt, M., Jacobs, E., & Sullivan, K. (2007). Neural basis of stereotype-induced shifts in women's mental rotation performance. *Social Cognitive and Affective Neuroscience, 2*(1), 12-19. doi: 10.1093/scan/nsl041

Fig. 1 Subjects completed six tasks in a fixed order. The imagination condition (nature scene vs. interpersonal contact) and stereotype threat condition (stereotype threat vs. no stereotype threat) were randomly assigned between-subjects. Subjects in the imagined nature scene condition were randomly assigned to a stereotype threat or no stereotype threat condition. All subjects in the imagined interpersonal contact condition were assigned to the stereotype threat condition.

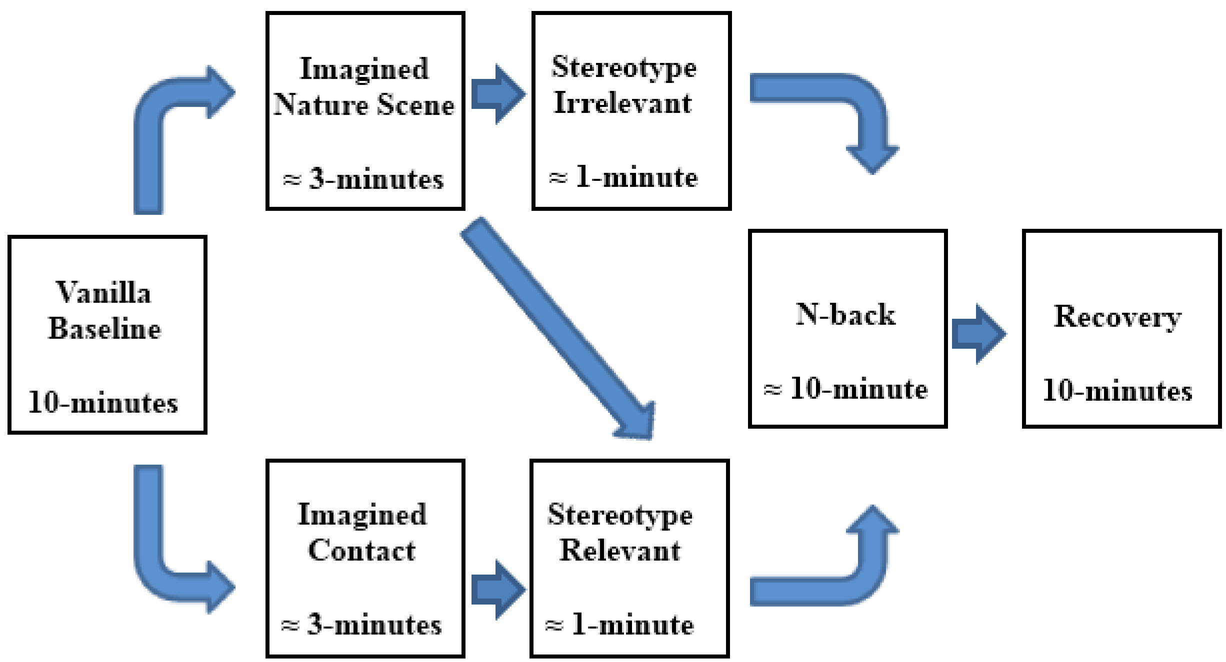

Fig. 2 Performance on the visuospatial n-back task was used to quantify the effects of the stereotype threat and imagined contact manipulations. Subjects were required to respond via a button press whether the presented square matches or does not match the stimulus presented n presentations ago. To increase the difficulty of the task, the value of n was adapted according to performance within each block of 20 trials. Trials from a 2-back are illlustrated below (non-match labels are omitted for pithiness).

