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Hanna Johnson
University of Wisconsin-Milwaukee

EFFECTS OF RESIDUAL AROUSAL AND COGNITIVE APPRAISAL ON PSYCHOPHYSIOLOGICAL REACTIVITY TO STRESS

by

Hanna Johnson

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ABSTRACT

EFFECTS OF RESIDUAL AROUSAL AND COGNITIVE APPRAISAL ON PSYCHOPHYSIOLOGICAL REACTIVITY TO STRESS

by

Hanna B. Johnson

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Generalized arousal can amplify emotional responses to a range of target stimuli, but it is not yet known whether perceiver characteristics moderate the effects of arousal as target characteristics do. This study investigated the effects of residual arousal from exercise on psychological and physiological reactivity to an active coping task, when individual appraisals of the task differed. Participants who endorsed either a positive or negative attitude toward job interviews underwent either a highly or minimally arousing exercise task, followed by a mock job interview, to which self-reported and cardiovascular responses were assessed. Using the Biopsychosocial Model of Challenge and Threat (BPSM–CT) as a framework, results showed that during the interview, participants with positive and negative prior attitudes exhibited cardiovascular response patterns consistent with physiological challenge and threat, respectively, while residual arousal from exercise led to more positive self-reports of the interview in both groups. The findings demonstrate that residual arousal can improve subjective evaluations of a motivated performance task, while pre-existing attitudes can influence task-related physiological reactivity.

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LIST OF ABBREVIATIONS

ANCOVA	analysis of covariance
ANS	Autonomic Nervous System
ASI-3	Anxiety Sensitivity Index-3
BAI	Beck Anxiety Inventory
BPSM–CT	Biopsychosocial Model of Challenge and Threat
CO	cardiac output
DBP	diastolic blood pressure
ECG	electrocardiogram, -graph, -graphy
HPA	hypothalamic–pituitary–adrenal axis
HR	heart rate
IAMS	Immediate Anxiety Measures Scale
ICG	impedance cardiogram, -graph, -graphy
LIV	Law of Initial Values
MAP	mean arterial pressure
PANAS	Positive and Negative Affect Schedule
SAM	sympathetic–adrenomedullary axis
SBP	systolic blood pressure
SV	stroke volume
TPR	total peripheral resistance
TSST	Trier Social Stress Test
VC	ventricular contractility

Effects of Residual Arousal and Cognitive Appraisal on Psychophysiological Reactivity to Stress

Two candidates wait in the hall before a job interview. One is confident and ready, optimistic that she is a good fit for the role, and feeling well-practiced after having done several other interviews this week. The other is anxious and distressed, worried that the job qualifications may be above her, and fearing that her mind will go blank at the questions. Both candidates are motivated to perform well, but one feels challenged by the task; the other, threatened. Sitting in the hall awaiting the interview, both are experiencing physiological changes: heart fluttering, muscles tense, senses tuned and alert. To what extent are these symptoms a product of their emotions, and to what extent are they the cause? Moreover, how is it possible that the two candidates have identical physical symptoms, despite contrasting thoughts and feelings?

Questions like these have gripped psychologists since the dawn of the field (James, 1884). But while the mind–body link has been probed extensively in theoretical and empirical work alike, several key questions about the relationship between psychological and physiological functioning remain unsatisfactorily answered. One of the most vital issues in this area concerns the role of the autonomic nervous system (ANS) in emotion. Specifically, there has been a long-standing debate as to whether particular emotions, like those described above, are associated with unique patterns of ANS activity. Whether, and under what conditions, such autonomic specificity exists, as well as what significance it may have in the experience of emotion, remain open questions.

Understanding how the ANS is organized in emotion is important not only for emotion theorists (e.g., Cannon, 1927; James, 1890; Schachter & Singer, 1962), but for numerous areas of applied psychology as well. The specificity question, in particular, has significant implications for the psychology of health and illness (Levenson, 2003). Emotional factors have long been

suspected as contributors to disease (Alexander, 1950), and certain (primarily negative) emotions are linked to various forms of ill health (Levenson, 2019), suggesting that different emotions may have meaningfully different effects on physiological functioning. Emotions are believed to partly explain the link between stress and illness (Levenson, 2019), for which there is now incontrovertible evidence (Schneiderman et al., 2005). But although these relationships are increasingly apparent, they are not well understood. For health psychology, therefore, defining how psychological processes relate to physiological ones, and vice versa, is an important and pressing question.

Arousal and Emotion

One branch of work that has informed this research area considerably is that which has focused on the afferent relationship between physiology and emotion, namely by studying the effects of physiological arousal on perceived emotion. "Arousal," though the term lacks a precise definition in the literature (Blascovich & Tomaka, 1996), has generally been used to mean activation of the sympathetic nervous system (Cacioppo et al., 1987; Cannon, 1915; Schachter & Singer, 1962), which is the meaning used here.

The most well-known of these works is the seminal study by Schachter and Singer (1962). Responding to what they saw as little evidence of physiological differentiation in emotion, Schachter and Singer probed whether cognitive factors could act as determinants of emotion. To test this, they sought to induce nonspecific arousal in their participants, and then to manipulate certain cognitive cues in the immediate environment, before asking the participants what they were feeling. In the study, they injected their participants with either epinephrine—an arousal-inducing drug—or a placebo, and either informed, misinformed, or did not inform them about the drugs' expected effects. Then, through the actions of a confederate, the study environment was manipulated to induce either amusement or anger in the participants. Schachter

and Singer assessed the participants' feelings and behaviors, and found that they reacted differently depending on the type of drug and information they had been given. Those who had received the epinephrine, but who had been misinformed or uninformed about its effects, reacted more emotionally than those who had been correctly informed about the drug's effects, and than those who had received the placebo drug. The researchers concluded that, because the epinephrine–ignorant participants were experiencing palpable somatic changes, but lacked a salient explanation for them, they had interpreted those changes as emotions, and had used the cues in their immediate environment—the amusing or angry confederate—to label them. From these findings, Schachter and Singer developed the two-factor theory of emotion, which posits that emotions are produced by a degree of physiological activation in combination with a cognitive label. In the discourse on autonomic specificity in emotion, Schachter and Singer's work has been taken as evidence against specificity theory, because the same underlying arousal was found to generate two different emotions.

Later studies have corroborated Schachter and Singer's findings using other means to induce arousal. Zillmann and colleagues, for example, found that "excitation" (sympathetic nervous system activity) from a highly emotional stimulus can amplify subsequent emotional experiences, a phenomenon known as excitation transfer (Zillmann, 2008). After watching a highly arousing film, for example, participants reported feeling more emotional during a subsequent film (Zillmann et al., 1974). Arousal from non-emotional sources, such as physical activity, can also augment perceptions of emotion. This method capitalizes on "residual arousal," wherein the arousing stimulus and the emotional target stimulus are separated by several minutes. Several minutes after vigorous exercise, a person is still physiologically aroused (i.e., their heart rate is still significantly elevated), but that arousal is no longer perceptible to them (Cacioppo et al., 1987). In effect, a person in a residual arousal state is aroused, but unaware of

it. A considerable body of research demonstrates that when emotional stimuli are presented during residual arousal, subjective ratings tend to be amplified (e.g., Gollwitzer et al., 1982; White et al., 1981; Zillmann et al., 1972; Zillmann & Bryant, 1974). This method of arousal therefore achieves the "ignorance" paramount to Schachter and Singer's procedure, but without the ethically dubious use of drugs or deception.

Research from Our Lab

Our lab has utilized residual arousal in a series of recent studies on autonomic activity in emotion. In one study (Nakajima et al., 2017), half of participants vigorously pedaled a stationary bike before watching each of two emotional video clips: one humorous and one sad. The others watched the videos without having exercised beforehand, and then all of the participants reported the emotions they felt during each video. We found that those who had exercised before the videos reported feeling more emotional than those who had not exercised. Specifically, the exercisers felt more positive during the humorous video and more negative during the sad video, but not vice versa. The exercise had therefore amplified participants' emotions, but only those that were appropriate for each video. A second study (Chen et al., 2022) found the same effect using a different method of arousal manipulation (sitting versus standing). Like the original study by Schachter and Singer, these findings highlight the critical importance of cognitive cues in labeling a perceived emotion. They additionally show that near-opposite emotions (amusement and sadness) can be generated by the same underlying arousal and within the same individual, which further demonstrates the malleability of nonspecific arousal.

In addition to the role of arousal in generating emotions, our studies were also concerned with how the two emotional videos affected physiological reactivity. To this end, we assessed several cardiorespiratory variables throughout the experiments. Interestingly, we found that measures of heart rate variability and respiration differed significantly between the humorous

and sad videos (Chen et al., 2022; Nakajima et al., 2017), suggesting that the two emotions had different influences on physiology. We were particularly intrigued by these two findings in juxtaposition: that general arousal had amplified both emotions, but that physiological reactivity had differed between them. We interpreted these results in terms of the question of autonomic specificity: although nonspecific arousal was sufficient in generating the two different emotions, patterns of reactivity may have become specific after the emotions were established. We therefore believe this series of studies shows something novel and significant about autonomic activity in emotion. In particular, our findings demonstrate the reciprocal nature of the relationship between autonomic and emotional processes, and affirm that cognitive factors play a critical role.

But these latest findings also inspired further questions. First, while our investigation and traditional work on this issue (e.g., Schachter & Singer, 1962; Zillmann et al., 1974) has primarily used prototypical emotional stimuli to evoke the intended emotions, this approach largely ignores characteristics of the individual that may influence the perception of feeling states. Theories on the construct and appraisal of emotions emphasize that personal factors, including personality traits, values, beliefs, and expectations, play a significant role in emotion (Averill, 1980; Lazarus, 1991; Roseman et al., 1996). In a neutral or ambiguous situation, for example, an individual's predispositions may determine how a perceived emotion is labeled. The potential influence of personal variables in arousal-moderated feeling states is therefore a logical next step for our work. Additionally, while our previous work has focused on affective experience in basic emotions, we are also interested in extending our investigation into more complex feeling states, and across multiple dimensions of psychological experience. Beyond basic emotions, are cognitions, behaviors, and self-perceptions similarly affected by arousal?

Psychological stress is a particularly compelling context for these latest research questions. Stress is a multidimensional state, encompassing cognitive, physiological and behavioral processes, in addition to emotional ones (Blascovich & Tomaka, 1996; Lazarus & Folkman, 1984). Additionally, stress is understood as an interaction between an individual and their environment (Krohne, 2001; Lazarus & Folkman, 1984; Tomaka et al., 1993). The perceived demands of a particular situation weigh against the apposite resources of the individual, and this process of cognitive appraisal determines whether, and to what degree, the situation is experienced as stressful (Lazarus & Folkman, 1984). As a multidimensional and multiply determined feeling state, the context of stress could therefore support a meaningful extension of our investigation.

Arousal and Stress

The arousal–stress relationship is especially intriguing because arousal plays an integral role in stress. Acute stress is associated with a rapid sympathetic response, and interpretations of the resulting arousal can influence how the stress is experienced. For example, among college students taking a stressful exam, those who were instructed to reappraise the exam-induced arousal as beneficial to their performance had less anxiety, lower cortisol levels, and better scores on the exam than those who were simply instructed to ignore the stress (Jamieson et al., 2021). Interpretations of stress-induced arousal, therefore, can significantly affect subsequent psychological and physiological reactivity.

