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Self-esteem and autonomic physiology: Self-esteem levels predict cardiac vagal tone

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ABSTRACT

Four studies examined the relationship between self-esteem and cardiac vagal tone (level of influence of the parasympathetic nervous system on the heart), a variable with health implications for heart disease and auto-immune disorders. Building on evidence that self-esteem provides a sense of security and that a sense of security affects cardiac vagal tone, we theorize that self-esteem should impact cardiac vagal tone. Two experiments showed that positive self-esteem relevant feedback increases cardiac vagal tone relative to negative feedback. Two correlational studies showed that higher self-esteem measured daily over the course of 2 weeks predicted higher resting cardiac vagal tone. Theoretical and physical health implications are discussed.

1. Introduction

Self-esteem appears to be a critical psychological construct, with many facets, and with implications that range from violence and conflict to happiness and mental health (e.g., Swann, Chang-Schneider, & Larson McClarty, 2007; Donnellan, Trzesniewski, Robins, Moffitt, & Caspi, 2005; Gaertner, Sedikes, & Chang, 2008; Greenberg, Pyszczynski, & Solomon, 1986; Orth, Robins, & Roberts, 2008). Given self-esteem's broad implications, it seems a distinct possibility that self-esteem also impacts our physical bodies in meaningful ways. Drawing on recent theorizing (Martens, Greenberg, & Allen, 2008), we examine one such potential effect of self-esteem, whether self-esteem impacts a particularly critical physiological system, the parasympathetic nervous system. Specifically, we suggest that self-esteem can increase resting levels of cardiac vagal tone, the level of influence on the heart of the vagus nerve—a primary vehicle for the parasympathetic branch of the autonomic nervous system.

The functioning of the vagus has been linked increasingly to an array of serious and potentially deadly physical health problems (e.g., Masi, Hawkley, Rickett, & Cacioppo, 2007; Thayer & Lane, 2007; Yien et al., 1997). The vagus appears to dampen sympathetic stress responses such as increases in norepinephrine (Levy, 1990) and cortisol (Bueno et al., 1989), responses that when heightened over prolonged periods of time may lead to or exacerbate cardiovascular problems (Krantz & Manuck, 1984; McEwen, 1998; Sapolsky, 1994). Work also suggests that vagal tone may down-regulate aspects of the inflammation response (Czura & Tracey, 2005) that if chronically over-active can aggravate or lead to auto-immune diseases (e.g., McEwen, 1998; Sapolsky, 1994). Thus, this examination should contribute to the literature aimed at understanding the relationship between self-esteem and physical illness (e.g., Creswell et al., 2007; Shimizu & Pelham, 2004; Stinson et al., 2008; Trzesniewski et al., 2006). In addition, it should enrich the literature on the intertwining of self-esteem-related constructs and physiology (e.g., Arndt & Goldenberg, 2002; O'Donnell, Brydon, Wright, & Steptoe, 2008; Seery, Blascovich, Weisbuch, & Vick, 2004; Taylor, Lerner, Sherman, Sage, & McDowell, 2003).

This hypothesis, that self-esteem increases cardiac vagal tone, emerges from theorizing and evidence that self-esteem increases feelings of security from threat, and that vagal tone increases in response to feelings of security (in turn dampening threat responding at the physiological level). This hypothesis does not suggest that self-esteem is the only psychological factor that influences vagal tone (e.g., recent research suggest that self-regulation, independent of security and threat, can impact vagal tone, Segerstrom & Nes, 2007), or that self-esteem affects vagal tone under all conditions or to the same extent under all conditions. The hypothesis is a more conservative one, as is necessarily the case with early or initial examinations of connections between psychological and physiological processes (Cacioppo & Tassinary, 1990). To study this connection, we conducted four studies. In the first two, we experimentally examined the impact of self-esteem on resting vagal tone. In the second two studies, we examined whether a more general natural relationship exists between people's average self-esteem levels (as measured daily over the course of 2 weeks) and vagal tone.