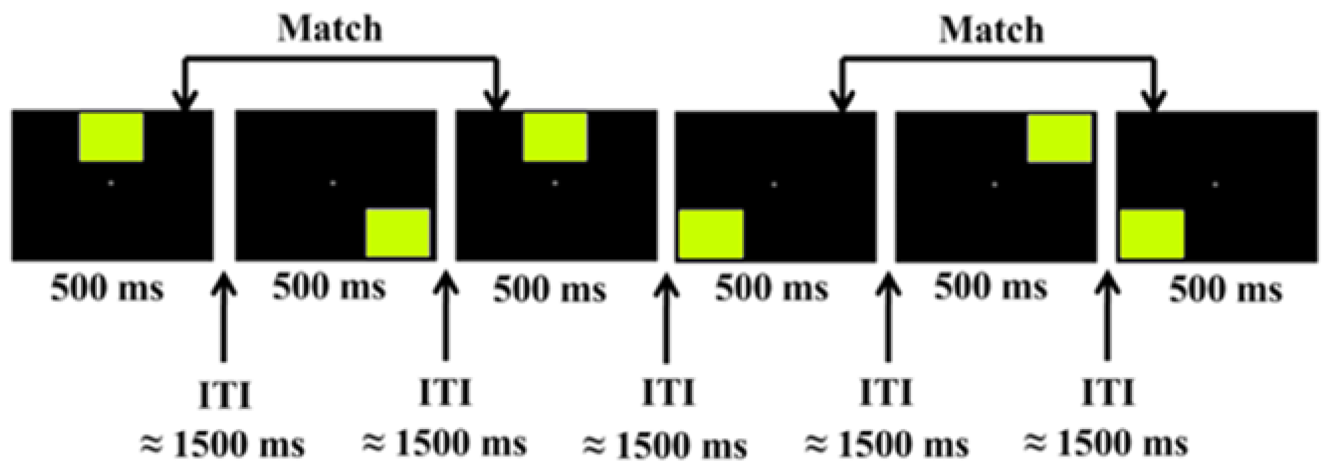

Figure 3

Whole Sample Analysis: Accuracy During Low and High Working Memory (WM) Loads

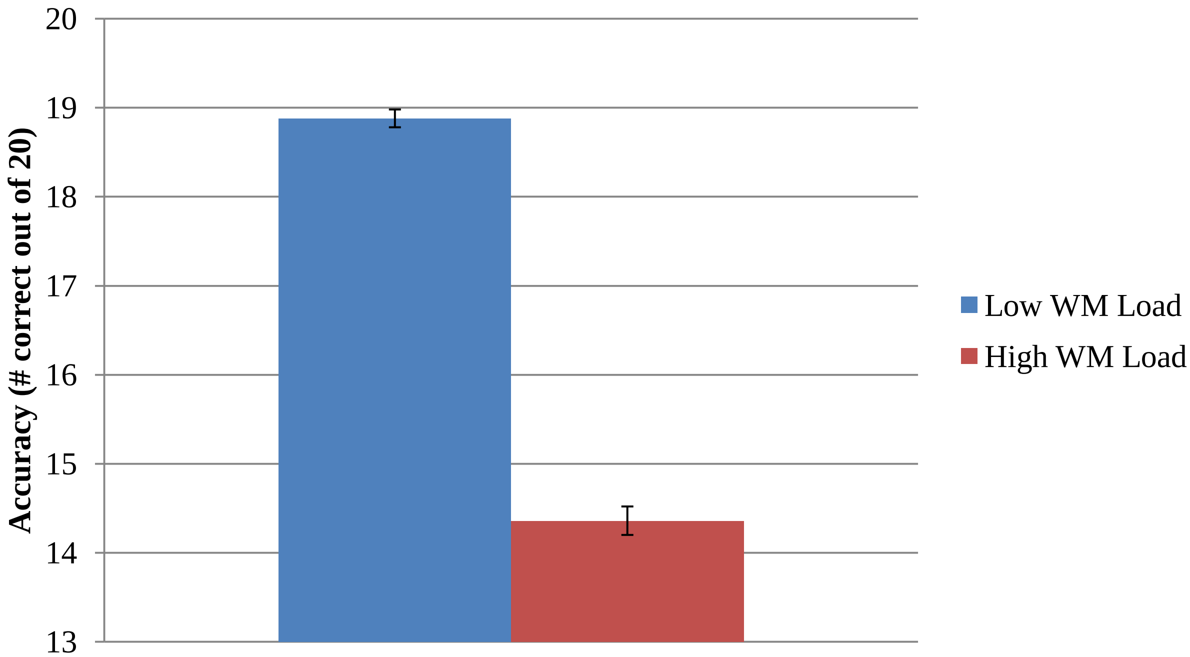

Figure 4

Whole Sample Analysis: Reaction Time During Various Working Memory (WM) Loads

