AN EXAMINATION OF CARDIAC VAGAL CONTROL INDICES AND COGNITIVE STRESS APPRAISAL IN CIGARETTE SMOKERS

By

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Cigarette smokers represent a vulnerable group for mounting a dysregulated stress response. One predominant determinant of the stress response is the autonomic nervous system’s ability to flexibly shift between arousal and rest states largely driven by the interplay between the sympathetic and parasympathetic nervous system branches. Cardiac vagal control (CVC) has been cited as one measure of autonomic flexibility with evidence suggesting that greater CVC is associated with more adaptive functioning and flexible emotional responding. However few studies have examined how measures of CVC relate to regulatory processes implicated in smoker stress-responsivity. The primary aim of this study sought to explore how two indices of CVC relate to smoker threat appraisal in response to a laboratory stress test. Sixty cigarette smokers underwent a modified trier social stress test during which they gave an impromptu speech to a panel of evaluators while unknowingly randomized to receive positive or negative social feedback. Resting and reactivity measures of CVC were computed, along with a post-task threat appraisal index reflecting the ratio of how demanding participants perceived the task to be relative to their available coping resources. In efforts to build off the exploratory nature of our first aim, we also examined whether social feedback condition moderated the effect of CVC on post-task threat appraisal. In contrast to previous empirical findings from healthy samples, we found no significant main or interactive effects of CVC indices and feedback condition on smoker post-task threat appraisal. Findings from this study have several implications when considering
the relationship between these variables in smokers and can be used to inform future investigative
efforts.
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I. Introduction:

a. Cardiac Vagal Control (CVC) and Autonomic Regulation in Stress Response:

Stress is defined as a state of threatened homeostasis that occurs when a physical or emotional stressor exceeds a certain threshold (Chrousos & Gold, 1992). The ability to mount an adaptive stress response is contingent on a host of physiological, psychological, and behavioral processes that seek to counteract the effects of a stressor and reestablish an organism’s state of homeostatic balance. One predominant determinant of the stress response is the autonomic nervous system’s (ANS) ability to flexibly shift between arousal and rest states largely produced by the sympathetic and parasympathetic nervous system branches. Cardiac vagal control (CVC) has been cited as one measure of this flexibility and can be estimated by heart rate variability (HRV) data in the high frequency range reflecting the variation in timing between successive heart beats (G. G. Berntson et al., 1997; Camm et al., 1996; Pumprla, Howorka, Groves, Chester, & Nolan, 2002; Shaffer & Ginsberg, 2017). CVC is also thought to reflect the parasympathetic nervous system’s (PNS) predominantly inhibitory influence on the electrical activity of the heart via the vagus nerve (T. Beauchaine, 2001; Porges, 1995a). When an organism perceives the surrounding environment as relatively stable or safe, the vagus nerve increases its inhibitory influence, or “brake”, on cardiac rhythm, resulting in reduced heart rate and the generation of a calm visceral state. Conversely, in the face of physical or psychological stress the vagus nerve disinhibits, i.e., withdraws its inhibitory brake, allowing for the sympathetic nervous system (SNS) to dominate cardiac control. The SNS’s excitatory influence on cardiac activity results in chronotropic and inotropic effects that allow the organism to rapidly mobilize and adapt to the demands of the situation (Berntson et al., 1994; Sinski, Lewandowski, Abramczyk, Narkiewicz, & Gaciong, 2006).

b. CVC as a physiological correlate of self-regulatory control: Considerations when interpreting resting measures
In addition to its role in autonomic regulation, CVC has also received increasing attention over the past two decades as a non-invasive, physiological correlate of regulatory ability associated with a wide range of self-control processes and outcomes. (Appelhans & Luecken, 2006; Balzarotti, Biassoni, Colombo, & Ciceri, 2017; T. Beauchaine, 2001; T. P. Beauchaine, 2015). For example cross-sectional work has found a significant relationship between levels of CVC at rest and a measure of self-control following failure, with greater CVC at rest associated with increased self-confidence and less ruminative thinking (Geisler & Kubiak, 2009). In the context of a laboratory mood induction, participants with higher resting levels of CVC were more likely to spontaneously suppress negative facial expressions when shown an aversive film, suggesting better down regulation of unwanted negative emotional expression (Pu, Schmeichel, & Demaree, 2010). Despite these findings and others, a recent meta-analysis examining CVC and emotion regulation suggests that resting measures of CVC are not always robust predictors of the conscious and unconscious strategies people use to manage their emotions (for a full review of studies see Balzarotti et al., 2017). For example, in contrast to other experimental studies, Frazier and colleagues (2004) found no significant relation between resting levels of CVC and subjective reports of arousal in response to a laboratory mood induction (Frazier, Strauss, & Steinhauer, 2004). Regarding processes of attention and cognitive control, Duschek et al. (2009) also found no relation between baseline CVC and attentional capacity during a cognitive test, while another study found an inverse relation between higher resting vagal tone and poorer performance on a visuospatial attention task (Cellini, Covassin, de Zambotti, Sarlo, & Stegagno, 2013; Duschek, Muckenthaler, Werner, & del Paso, 2009). Further, a meta-analytic review of resting HRV (i.e., resting CVC) and self-control performance on laboratory tasks found a small association between HRV and self-control that was further reduced and rendered non-significant once accounting for observed publication bias (Zahn et al., 2016).

c. **Vagal reactivity as an alternative, potentially more reliable, marker of CVC**
While these inconsistencies pose challenges to interpreting the significance of resting CVC as a biomarker of regulatory control, the broader relationship between CVC and processes of self-regulation should not be overlooked. One alternative means by which to examine CVC is in vivo, i.e., via transient changes in vagal activity in response to experimental manipulation. Work in this area suggests that greater vagal withdrawal (i.e., greater CVC) in response to laboratory stress (Hansen, Johnsen, & Thayer, 2003; Muhtadie, Koslov, Akinola, & Mendes, 2015) and mood induction (Butler, Wilhelm, & Gross, 2006; Frazier et al., 2004) is associated with stress responsivity. For example, in Butler et al.’s (2006) study, women instructed to either suppress or reappraise emotions in response to a sad film evidenced greater increases in PNS activity relative to uninstructed controls, indicating an association between cognitively guided regulatory effort and CVC. A systematic review of CVC and adaptive functioning extended these findings to children. Specifically, the authors found greater levels of vagal reactivity to be associated with less externalizing and internalizing symptoms, as well as fewer cognitive and academic problems (Graziano & Derfinko, 2013). While another meta-analysis examining the association between CVC reactivity and structural dimensions of psychopathology found a small association with significant heterogeneity observed across investigations, the authors emphasize the lack of standardized assessment methods for measuring CVC reactivity as a significant contributor to these discrepant findings (Theodore P Beauchaine et al., 2019). Systematic differences in methodological rigor aside, relative to CVC at rest, measures of vagal reactivity are presumed to reflect in vivo regulatory efforts and may potentially serve as more reliable and valid markers of CVC and self-regulation in the context of stress.

d. **Support for a flexibility hypothesis: Measures of CVC reactivity reflecting general exertions of regulatory control**