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2. Self-esteem

2.1. Theory

This theorized connection between self-esteem and cardiac vagal tone (Martens et al., 2008) rests in part on the case that self-esteem provides people with feelings of security when faced with threat, i.e., with protection from threat responding. Self-esteem-related theories generally converge on this function of self-esteem. Terror management theory (TMT; e.g., Greenberg, Solomon, & Pyszczynski, 1997) puts forth that for other animals security or safety is about protection from immediate physical threats, but that for humans, who live in a symbolic and extremely social world, security is also provided by one's symbolic and abstract sense of self and more specifically, living up to consensually agreed upon standards that dictate what is good. Self-esteem thus provides a feeling of security from threat, resulting in dampened responding to threat. Making a similar prediction, Self-affirmation Theory (e.g., Sherman & Cohen, 2006; Steele, 1988) asserts that a general or overarching sense of self-integrity or self-esteem provides greater flexibility in coping with threats. Drawing on prior self-esteem theorizing (Hobfoll, Nadler, & Leiberman, 1986; Taylor & Brown, 1988), the theory conceives of self-esteem as a potential resource, and with more of it come more possibilities in the way one can compensate for threats to any given component of the self.[1]

2.2. Research

A good deal of evidence has accumulated to support this theorizing that high self-esteem predicts diminished threat-related responding. For example, measures of self-reported state self-esteem correlate inversely with state threat-related emotions such as anxiety, hostility, and depression (e.g., Heatherton & Polivy, 1991), and high trait self-esteem predicts lower levels of anxiety (e.g., Brockner, 1983), depression (e.g., Harter, 1990; Orth et al., 2008; Schmitz, Kugler, & Rollnik, 2003; Watson, Suls, & Haig, 2002), aggression (e.g., Donnellan et al., 2005), defensiveness in response to rejection (Ford & Collins, 2010), physiological fight or flight responses (Taylor, Lerner, Sherman, Sage, & McDowell, 2003), and stress in response to taxing life circumstances (e.g., Hobfoll & London, 1986; Petrie & Rotherham, 1982).

Experimental manipulations of self-esteem also show this threat-buffering effect. Increasing self-esteem by way of positive personality feedback or intelligence feedback dampens self-reported anxiety and sympathetic arousal in response to threat of electric shock (Greenberg et al., 1992) and dampens heart rate increases in response to a public speaking stressor (Rector & Roger, 1997). In a similar vein, self-affirmation manipulations—bolstering valued characteristics of the self—consistently dampen threat responses, including stereotype threat performance decrements (Martens, Johns, Greenberg, & Schimel, 2006), biases in response to failure and anticipated threats (Arndt, Schimel, Greenberg, & Pyszczynski, 2002; Sherman & Kim, 2005), defensive responding to reminders of mortality and worldview inconsistent information (Cohen, Sherman et al., 2007; Schmeichel & Martens, 2005), and sympathetic cortisol responses to a public speaking stressor (Creswell et al., 2005).

Some theorizing, however, suggests that high trait self-esteem can predict *greater* defensiveness and aggressiveness (Baumeister, Campbell, Krueger, & Vohs, 2003). Yet this perspective appears to conflate high self-esteem with narcissism (e.g., Swann et al., 2007). In research that has measured self-esteem and narcissism together, statistically controlling for narcissism boosts an inverse correlation between self-esteem and anti-social behavior (Paulhus, Robins, Trzesniewski, & Tracey, 2004; Tracey, Cheng, Robins, & Trzesniewski, 2009). Further, those high in narcissism will essentially admit to inflating their self-esteem ratings—that in fact their self-esteem is not as high as it appears on the measure (Olson, Fazio, & Hermann, 2007). In sum, there is a good deal of evidence, when taken together, that higher levels of self-esteem provide security from threat and diminished threat-related responses.

3. Cardiac vagal tone

3.1. Theory

Paralleling self-esteem, vagal tone appears to buffer or down-regulate physiological threat. As mentioned, the vagus is a primary nerve in the parasympathetic nervous system (PNS), which together with the sympathetic nervous system (SNS) comprises the autonomic nervous system (ANS) that regulates the vital organs in the body. At the heart, the vagus functions to slow and calm the heart's activity (Costanzo, 2002; Lovallo & Sollers, 2000). In addition, the vagus dampens the effects of sympathetic fight or flight responses (e.g., Levy, 1995; Rosenblueth & Simeone, 1934; Uijtdehaage & Thayer, 2000).