Extraneous arousal can also affect perceptions of stress. For example, in one study (Sterling & Gaertner, 1984), a subset of participants was aroused via exercise prior to a feigned emergency, where a confederate appeared to need help. For some participants, the emergency was unambiguous: after a loud crash from another room, the confederate could be heard moaning in distress. But for others, the situation was not as clear: after the crash, there was only silence.

The researchers found that arousal had different effects depending on whether the emergency was ambiguous or not. For participants who heard the moaning, those who had been aroused perceived the situation as more of an emergency and intervened faster than those who had not been aroused. In the ambiguous condition, the opposite was true: those who were aroused perceived less of an emergency and were slower to help. Arousal, therefore, had bidirectional effects on perceptions and behavior during the emergency, depending on the environmental cues.

The transactional nature of stress has led some to investigate whether dispositional factors, in addition to situational ones, can moderate the effects of arousal. One study (Brown & Curhan, 2013) explored this in the context of negotiation, a task that, while typically considered stressful, is viewed favorably by some and unfavorably by others. The researchers investigated whether participants' pre-existing attitudes about negotiation would moderate the effects of extraneous arousal on their subjective experience of a negotiation task. In the study, participants negotiated with a confederate while walking either quickly (high arousal) or slowly (low arousal) on a treadmill. The negotiations were stopped before any agreements were reached, and the participants then reported how they felt about the task. However, the researchers had also assessed each participant's pre-existing attitude toward negotiation several weeks earlier: in a seemingly unrelated questionnaire, the participants had been asked whether they generally looked forward to (positive attitude) or dreaded (negative attitude) negotiating. Based on this information, the researchers found that arousal had polarized evaluations of the negotiation task based on pre-existing attitudes: among participants with positive pre-existing attitudes, those who were more aroused felt more positive about the negotiation than those who were less aroused, and among participants with negative pre-existing attitudes, those who were more aroused felt more negative.

These studies demonstrate that, much like what our previous work has shown in the context of emotion, extraneous arousal can interact with cognitive factors to moderate the experience of stress. Moreover, consistent with the transactional model of stress, these moderating factors can include not only characteristics of the situation, but characteristics of the individual as well.

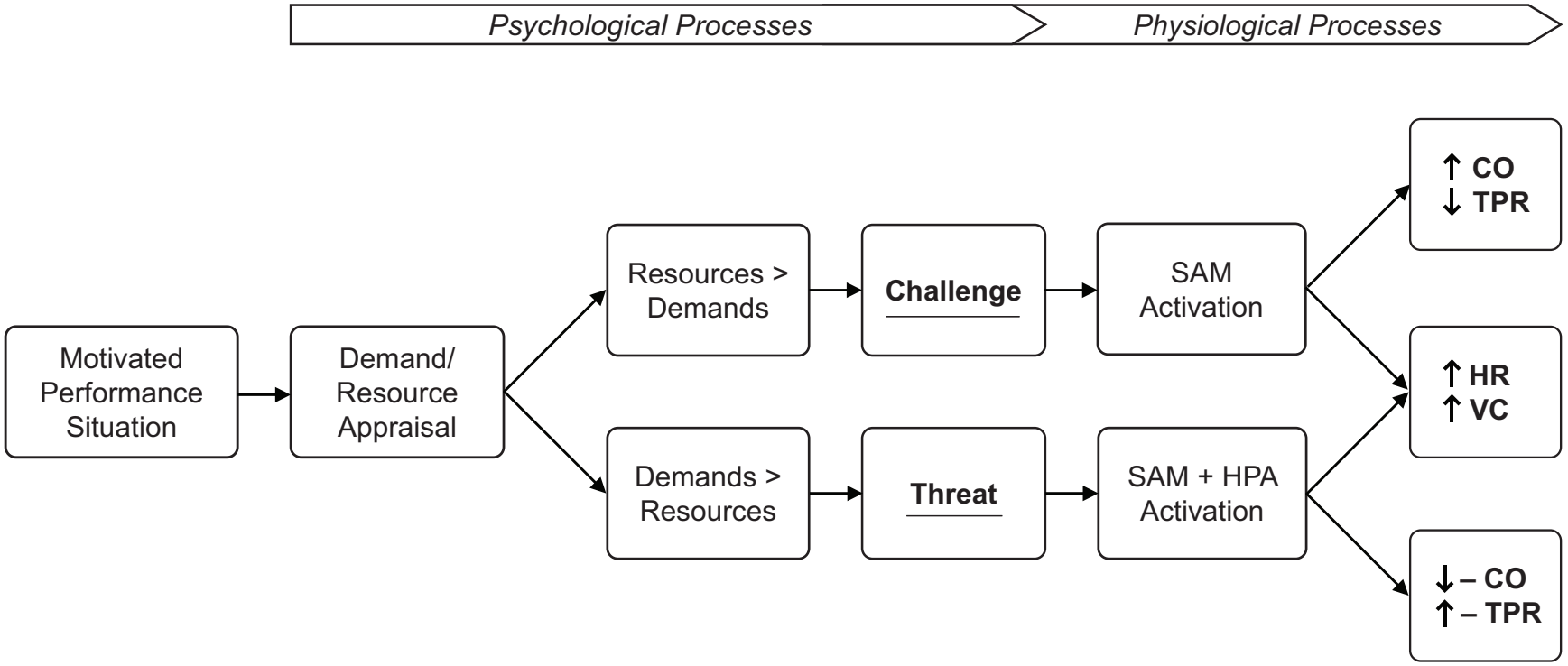
But while these studies have shown such effects on various subjective outcomes associated with stress, none to our knowledge have examined the effects of extraneous arousal on physiological reactivity to stress, including whether or how arousal-moderated evaluations may affect subsequent physiological responses. Understanding how physiology is affected in these circumstances is important because physiological processes are the mechanisms by which stress adversely affects health (McEwen & Stellar, 1993). Additionally, physiological measures allow for continuous, real-time assessment of stress reactivity, and capitalize on autonomic processes that are not susceptible to demand characteristics. A comprehensive investigation of stress reactivity should therefore incorporate physiological responses in addition to psychological ones.

The Biopsychosocial Model of Challenge and Threat

The prevailing model of stress that integrates the psychological and physiological dimensions of active coping is the Biopsychosocial Model of Challenge and Threat (BPSM–CT; Blascovich, 2014; Blascovich & Tomaka, 1996). Built upon established cognitive (Lazarus & Folkman, 1984) and physiological (Dienstbier, 1989; Obrist, 1981) theories of stress and coping, the BPSM–CT presents a framework for the cognitive processes involved in stress appraisal as well as the physiological coping mechanisms they bring about. Like other prominent models of stress and coping, the BPSM–CT considers the interaction between individual and environment critically significant. Based on the ratio of perceived environmental demands to perceived

Figure 1

The Biopsychosocial Model of Challenge and Threat



Note. Adapted from "The Biopsychosocial Model of Challenge and Threat: Using the Heart to Measure to Mind," by M. D. Seery, 2013, *Social and Personality Psychology Compass*, *7*(9), p. 638 (https://doi.org/10.1111/spc3.12052). Copyright 2013 by John Wiley & Sons Ltd.

individual resources, the model defines two relative states of appraisal: *challenge*, where resources outweigh demands, and *threat*, where demands outweigh resources (Figure 1).

A defining principle of the BPSM–CT is that these two appraisal states result in characteristically different patterns of autonomic (particularly cardiovascular) reactivity. These distinctive patterns occur because, according to the model, challenge and threat differentially activate the two major biological stress-response systems, the sympathetic–adrenomedullary (SAM) and hypothalamic–pituitary–adrenal (HPA) axes. According to the model, challenge and threat both activate the SAM axis, the fast-acting, sympathetic response, but threat additionally activates the HPA axis, the slower, neuroendocrine response. In the cardiovascular system, SAM activation leads to increased heart rate (HR), cardiac output (CO) and ventricular contractility (VC), and decreased total peripheral resistance (TPR). Simultaneous HPA activation counteracts some of these effects, attenuating increases in CO and decreases in TPR. Because both challenge and threat states activate the SAM axis, both states are associated with increased HR and VC, a response pattern that is typical of active coping (Obrist, 1981) and indicative of task engagement, a prerequisite for both challenge and threat (Blascovich, 2013). But the activation of the HPA axis exclusively in threat leads to key differences in CO and TPR responses between the two states. Challenge is associated with increased CO and decreased TPR, while threat is associated with relatively stable CO and TPR. Therefore, according to the model, these four variables (HR, VC, CO, and TPR) can be used to infer relative states of appraisal, and differentiate challenge from threat (Blascovich, 2013).

Summary of Past Research

In summary, the nature and significance of autonomic activity in emotion is a compelling and open question in psychophysiology. Physiological arousal (and moreover, interpretation of that arousal) is a major determinant of feeling states, and, by extension, myriad related outcomes.

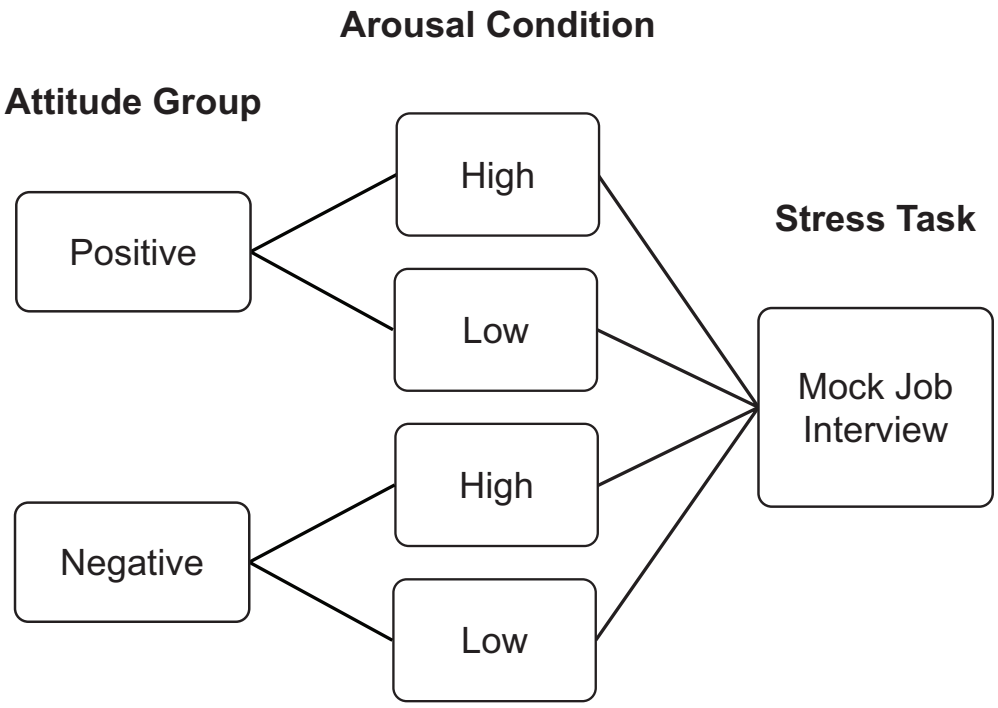
Interpretations are also critically important in the context of stress, where the interaction between situational and individual characteristics consequentially influences how stress is evaluated. According to the BPSM–CT, these different evaluations have distinct physiological corollaries. However, it is not yet known how extraneous arousal would modify psychophysiological reactivity to stress, including appraisals of challenge and threat, and their attendant physiological responses, nor how individual predispositions may moderate those relationships. These are the aims of the present research.