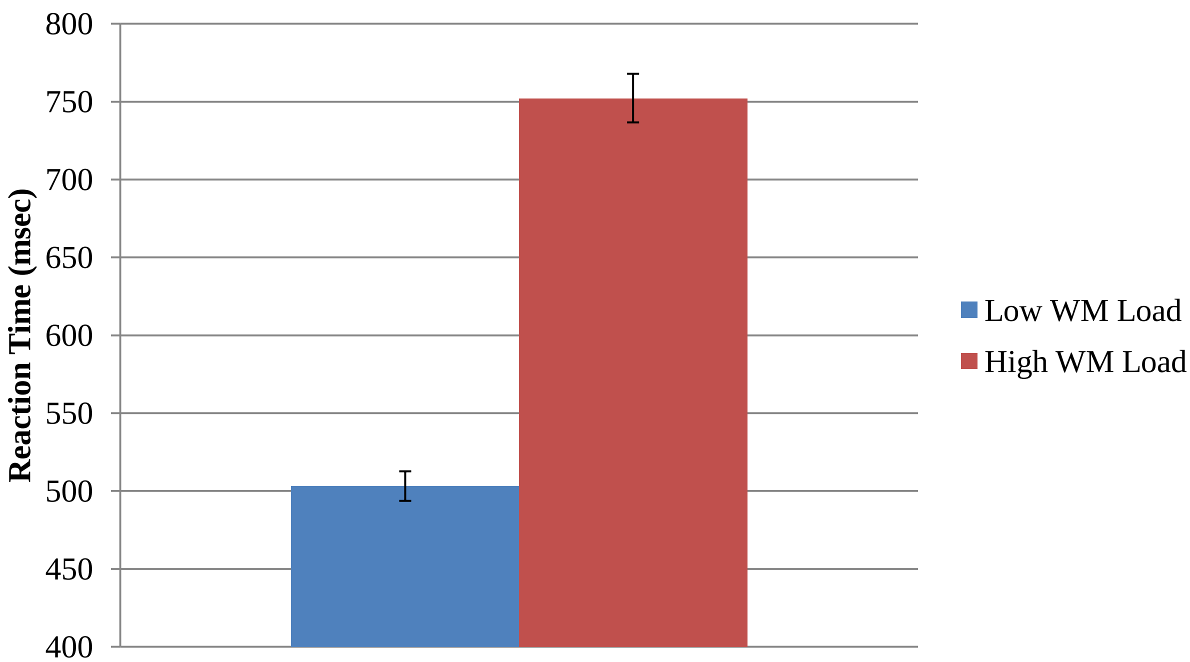

Figure 5

Stereotype Threat Lengthens Average Reaction Time During The N-back

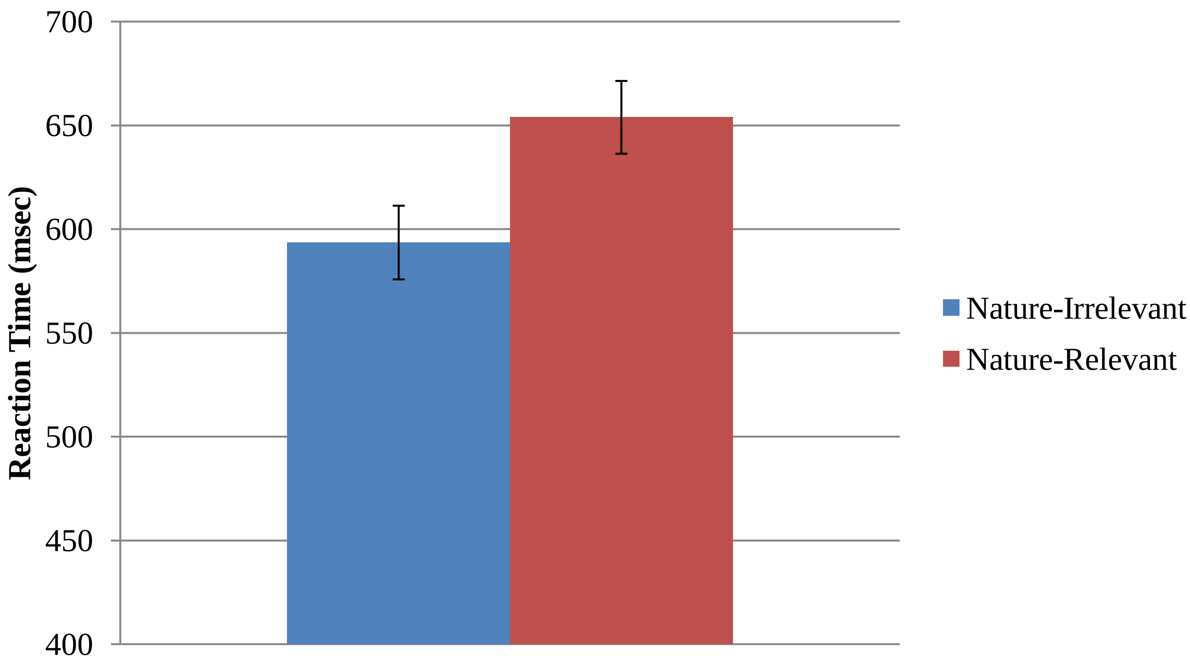

Figure 6

Imagined Contact Marginally Shortens Average Reaction Time Under Stereotype Threat