Psychophysiological theorizing elaborates on this physiological function of vagal tone (calming and SNS-inhibiting). Polyvagal Theory (Porges, 1995) explains that vagal tone serves as a "persistent brake to inhibit the metabolic potential" in mammals and that release of this brake potentiates sympathetic fight or flight arousal (Porges, 1995, p. 306). Further, Polyvagal Theory characterizes the psychological circumstances that affect vagal tone in mammals. In mammals, vagal levels are generally or tonically high, and the vagus withdraws its inhibitory influence when there is a potential need to respond to threat, and so a potential need to activate the SNS in order to fuel mobilization. When a mammal feels secure and protected from threat, vagal tone is high; when a mammal feels vulnerable to threat, vagal tone is diminished in order to potentiate the fight or flight response.

3.2. Measurement and research

In the past two decades, advances in the ability to measure cardiac vagal tone easily and non-invasively in humans has triggered a surge in research. Briefly, these vagal tone indices are derived from examining aspects of variability in heart rate, which are extracted from heart signal recordings (i.e., EKG recordings) generally of 2 min or more. The most common of these measures the heart rate variability that corresponds with the respiration cycle, termed respiratory sinus arrhythmia (RSA). This expression of vagal tone emerges because inhalation inhibits vagal outflow to the heart (which speeds up heart rate), whereas expiration allows for the resuming of this outflow (which slows down heart rate). Thus, the greater this variability, the higher the cardiac vagal tone. See Fig. 1 for a visual depiction of individuals with high and low cardiac vagal tone as reflected by high and low RSA.

Research with humans supports the analysis that resting levels of vagal tone manifest at higher levels when we feel secure (when our minds tell us that we are safe) and at lower levels when we feel insecure and vulnerable. Lower levels of anxiety-related disorders (e.g., Cohen et al., 1997; Rechlin, Weis, Spitzer, & Kaschka, 1994),

[1] Other prominent theories about self-esteem focus less on the relationship between self-esteem and threat and more on the contributors to self-esteem. For example, theories focus on self-esteem as impacted by social inclusion (sociometer theory; Leary, Tambor, Terdal, & Downs, 1995), positive feedback from important others, and developing skills and competencies (e.g., Harter, 1990). Yet these theories also easily co-exist with the premise that self-esteem should increase people's sense of security and in turn "buffer people against anxieties of all sorts" (Leary, 2004, p. 479).