Present Study

This study investigated how nonspecific arousal affects cognitive, emotional, and physiological responses to an active coping task, when individual appraisals of that task differ. In the study, participants exercised either lightly (low arousal) or vigorously (high arousal) before

Figure 2

Design of the Present Study



performance of an active coping task, about which the participants had either positive or negative pre-existing attitudes (Figure 2). A mock job interview served as the active coping task, as it is part of a widely used protocol in stress research (i.e., Trier Social Stress Task [TSST]; Kirschbaum et al., 1993), and individual attitudes toward job interviews vary significantly (McCarthy & Goffin, 2004; Petruzziello et al., 2022). Using the BPSM–CT as an organizing framework, the primary dependent variables included cognitive (challenge and threat) appraisals, positive and negative affect, cognitive and somatic anxiety, perceived performance, and cardiovascular (HR, CO, and TPR) reactivity associated with the task.

Hypotheses

Consistent with prior research (Brown & Curhan, 2013; Chen et al., 2022; Nakajima et al., 2017), it was hypothesized that residual arousal would polarize subjective evaluations of the job interview task, based on pre-existing attitudes. Specifically, in participants with positive pre-existing attitudes toward job interviews, those who were more aroused before the interview would report greater relative challenge appraisals, greater positive affect, less anxiety, and greater perceived performance than those who were less aroused. Conversely, in participants with negative pre-existing attitudes, those who were more aroused would report greater relative threat appraisals, greater negative affect, greater anxiety, and worse perceived performance than those who were less aroused. In regard to cardiovascular reactivity, it was hypothesized that those in the positive attitude group would exhibit more challenge-like cardiovascular reactivity to the task, defined as increased HR, increased CO and decreased TPR from baseline, while those in the negative attitude group would exhibit more threat-like reactivity, defined as increased HR, unchanged CO, and unchanged TPR.

Method

Participants

Adult undergraduate students from the University of Wisconsin–Milwaukee were recruited for the study through the University's online study management website. Eligibility criteria were assessed through a pre-screening survey. Participants were eligible to participate if they reported having either a positive or negative (as opposed to neutral) pre-existing attitude toward job interviews, and, to ensure that these attitudes were based on actual experience, reported having had at least one prior job interview. Because the study involves cardiovascular measurements and a potentially vigorous exercise task, participants who had cardiovascular abnormalities (such as heart arrhythmia or hypertension), were taking medications that specifically affect the cardiovascular system (such as beta blockers or steroids) or had any condition that could be exacerbated by a brief period of vigorous exercise, were excluded.

Twenty students participated in the study. Of these, 10 (50.0%) were women, 2 (10.0%) were Black, and 3 (15.0%) were of Hispanic, Latino/a/x/e, or Spanish origin. They ranged in age from 19–59 (M = 25.70; SD = 9.48). Participant demographic information is reported in Table 1.

Table 1

Demographic Characteristics of the Participants

Variable	Positive Attitude Group n = 10	Negative Attitude Group n = 10
Age	23.90 (6.40)	27.50 (11.83)
Gender		
Men	6 (60%)	4 (40%)
Women	4 (40%)	6 (60%)
Race		
White	8 (80%)	10 (100%)
Black	2 (20%)	0 (0%)
Ethnicity		
Hispanic, Latino/a/x/e, or Spanish	0 (0%)	3 (30%)

Note. Values are M (SD) or n (%).

Materials

Tasks

Arousal Manipulation. To manipulate physiological arousal during the interview, the study used an exercise procedure adapted from Cacioppo et al. (1987). Participants pedaled a stationary bicycle for five minutes at a speed and intensity that brought their heart rate to a level determined by their experimental condition. In the high arousal condition, participants elevated their heart rate to 185% of its resting level or greater; in the low arousal condition, participants kept their heart rate under 135% of its resting level. A pulse oximeter attached to the participant's fingertip provided a continuous measure of their heart rate, and they were allowed to adjust their pedaling speed and the bike's resistance level as desired to achieve their target heart rate. After reaching the target range, both groups maintained it for five minutes. Previous research (Cacioppo et al., 1987) and preliminary testing indicated that participants in the high arousal condition would be in a residual arousal state (i.e., aroused, but unaware of it) approximately 5–8 minutes after cessation of exercise, and that participants in the low arousal condition would no longer be aroused at that time.

Mock Job Interview. A modified version of the TSST (Kirschbaum et al., 1993) served as the active coping task. Participants were asked to imagine that they were about to interview for their "dream job," and that their performance in the interview would be evaluated and used to determine their compensation. They were given one minute to prepare for the interview with a printed list of five questions (e.g., "What are your greatest strengths?" and, "Why do you want this job?" [Appendix A]), paper, and pencil.

The interview was conducted by a secondary experimenter, blind to experimental condition, who entered the study room after the preparation period and sat at a table approximately six feet away, facing the participant. She began the interview by asking the

participant to state the "dream job" for which they had prepared answers. She then asked each of the five interview questions in order, allowing the participant to answer each question to the depth they were inclined. During the interview, the interviewer, who was wearing a face mask, maintained a neutral expression and appeared to take notes. After all five questions had been asked and answered, the interviewer thanked the participant and exited the room.

The TSST reliably produces sympathetic and neuroendocrine stress responses (Dickerson & Kemeny, 2004), and appraisal factors have been shown to moderate these responses (Allen et al., 2014). The TSST has also previously been used in studies applying the BPSM–CT (Jamieson et al., 2012; Mendes et al., 2007).

Measures

Pre-Existing Attitude toward Job Interviews. A one-item pre-screening measure, adapted from Brown and Curhan (2013), assessed participants' pre-existing attitudes toward job interviews. Respondents rated the extent to which they generally dread (–3) or look forward to (+3) job interviews on a 7-point Likert scale. Negative responses indicate a negative pre-existing attitude, positive responses indicate a positive pre-existing attitude, and a response of 0 indicates a neutral attitude.

Beck Anxiety Inventory. The Beck Anxiety Inventory (BAI; Beck et al., 1988; Appendix B), a 21-item self-report measure of anxiety, was used to assess baseline anxiety. In this inventory, participants indicate the degree to which they have experienced common symptoms of anxiety (e.g., "faint/lightheaded," "nervous," "fear of worst happening") during the past week. Responses are given on a 4-point Likert scale from 0 (not at all) to 3 (severely). Responses are summed, yielding a score ranging from 0 to 63 points, where a higher score indicates a greater level of anxiety. The BAI is one of the most widely used research measures of anxiety, and it has demonstrated good internal consistency (Cronbach's $\alpha = .92$), reliability ($r =$

.75 over one week) (Beck et al., 1988), and convergent validity with the State-Trait Anxiety Inventory (Fydrich et al., 1992).

Anxiety Sensitivity Index-3. The Anxiety Sensitivity Index-3 (ASI-3; Taylor et al., 2007; Appendix C) was used to assess sensitivity to anxiety (fear of anxiety sensations). In this 18-item questionnaire, respondents indicate the extent to which they are bothered by common symptoms of anxiety. Participants answer questions such as, "It is important for me not to appear nervous," and "It scares me when my heart beats rapidly" on a 5-point Likert scale from 0 (very little) to 4 (very much). Responses are summed for a total score ranging between 0 and 72 points, where a higher score indicates greater sensitivity to anxiety. The measure has shown robust internal consistency, reliability, and convergent and discriminant validity (Taylor et al., 2007).

Cognitive Appraisals. Cognitive (challenge and threat) appraisals of the interview task were assessed with a 6-item questionnaire adapted from Mendes et al. (2007) and Jamieson et al. (2012). In the pre-task version of this questionnaire (Appendix D), after receiving instructions for the task, participants rated their agreement to three items pertaining to perceived demands (i.e., "The task will be demanding," "…will be stressful," and "…will be threatening") and three items pertaining to perceived resources (i.e., "I have the abilities to perform well," "I will be able to cope with the task," and "The task will be a positive challenge") on 7-point Likert scales from 1 (strongly disagree) to 7 (strongly agree). In the post-task version (Appendix E), items were adjusted for verb tense (i.e., "The task was demanding"). For each version, demand and resource items were averaged separately, and a "challenge–threat index" was calculated from the ratio of resources to demands (Mendes et al., 2007; Tomaka et al., 1993). Higher scores on the index indicate greater perceived challenge relative to perceived threat.

Positive and Negative Affect. Positive and negative affect associated with the interview were assessed with the short form of the Positive and Negative Affect Schedule (PANAS;

Mackinnon et al., 1999; Watson et al., 1988), a 10-item self-report scale consisting of five positive (e.g., "excited," "inspired," and "determined") and five negative (e.g., "distressed," "upset," and "nervous") feeling words. Participants rated the extent to which they felt each emotion during the interview on a 5-point Likert scale from 1 (very slightly or not at all) to 5 (extremely). Scores on the positive and negative items were summed separately to yield measures of positive and negative affect, respectively, and higher scores indicate greater levels of affect. The short form of the measure has demonstrated good reliability and validity (Mackinnon et al., 1999). See Appendix E.

Cognitive and Somatic Anxiety. The Immediate Anxiety Measures Scale (IAMS; Thomas et al., 2002) assessed symptoms of cognitive and somatic anxiety associated with the interview, as well as their perceived effects on performance. The instructions provided written definitions of cognitive and somatic anxiety, and participants rated the degree to which they felt symptoms of each component of anxiety during the interview on a 7-point Likert scale from 1 (not at all) to 7 (extremely). Participants also rated the degree to which they felt that these symptoms facilitated or inhibited their performance in the interview on a 7-point Likert scale from –3 ("Very negative. *It hindered me.*") to +3 ("Very positive. *It helped me.*"). The IAMS has shown good reliability and validity (Thomas et al., 2002), and has previously been used in investigations of challenge and threat (Moore et al., 2012; Trotman et al., 2018; Williams et al., 2017). See Appendix E.

Perceived Performance. Participants rated how well they thought they performed in the interview on a 7-point Likert scale from 1 (not well at all) to 7 (very well). See Appendix E.

Cardiovascular Measures. Electrocardiography (ECG) and impedance cardiography (ICG) were recorded using Biopac SS2L and SS31L transducers (Biopac Systems, Inc., Goleta, CA) and integrated with a Biopac MP36 acquisition device (Biopac Systems, Inc.) at a sampling

frequency of 1000 Hz. ECG spot electrodes were placed in a lead II configuration using the wrist and ankle as connection sites. ICG was recorded with four strips of mylar electrode tape placed on the neck and torso in a tetrapolar configuration, in accordance with published guidelines (Sherwood et al., 1990). The ICG passes a 100 kHz current through the two outer electrodes and measures voltage across the two inner electrodes to assess basal thoracic impedance (Z_0) and its first derivative (dZ/dt).