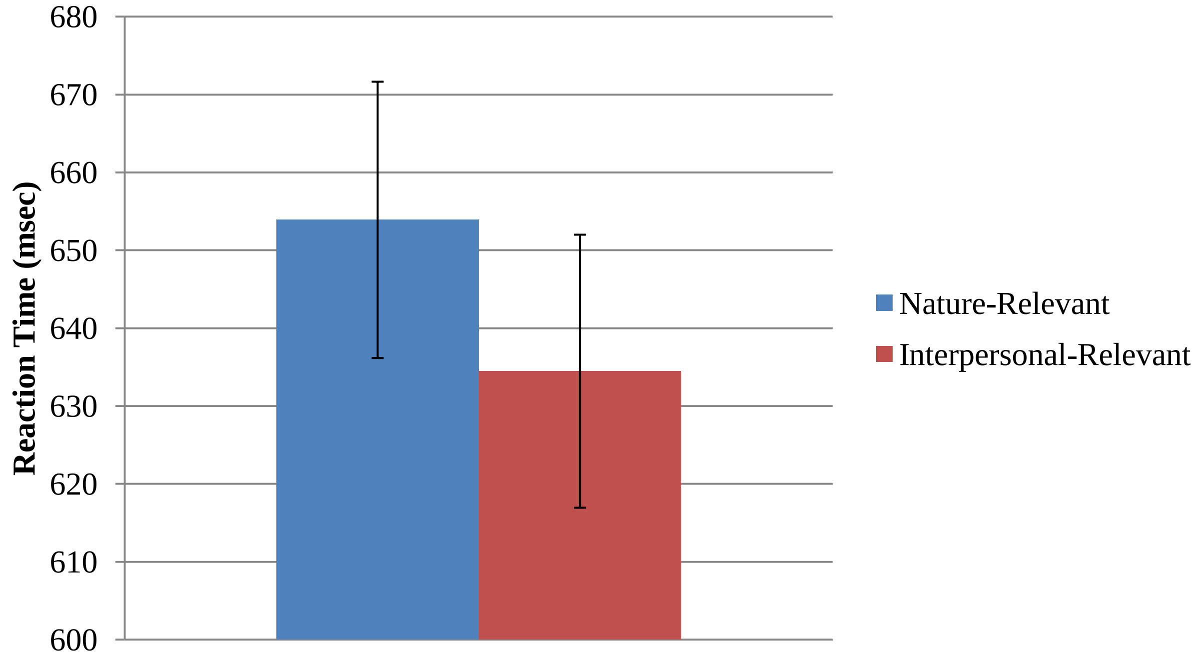

Figure 7

Whole Sample Analysis: IBI During Low and High Working Memory (WM) Load

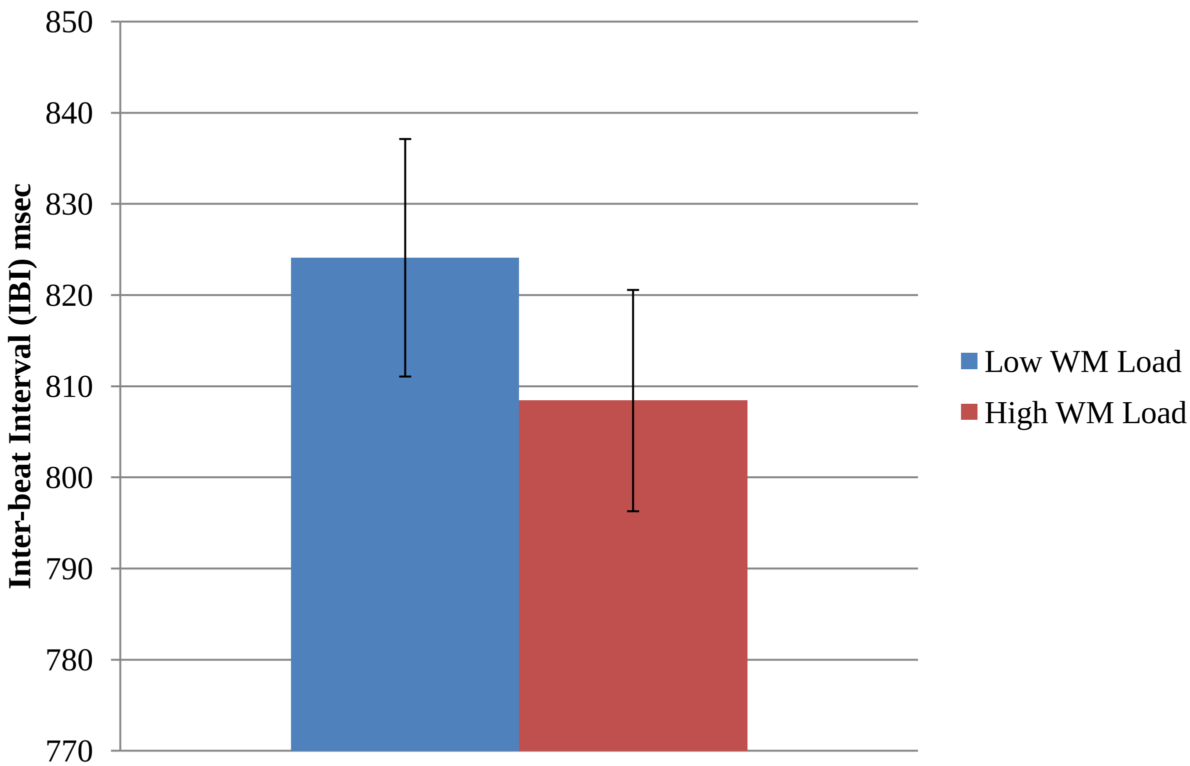

Figure 8