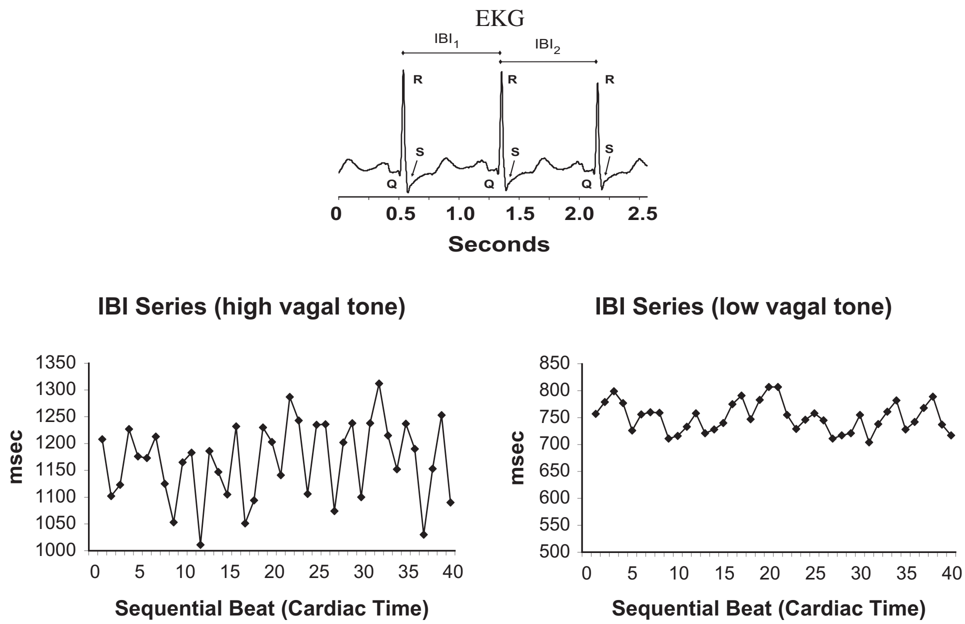

Fig. 1. Upper panel: Sample EKG waveform for three consecutive heart beats, resulting in two interbeat intervals (IBIs), calculated as the time in milliseconds between successive R spikes. Lower panel: IBI series for 40 IBIs for two people. The *y*-axis shows the time in milliseconds of each IBI, and the *x*-axis represents each sequential IBI. Note the rhythmic oscillation of the IBI series, which reflects heart rate slowing with exhalation, and speeding with inhalation. This variability in heart rate that occurs in time with breathing—termed respiratory sinus arrhythmia (RSA)—is greater for individuals with higher cardiac vagal tone (left panel) than those with low cardiac vagal tone (right panel).

low attachment anxiety (Diamond & Hicks, 2005), less severe depressive symptoms (e.g., Chambers & Allen, 2002; Dalack & Roose, 1990), less negative affect in response to threatening stimuli (Demaree, Robinson, Everhart, & Schmeichel, 2004), and less hostility (Demaree & Everhart, 2004; Diamond & Hicks, 2005) all predict higher vagal tone.[2]

4. Examining cardiac vagal tone as an outcome of self-esteem

If security and feeling protected from threat manifests at the physiological level in higher resting vagal tone, and self-esteem contributes to a feeling of security, then self-esteem may influence vagal tone such that higher self-esteem increases resting vagal tone. We do not wish to argue that self-esteem and vagal tone should always co-vary. For example, if a more general feeling of security impacts vagal tone, then we should expect changes in vagal tone as a function of security independent of self-esteem. Further, in any given situation a particular variable that affects vagal tone may obscure an effect of self-esteem on vagal tone. Thus, what is termed an *outcome* relationship (Cacioppo & Tassinary, 1990) seems the most plausible at this juncture—that only under some conditions should self-esteem influence cardiac vagal tone, and that self-esteem is not the only variable to influence vagal tone. Here we present four studies—two experimental and two correlational—that examine this untested psychological–physiological outcome relationship. Further, given self-esteem's tendency to relate to mood (e.g., Brown & Mankowski, 1993; Crocker, Sommers, & Luhtanen, 2002), we consider the degree to which affect might account for the effects of self-esteem in both the experimental and correlational context.

[2] We review research only with adults here. Research suggests that vagal tone may function differently in children and infants—for example, vagal tone controls the heart less in infancy and early childhood than in adulthood (e.g., Izard, Porges, Simons, Haynes, & Cohen, 1991; Porges, Doussard-Roosevelt, Portales, & Suess, 1994).

5. Study 1

To begin examining our hypothesized connection we first sought to show that manipulating self-esteem relevant feedback affects resting levels of cardiac vagal tone, such that positive feedback increases vagal tone relative to negative feedback. To do so we adopted a method used successfully in prior work to manipulate self-esteem (Greenberg et al., 1992). Specifically, we provided participants with either bogus positive or negative personality feedback, and then examined resting cardiac vagal tone, controlling for vagal tone measured before the feedback.

5.1. Method

5.1.1. Participants

Seventy-eight introductory psychology students at the University of Arizona participated in exchange for partial course credit. This study received ethics approval from the University of Arizona Human Subjects Committee. Five participants were excluded from the analyses because during the debriefing they expressed strong suspicion about the validity of the personality feedback. In addition, one participant was excluded from analyses because extreme noise in the EKG signal precluded accurate interpretation, another because of an experimenter error, and another because of an equipment malfunction during the EKG recording. This left a total of seventy participants (26 males, 44 females; mean age = 19.01 years) for analyses.

5.1.2. Procedure

We tested participants individually. The experimenter greeted participants upon entering the laboratory, led them to a sound dampened chamber in which they would remain for the duration of the experiment, and explained the purported purpose of the study. The experimenter told participants that the study was about how the two sides of the brain interact and what this might mean for people's personalities. The experimenter told participants that to investigate this they would wear sensors on the left and right sides of their bodies, and that the sensors would "help measure activity in the brain, because the left side of the body is connected to the right side of the brain, and the right side of the body is connected to the left side of the brain." The experimenter then told participants that in order to investigate how personality interacts with this type of brain communication, a personality report was compiled from psychological questionnaires they answered in a mass survey session at the beginning of the semester.