The ECG and ICG signals were recorded and processed with Acqknowledge (Biopac Systems, Inc.) software. HR (BPM) was derived from the R–R interval of the ECG signal and averaged over 60-second epochs. Stroke volume (SV [ml]) was calculated using the Kubicek equation (Kubicek et al., 1966). CO (L/min) was calculated using the formula:

$$CO = (SV \times HR) \div 1000$$

Systolic (SBP) and diastolic (DBP) blood pressure (mmHg) were taken at each phase of the experiment with an automatic blood pressure cuff (Omron HEM-741CREL) attached to the participant's upper arm. Mean arterial pressure (MAP [mmHg]) was calculated using the formula:

$$MAP = \frac{2}{3}(DBP) + \frac{1}{3}(SBP)$$

TPR (mmHg · min/L) was calculated using the formula:

$$TPR = MAP \div CO$$

Procedure

Recruitment & Assignment to Conditions

Prospective participants took a pre-screening survey that assessed their pre-existing attitudes toward job interviews and prior experience with job interviews (i.e., "To date, how many job interviews have you had?"). Basic demographic information and baseline measures of

anxiety (BAI) and anxiety sensitivity (ASI-3) were also collected in the pre-screen. Participants who met the pre-screen requirements could elect to enroll in the study, which was described as one investigating the effects of exercise and feeling states on the cardiovascular system. Participants were advised that the study involved exercising and answering questions from an experimenter. Those who responded negatively (–1 to –3) to the pre-screening attitude question were allocated to the negative attitude group, and those who responded positively (+1 to +3) were allocated to the positive attitude group. Within each group, participants were randomly assigned to one of two experimental conditions: high arousal or low arousal.

Welcome, Introduction, & Informed Consent

Participants were met at the lab by the primary experimenter, who was blind to the participant's attitude group. The experimenter introduced the study, verified the eligibility criteria, and obtained the participant's written, informed consent. The participant sat at the study table while the experimenter attached the ECG, ICG, and blood pressure cuff. The participant remained seated while five minutes of resting baseline data were recorded. The experimenter left the study room during the baseline period in order to monitor the recordings from an adjoining room.

Exercise Task

The exercise task was presented as a test of how the cardiovascular system responds to exercise. To create the illusion that physiological measures were being taken during the task, the ICG remained attached to the participant during the task, though no actual recording was made. The ECG transducer and blood pressure cuff were disconnected for mobility. The participant's resting heart rate, assessed during the prior baseline period, was used to calculate their target heart rate level for the task as described above. Including instructions for the task, initial

pedaling to reach the designated heart rate range, and the five minutes to maintain that level, the task took about eight minutes.

Post-Arousal Period

After exercise, the experimenter directed the participant back to the study desk and reattached the ECG and blood pressure cuff. One minute of physiological data was recorded to obtain a "post-arousal baseline." The experimenter then presented the instructions for the interview task. Directly after receiving the instructions, the participant completed the pre-task cognitive appraisal measure about the upcoming task. The post-arousal period was designed so that approximately five minutes elapsed between the cessation of exercise and the start of the interview, in order for those in the high arousal condition to be in a residual arousal state during the interview (Cacioppo et al., 1987; Reisenzein & Gattinger, 1982).

Mock Job Interview

After the participant's one-minute preparation period, the secondary experimenter entered the study room and conducted the interview as described above. After the interview, the participant completed the post-task cognitive appraisal measure, along with the PANAS, IAMS, and perceived performance measures.

Debriefing, Compensation, and Dismissal

After all study tasks were completed, a final, five-minute resting baseline period was recorded. The experimenter then administered a brief questionnaire that probed "suspicion" (i.e., "What do you think the purpose of this study was?") and solicited comments about the study. Participants were given a printed debriefing form, thanked for their participation, and dismissed. As compensation for participation, participants received extra credit in their psychology courses and a $10 gift card.

Data Preprocessing and Analysis

As is typical in stress research, within-person reactivity (or change from baseline) scores for each physiological measure were used as the primary dependent variables in the analyses (Kamarck & Lovallo, 2003). Reactivity scores were calculated by subtracting measures taken during the last minute of the baseline period from those taken during the first minute of the interview period. A single-measure index of physiological challenge and threat was computed from the CO and TPR reactivity scores (Casad & Petzel, 2018). These scores were standardized and summed, with TPR scores given a weight of –1 and CO scores given a weight of +1. Higher scores on the resulting index indicate relative challenge, and lower scores indicate relative threat (Casad & Petzel, 2018; Seery, 2011). Data were analyzed using SPSS 28.0 (IBM SPSS Statistics, Armonk, NY). The alpha level was set at .05 for all analyses.

Results

Pre-Experimental and Baseline Characteristics

Of the 20 participants, 10 (50.0%) endorsed a positive attitude toward job interviews, and 10 (50.0%) endorsed a negative attitude. On the –3 to 3 attitude scale, the mean score for the positive group was 2.00 (*SD* = 0.82), and the mean score for the negative group was –1.50 (*SD* = 0.71). The positive and negative attitude groups did not differ significantly in age, $t(18) = -0.85$,

Table 2

Pre-Experimental Survey Scores

Variable	Positive Attitude Group	Negative Attitude Group
Attitude Score	2.00 (0.82)	–1.50 (0.71)
Number of Prior Interviews	6.00 (2.75)	5.90 (3.23)
Beck Anxiety Inventory	7.10 (6.84)	13.40 (11.41)
Anxiety Sensitivity Index	10.70 (14.6)	20.80 (11.27)

Note. Values are *M* (*SD*).

p = .408, nor in distributions of gender, χ^2 (1, N = 20) = 0.80, p = .371, race, χ^2 (1, N = 20) = 2.22, p = .136, or ethnicity, χ^2 (1, N = 20) = 3.53, p = .060. The groups were also equivalent in pre-experimental assessments of anxiety, t(18) = –1.50, p = .152, and anxiety sensitivity, t(18) = –1.73, p = .102, as well as in number of prior job interviews, t(18) = 0.75, p = .941. Pre-experimental survey scores for each group are reported in Table 2.

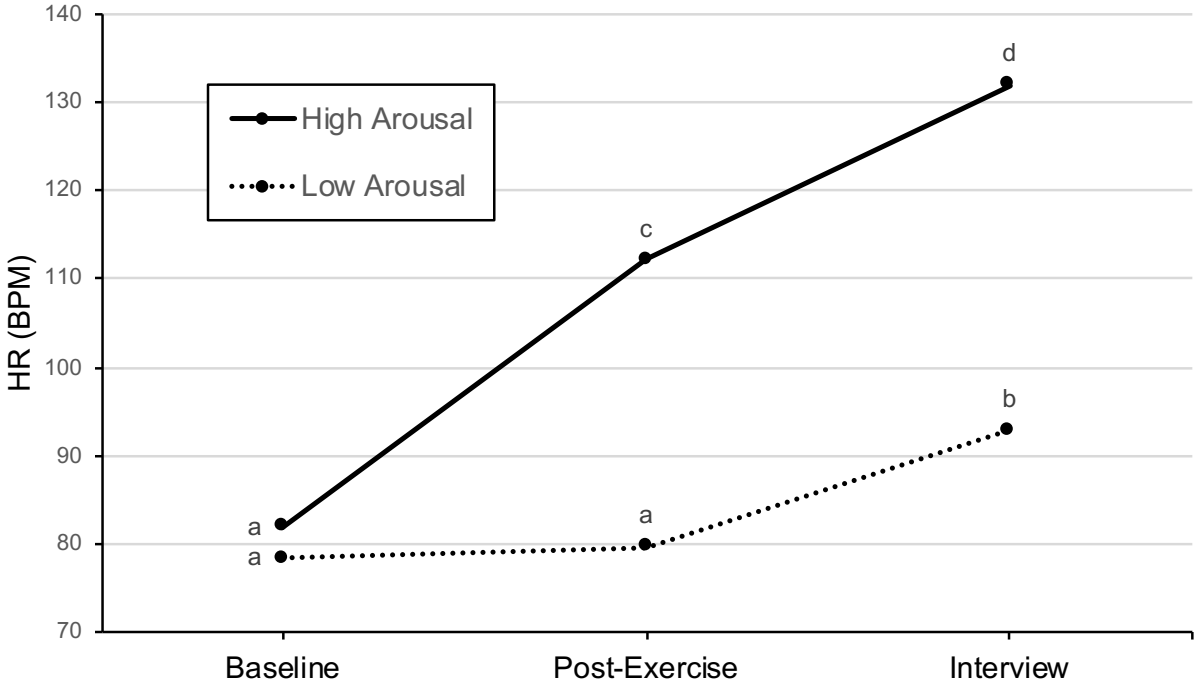
There was a difference, however, in baseline heart rate. The negative attitude group had significantly higher heart rates (M = 88.25, SD = 10.99) than the positive attitude group (M = 72.23, SD = 10.05), F(1, 18) = 11.59, p = .003, η^2_p = .392. The other baseline physiological measures (i.e., SBP, DBP, SV, CO, and TPR) did not differ between the groups, F(1, 18) = 0.15–0.94, p = .345–.904. Participants in the low and high arousal conditions, which were randomly assigned, did not differ with respect to any of the demographic, pre-experimental, or baseline physiological variables (all ps > .10).

Manipulation Checks

After the arousal manipulation, participants in the high arousal condition had significantly higher heart rates (M = 112.16, SD = 11.29) than those in the low arousal condition (M = 79.69, SD = 17.46), F(1, 18) = 24.39, p < .001, η^2_p = .575, indicating that the arousal manipulation was effective in selectively inducing arousal. The low arousal group's post-exercise heart rate was not significantly different from baseline, F(1, 9) = 0.33, p = .579, indicating that, as intended, the low arousal condition had a negligible effect on physiology. Heart rates in both arousal groups increased significantly from post-exercise to the interview (low arousal: F[1, 9] = 56.03, p < .001, η^2_p = .862; high arousal: F[1, 9]) = 14.01, p = .005, η^2_p = .609), indicating that the interview was successful as an active coping task. Heart rates across the study are depicted in Figure 3.

Figure 3

Heart Rates Across the Study by Arousal Group



Note. Means without a common label differ significantly ($p < .05$).

Physiological Reactivity to the Interview

To test the effects of pre-existing attitudes on physiological reactivity to the interview, one-way (positive attitude vs. negative attitude) analyses of covariance (ANCOVAs) were conducted with HR reactivity, MAP reactivity, SV reactivity, CO reactivity, TPR reactivity, and scores on the physiological challenge–threat index as the dependent variables and BAI and ASI-3 scores as covariates. To compensate for the multiple comparisons, the Benjamini–Hochberg (1995) procedure was applied. This procedure corrects for multiway comparisons by controlling the false discovery rate, a strategy that affords more power than controlling for familywise error rate, as in a Bonferroni correction (Thissen et al., 2002). An accepted false discovery rate (Q) of 10% was used. Because of the effects of the arousal manipulation on the physiological variables

of interest (Berntson et al., 1994), these analyses were performed separately for each arousal condition (Chen et al., 2022; Nakajima et al., 2017).

Low Arousal Condition

Within the low arousal condition, the analyses revealed no significant effects of pre-existing attitude on physiological reactivity (all *p*s > .05) (Table 3), indicating that the positive and negative attitude groups did not differ significantly in physiological reactivity to the interview. However, the observed group means for all variables were in the hypothesized directions. As shown in Figure 4, the positive attitude group had greater cardiac reactivity (i.e., SV [M_{diff} = 30.40, *SE* = 18.55] and CO [M_{diff} = 2.62, *SE* = 1.31]) and lesser vascular resistance (i.e, MAP [M_{diff} = 20.18, *SE* = 4.51] and TPR [M_{diff} = 3.37, *SE* = 1.16]) than the negative attitude group, a reactivity profile consistent with relative physiological challenge. These response patterns were reflected in group differences in the physiological challenge–threat index, such that the positive group exhibited more relative challenge than the negative group (M_{diff} = 2.97, *SE* = 1.16), though this difference was also not significant.