Whole Sample Analysis: LF-HRV During Low and High Working Memory (WM) Load

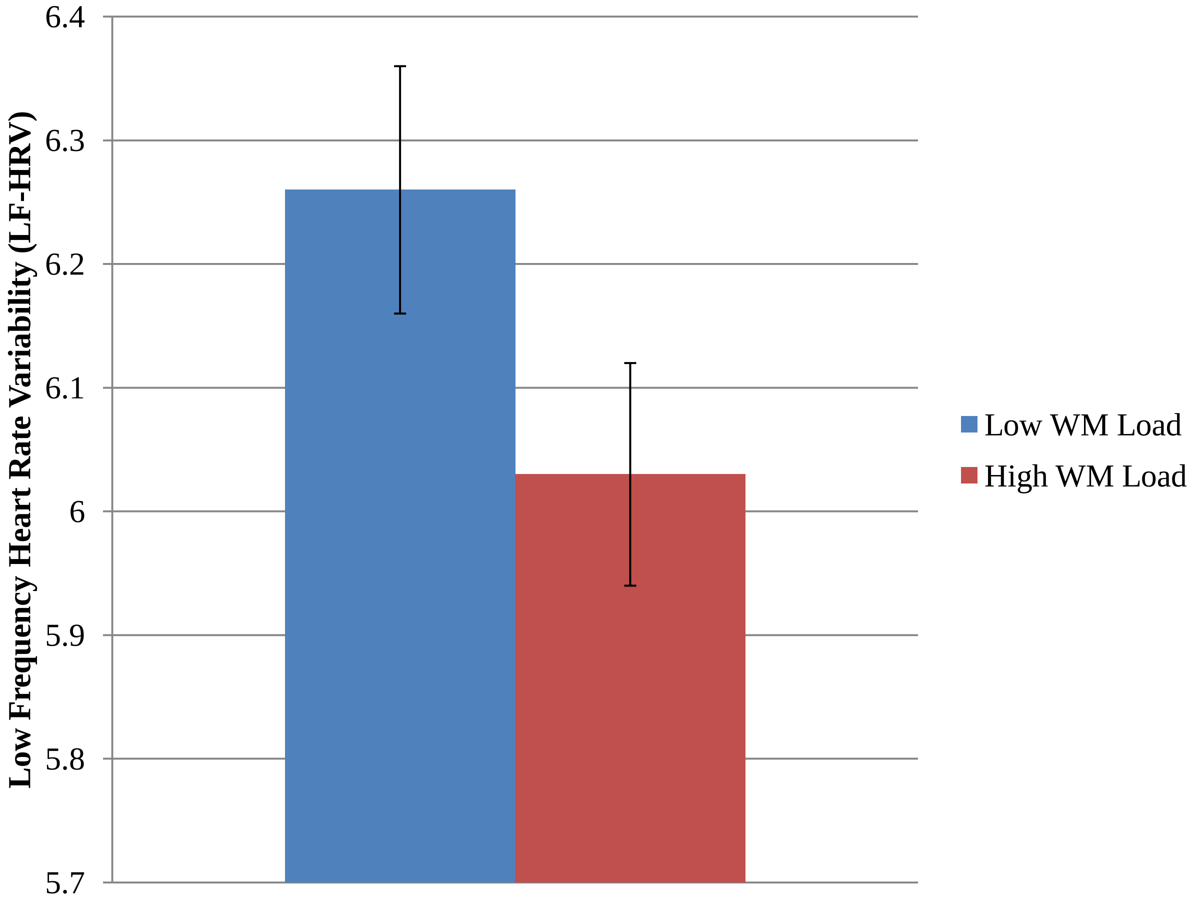

Figure 9

Whole Sample Analysis: HF-HRV During Low and High Working Memory (WM) Load