Despite findings associated with CVC reactivity appearing more consistent, work in this domain is not without interpretive caveats. While some (e.g., Christie & Friedman, 2004) have argued that CVC reactivity reflects shifts in emotional expression or experience, whereby reduced
CVC (i.e., less withdrawal of the vagal brake) in response to an event is broadly associated with negative affective states, evidence for this perspective is largely mixed (Balzarotti et al., 2017). More consistent empirical work suggests CVC regulation reflects the general exertion of self-regulatory effort irrespective of the associated shift in emotional experience that may occur. For example, in Frazier et al.’s (2004) mood induction study, where resting CVC was unrelated to measures of film response, greater CVC reactivity was observed in the context of emotionally salient vs. neutral stimuli, irrespective of positive or negative valence (Frazier et al., 2004). The observation that CVC reactivity is related to emotional salience, regardless of valence, goes against the perspective that CVC reactivity functions specifically to regulate negative affective states. In accord with the conceptualization of CVC reactivity reflecting the general exertion of regulatory effort, CVC reactivity occurring in response to both positive and negative stimuli may reflect general metabolic efforts used to redirect resources and energy that enable an individual to attend to and engage with the stimuli in their environment (i.e., attention allocation, information processing). Muhtadie and Mendes’ (2015) examination of CVC reactivity in response to a social stress test, where participants received real-time positive or negative social feedback during a mock job interview, further extends this claim. The researchers examined whether social feedback condition moderated the effect of vagal withdrawal on participant self-reported shame post-interview. They found that participants who evidenced greater CVC reactivity across both feedback conditions exhibited heightened social sensitivity. Specifically, greater vagal withdrawal in the context of negative feedback was associated with greater self-reported shame, whereas in the context of positive feedback, greater withdrawal was associated with less self-reported shame. Findings from this study not only support the notion that CVC reactivity reflects the general exertion of regulatory effort, that occurs irrespective of affective outcome (i.e., more or less self-reported shame), but also suggests CVC reactivity may facilitate one’s ability to adaptively assess surrounding context cues (Muhtadie et al., 2015; Porges, 1995b). Under this perspective, a reflection of optimal CVC is the ability of the vagus nerve to withdraw just enough
such that the individual is able to adequately attend to environmental stimuli and generate a physiological arousal state appropriate to the situation (H. G. Kim, Cheon, Bai, Lee, & Koo, 2018; Porges, 1995a, 1995b). Empirical and theoretical support for this flexibility hypothesis indicate greater CVC reactivity during tasks of high attention and cognitive demand reflect greater self-regulatory effort (Butler et al., 2006; Gyurak & Ayduk, 2008; Muhtadie et al., 2015; Thayer, Hansen, Saus-Rose, & Johnsen, 2009; Thayer & Lane, 2000).

e. The role of cognitive appraisal in the context of stress

In efforts to develop a more cohesive picture for what contributes to an adaptive stress response, attention should also be allocated to other non-physiological regulatory processes that may onboard and integrate with physiological processes in the context of stress and impact well-being. For example, cognitive appraisal, or how an individual perceives the demands of a stressor in relation to their available coping resources, has been cited as a critical determinant of the stress response (Lazarus & Folkman, 1984). Comprised of primary and secondary appraisals, cognitive appraisal is posited to have a greater influence on one’s mental health than an actual stressor itself (Lazarus, 1966; Lazarus & Folkman, 1984). Specifically, primary appraisal assesses how a potentially stressful event may influence an individual’s well-being, while secondary appraisal evaluates how an individual’s available physical, psychological, and social coping resources weigh relative to the perceived demands of the situation. Stressful events anticipated to result in harm or loss, or seen to have already caused harm or loss, are viewed as threats, while stressors that can be overcome and result in potential growth are viewed as challenges (J Blascovich & Mendes, 2000; Tomaka, Blascovich, Kibler, & Ernst, 1997).

f. Model of Neurovisceral Integration: A theoretical framework of CVC and Threat Appraisal:

Given that perceptions of threat and safety are inherent elements of stressors, how an organism appraises a stressor is therefore closely linked to the type of physiological response generated by the ANS and other stress-related systems (H. G. Kim et al., 2018). Theoretical
frameworks of CVC, including Thayer and colleagues’ Model of Neurovisceral Integration, suggest that measures of CVC serve as peripheral markers of the prefrontal cortex’s inhibitory influence over subcortical regions in the brain implicated in defensive behavior. This broader composition of brain structures associated with self-regulatory processes, also known as the Central Autonomic Network (CAN), is presumed to exert control over the ANS branches resulting in the interplay between the PNS and SNS, which in turn produces HRV (Thayer & Friedman, 2002; Thayer et al., 2009; Thayer & Lane, 2000). On the one hand, from an evolutionary perspective, a default threat response, characterized by greater CVC reactivity, to novel or uncertain stimuli is presumed to be advantageous as it prepares the ANS to rapidly mobilize and respond if need be (Porges, 1995b; Thayer, Ahs, Fredrikson, Sollers, & Wager, 2012). However, individuals who are more likely to appraise the demands of a stressor as continuously exceeding their available coping resources may be at greater risk for generating an inappropriate stress response in both physical and psychological domains.

Empirical support for CVC and appraisal: The potential for generating a dysregulated stress response

To avoid living under continuous perceptions of threat, it is therefore critical for an individual to be able to determine if and when a threat appraisal is appropriate given their surrounding context. Thayer et al. (2012) suggest that CVC may be a marker of the degree to which a healthy brain is able to provide context-dependent regulation, whereby measures of CVC are argued to be associated with neural structures involved in the appraisal of threat and safety. Findings from neuroimaging studies support this claim suggesting that CVC may be linked to cortical brain regions implicated in appraisal of a situation as stressful (Thayer et al., 2012). Observational lab findings further extend this assertion with one study demonstrating that participants with lower resting CVC evidenced an impaired ability to inhibit attention to fearful vs. neutral face cues (Park, Van Bavel, Vasey, & Thayer, 2012). The authors posit that one implication of this failure is that the inability to regulate attention away from affectively
significant stimuli may lead to prolonged fear processing of threat related information and, in turn, generate an exaggerated stress response. A meta-analytic review of stress and measures of HRV found the most consistent factor associated with observed variations in HRV in the context of stress to be low PNS activity, characterized by decreases in the high-frequency HRV band and increases in the low-frequency HRV band (H. G. Kim et al., 2018). According to this perspective, diminished or excessive stress-related changes in HRV spectral components associated with PNS and SNS activity may serve as indicators for poor regulatory control and may increase one’s proclivity for generating a dysregulated stress response.

h. Individuals who smoke cigarettes are at increased risk for generating a dysregulated stress response

Implications for poor autonomic and self-regulatory control are particularly relevant for populations where stress is tightly linked to deleterious health behaviors and poor prognostic outcomes. Individuals who smoke cigarettes represent one considerably vulnerable group. Indeed, stressful life events are associated with the onset and maintenance of smoking behavior in established smokers and are frequently cited as risk factors for smoking relapse and poor cessation outcomes (S. Cohen & Lichtenstein, 1990; McKee, Maciejewski, Falba, & Mazure, 2003). Greater emotional reactivity to stress induction has also been associated with shorter duration of past quit attempts (Calhoun, Dennis, & Beckham, 2007), and both general and acute levels of psychological distress have been linked to stress-induced smoking during a prospective quit attempt (Siegel, Korbman, & Erblich, 2017). Moreover, acute stress reactivity, as indexed by self-report measures of emotional distress, has been found to predict the number of cigarettes smoked during a two-week quit attempt and to mediate the relationship between general distress and stress-induced smoking (Siegel et al., 2017). Such findings highlight the impactful nature of stress on smoking behavior and call for further examination of factors that contribute to smoker stress reactivity. However, research investigating vagal activity as a component of the stress response and how it contributes to smokers’ subjective experience of stress remains understudied.
Evidence for CVC and appraisal independently contributing to smoker stress reactivity