High Arousal Condition

Within the high arousal condition, the analyses also showed no significant effects of pre-existing attitude on physiological reactivity (all *p*s > .10) (Table 3), but the group means were again in the expected directions. As in the low arousal condition, the positive attitude group in the high arousal condition had greater CO (M_{diff} = 1.71, *SE* = 3.20) and lesser TPR (M_{diff} = 2.73, *SE* = 2.10), resulting in higher scores on the physiological challenge–threat index (M_{diff} = 0.90, *SE* = 0.97), than their negative attitude counterparts. Changes from baseline in the physiological variables are depicted in Figure 4. Physiological measures for all participant groups are reported in Table 4.

Table 3

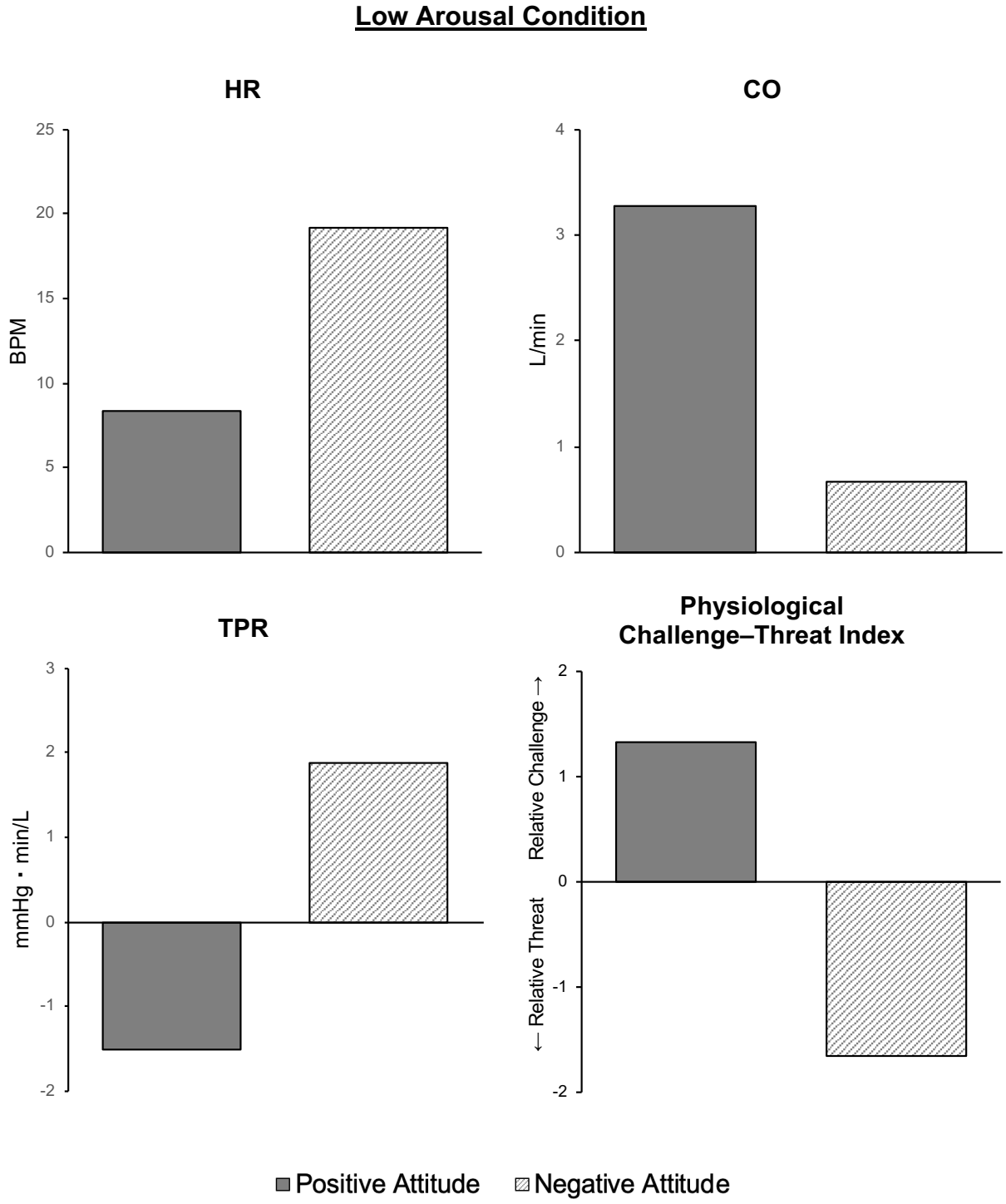
Analyses of Variance for the Physiological Variables

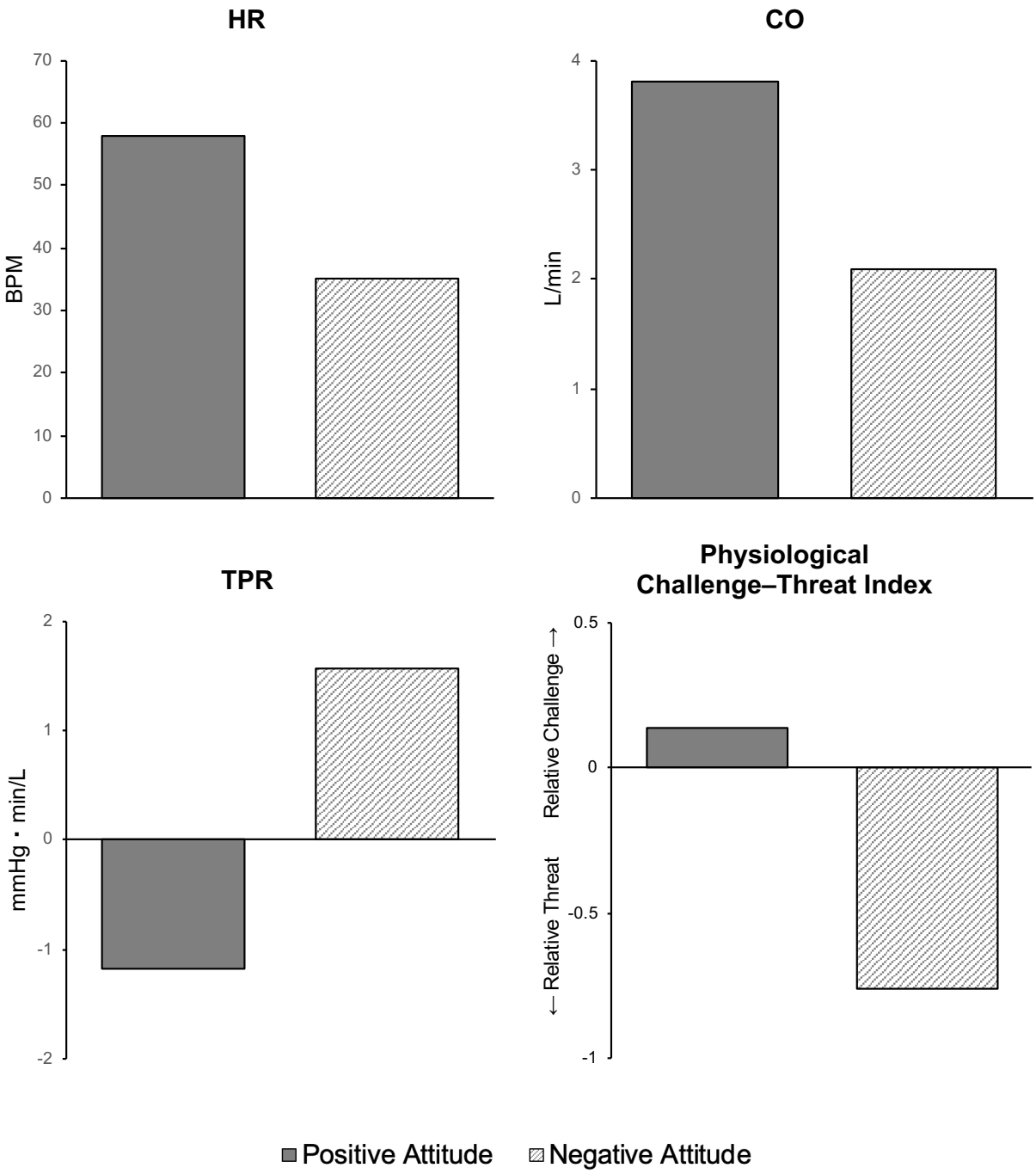
Variable	Attitude (Positive vs. Negative)			
	Low Arousal		High Arousal	
	$F(1, 5)$	p	$F(1, 5)$	p
ΔHR	4.53	.087	2.76	.172
ΔMAP	5.99	.058	4.09	.113
ΔSV	0.81	.411	0.02	.905
ΔCO	1.20	.323	0.12	.743
ΔTPR	2.53	.173	0.74	.440
pCTI	1.98	.210	0.37	.576

Note. Separate one-way (positive attitude vs. negative attitude) analyses of variance were conducted for each arousal group. ΔHR: heart rate reactivity, ΔMAP: mean arterial pressure reactivity, ΔSV: stroke volume reactivity, ΔCO: cardiac output reactivity, ΔTPR: total peripheral resistance reactivity, pCTI: physiological Challenge–Threat Index.

Figure 4

Changes in Physiological Measures from Baseline to Interview





Note. HR: heart rate, CO: cardiac output, TPR: total peripheral resistance.

Table 4

Physiological Measures Across the Study

Measure	Baseline		Post-Exercise		Interview	
	Positive Attitude	Negative Attitude	Positive Attitude	Negative Attitude	Positive Attitude	Negative Attitude
			Low Arousal			
HR (BPM)	71.8 (10.9)	85.2 (14.9)	72.3 (16.1)	87.1 (17.0)	83.3 (11.5)	102.3 (17.7)
SBP (mmHg)	124.4 (14.0)	123.2 (24.9)	125.2 (13.4)	134.8 (27.5)	141.2 (10.7)	157.4 (34.0)
DBP (mmHg)	71.2 (11.8)	78.0 (16.9)	73.4 (13.0)	75.6 (6.8)	84.2 (3.1)	98.8 (10.4)
SV (mL)	143.3 (62.6)	130.5 (77.2)	154.7 (52.6)	145.5 (48.7)	160.7 (47.1)	135.8 (53.1)
CO (L/min)	9.9 (3.2)	11.1 (7.4)	10.6 (1.8)	13.0 (7.0)	13.0 (3.1)	14.8 (8.2)
TPR (mmHg · min/L)	9.9 (3.6)	10.8 (4.6)	8.9 (2.6)	9.0 (3.9)	8.3 (1.9)	9.8 (3.8)
			High Arousal			
HR (BPM)	72.7 (10.4)	91.4 (5.2)	106.8 (8.7)	117.5 (11.8)	130.5 (13.3)	133.2 (16.6)
SBP (mmHg)	118.2 (5.5)	115.8 (5.9)	131.6 (16.3)	136.2 (8.8)	152.5 (8.2)	130.5 (22.9)
DBP (mmHg)	75.0 (4.2)	75.4 (5.0)	79.4 (7.2)	78.6 (2.7)	115.0 (24.1)	90.5 (19.3)
SV (mL)	114.3 (31.5)	121.2 (38.8)	136.1 (57.7)	104.9 (20.5)	108.1 (51.2)	109.5 (33.3)
CO (L/min)	8.5 (3.0)	11.0 (3.0)	14.3 (5.2)	12.2 (2.0)	14.5 (7.8)	14.9 (5.3)
TPR (mmHg · min/L)	11.9 (4.7)	8.6 (2.5)	7.6 (3.1)	8.2 (1.4)	12.8 (6.5)	8.3 (4.1)

Note. Values are *M* (*SD*). HR: heart rate, SBP: systolic blood pressure, DBP: diastolic blood pressure, SV: stroke volume, CO: cardiac output, TPR: total peripheral resistance.