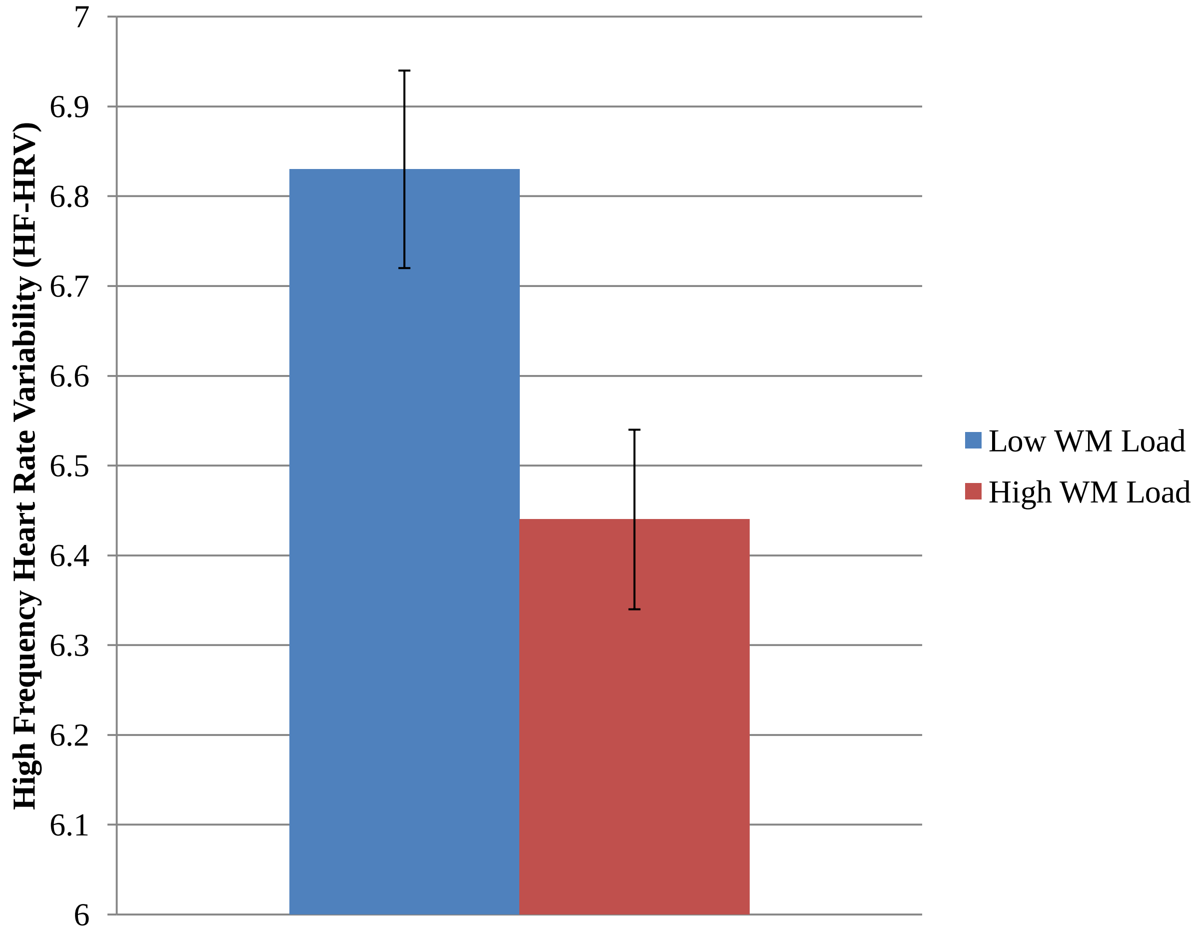

Figure 10

Increased Vagal Suppression During The N-back Under Stereotype Threat

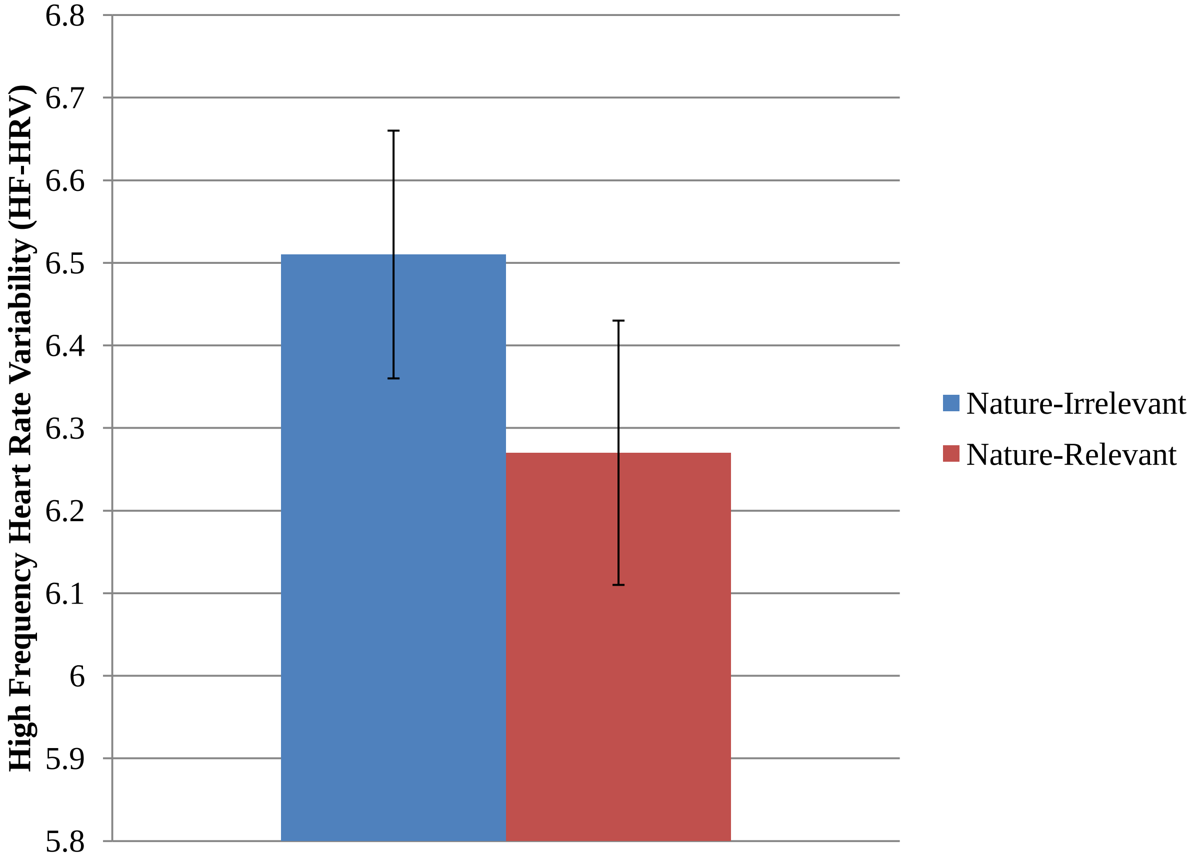

Figure 11