Examination of the relationship between CVC and cognitive appraisal in smokers may serve as one approach for addressing this research gap. Indeed, extant work has shown that stress appraisal may be particularly relevant for smokers. For example, the perceived ability to handle emotional distress without smoking, prior to a quit attempt, has been shown to predict abstinence at 12-months follow up (Nohlert, Ohrvik, & Helgason, 2018). Hajek et al. (2010) also found that changes in smoking status over a 1-year period were associated with changes in perceived stress among smokers attempting cessation (Hajek, Taylor, & McRobbie, 2010). Missing from the literature are studies taking an integrated approach toward understanding the role of physiological and subjective stress responding on smoking. Yet, the relationship between smoking and autonomic dysfunction has also been well characterized (Bodin et al., 2017; Dinas, Koutedakis, & Flouris, 2013; Middlekauff, Park, & Moheimani, 2014). Dinas et al.’s (2013) review found marked dysregulations in autonomic function, characterized by heightened SNS activity, reduced PNS modulation and overall HRV, in response to both acute and chronic cigarette use, as well as to active and passive exposure to cigarette smoke. This is particularly salient as markedly reduced CVC, as a function of smoking, may impede regulatory efforts necessary to refrain from smoking during prospective quit attempts. In line with this perspective, reduced CVC in response to laboratory stress has been associated with increased likelihood of smoking and greater smoking reward (Ashare et al., 2012). Moreover, observed increases in autonomic regulation during continued smoking abstinence suggest that the diminishing effects of cigarette use on CVC are potentially reversible (Minami, Ishimitsu, & Matsuoka, 1999; Yotsukura et al., 1998).

Limited work has examined CVC in relation to cognitively based regulatory control processes (i.e., appraisal) in smokers in the context of stress.

Despite independent lines of research supporting the relation of CVC, stress appraisal,
and smoking, limited work has examined how indices of CVC relate to cognitively based regulatory control processes in smokers in the context of stress. Indeed, examinations of CVC as a marker of self-regulation have predominantly focused on healthy samples. A majority of studies tend to exclude daily cigarette smokers, or control for smoking status when interpreting findings, which may preclude understanding of CVC as a marker of regulatory control in this vulnerable population. Deficits in autonomic functioning and how they correspond with other regulatory processes that may onboard in the context of stress (i.e., threat appraisal), may serve as identifiable targets of treatment intervention for smokers prone to stress-precipitated smoking and poor cessation outcomes. Moreover, previous work noting inconsistencies in findings associated with CVC at rest in healthy samples, along with observed deficits in autonomic functioning that inherently arise from cigarette use, call for further attention to how resting and reactivity measures of CVC may differentially present in smokers.

k. Purpose of the current study

The purpose of the current study is to examine how two indices of CVC relate to smoker threat appraisal in response to a laboratory stress test. To our knowledge few, if any, studies have examined the association between both resting and reactivity measures of smoker CVC and processes of self-regulation in the context of stress. Given theoretical frameworks of CVC are primarily informed by findings from healthy samples, research exploring if and how these perspectives may translate to individuals who smoke is needed. As such our primary aim seeks to explore the relations between CVC at rest and CVC reactivity on smoker post-task threat appraisal. Participants were randomized to complete an evaluative task during which they received real-time positive or negative social feedback, while measures of appraisal were assessed and physiology was continuously recorded. In accord with extant theoretical and empirical work linking higher resting CVC and greater CVC reactivity to various measures of adaptive functioning and regulatory control in healthy samples (Thayer & Friedman, 2002), evidence of a relation between greater CVC rigidity (i.e., lower CVC at rest and less CVC
reactivity) and higher post-task threat appraisal scores in response to stress is conceivable. In
efforts to build off the exploratory nature of our first aim and further investigate a flexibility
hypothesis of CVC, we will also examine whether social feedback condition (positive vs. negative) moderates the effect of CVC on post-task threat appraisal. In accord with the perspective that CVC reflects the general exertion of self-regulatory effort used to promote adaptive responding consistent with environmental demands (Muhtadie et al., 2015; Porges, 1995a, 1995b), we predict that smokers evidencing greater CVC on both resting and reactivity measures will respond to negative feedback with higher post-task threat appraisal scores, whereby the demands of the task will outweigh individual coping resources. Conversely, smokers evidencing greater CVC in response to positive feedback will report lower post-task threat appraisal scores, where coping resources outweigh perceived demands.

II. Method:

Participants:

Participants were recruited from the local New Brunswick area via online and posted advertisements in the community (e.g. Craigslist, community bulletin boards, newspaper advertisements, etc.). Eligible participants were 1) 21-45 years old, 2) smoked at least ten cigarettes per day, 3) were computer proficient, and 4) fluent in English. Exclusion criteria included 1) history or presence of bipolar spectrum or psychotic spectrum disorders, 2) current suicidal or homicidal ideation, 3) evidence of current (non-nicotine) substance use disorder, or 4) reported use of a pharmacological aid for smoking cessation and/or active attempts to reduce cigarette use in the past month. Individuals with visual, hearing, or cognitive impairments that would interfere with study participation or provision of informed consent, as well as medical conditions and medication use contraindicated for participation in a stress provocation or that might confound autonomic nervous system reactivity were also excluded.
**Procedure:**

The data reported in this paper was collected as part of a larger study examining how differences in threat appraisal, and associated differences in physiological response profiles, predict smoking cognitions and behaviors in daily smokers. Study participation included 1 laboratory visit. Prior to the scheduled visit, participants were screened for basic eligibility criteria during an initial phone screen and were emailed a unique link to a battery of online questionnaires to be completed using Qualtrics prior to their lab visit. Completion of online surveys took approximately 1 hour. Participants who did not complete the online questionnaires prior to their study visit were administered the online surveys at the start of their scheduled lab appointment following informed consent procedures. The total duration of study participation, including completion of online questionnaires and laboratory visit, lasted 3-4 hours.

Upon arrival participants were consented using procedures approved by the Rutgers University Institutional Review Board and were re-assessed for study inclusion/exclusion criteria via a brief interview. Breath levels of carbon monoxide (CO) were obtained at the start of the visit to verify smoking status (CO > 8ppm; Javors, Hatch, & Lamb, 2005). Following consent and verification of smoking status, participants were asked to smoke a cigarette in order to standardize baseline craving and control for variability in nicotine withdrawal before being hooked up to the physiological recording equipment and undergoing a laboratory stress provocation. Additional measures of mood, craving, nicotine withdrawal, smoking topography, and HPA-axis reactivity were also recorded at several time points throughout the laboratory visit. At the end of the visit participants were debriefed and compensated $80.

*Laboratory Stress Provocation: Trier Social Stress Test*

The modified Trier Social Stress Test (TSST) is a standardized laboratory protocol for inducing moderate psychological distress in a controlled setting where participants are asked to compose and deliver a speech in front of confederate evaluators (Birkett, 2011; Taylor et al.,
Participants were unknowingly randomized to receive positive (e.g. Challenge) or negative (e.g. Threat) confederate feedback during their speech.

Study participants were provided a separate informed consent detailing the procedures of the TSST upon its introduction. After providing written consent, participants were asked to give a 5-minute speech explaining why they believe they are the best applicant for a job of their choosing in front of a panel of judges with expertise in speech evaluation and in reading non-verbal behavior. Participants were provided a 2-minute preparation period where they could mentally prepare their speech without taking any notes. During this 2-minute period participants were randomized to receive positive (e.g. smiling, nodding, etc.) or negative (e.g. frowning, head shaking, etc.) non-verbal feedback. Confederate evaluators, one male and one female, with at least one matched for race/ethnicity, then entered the room, sat across from the participant, and instructed them to begin the 5-minute speech task. Approximately 30 seconds into the speech, the evaluators began to slowly ease into the provision of their assigned positive or negative non-verbal feedback. At the end of 5 minutes the evaluators then engaged the participant in a 5-minute question and answer session to extend the stressor; during this time, evaluators continued to provide positive or negative feedback. Following the speech and Q&A portions, the evaluators left the room and participants were allotted a 5-minute recovery period before being provided instructions for the next portion of the study.