Self-Reported Reactivity to the Interview

The pre- and post-task appraisals of challenge and threat were highly correlated, $r(20) = .80$, $p < .001$. For ease of analysis, only the post-task appraisal was considered in the following analyses.

Effects of Pre-Existing Attitude and Arousal on Self-Reported Variables

To assess the effects of pre-existing attitude and residual arousal on subjective experience of the interview task, two-way ANCOVAs were performed with attitude group and arousal condition as the independent variables, BAI and ASI-3 scores as covariates, and scores on the self-reported challenge–threat index, positive affect, negative affect, cognitive and somatic anxiety, and perceived performance as the dependent variables. The Benjamini–Hochberg procedure was again applied, as described above.

Contrary to the hypotheses, there were no significant differences between attitude groups on the self-reported variables (all ps > .30) (Table 5). Though these results did not reach a level of statistical significance, all group means were in the expected directions, such that the positive attitude group made overall more positive self-reports than the negative attitude group. The positive group appraised the task as more of a challenge ($M_{diff} = 0.66$, $SE = 0.65$), experienced more positive ($M_{diff} = 1.80$, $SE = 1.50$) and less negative affect ($M_{diff} = 0.68$, $SE = 1.18$), experienced less anxiety ($M_{diff} = 0.42$, $SE = 0.91$), and perceived their performance as better ($M_{diff} = 0.50$, $SE = 0.38$) than the negative attitude group.

Also contrary to the hypothesis, there were no significant interactions between attitude group and arousal condition on any of the self-report variables (all ps > .10) (Table 5), indicating that residual arousal did not moderate responses based on pre-existing attitudes. There were, however, main effects of arousal on some of the variables. Participants in the high arousal condition reported significantly more positive affect ($M_{diff} = 6.26$, $SE = 1.49$), $F(1, 14) = 8.30$, p

Table 5

Analyses of Variance for the Self-Reported Variables

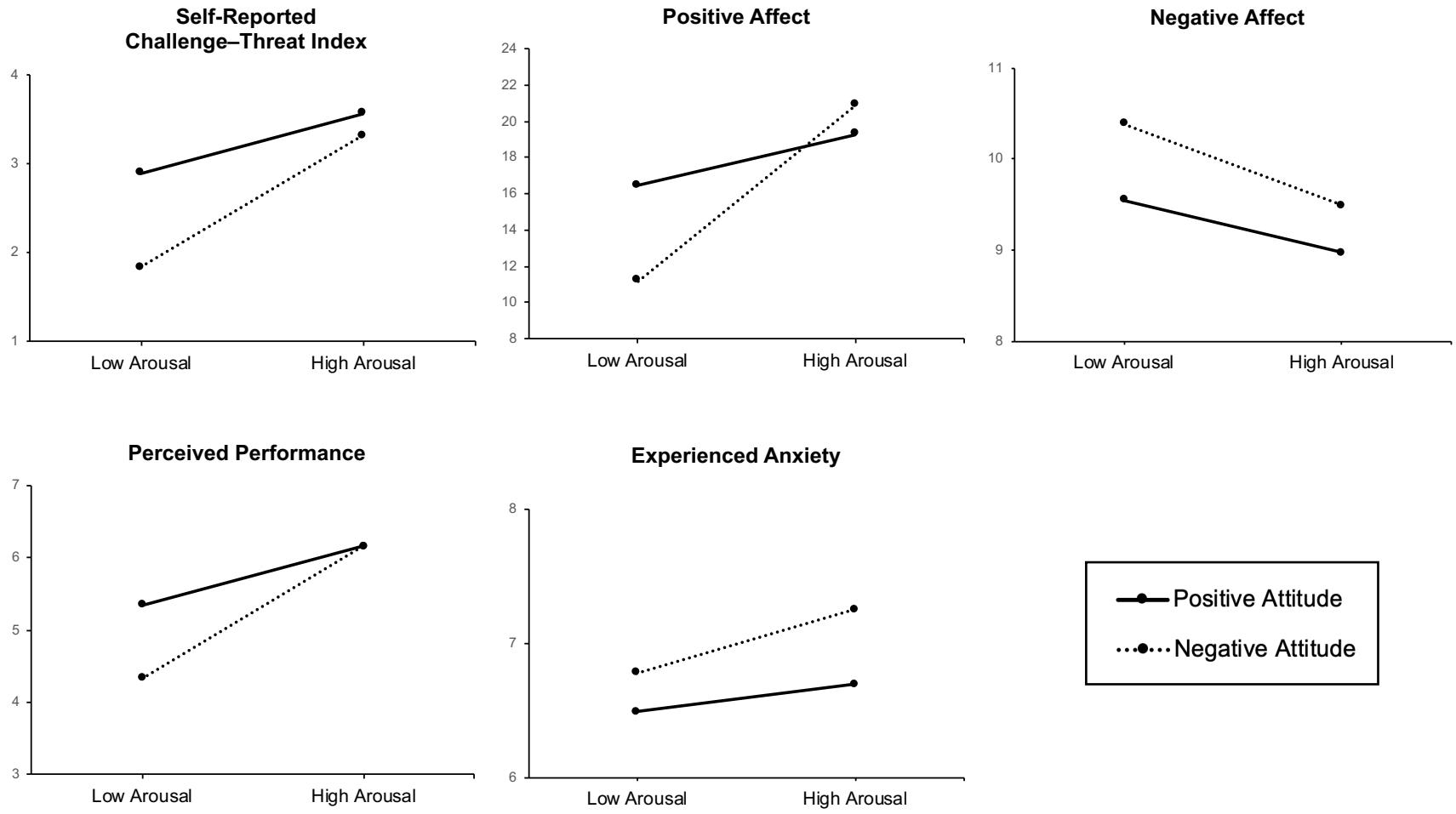
Variable	Attitude (Positive vs. Negative)		Arousal (High vs. Low)		Attitude * Arousal		Anxiety Sensitivity (High vs. Low)		Anxiety Sensitivity * Arousal	
	$F(1, 14)$	p	$F(1, 14)$	p	$F(1, 14)$	p	$F(1, 16)$	p	$F(1, 16)$	p
srCTI	0.47	.504	1.31	.272	0.20	.660	7.93	.012*	1.92	.185
Positive Affect	0.66	.429	8.30	.012*	2.70	.122	5.81	.028*	<0.01	.967
Negative Affect	0.15	.702	0.19	.670	0.01	.922	2.68	.121*	4.35	.053
Anxiety	0.10	.756	0.07	.801	0.01	.919	4.79	.044*	3.98	.063
Performance	0.83	.379	5.71	.031*	0.94	.350	4.05	.061*	0.16	.693

Note. srCTI: self-reported Challenge–Threat Index.

* indicates significance after correction with Benjamini–Hochberg Procedure ($Q = .10$)

Figure 5

Evaluations of the Interview by Attitude Group and Arousal Condition



= .012, η^2_p = .372, and perceived their performance as significantly better (M_{diff} = 1.32, *SE* = 0.38), $F(1, 14) = 5.71$, $p = .031$, $\eta^2_p = .290$, than those in the low arousal condition, indicating that residual arousal amplified these ratings irrespective of pre-existing attitudes. The effects of pre-existing attitude and arousal on the self-reported outcomes are depicted in Figure 5.

Supplementary Analysis of Anxiety Sensitivity

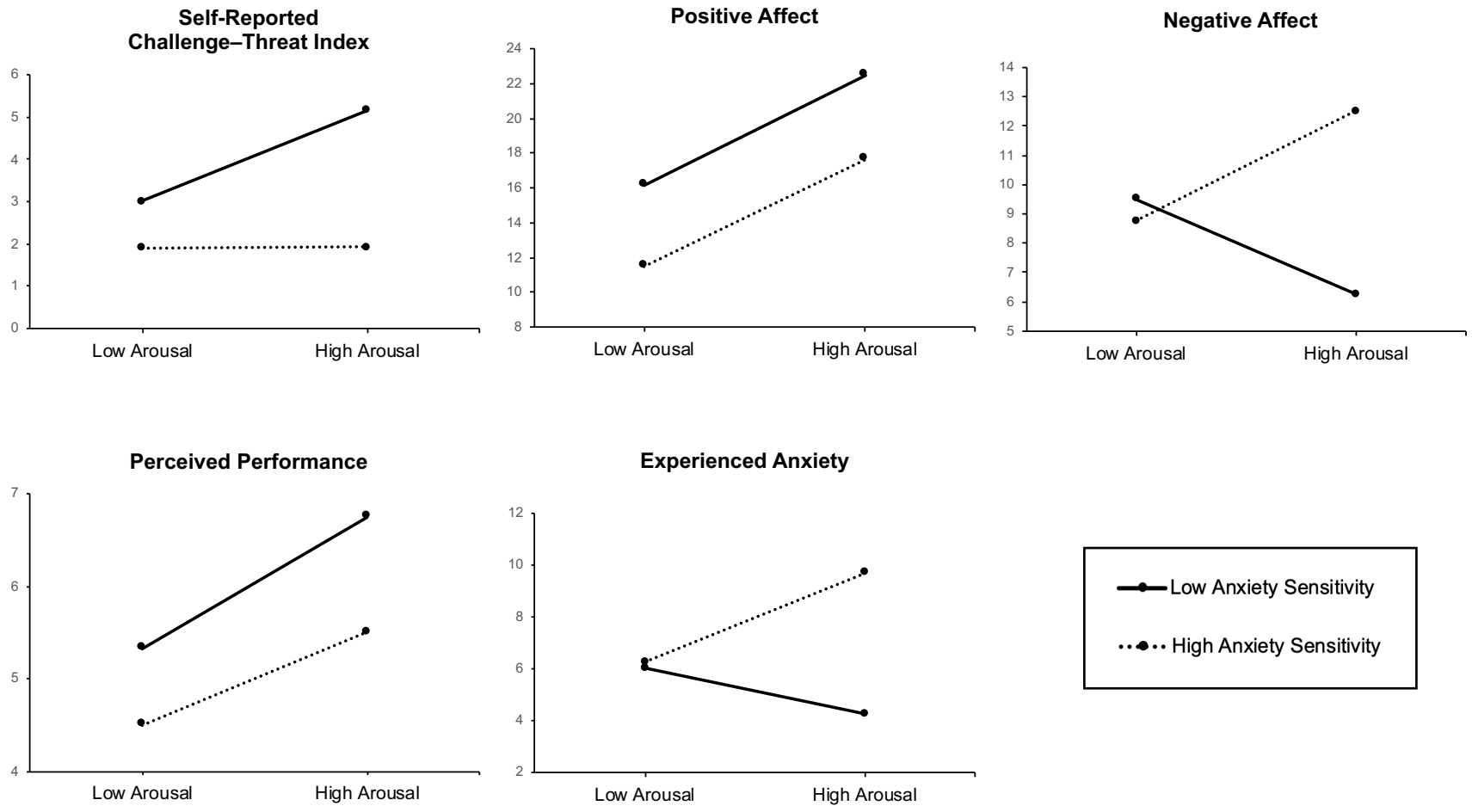
The covariate analyses indicated that anxiety sensitivity was a significant predictor of several of the self-reported dependent variables. As such, we became interested in whether anxiety sensitivity—discomfort with physical anxiety symptoms—would interact with arousal on the self-reported outcomes. Supplementary analyses were performed to test the role of anxiety sensitivity as an independent variable for these outcomes. To do this, scores on the ASI-3 were split at the median into groups of relatively high and low anxiety sensitivity, and the analyses were repeated with anxiety sensitivity in place of pre-existing attitude as an independent variable.