Imagination and Vagal Suppression During The N-back Under Stereotype Threat

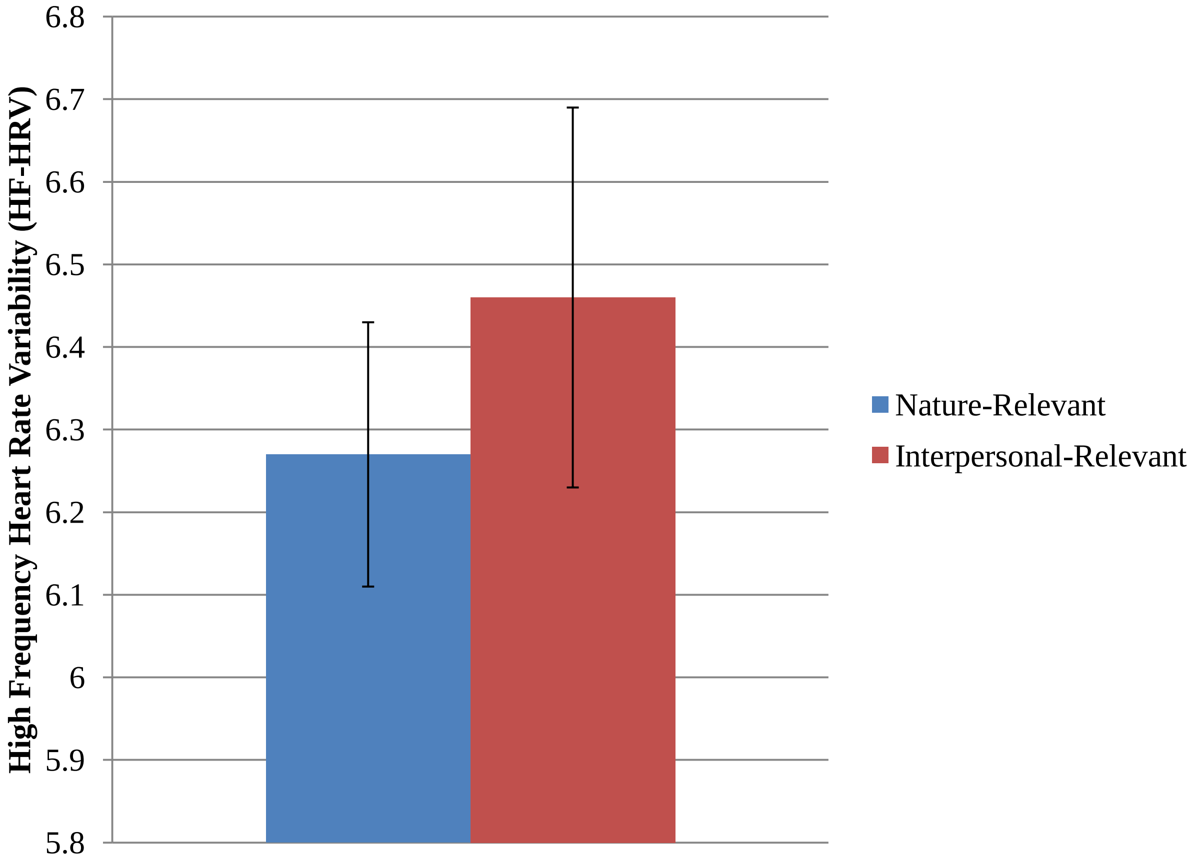

Figure 12

Imagination and Stereotype Threat Effects By Perception of Task Influence