Measures and Administration:

Demographics and Smoking-relevant indices

A participant information form was used to confirm that participants adhered to provided instructions prior to their lab visit as well as to confirm other eligibility criteria obtained during the initial phone screen including age, sex, and body mass index (BMI). To ascertain the number of cigarettes smoked per day, participants completed the Timeline Followback (TLFB) at the start of the lab visit assessing daily cigarette use over the past 28 days (Robinson, Sobell, Sobell, & Leo, 2014). Nicotine dependence was evaluated using the Fagerström Test for Cigarette
Dependence (FTCD; previously identified as the Fagerström Test for Nicotine Dependence (FTND)), a 7-item measure used to assess quantity of cigarette consumption, compulsion to use, and nicotine dependence. The scale includes yes/no items (scored as 1 or 0) and multiple-choice items (scored from 0-3). Item scores are summed to give a total score from 1-10 with higher scores indicative of greater dependence (Fagerström, 2011; Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991). In the current investigation, internal consistency for the FTCD scale was $\alpha = 0.31$. The low value observed here is consistent with previous reports for this measure (Etter, Duc, & Perneger, 1999). Lastly, a Smoking History Questionnaire (SHQ) was administered to assess participants smoking history and patterns of use (i.e., age of onset of smoking initiation, years being a daily smoker, etc.) (Brown, Lejuez, Kahler, & Strong, 2002).

**Cognitive Stress Appraisal**

Cognitive stress appraisals were assessed both prior to and after the TSST using the Primary and Secondary Appraisal (PASA) Scale, an 11-item measure used to assess how demanding an individual perceives a task to be in relation to their available coping resources (Gaab, Rohleder, Nater, & Ehlert, 2005). Perceived resources are assessed with five items (e.g. I performed well on this task) and perceived demands with six items (e.g. The task was stressful), rated on a 7-point scale (ranging from 1= “Strongly Disagree” to 7= “Strongly Agree”). Task appraisal scores were used to compute a threat-ratio, as the ratio of demands over resources, which served as a threat appraisal index: smaller numbers were associated with “challenge” states (e.g. when resources outweigh demands), and higher numbers were associated with “threat” states (e.g. when demands outweigh resources) (J Blascovich & Mendes, 2000; Mendes, Gray, Mendoza-Denton, Major, & Epel, 2007; Tomaka et al., 1997). In addition to being a well-established scale, based on theoretical constructs of cognitive appraisal and Lazarus and Folkman’s (1984) theory of stress, the ratio index used in the current investigation has been widely used in the challenge and threat literature (Jim Blascovich & Tomaka, 1996; Carpenter, 2016; Feinberg & Aiello, 2010). In the current sample, both the demand ($\alpha = 0.80$) and resource
(α = 0.81) items used to compute our post-task threat appraisal index yielded good internal consistency. A pre-task threat ratio was also computed to assess how demanding participants perceived the task to be in relation to their available coping resources directly after being introduced and preparing for the task, but prior to completing the TSST procedures and receiving social feedback. The computed pre-task threat ratio was accounted for in each primary and secondary analysis as a model covariate. Pre-task demand (α = 0.83) and resource (α = 0.84) items also yielded good internal consistency.

*Physiological Data Acquisition and Processing:*

Physiological data derived from electrocardiograph (ECG) and impedance cardiograph (ICG) recordings was acquired using Acknowledge Software and wireless MP150 Data Acquisition Systems (BIOPAC Systems Inc) with a sampling frequency of 1000 Hz. ECG sensors were placed using a modified lead II configuration with one disposable, pre-gelled snap silver chloride electrode placed on the lateral edge of the right collarbone and the other positioned on the front left side of the participant’s torso on their lower most rib; a ground electrode was placed on the last right rib. For ICG, two pairs of mylar tapes were placed around the participant’s neck and torso.

After attaching the physiological recording equipment, participants were instructed to sit upright in a comfortable chair in front of a computer screen. Participants were then led through a series of computerized tasks before undergoing the TSST. In total, ECG data was recorded in 5- and 2-minute segments, for a total of 27-minutes. Participants were first asked to complete a 5-minute baseline “Plain Vanilla” task. The plain vanilla is a low demand cognitive task used to standardize mental activity across participants while recording baseline physiological activity (Jennings, Kamarck, Stewart, Eddy, & Johnson, 1992). Specifically, participants are instructed to look at the computer as a series of different colored squares sequentially present on the screen (lasting 10 seconds each). Participants are asked to silently track how many blue squares they see over the course of the task.
Following the baseline plain vanilla task, participants moved on to complete a 5-minute (minutes 6-10) computerized attention manipulation dot-probe task (adapted from (Alvarez & Franconeri, 2007). The dot-probe is a mildly demanding cognitive task that requires participants to focus on a cross in the middle of the computer screen as they keep track of moving dots in their peripheral vision. Participants are asked to keep track of certain dots that first start off yellow, but as they move around the screen transition to black. At the end of each trial all the dots stop moving and participants are asked to use the mouse to identify which dots were initially yellow. Participants completed 16 trials of the task, with the number of moving dots on the screen increasing every 4 trials.

Following the dot-probe, physiology data was continuously recorded as participants underwent the TSST. Minutes 11-22 captured vagal activity during each phase of the TSST procedures (2-minute prep, 5-minute speech, 5-minute Q&A period). The final recording (minutes 23-27) consisted of a 5-minute recovery period. See Figure 1 for a timeline of study procedures and measure administration.

Indices of Cardiac Vagal Control:

For the present report two indices of vagal activity were computed allowing us to examine resting and reactivity measures of CVC. CVC at rest was indexed as the average respiratory sinus arrhythmia (RSA) during the 5-minute plain vanilla baseline period. RSA is
used to measure the magnitude of CVC at the respiratory frequency (e.g., 0.12-0.40 Hz), and has been cited as a reliable, non-invasive index of parasympathetic control of cardiac function (Berntson, Cacioppo, & Quigley, 1993). To measure transient changes in CVC in response to laboratory stress induction, a CVC reactivity variable was computed as the difference between the lowest RSA value during the TSST and the highest RSA value during baseline. This approach for computing CVC reactivity as task minus baseline is consistent with established guidelines (Gary G Berntson et al., 1997). However, to further facilitate interpretation of negative scores, computed difference values were multiplied by -1 such that greater vagal withdrawal would reflect positive CVC reactivity scores.

ECG data were scored offline in one-minute epochs using Mindware software, version 3.1.12, (Mindware Technologies, LTD). Z0 readings derived from ICG were used to estimate respiration and the interbeat interval (IBI) derived from ECG readings using a peak identification algorithm identifying R-peaks. R-peak detection was based on a low pass filter setting of 0.003 Hz and a high pass filter of 0.42. Data was linearly detrended and a baseline and muscle noise filter were used for signals between 0.25 and 0.40 Hz. HRV in the high frequency range was defined as the natural log of the variance occurring between 0.12 and 0.40 Hz, corresponding with RSA, which is the default setting in Mindware (Mindware Technologies, LTD, Gahanna, OH). Data underwent additional cleaning, including removal of misplaced R-peaks and insertion of missing R-peaks, with no more than one R-peak estimated within a one-minute segment. We allowed for the removal of up to 10 seconds of poor-quality data at the beginning or end of a minute-long segment. Insertion of R-peaks was based on estimation from remaining data, RR interval distance from measured and cleaned ECG recording, or by dividing long R-peaks into equal intervals.