After this "study overview," the experimenter attached the electrodes to prepare the participants for EKG recording. Further, the experimenter told participants that accurately recording signals necessitates periodically re-calibrating the equipment while the participants sit quietly with hands on their lap and feet on the floor. The experimenter explained that they would begin at this point with approximately 4 min of re-calibration. The experimenter then exited the chamber. In actuality, this time was not for re-calibration but for taking a baseline EKG recording.

After the first EKG recording period, the experimenter re-entered the chamber and instructed the participants to begin a lexical decision computer task that, bolstering the cover story, involved participants using both their left and right hands ostensibly for the purpose of examining the communication between the left and right sides of the body. After this task, participants completed a mood measure, the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). This consisted of rating how much they felt each of twenty emotions "right now, at the present moment" on a 5-point scale (where 1 = *very slightly or not at all* and 5 = *extremely*). The words were *interested, distressed, excited, upset, strong, guilty, scared, hostile, enthusiastic, proud, irritable, alert, ashamed, inspired, nervous, determined, attentive, jittery, active*, and *afraid*. The ten negative items were averaged to comprise a measure of negative mood ($M = 1.46$, $SD = .40$, $alpha = .77$) and the ten positive items were averaged to comprise the measure of positive mood ($M = 3.09$, $SD = .71$, $alpha = .86$).

After this mood assessment, the experimenter entered the chamber, told participants there would be a break before a second set of computer tasks, and that during the break they could take a look at their personality report compiled from the mass survey questions. The experimenter added that because the laboratory acquired this information from participants, the lab was required to offer to show this report to participants, and that people "usually say it's pretty accurate and find it interesting to look at." The experimenter then left the room, ostensibly to print out the report, and asked participants again to sit quietly to make re-calibrating later easier. The experimenter took an EKG recording of approximately 3 min at this point to acquire a second baseline vagal tone measurement.

After this 3 min recording, the experimenter re-entered the chamber to give the personality report to the participants. The personality report served as the vehicle for the self-esteem manipulation, and was handed to participants in a folder to keep the experimenter blind to the feedback condition. Some participants received a very positive report, whereas others received a negative report. At the top of the feedback form, to add to its credibility, we printed the participant's name, gender, and the mass testing date. Below was one of two paragraphs, adapted from a similar manipulation used successfully to manipulate self-esteem in previous research (Greenberg et al., 1992). The feedback was made general enough as to be applicable to most people. The positive feedback included statements such as "While you may feel that you have some personality weaknesses, your personality is fundamentally strong" and "Most of your aspirations tend to be pretty realistic." The negative feedback included statements such as "While you may feel you have some personality strengths, your personality weaknesses affect your life to a much greater extent" and "Most of your aspirations are unrealistic."

Once given, the experimenter left the room for 3 min in order to allow the participants to view the report in private. Then the experimenter entered the chamber to take the folder and to ask participants to sit still for approximately 3 min during re-calibration. During this 3-min period, the experimenter took a third EKG recording, with which we acquired our post-feedback measure of vagal tone. The experimenter then re-entered the chamber to begin participants on the second set of computer tasks, described as similar to the first set of tasks and given again to ostensibly acquire a more stable reading. The tasks were the same as before—the lexical decision task followed by the PANAS. Again we computed the negative affect subscale ($M = 1.38$, $SD = .39$, $alpha = .78$) and positive affect subscale ($M = 2.93$, $SD = .77$, $alpha = .90$) of the PANAS. Lastly, participants answered a question included as a manipulation check. They rated the statement "How did the personality feedback make you feel about yourself?" on a 9-point scale (where 1 = *very bad* and 9 = *very good*). Supporting the intended effect of the feedback on self-esteem, the positive feedback clearly made participants feel better about themselves ($M = 7.79$, $SD = .86$) than the negative feedback ($M = 3.27$, $SD = 1.66$), $F(1, 64) = 192.11$, $p < .001$. After completion of the study, participants were thoroughly probed for suspicion and debriefed—the experimenter spent approximately 15 min sensitively debriefing each participant, so that they left the experiment feeling good about their participation.