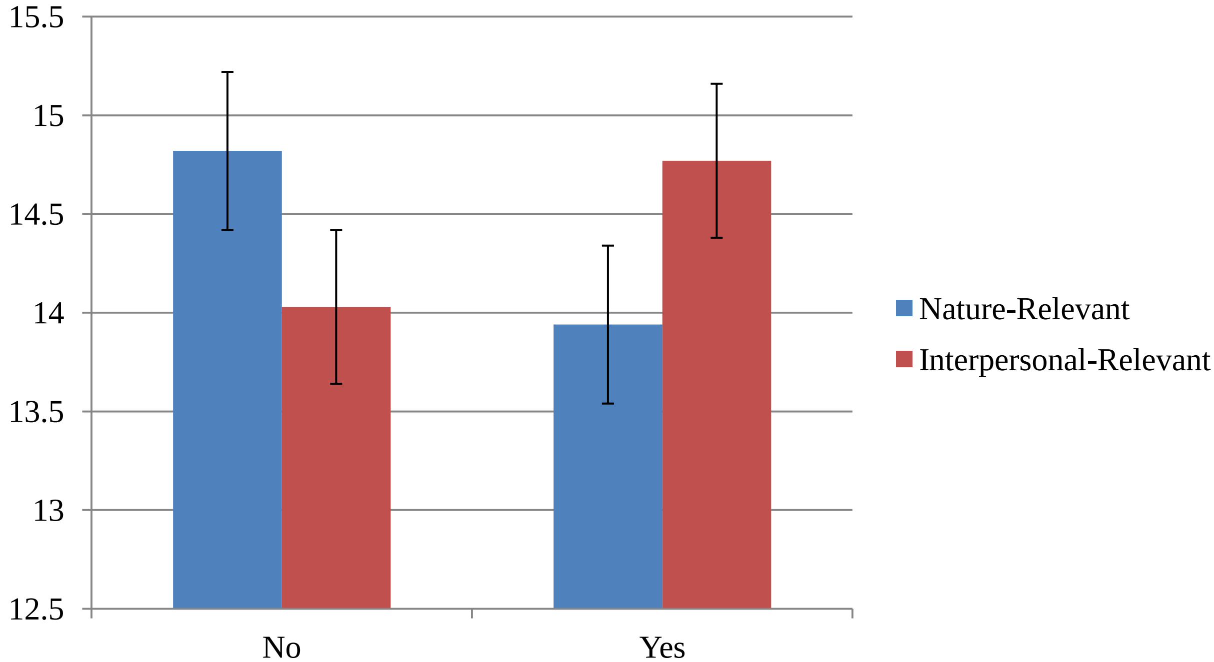

Table 1

Did The Stereotype Threat Instructions Influence Your Task Performance?

	Nature Irrelevant	Nature Relevant	Interpersonal Relevant
No	73%	47%	53%
Yes	27%	53%	47%