III. Data Analytic Strategy:

General Approach
Sample descriptive characteristics were first examined including data distributions and identification of potential outliers. Potential outliers were revisited to ensure validity and z-tests were used to assess skew and kurtosis for non-normally distributed data to be considered for transformation. Specifically, a z-score was obtained for each predictor and criterion variable of interest by dividing the skew and excess kurtosis values for each variable’s distribution by their respective standard errors. For medium-sized samples ($50 < n < 300$) the null hypothesis, assuming a normal distribution, is rejected at absolute z-values over 3.29, corresponding with an alpha level of 0.05 (H.-Y. Kim, 2013). Pearson’s zero-order correlations were then conducted between theoretically relevant covariates, including Age, Sex, CPD, which have been found to be empirically related to CVC, and predictor and criterion variables of interest. Correlations observed at $r \geq .20$ were included as model covariates (J. Cohen, 1988, 1992). Power analyses were based on our secondary aim and indicated a sample size of 60 is required to detect a medium effect size ($f^2 = .167$ [$R^2$ change/$1$-cumulative $R^2$] = .167) via multiple regression analyses with up to 6 covariates accounting for up to 30% of the anticipated variance, and the 2 CVC predictors adding up to 10% variance beyond this with an alpha set at .05.

For our first aim, exploring the relation between CVC indices and smoker post-task threat appraisal three regression models were computed using SPSS Version 26. For Models 1 and 2, CVC at rest and CVC reactivity variables were entered as single independent predictors, respectively, with the computed post-task threat ratio entered as the dependent variable. These first two models allowed us to assess the independent effects of each CVC index on post-task threat appraisal before computing a third model intended to explore whether CVC reactivity held predictive utility above and beyond any pre-existing influence of CVC at rest. For the third model CVC at rest was entered in the first step as the independent predictor and the computed post-task threat appraisal as the dependent variable. CVC reactivity was then entered next, in hierarchical fashion, and served as the second predictor variable in the model. This approach allowed us to
assess the relation between CVC at rest and smoker post-task appraisal, while simultaneously covarying for its effect when interpreting CVC reactivity’s relation to threat appraisal. Following initial computation of each model we re-examined these relations by entering identified model covariates at step 1.

For our second aim, three moderated regression analyses were computed using SPSS PROCESS v3 macro to assess if the effects of CVC at rest and CVC reactivity on post-task threat appraisal varied as a function of social feedback condition (i.e., positive or negative feedback). Specifically, three conditional process models (PROCESS Model 1, Moderation), which use ordinary least squares (OLS) regression to estimate regression models were computed (Hayes, 2017). PROCESS produces 95-percentile bias-corrected intervals, estimated using a random resampling process with 1,000 samples (i.e., bootstrapping). This approach assists in minimizing sampling error and produces unstandardized parameter estimates. For each of the first and second moderated regression models (see Figure 2) either CVC at rest or CVC reactivity served as the predictor variable (X-variable), social feedback randomization as the moderator (M-variable), and post-task threat appraisal as the outcome variable (Y-variable). Consistent with our first aim, the third moderated regression model in this series also covaried for the effect of CVC at rest. Each moderation analysis also adjusted for identified model covariates. Moderation analyses for this project utilized 95-percentile bias-corrected confidence intervals (CI), estimated via bootstrapping analyses, to determine statistical significance of main and interaction effects. Regression diagnostics will also be conducted and examined for each model.

IV. Results:

Participant Characteristics and Randomization:

Our final sample included 60 adult daily smokers (62% male), aged 34.57 years (SD=7.05), who smoked 14.05 cigarettes per day (SD=4.89), with FTCD scores of 3.80 (SD=1.49) corresponding with mild dependence, and BMI of 25.30 (SD=3.51). Calculated skew
and kurtosis z-values revealed no significant outliers and each variable’s distribution as normal (all $zs < 3.29$). Table 1 provides additional sample characteristics, along with results of zero-order (bivariate) correlations between demographic, predictor, and criterion variables of interest. Thirty-three participants (55%) were randomized to receive positive social feedback. Independent t-tests were conducted and showed no significant differences in age, sex, BMI, dependence scores, or cigarettes per day between positive and negative feedback groups (all $ps > .05$). Table 2 further details mean differences in sample characteristics across conditions.

**Cognitive Stress Appraisal:**

On average, participants reported resource scores of 4.93 ($SD=1.32$) and demand scores of 4.40 ($SD=1.35$) during primary appraisal, and average resource scores of 3.48 ($SD=1.46$) and demand scores of 3.67 ($SD=1.50$) during secondary appraisal. A threat-ratio was computed as the ratio of demands over resources, which served as an index of pre-threat appraisal ($M=.83$, $SD=.73$) and post-threat appraisal ($M=1.04$, $SD=.98$) scores in relation to the TSST. Independent $t$-tests were also conducted to examine mean differences in pre- and post-threat appraisal between the two feedback groups. While no significant differences were observed between groups for pre-appraisal ($t(58) = 1.16$, $p=.25$), significant differences were observed for post-task threat appraisal scores ($t(58)=-2.71$, $p=.01$). Calculated skew and kurtosis z-values revealed each pre- and post-threat ratio variable’s data to be non-normally distributed ($zs > 3.29$). Two outliers at the high end of each variable’s distribution were identified and transformed using a modified winzoration approach. This involved an asymmetrical conversion of each individual data point to the next highest value identified within the distribution not considered as extreme. An additional unit of 1 was then added to each winzorized score to maintain the variable’s initial distribution order. Winzoration is acknowledged as an appropriate means for addressing outliers and preserving statistical power in small sample sizes (Reifman & Keyton, 2010). However, analyses using both winzorized and non-winzorized primary and secondary appraisal scores yielded
similar results, therefore non-winorized variables were retained and all findings reported here reflect raw values for the pre- and post-threat appraisal scores.

Mean Autonomic Functioning:

Of the n=60 randomized participants, 27 minutes, or 1,620 seconds, of ECG data was recorded for each participant. In accord with scoring procedures described above, a total of 61 minutes were deemed unscorable or invalid, and thus deleted from the data set. To accommodate for this, one-minute epoch RSA values were imputed for 5 participants, totaling 61 epochs, or imputation of 3.77% of RSA values. For the current report, data from ECG recordings during baseline and the TSST were used to compute resting and reactivity indices of CVC. Mean baseline RSA, which served as our resting index of CVC, was 6.01 ms² (SD=1.29 ms²), while mean RSA during the TSST was 5.81 ms² (SD=1.15 ms²). The average difference between lowest RSA during TSST and highest RSA during baseline were computed and multiplied by -1 in order to derive our CVC reactivity index (M=1.41 ms², SD=1.20 ms²). Independent t-tests showed no significant differences between groups on either CVC (ps > .05).

CVC Indices Predicting Threat Appraisal:

Primary Analysis: For our first aim, three linear regression models were computed to explore the predictive utility of each CVC index (CVC at rest vs. CVC reactivity) on smoker post-task threat appraisal. Results revealed neither CVC index, when entered independently in models 1 and 2 or when entered in hierarchical fashion in model 3, served as significant predictors of post-task threat appraisal. To examine if the inclusion of theoretical covariates modified these results each main model was recomputed to include age and pre-task appraisal given their significant correlation with CVC indices (see Table 1). After controlling for age and pre-task appraisal all of the main models became significant: Model 1 (F(3,56)= 36.85, p<.001); Model 2 (F(3,56)= 36.06, p<.001); Model 3 (F(4,55)= 27.16, p<.001) For each model pre-task appraisal had a significant positive effect on post-task appraisal, with higher pre-task threat appraisal scores associated with higher post-task threat appraisal scores. Across all recomputed
models no significant associations between age or CVC indices on post-task threat appraisal were observed. Table 3 provides covariate and CVC variable coefficients from the third hierarchical model in relation to post-task threat appraisal scores.