After correction with the Benjamini–Hochberg procedure, this analysis revealed a significant main effect of anxiety sensitivity on all of the self-reported variables (Table 5). Compared to those with low anxiety sensitivity, participants with high sensitivity to anxiety appraised the interview as significantly more of a threat (M_{diff} = 2.17, *SE* = 0.55), $F(1, 16) = 7.93$, $p = .012$, $\eta^2_p = .331$, experienced significantly less positive affect (M_{diff} = 4.75, *SE* = 1.39), $F(1, 16) = 5.81$, $p = .028$, $\eta^2_p = .266$, and more negative affect (M_{diff} = 2.75, *SE* = 1.19), $F(1, 16) = 2.68$, $p = .121$, $\eta^2_p = .144$, experienced significantly more anxiety (M_{diff} = 2.83, *SE* = 0.92), $F(1, 16) = 4.79$, $p = .044$, $\eta^2_p = .230$, and perceived their performance as significantly worse (M_{diff} = 1.04, *SE* = 0.37), $F(1, 16) = 4.05$, $p = .061$, $\eta^2_p = .202$.

There were no significant interactions between anxiety sensitivity and arousal on the self-reported variables (Table 5), but two interactions approached significance. The effects of anxiety

Figure 6

Evaluations of the Interview by Anxiety Sensitivity Group and Arousal Condition



sensitivity and arousal appeared to interact on the measures of negative affect, $F(1, 16) = 4.35$, $p = .053$, $\eta^2_p = .214$, and anxiety, $F(1, 16) = 3.98$, $p = .063$, $\eta^2_p = .199$. From the low to high arousal conditions, both measures appeared to diverge on the basis of sensitivity group. In the low sensitivity group, high arousal resulted in less negative affect ($M_{diff} = 3.25$, $SE = 1.15$) and anxiety ($M_{diff} = 1.75$, $SE = 1.26$) than low arousal. But for participants with high anxiety sensitivity, high arousal led to more negative affect ($M_{diff} = 3.75$, $SE = 1.91$) and anxiety ($M_{diff} = 3.42$, $SE = 1.28$) than low arousal. The effects of anxiety sensitivity and arousal on the self-reported outcomes are depicted in Figure 6.

Discussion

This study exposed participants with differing prior attitudes towards job interviews to a physiological arousal manipulation and a mock job interview, in order to investigate the effects of residual arousal and cognitive appraisal on psychophysiological reactivity to stress. The results showed that participants with different pre-existing attitudes toward job interviews had different physiological responses to the mock job interview, although these differences were not statistically significant. When confronted with the interview, participants who endorsed a negative attitude toward interviews exhibited a cardiovascular response pattern consistent with physiological threat, while participants with a positive attitude exhibited one consistent with physiological challenge.

This differential response did not extend to the self-report variables, such that participants with positive versus negative attitudes did not significantly differ in their cognitive appraisals, affect, anxiety, or perceived performance in the interview. However, such an effect did emerge when participants were grouped on the basis of anxiety sensitivity, rather than pre-existing attitude. Participants who were relatively more sensitive to anxiety reported more negative evaluations on all of the self-reported measures than those who were relatively less sensitive to

anxiety. Arousal did not polarize self-reported outcomes on the basis of either pre-existing attitude or anxiety sensitivity. Rather, arousal amplified ratings on several of the measures, regardless of individual predispositions. Each of these findings will be discussed in turn, followed by implications and limitations of the work, and future directions for this research.

Physiological Reactivity to the Interview

Although differences in the physiological variables were not significant, participants with positive versus negative pre-existing attitudes toward job interviews appeared to exhibit qualitatively different patterns of physiological reactivity during the mock job interview. Specifically, in both arousal conditions, the positive attitude group showed overall greater cardiac reactivity (i.e., SV and CO) and lesser vascular resistance (i.e., TPR) than the negative attitude group. As defined by the BPSM–CT, the response patterns observed in the positive and negative attitude groups are consistent with profiles of physiological challenge and threat, respectively.

For all participants, HR increased from baseline to the interview. Increased HR indicates a sympathetic response, which is commonly triggered during active coping and motivated performance situations (Obrist, 1981), regardless of challenge or threat appraisal (Seery, 2013). Responses in the other cardio- and hemodynamic measures diverged between attitude groups. In the positive attitude group, SV and CO increased, while TPR decreased from baseline. This pattern of increased cardiac reactivity with vasodilation indicates SAM activation without concurrent HPA activation (Blascovich & Tomaka, 1996), a profile consistent with physiological challenge (Seery, 2013). Participants in the negative attitude group exhibited comparatively lesser cardiac reactivity, along with vasoconstriction. From baseline to the interview, SV decreased, while MAP and TPR increased, a pattern which, with the observed increase in HR,

indicates simultaneous SAM and HPA activation (Blascovich & Tomaka, 1996), consistent with physiological threat (Seery, 2013).

Notably, the negative attitude group began the study with higher HR than the positive attitude group. Because the study used a quasi-experimental design in which participants self-selected into attitude groups, it was not possible to ensure group equivalence at baseline. In fact, it is possible that the difference in HR was due to factors related to the attitude variable itself. For instance, those with negative attitudes toward job interviews may hold negative attitudes toward other social situations, such as the study itself, and their higher HR may indicate greater stress or anxiety. But HR is an ambiguous measure when considered in isolation, and differences in HR can result from a number of psychological and physical factors.

Such differences can be problematic, however, because they may affect subsequent reactivity in the affected variables. Specifically, higher baseline levels may limit further increases (such as those caused by an experimental stimulus) due to negative feedback processes, a principle known as the Law of Initial Values (LIV; (Wilder, 1962). However, the LIV applies mainly to baseline differences that result from autonomic manipulations, and less so to those which are due to individual differences (Berntson et al., 1994), which is the likely origin of the difference observed here. In support of this notion, the HR variable did not show an LIV-like effect in reactivity to the interview in the low arousal condition: in addition to having higher HR at baseline, the negative attitude group also had greater increases in HR during the interview. Therefore, it seems that within-person reactivity, the primary dependent variable, was not significantly affected by the nonequivalence at baseline. Still, more data should be collected to determine whether this difference was incidental to the small sample size, or an authentic characteristic of the attitude groups.

Overall, the differences observed in cardiac and vascular response suggest that physiological reactivity to the interview differentiated into prototypical patterns of challenge and threat based on participants' pre-existing attitudes. These findings are consistent with those of other "free appraisal" studies in the BPSM–CT literature (Blascovich & Tomaka, 1996), which find that cardiovascular reactivity to a given task may differ based on individual appraisals of it. The attitude measure as an index of appraisal is unique here, though. The findings demonstrate that general attitudes toward a motivated performance situation may serve as cognitive antecedents of physiological reactivity to that situation. The measure was used here to inconspicuously allocate participants to appraisal groups before the experimental session, so it may be useful to future challenge-and-threat studies with the same objective.

Effect of Pre-Existing Attitude on Self-Reported Variables

Contrary to the hypotheses, the positive and negative attitude groups did not differ significantly in their evaluations of the interview task, as measured by the self-reported variables. However, the general pattern of responses did indicate more favorable self-reports by the positive attitude group across all measures. Though the differences were not statistically significant, the positive attitude group appraised the task as more of a challenge, felt more positive affect and less negative affect, experienced less anxiety, and perceived their performance as better than the negative attitude group. The influence of pre-existing attitudes therefore appeared to emerge across multiple phenomenological outcomes, including emotions, cognitions, and self-perceptions. It is likely that sample size hindered the statistical results, and more data should be collected to better assess these relationships.

Effect of Arousal on Self-Reported Variables

Contrary to the hypotheses, arousal did not appear to polarize the self-report measures on the basis of attitude. Rather, the effects of arousal were similar in both attitude groups. Compared

to those in the low arousal condition, those in the high arousal condition reported more positive affect and better performance on the task, regardless of their pre-existing attitudes. The lack of an interaction effect is inconsistent with the study by Brown and Curhan (2013), who, using a similar design, found that arousal polarized evaluations of a negotiation task based on prior attitudes to negotiation.

That arousal had main effects, rather than interaction effects, suggests that in labeling the arousal-moderated feeling states, other cognitive cues may have been more salient than participants' pre-existing attitudes. This notion is supported by the fact that, regardless of pre-existing attitude, participants' evaluations of the interview were generally positive. The overall mean rating on the challenge–threat index, which represents the ratio of perceived resources to perceived demands, was 2.90 (*SD* = 2.00), indicating that participants widely regarded the task as more of a challenge than a threat. They also rated their performance very favorably (*M* = 5.50 [*SD* = 1.28] on the 1 to 7 scale). The default impression of the interview may therefore have been a positive one, which was further amplified for those in the arousal condition. While this interpretation is consistent with the findings of our previous research, that arousal generates more positive ratings of positive stimuli, it also means that the present findings fall short of answering whether characteristics of an individual, above and beyond those of a target stimulus, can inform arousal-moderated ratings. In this case, it is likely that a bigger sample size is needed to detect the presumably subtler influences of pre-existing attitudes.

It is interesting to note that in the low arousal condition of Brown and Curhan's study, evaluations of the negotiation were similar between attitude groups, and they only diverged in the high arousal condition. This is in contrast to the present study, where evaluations appeared to differ under low arousal, but did not diverge further under high arousal. It is possible that the more neutral starting point in Brown and Curhan's study may have allowed attitudes to more

readily influence appraisals when arousal was introduced. It may therefore be beneficial for future work on this issue to employ a more neutral (i.e., more "threatening") interview scenario. The TSST literature suggests that this could be achieved by modifying one or more of the experimental conditions, including using a panel of interviewers (versus just one), a free speech format (versus a question-and-answer format), and actual or purported video recording of the interview (Narvaez Linares et al., 2020; Wiemers et al., 2013).

Effect of Anxiety Sensitivity on Self-Reported Variables

While the pre-experimental assessment of anxiety sensitivity was initially included as a covariate in the primary analyses, the supplementary analysis of anxiety sensitivity as an independent variable showed that it was itself an important predictor of the self-reported variables. Compared to participants with low sensitivity, those with high sensitivity to anxiety reported significantly lower challenge–threat appraisals, less positive affect, more negative affect, more anxiety, and worse perceived performance. While arousal did not significantly polarize these responses, there did appear to be bidirectional effects of arousal in some of the variables. Specifically, in the high arousal condition, the variables that were not amplified by arousal outright appeared to diverge between the low and high sensitivity groups. From low to high arousal, participants with low anxiety sensitivity reported less negative affect and anxiety, while those with high anxiety sensitivity reported more.