5.1.3. Physiological recording and data reduction

To prepare for the physiological recording, the experimenter gently abraded the skin just below each elbow on the inside of the arm, and on the left temple. The experimenter then applied conductive gel to three silver–silver chloride electrodes and affixed these with adhesive collars to the three abraded locations. The electrode on the left temple served as a ground. The electrode leads were plugged into a BioPac AC amplifier and the EKG signal, sampled at 500 Hz and amplified 500 times, was recorded using Acknowledge software.

Estimates of cardiac vagal control were extracted from the EKG series using the freely-available software suite of QRSTool and CMetX (Allen, Chambers, & Towers, 2007; available for download at www.psychofizz.org). To extract the measure of cardiac vagal tone, a 35-Hz low pass digital filter was applied to the raw EKG data before importing the data from each recording period into QRSTool, software that enables point and click recognition of heart beats (R-spikes) and artifact correction in order to obtain an interbeat interval series.

Next, we used CMetX to derive two metrics of cardiac vagal tone from the interbeat interval series: High frequency heart rate variability (HF HRV, the log of the variance of the interbeat interval series in the .12–.40 Hz respiratory band), and the cardiac vagal index (CVI, derived by log transforming the product of the beat to beat variability and the overall heart rate variability; Toichi, Sugiura, Murai, & Sengoku, 1997). Work comparing these measures shows they correlate highly ($rs = .89–.95$, Allen et al., 2007), and both have been validated using pharmacological means (e.g., Toichi et al., 1997). In Study 1 they also correlated quite highly at all three time periods—at the first baseline, the second baseline, and just after the personality feedback, $rs = .96$, .93, and .92, respectively. Thus, in the vagal tone analyses, a composite was computed by averaging the standardized z-scores of each.

5.2. Results and discussion

5.2.1. Main analyses

To examine the main hypothesis that the feedback manipulation would affect vagal tone we conducted a two-way ANCOVA (personality feedback: negative feedback vs. positive feedback) with the vagal tone composite acquired after the feedback as the dependent measure, controlling for both baseline vagal tone measurements. A marginal main effect emerged for feedback, $F(1, 66) = 3.46$, $p = .07$, Cohen's $d = .46$. Positive feedback increased vagal tone (*adjusted* $M = .11$, *actual* $M = .12$, $SE = .07$, $SD = 1.06$) relative to negative feedback (*adjusted* $M = -.07$, *actual* $M = -.08$; $SE = .07$, $SD = .88$).[3] Further, the better participants reported the feedback made them feel about themselves (on the manipulation check item), the more vagal tone increased, $Beta = .11$, $SE = .02$, $t = 2.39$, $p < .05$, $sr^2 = 08$.

5.2.2. Positive and negative affect

To complement this examination of the effect of feedback on change in vagal tone, we acquired mood ratings both before and after the feedback. This allowed us to test whether the change in mood accounts for the effect of feedback on vagal tone. If the effect of feedback remains significant while controlling for change in mood, we can be more confident that the changes in vagal tone emerged as a consequence of state changes in self-esteem, and not merely mood.

To conduct this analysis, we first derived measures of mood change by partialing out pre-feedback positive and negative mood scores from post-feedback positive and negative mood scores, respectively. In other words, we computed the residual post-feedback mood scores when controlling for pre-feedback mood scores. Conceptually, these residualized mood scores are the difference between the post-feedback mood scores and mood scores that would be predicted by the pre-feedback mood scores. In an ANCOVA, we then examined the effect of feedback on vagal tone controlling for the residualized positive and negative mood scores as well as baseline vagal tone. The main effect for feedback—$p = .08$—looked similar to the effect that emerged without controlling for change in mood ($p = .07$). In addition, the positive and negative mood change scores did not predict change in vagal tone, $ps > .80$.