Secondary Analysis: For our second aim three moderated regression models were computed to examine if the effects of (1) CVC at rest and (2) CVC reactivity on post-task threat appraisal varied as a function of social feedback condition (i.e., positive or negative feedback). The first model examining the interactive effects of CVC at rest and condition on post-task threat appraisal was not significant ($F(3,56)=2.59, p=0.06, R^2=0.12, f^2=0.14$). However, within the model the effect of randomization was significant ($b=-0.64, p=0.01$), with individuals randomized to the positive feedback condition reporting lower post-threat appraisal scores (i.e., greater resources to demands). Table 4 provides full model results. When re-examining this first model covarying for participant age and pre-threat appraisal scores the re-computed model was significant ($F(5,54)=26.38, p<0.001, R^2=0.71, f^2=2.45$; Table 5). The effect of feedback condition remained significant ($b=-0.42, p=0.01$) and a significant effect was also observed for pre-threat appraisal ($b=1.03, p<0.001$), with higher pre-threat appraisal associated with higher post-threat appraisal.

The second moderation model examining the interactive effects of CVC reactivity and social feedback condition on post-threat appraisal was trending significance ($F(3,56)=2.82, p=0.05, R^2=0.13, f^2=0.15$; Table 6). The effect condition was significant ($b=-0.67, p=0.01$), with no significant main or interactive effects observed for either CVC reactivity or CVC reactivity x feedback condition ($ps > 0.05$). When re-examining this second model, controlling for age and pre-threat appraisal, the overall model became significant ($F(5,54)=26.14, p<0.001, R^2=0.71, f^2=2.45$; Table 7), with significant effects for feedback condition ($b=-0.44, p<0.01$) and pre-threat appraisal ($b=1.03, p<0.001$): lower pre-threat appraisal and positive feedback randomization were associated with lower post-threat appraisal scores.
The third moderation model examining the interactive effects of CVC reactivity and social feedback condition on post-threat appraisal when accounting for CVC at rest was not significant ($F(4,55)=2.11, p=0.09, R^2=0.13, f^2=0.15$; Table 8). However, consistent with the first two models, the effect of social feedback condition was significant in this third model ($b=-0.66, p=0.01$). Similarly, when recomputing the third model, controlling for age and pre-threat appraisal, the overall model became significant ($F(6,53)=21.65, p<0.001, R^2=0.71, f^2=2.45$; Table 9), with significant effects observed for feedback condition ($b=-0.44, p=0.01$) and pre-threat appraisal ($b=1.03, p<0.001$), but no other significant main or interactive effects for either CVC index (all $ps > 0.05$).

V. Discussion:

Cardiac vagal control (CVC) has been identified as a measure of autonomic flexibility reflecting changes in cardiac rhythm associated with the interplay between the parasympathetic (PNS) and sympathetic (SNS) nervous system branches. CVC has also been identified as a physiological correlate of self-regulatory ability associated with flexible emotional responding and adaptive functioning. However few studies have examined how indices of CVC present in smokers, specifically how CVC relates to other non-physiological regulatory processes that may onboard in the context of stress and implicate smoker stress responsivity. This study explored the linear relations between resting and reactivity measures of CVC and cognitive stress appraisal in a sample of smokers who underwent a socioevaluative stress test. To discern if the effects of CVC on cognitive stress appraisal varied as a function of environmental demands, a priori secondary analyses were conducted examining the interactive effects of CVC indices and the type of socioevaluative feedback received (positive or negative) on smoker post-task threat appraisal. In contrast with previous empirical findings, our primary and secondary analyses showed no significant main or interactive effects of CVC indices and social feedback on smoker post-task threat appraisal. Findings from this study have several implications when considering the
relationship between these variables in smokers and can be used to inform future investigative efforts.

First, dysregulations in autonomic functioning associated with smoking have been well characterized in the literature and may have obfuscated the ability to detect the distinct effects of CVC indices on stress appraisal in this sample (Bodin et al., 2017; Dinas et al., 2013; Hayano et al., 1990; Middlekauff et al., 2014). In Kim et al.’s (2018) meta-analysis of CVC and stress, the authors posit that a patient’s medical and psychological history are essential when evaluating the relationship between CVC and stress-related outcomes. Research examining the association between increased cardiovascular risk and Post-Traumatic Stress Disorder (PTSD), another condition marked by dysregulated stress response, also lends support for how modifiable behavioral factors, such as smoking, can affect CVC findings. For example, Dennis et al.’s (2014) study found smoking, alcohol dependence, and sleep disturbance to account for 94% of the observed variance between PTSD symptoms and attenuated CVC in a sample of young adults with and without PTSD (Dennis et al. 2014). Findings such as this not only represent an intermediary set of behavioral mechanisms that might link aspects of clinical pathology and CVC, but further underscore the challenges smoking can introduce when trying to interpret the relatedness of these constructs. However the lack of association between CVC indices and smoker stress appraisal reported here is still surprising given that the CVC values in the current investigation are comparable to other studies that have observed significant associations between CVC and other self-regulatory processes in healthy samples (Muhtadie et al., 2015). Future work examining indices of CVC and stress appraisal in smokers would benefit from incorporating a control, non-smoker comparison group to further discern the distinct effects of autonomic function on stress appraisal between groups.

Inconsistent findings across investigations may also speak to the limitations that linear models and the use of mean vagal change scores as a source of comparison introduce when trying
to discern subtle differences in CVC reactivity patterns. The use of more dynamic analytic approaches may assist in addressing this limitation by characterizing unique patterns of autonomic activity and their relation to processes of self-regulation that linear models may not be able to adequately detect. Obradovic et al.’s (2017) utilization of piecewise growth curve modeling examining child executive functioning (EF) skills in relation to trajectories of CVC reactivity during a socio-emotional challenge serves as one example of this (Obradović & Finch, 2017). In addition to finding that a piecewise model estimating a quadratic slope for CVC reactivity provided a better fit of their data than a single linear model, they also observed unique differences in CVC response patterns associated with emotionally-salient vs. emotionally-neutral measures of child EF skills. Higher scores on a working memory task, presumed to reflect EF skills more frequently applied in emotionally neutral contexts, were associated with gradual curvilinear decreases in RSA. Conversely, higher scores on a delay-of-gratification task, presumed to reflect EF skills more frequently applied in motivational and emotionally laden contexts, were associated with gradual curvilinear increases (Obradović & Finch, 2017). Dynamic approaches such as this not only allow for a more nuanced examination for how CVC reactivity patterns unfold overtime, but further suggest that distinct patterns of CVC reactivity may differentially relate to processes of regulatory control that vary with environmental demands. The application of analytic approaches that are able to tease apart such distinctions might further explain why a lack of consistent findings of CVC in relation to processes of self-regulation are frequently observed across investigations (Theodore P Beauchaine et al., 2019; Zahn et al., 2016). Application of such an approach in the current dataset may unveil if the significant quadratic CVC changes occurring in response to laboratory challenges frequently observed among children (Brooker & Buss, 2010; Miller et al., 2013; Obradović & Finch, 2017) also occur in smokers. Applying this approach here may also uncover if significant differences in growth curve traits (i.e., estimated turning point between CVC slopes, rate of change for each CVC slope) are present in smokers receiving positive vs. negative social feedback. If differences in CVC reactivity
trajectories were observed across conditions this might lend further support for how CVC may
interact with stimuli in one’s environment and influence cognitive appraisal.