Anxiety sensitivity is the degree to which one fears anxiety-related symptoms, and tends to misinterpret such sensations as harmful (Mantar et al., 2011). High anxiety sensitivity is a psychological risk factor known to exacerbate negative emotional states (McCracken & Keogh, 2009; Zvolensky et al., 2014), which likely explains why it was associated with an overall more negative pattern of self-reports. But the physical symptoms of anxiety feared by those with anxiety sensitivity (e.g., heart palpitations, facial flush, and shortness of breath) are similar to

those of arousal more generally, including that induced by exercise. It is perhaps not surprising then, that those with high sensitivity to anxiety would report even more negative responses in the high arousal condition. Prior research shows that high anxiety sensitivity is associated with anxiogenic (Farris et al., 2019) and negative affective (Smits et al., 2010) responses to exercise, consistent with the pattern observed here.

Implications

Psychophysiology of Emotion

These findings corroborate and expand on our previous work on generalized arousal and physiological specificity in emotion. As in previous studies (Chen et al., 2022; Nakajima et al., 2017), we found that nonspecific arousal affected the perception of feeling states, but that patterns of physiological reactivity differed between states. The results further substantiate the view that nonspecific arousal is sufficient to generate diverse feeling states, but that physiological reactivity differentiates once these states are established. We have now replicated this basic finding using various sources of arousal, various target stimuli, and various cognitive determinants of emotion. The present study makes a particularly important contribution to this investigation because it demonstrates the effect in a context where specific patterns of reactivity (i.e., physiological challenge and threat) could be postulated *a priori*.

Owing to this, the measures of challenge and threat may be auspicious for continued research on this issue. In particular, one of the unsolved problems in this field involves pinpointing *when* emotion-related physiological states begin to differentiate, a question generally believed to be fraught with measurement issues. However, because the physiological indices of challenge and threat are better defined than those of basic emotions, and can be measured sufficiently in intervals much shorter than that required of other emotion-relevant variables, such as heart rate variability, they may be well suited for work on this question. Using shorter and

more frequent epochs for the physiological responses, along with near moment-to-moment self-reports—an innovation of our previous work (Nakajima et al., 2017)—it may be possible to more precisely determine when physiological responses align with self-reported ones, and thus begin to answer this longstanding question.

Stress and Health

The difference in physiological response between attitude groups implies differential activation of the two major biological stress responses. This outcome has important implications because the two mechanisms differ not only in their immediate physiological responses, but in their long-term effects as well. While SAM activation on its own is considered adaptive and largely benign (Blascovich, 2008; Dienstbier, 1989), concurrent activation of SAM and HPA, as in the threat response, has effects that can be considerably detrimental to health (Blascovich, 2008). In this condition, the opposing influences in the cardiovascular system—increased cardiac activity with constriction of the vasculature—put significant strain on the arteries, producing accumulative wear and tear when the response is chronically or repeatedly activated. This damage can lead directly to cardiovascular and immune dysfunction, and indirectly to various other forms of ill health (Blascovich, 2008; Schneiderman et al., 2005). It is therefore of significant interest to health psychologists to identify antecedents of the two stress responses, and in particular, to characterize etiologies of the threat response.

For that reason, it is noteworthy that differential activation of the two responses was found on the basis of pre-existing attitudes. To my knowledge, this is the first study to show that such attitudes can influence challenge and threat responses. While the finding is intriguing, the broad nature of this variable means that it will be pertinent for future research to identify the likely mediators of this relationship, which may include factors related to personality, self-concept, or prior experiences with the attitude object, among others.

Limitations

Several factors limit interpretations of the study's results. First, although the one-question attitude measure was successful in stratifying participants by physiological challenge and threat reactivity, the measure was necessarily a very general one. It could not capture the specific factors that influence respondents' attitudes toward interviews, which are undoubtedly numerous and various. Additionally, because participants self-selected into attitude groups, the relationships observed between attitudes and the measured outcomes cannot be strictly interpreted as causal ones.

Second, the mock job interview was successful as an active coping task, but as a laboratory replica, may have lacked ecological validity. Interviewee motivations, preparation methods, and interview subject matter, among other things, may differ considerably between mock interviews and real ones. These factors may have also contributed to a lack of construct validity in the attitude measure, which referenced real-world interviews.

Third, challenges in recruitment, which may be attributed to the limited research timeline, reluctance of participants to perform an exercise task, and the ongoing COVID-19 pandemic, led to a smaller than desired sample size, which may explain some of the insignificant results. However, the trends observable at present are highly encouraging, and the study will continue recruiting participants in order to reach the full, desired sample size.

Conclusion

This study demonstrated that residual arousal from exercise can affect subjective evaluations of a motivated performance task, and that pre-existing attitudes toward the task can influence patterns of physiological reactivity to it. The results demonstrate how individual predispositions interact with physiological arousal to influence subjective perceptions of, and physiological reactivity to, active coping stressors. The work therefore has implications for the

psychophysiology of emotion and the link between stress and health, and it contributes to our broader understanding of the complex and interdependent relationship between psychological and physiological processes.

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Appendix A

Mock Job Interview Questions

1. Tell me about yourself.
2. Why are you the best candidate for this position?
3. What are your greatest strengths?
4. What are your weaknesses?
5. Why do you want this job?

Appendix B

Beck Anxiety Inventory (BAI)

Instructions: Below is a list of common symptoms of anxiety. Please carefully read each item in the list. Indicate how much you have been bothered by that symptom during the past month, including today, by circling the number in the corresponding space in the column next to each symptom.

Symptom	Not at all	Mildly but it didn't bother me much	Moderately — it wasn't pleasant at times	Severely — it bothered me a lot
1. Numbness or tingling	0	1	2	3
2. Feeling hot	0	1	2	3
3. Wobbliness in legs	0	1	2	3
4. Unable to relax	0	1	2	3
5. Fear of worst happening	0	1	2	3
6. Dizzy or lightheaded	0	1	2	3
7. Heart pounding/racing	0	1	2	3
8. Unsteady	0	1	2	3
9. Terrified or afraid	0	1	2	3
10. Nervous	0	1	2	3
11. Feeling of choking	0	1	2	3
12. Hands trembling	0	1	2	3
13. Shaky/unsteady	0	1	2	3
14. Fear of losing control	0	1	2	3
15. Difficulty in breathing	0	1	2	3
16. Fear of dying	0	1	2	3
17. Scared	0	1	2	3
18. Indigestion	0	1	2	3
19. Faint/lightheaded	0	1	2	3
20. Face flushed	0	1	2	3
21. Hot/cold sweats	0	1	2	3

Appendix C

Anxiety Sensitivity Index-3 (ASI-3)

Instructions: Circle the number from the scale below that best describes how typical or characteristic each of the 16 items is of you. You should make your ratings in terms of how much you agree or disagree with the statement as a general description of yourself.

Characteristic	Very little	A little	Some	Much	Very much
1. It is important for me not to appear nervous.	0	1	2	3	4
2. When I cannot keep my mind on a task, I worry that I might be going crazy.	0	1	2	3	4
3. It scares me when my heart beats rapidly.	0	1	2	3	4
4. When my stomach is upset, I worry that I might be seriously ill.	0	1	2	3	4
5. It scares me when I am unable to keep my mind on a task.	0	1	2	3	4
6. When I tremble in the presence of others, I fear what people might think of me.	0	1	2	3	4
7. When my chest feels tight, I get scared that I won't be able to breathe properly.	0	1	2	3	4
8. When I feel pain in my chest, I worry that I'm going to have a heart attack.	0	1	2	3	4
9. I worry that other people will notice my anxiety.	0	1	2	3	4
10. When I feel "spacey" or spaced out I worry that I may be mentally ill.	0	1	2	3	4
11. It scares me when I blush in front of people.	0	1	2	3	4
12. When I notice my heart skipping a beat, I worry that there is something seriously wrong with me.	0	1	2	3	4
13. When I begin to sweat in a social situation, I fear that people will think negatively of me.	0	1	2	3	4
14. When my thoughts seem to speed up, I worry that I might be going crazy.	0	1	2	3	4
15. When my throat feels tight, I worry that I could choke to death.	0	1	2	3	4
16. When I have trouble thinking clearly, I worry that there is something wrong with me.	0	1	2	3	4
17. I think it would be horrible to faint in public.	0	1	2	3	4
18. When my mind goes blank, I worry that there is something terribly wrong with me.	0	1	2	3	4

Appendix D

Pre-Interview Questions

1. Thinking about the upcoming interview task, please rate your agreement with each statement.

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
	1	2	3	4	5	6	7
a. The task will be demanding.	○	○	○	○	○	○	○
b. The task will be stressful.	○	○	○	○	○	○	○
c. The task will be threatening.	○	○	○	○	○	○	○
d. I have the abilities to perform well.	○	○	○	○	○	○	○
e. I will be able to cope with the task.	○	○	○	○	○	○	○
f. The task will be a positive challenge.	○	○	○	○	○	○	○

Appendix E

Post-Interview Questions

1. Thinking about the interview task you just completed, please rate your agreement with each statement.

	Strongly Disagree 1	Disagree 2	Somewhat Disagree 3	Neither Agree nor Disagree 4	Somewhat Agree 5	Agree 6	Strongly Agree 7
a. The task was demanding.	○	○	○	○	○	○	○
b. The task was stressful.	○	○	○	○	○	○	○
c. The task was threatening.	○	○	○	○	○	○	○
d. I had the abilities to perform well.	○	○	○	○	○	○	○
e. I was able to cope with the task.	○	○	○	○	○	○	○
f. The task was a positive challenge.	○	○	○	○	○	○	○

2. Thinking about how you felt ***during the interview***, please indicate the extent to which you felt each emotion.

	Very Slightly or Not at All 1	A Little 2	Moderately 3	Quite a Bit 4	Extremely 5
a. Distressed	○	○	○	○	○
b. Excited	○	○	○	○	○
c. Upset	○	○	○	○	○
d. Scared	○	○	○	○	○
e. Enthusiastic	○	○	○	○	○
f. Alert	○	○	○	○	○
g. Inspired	○	○	○	○	○
h. Nervous	○	○	○	○	○
i. Determined	○	○	○	○	○
j. Afraid	○	○	○	○	○

3. How well do you think you performed on the interview task?

Not well at all						Very well
1	2	3	4	5	6	7
○	○	○	○	○	○	○

— Please continue on back —

4. Please read the following definitions of **cognitive anxiety** and **somatic anxiety**:

Cognitive anxiety is the mental component of anxiety and may be characterized by thoughts such as concerns or worries about an event, for example about the way you perform or the importance of the event.

Somatic anxiety is the perception of your physical state and may be characterized by symptoms such as physical nervousness, butterflies in the stomach, tense muscles, and increases in heart rate.

a. To what extent did you experience **cognitive anxiety** during the interview?

Not at all			Moderately			Extremely
1	2	3	4	5	6	7
○	○	○	○	○	○	○

b. What effect did this **cognitive anxiety** have on your performance in the interview?

Very negative *It hindered me.*			No effect			Very positive *It helped me.*
-3	-2	-1	0	1	2	3
○	○	○	○	○	○	○

c. To what extent did you experience **somatic anxiety** during the interview?

Not at all			Moderately			Extremely
1	2	3	4	5	6	7
○	○	○	○	○	○	○

d. What effect did this **somatic anxiety** have on your performance in the interview?

Very negative *It hindered me.*			No effect			Very positive *It helped me.*
-3	-2	-1	0	1	2	3
○	○	○	○	○	○	○