The significant influence of pre-task appraisal scores on smoker post-task threat appraisal
observed in the current report is also notable. In Gaab et al.’s (2005) study where the PASA scale
was initially developed to examine the role of psychological processes related to acute
neuroendocrine response patterns of stress, anticipatory cognitive appraisal was found to account
for a significant 35% of the variance in salivary cortisol response in healthy males who
underwent the TSST (Gaab et al., 2005). Interestingly, the researchers found no significant
association between post-task appraisal and cortisol reactivity. While Gaab et al. (2005) used a
different scale to assess post-task appraisals in their study, the findings reported here suggest that
the lack of association between retrospective appraisal processes and physiological stress
response patterns has previously been observed. Our results showing no significant association
between CVC indices and post-task threat appraisal suggest that this lack of association may be
applicable for both central and peripheral markers of stress responsivity. The potential influence
of anticipatory appraisal on physiological stress response is also supported by findings from
treatment outcome studies of cognitive behavior stress management interventions. Specifically,
modulation of cognitive appraisal processes have been shown to result in short and long-term
reductions in cortisol responses (Gaab et al., 2003; Hammerfald et al., 2006). Denson et al.’s
(2011) examination of cognitive reappraisal instruction on healthy women CVC extends these
findings to peripheral correlates of regulation. Participants provided prior instruction to re-
appraise their emotional reactions in response to an anger-inducing film (i.e., adopt a neutral
attitude) evidenced greater increases in CVC relative to participants instructed to suppress their
emotional reactions (i.e., adopt a neutral facial expression) or provided no instruction (Denson,
Grisham, & Moulds, 2011). Participants in the reappraisal condition also showed no significant
increase in self-reported anger following the film compared to participants in the suppression and
control conditions. Future work examining the effects of anticipatory appraisal and the use of cognitive reappraisal strategies on subsequent cortisol and autonomic response patterns in smokers is needed. When considering the clinical implications of these findings, should they replicate in smokers, smoking cessation interventions may benefit from targeting anticipatory appraisal processes as one way to reduce stress-precipitated smoking patterns.

It is also notable that most work examining cognitive appraisal and cardiovascular reactivity to stress have focused on SNS-based measures. While the relationship between these measures (i.e., Peripheral Resistance, Systolic Blood Pressure) and the threat ratio index used in this study have been well established in the challenge and threat literature (Jim Blascovich, Mendes, Tomaka, Salomon, & Seery, 2003; Jim Blascovich & Tomaka, 1996; Tomaka et al., 1997), few, if any, studies have looked at this relation using PNS-based measures. Given the role of parasympathetic withdrawal on changes in heart rate it is surprising so few studies have explored this. The limited work in this domain poses challenges when trying to translate the theoretical and empirical relevance of these frameworks to putative measures of vagal function like that of CVC. Future work incorporating both PNS and SNS measures is needed to develop a more comprehensive understanding for how cardiovascular reactivity patterns relate to cognitive appraisal in the context of stress. It’s possible that SNS-measures may be more relevant for measuring the physiological arousal states associated with challenge and threat appraisals, whereas PNS-measures may be more relevant for measuring the meta-cognitive-affective regulatory processes (i.e., attention allocation, emotion regulation, etc.) used to inform the release of metabolic resources associated with generating these states. However, this assumption may also simply reflect an unequal emphasis of cardiovascular measures cited throughout the history of the psychophysiological literature more broadly (i.e., previous studies focusing more on SNS-measures and more recent studies focusing on PNS-measures). Ongoing work incorporating multiple measures of autonomic activity is needed to further clarify how the PNS and SNS
branches may interact and differentially contribute to cognitive appraisal and the generation of an adaptive stress response.

Study designs that consider the relative contributions of and interactions between both PNS and SNS branches may also assist in providing a more comprehensive picture of smoker autonomic response patterns in the context of stress. Ashare et al.’s (2012) investigation of whether changes in autonomic reactivity mediate the ability to resist smoking following acute stress provides support for this multi-measure approach. Specifically, the authors used HF-HRV to examine vagal function and a low-to-high frequency HRV ratio (LF/HF) to examine shifts in sympathovagal balance in a sample of abstinent smokers exposed to a stress-imagery induction. Relative to a relaxing-imagery control condition, they found that smokers evidencing greater decreases in HF-HRV (i.e., greater vagal withdrawal) showed greater ability to resist smoking following stress. However, despite larger increases in the LF/HF ratio measure also occurring in response to stress-imagery, there was no association between shifts in sympathovagal balance following acute stress and time to smoking lapse (Ashare et al., 2012). While the use of the LF/HF ratio as a metric of sympathovagal balance has received criticism in the psychophysiology literature (Gary G Berntson et al., 1997), findings suggest that reductions in vagal function may be more relevant for stress-precipitated smoking outcomes compared to overall shifts in sympathovagal balance that may co-occur.

While the current study does not provide evidence for the relationship between indices of CVC and cognitive stress appraisal in smokers, these findings highlight certain methodological challenges that may arise when interpreting associations between autonomic functioning and stress reactivity in this population. Future work examining differences in CVC and cognitive appraisal in smokers and non-smokers might further delineate dysregulations in autonomic functioning associated with smoking from dysregulations associated with heightened stress reactivity. This study also provides consideration for the significant effect anticipatory appraisal
processes may have on stress response patterns in both psychological and physiological domains. Ongoing work examining factors that facilitate a greater understanding for what contributes to an adaptive stress response in smokers is required. While stress itself is inevitable, modifying how smokers anticipate, cope with, and regulate stress may serve as one avenue of approach for improving cessation outcomes.
Moderation of Social Feedback Condition on the Relation between Cardiac Vagal Control and Threat Appraisal

Figure 2: Conceptual model of social feedback condition (positive vs. negative) moderating the relation between resting and reactivity measures of cardiac vagal control and post-task threat appraisal
Table 1: Sample Characteristics and Zero-Order (or bivariate) correlations between study predictors and criterion variables of interest.

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td>1</td>
<td>-0.02</td>
<td>-0.10</td>
<td>0.40*</td>
<td>0.07</td>
<td>-0.01</td>
<td>0.00</td>
<td>-0.37**</td>
<td>0.14</td>
<td>34.57 (7.05)</td>
</tr>
<tr>
<td>2. Sex</td>
<td>1</td>
<td>0.10</td>
<td>-0.20</td>
<td>0.13</td>
<td>-0.25</td>
<td>-0.24</td>
<td>0.14</td>
<td>0.15</td>
<td></td>
<td>62% Male</td>
</tr>
<tr>
<td>3. BMI</td>
<td>1</td>
<td>-0.12</td>
<td>-0.10</td>
<td>0.13</td>
<td>0.02</td>
<td>0.03</td>
<td>-0.21</td>
<td></td>
<td></td>
<td>25.30 (3.51)</td>
</tr>
<tr>
<td>4. FTCD</td>
<td>1</td>
<td>0.39*</td>
<td>-0.17</td>
<td>-0.02</td>
<td>-0.17</td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
<td>3.80 (1.49)</td>
</tr>
<tr>
<td>5. CPD</td>
<td>1</td>
<td>-0.04</td>
<td>0.06</td>
<td>-0.10</td>
<td>-0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14.05 (4.89)</td>
</tr>
<tr>
<td>6. Pre-Appraisal</td>
<td>1</td>
<td>0.81**</td>
<td>-0.05</td>
<td>-0.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.83 (0.73)</td>
</tr>
<tr>
<td>7. Post-Appraisal</td>
<td>1</td>
<td>-0.13</td>
<td>-0.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.04 (0.98)</td>
</tr>
<tr>
<td>8. CVCreast</td>
<td>1</td>
<td>0.43*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.01 (1.29)</td>
</tr>
<tr>
<td>9. CVCreac</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.41 (1.20)</td>
</tr>
</tbody>
</table>

Note: *p < .05, **p < .01 Sex (1 = Female, 2 = Male); Body Mass Index (BMI); Fagerström Test of Cigarette Dependence (FTCD); Cigarettes per Day (CPD); Average Baseline RSA (CVCreast); High Baseline RSA-Low Speech RSA (CVCreac)

Table 2: Independent T-Tests Examining Differences in Sample Characteristics Between Randomized Social Feedback Conditions

<table>
<thead>
<tr>
<th>Social Feedback Condition</th>
<th>Negative N=27</th>
<th>Positive N=33</th>
<th>Independent Samples T-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>60% Male</td>
<td>64% Male</td>
<td>t(58) = -0.34, p = .73</td>
</tr>
<tr>
<td>Age</td>
<td>35.30 (7.16)</td>
<td>33.97 (7.00)</td>
<td>t(58) = .72, p = .47</td>
</tr>
<tr>
<td>BMI</td>
<td>24.97 (3.32)</td>
<td>25.58 (3.69)</td>
<td>t(58) = -.66, p = .51</td>
</tr>
<tr>
<td>FTCD</td>
<td>3.93 (1.52)</td>
<td>3.69 (1.49)</td>
<td>t(57) = .61, p = .55</td>
</tr>
<tr>
<td>CPD</td>
<td>14.19 (5.48)</td>
<td>13.94 (4.43)</td>
<td>t(58) = .19, p = .85</td>
</tr>
<tr>
<td>Pre-threat</td>
<td>.95 (0.93)</td>
<td>.73 (0.51)</td>
<td>t(58) = 1.16, p = .25</td>
</tr>
<tr>
<td>Post-threat</td>
<td>1.40 (1.31)</td>
<td>.74 (.41)</td>
<td>t(58) = 2.71, p = .01</td>
</tr>
<tr>
<td>CVCreast</td>
<td>5.88 (1.11)</td>
<td>6.12 (1.42)</td>
<td>t(58) = -.73, p = .47</td>
</tr>
<tr>
<td>CVCreac</td>
<td>1.46 (1.14)</td>
<td>1.37 (1.26)</td>
<td>t(58) = .29, p = .77</td>
</tr>
</tbody>
</table>
Table 3. Summary of Aim 1 Hierarchical Regression Analysis of CVC indices and Theoretical Covariates Predicting Smoker Post-Task Threat Appraisal

* \( p < .05 \). ** \( p < .01 \).

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>( \beta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.03</td>
<td>0.013</td>
<td>-0.025</td>
</tr>
<tr>
<td>Pre-Appraisal</td>
<td>1.075</td>
<td>0.105</td>
<td>0.804**</td>
</tr>
<tr>
<td>CVCrest</td>
<td>-0.068</td>
<td>0.075</td>
<td>-0.089</td>
</tr>
<tr>
<td>CVCreac</td>
<td>-0.010</td>
<td>0.076</td>
<td>-0.013</td>
</tr>
</tbody>
</table>

Table 4. Effects of CVC at rest and Social Feedback Condition on Post-Task Threat Appraisal

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>t</th>
<th>( p )</th>
<th>LLCI</th>
<th>ULCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>1.39</td>
<td>7.59</td>
<td>0.00</td>
<td>0.00</td>
<td>1.02</td>
<td>1.75</td>
</tr>
<tr>
<td>CVCrest</td>
<td>-0.08</td>
<td>-0.50</td>
<td>0.62</td>
<td>-0.42</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Condition</td>
<td>-0.64</td>
<td>-2.58</td>
<td>0.01</td>
<td>-0.04</td>
<td>-0.14</td>
<td></td>
</tr>
<tr>
<td>CVCrest x Cond</td>
<td>0.01</td>
<td>0.07</td>
<td>0.95</td>
<td>-0.39</td>
<td>0.42</td>
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</tr>
</tbody>
</table>
**Table 5** Effects of CVC at rest and Social Feedback Condition on Post-Task Threat Appraisal Controlling for Age and Pre-Threat Appraisal.

<table>
<thead>
<tr>
<th></th>
<th>$R^2$</th>
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<th>$p$</th>
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<tbody>
<tr>
<td></td>
<td>0.71</td>
<td>26.38</td>
<td>&lt;0.001</td>
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<tbody>
<tr>
<td>Constant</td>
<td>0.62</td>
<td>1.48</td>
<td>0.14</td>
<td>-0.22</td>
<td>1.45</td>
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<td>Age</td>
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<td>-0.55</td>
<td>0.58</td>
<td>-0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Pre-Appraisal</td>
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<td>10.40</td>
<td>&lt;0.001</td>
<td>0.84</td>
<td>1.23</td>
</tr>
<tr>
<td>CVCrest</td>
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<td>-0.98</td>
<td>0.33</td>
<td>-0.30</td>
<td>0.10</td>
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<tr>
<td>Condition</td>
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<td>-2.86</td>
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<td>0.05</td>
<td>0.43</td>
<td>0.67</td>
<td>-0.19</td>
<td>0.29</td>
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**Table 6** Effects of CVC reactivity and Social Feedback Condition on Post-Task Threat Appraisal

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<td>1.04</td>
<td>1.77</td>
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<tr>
<td>CVCreact</td>
<td>-0.12</td>
<td>-0.76</td>
<td>0.45</td>
<td>-0.44</td>
<td>0.20</td>
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<tr>
<td>Condition</td>
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<td>-2.73</td>
<td>0.01</td>
<td>-1.15</td>
<td>-0.18</td>
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<tr>
<td>CVCreact x Cond</td>
<td>0.02</td>
<td>0.09</td>
<td>0.93</td>
<td>-0.39</td>
<td>0.43</td>
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Table 7: Effects of CVC reactivity and Social Feedback Condition on Post-Task Threat Appraisal Controlling for Age and Pre-Threat Appraisal.

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<th>$p$</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>0.84</td>
<td>0.71</td>
<td>26.14</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<th>ULCI</th>
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<td>1.25</td>
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<td>-0.09</td>
<td>0.93</td>
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<td>0.02</td>
</tr>
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<td>0.83</td>
<td>1.23</td>
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<td>-0.87</td>
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<td>-0.27</td>
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<tr>
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<td>-2.98</td>
<td>0.00</td>
<td>-0.73</td>
<td>-0.14</td>
</tr>
<tr>
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<td>0.42</td>
<td>0.68</td>
<td>-0.20</td>
<td>0.30</td>
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Table 8: Effects of CVC reactivity and Social Feedback Condition on Post-Task Threat Appraisal Controlling for CVC at rest

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<td>2.11</td>
<td>0.09</td>
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</table>

<table>
<thead>
<tr>
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<td>-0.40</td>
<td>0.44</td>
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Table 9 Effects of CVC reactivity and Social Feedback Condition on Post-Task Threat Appraisal Controlling for CVC at rest, Age, and Pre-Threat Appraisal.

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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<tr>
<td>$R$</td>
<td>$R^2$</td>
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<td>$p$</td>
</tr>
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<td>0.84</td>
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<table>
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<td>0.02</td>
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<td>10.26</td>
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<td>1.23</td>
</tr>
<tr>
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<td>-0.69</td>
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<td>0.42</td>
<td>0.68</td>
<td>-0.20</td>
<td>0.30</td>
</tr>
</tbody>
</table>
References


Fagerström, K. (2011). Determinants of tobacco use and renaming the FTND to the Fagerström Test for Cigarette Dependence. *Nicotine & Tobacco Research, 14*(1), 75-78.