Looking at the PANAS in even further detail, we also examined the two emotion items most closely related to self-esteem, those assessing pride and shame (Brown & Marshall, 2001; Neidenthal, Tangney, & Gavinski, 1994; Tracey et al., 2009). As with the broader subscales of positive and negative mood, the effect of feedback on change in vagal tone looked the same when controlling for change in pride and shame ($p = .07$). Further, in this analysis, neither shame nor pride significantly predicted change in vagal tone, though change in shame showed hints of an effect ($p = .15$, $sr^2 = .005$). In sum, controlling for negative and positive mood, as well as specifically for shame and pride, did not alter the findings—the effect of the self-esteem feedback held.

6. Study 2

The results of Study 1 provided evidence that positive self-esteem relevant feedback increases vagal tone relative to negative self-esteem relevant feedback. However, the effect of feedback was only marginally significant. It is possible that we only observed a marginal effect in Study 1 because of the broad nature of the self-esteem feedback used, i.e., the feedback was not derived to target participants' idiosyncratic self-esteem contingencies. Thus in Study 2 we recruited only people who based their self-esteem on their intelligence, and then gave them either negative or positive feedback about their intelligence in order to observe the effect on vagal tone.

We also included an additional condition in Study 2—a neutral control condition. In Study 1 we found evidence that positive self-esteem related feedback increased vagal tone *relative* to negative feedback, but the design did not allow for ascertaining whether the positive feedback increased vagal tone, the negative feedback decreased vagal tone, or both. Thus, in Study 2 we included a condition in which participants received no feedback at all.

6.1. Method

6.1.1. Participants

Fifty-seven introductory psychology students at the University of Alberta participated in exchange for partial course credit. This study received ethics approval from the University of Alberta Arts, Science and Law Research Ethics Board. Participants were selected on the basis of their responses to three questions included in a mass screening session at the beginning of the semester. The questions, designed to assess the extent to which participants' self-esteem was invested in the belief that they are intelligent, read: "My self-esteem is influenced by how smart people think I am," "I feel better about myself when I feel intelligent," and "I don't care how smart I appear to other people" (reverse scored). Only students scoring 5 or above (on a 7-point scale, where 1 = *completely disagree* and 7 = *completely agree*) to all three questions were eligible to participate in the experiment. Participants were randomly assigned to one of three conditions (IQ feedback: negative vs. no feedback vs. positive). Of the fifty-seven participants, one was excluded from the analysis for visibly exhibiting abnormal and extremely rapid respiration. This left 56 participants (28 males, 28 females; mean age = 18.96 years) for data analysis.

6.1.2. Procedure

In the experimental sessions, we tested participants individually. A same-sex experimenter greeted participants upon entering the laboratory, and seated them at a table while explaining the purported purpose of the study. It was presented as an investigation of the relationship between intelligence and a newly developed construct named *psycho-physical fitness* (PPF). The experimenter explained further that intelligence would be measured by having participants complete a short IQ test, and PPF would be assessed thereafter by simultaneously measuring participants' heart rate while they performed a lexical decision task. Thus, participants were blind to the true purpose of the study.

Participants were then led to a comfortable stationary chair where they remained for the duration of the procedure. Before beginning the IQ test, participants were affixed with the requisite electrodes for the EKG measurement and completed a few practice trials of the lexical decision task. Upon completion of the practice trials, the experimenter connected the electrodes to the leads in order to monitor participants' heart rate. Participants were instructed to sit perfectly still in a comfortable and relaxed position, while the experimenter calibrated the machine. In actuality, this time was for taking a baseline EKG recording. After a 3-min measurement period, participants proceeded to the IQ test.

The IQ test was administered to participants via computer. This test (identical to that used by Hayes, Schimel, Faucher, & Williams, 2008) consisted of twenty multiple-choice questions of varying difficulty. Each question was followed by four or five possible responses. Questions involved mathematical and logical reasoning, pattern recognition, and general trivia. Participants were told that their score would reflect a combination of whether or not they answered correctly and the amount of time taken to answer each question.

Upon completion of the IQ test, participants were randomly assigned one of three feedback manipulations. The experimenter was blind to this assignment of condition. In the positive feedback

[3] We excluded gender from analyses in all of the studies because it did not interact with any of the independent variables, $ps > .20$. Only in Study 4 did gender produce a main effect: women had higher vagal tone ($M = .22$, $SD = .83$) than men ($M = -.62$, $SD = 1.16$), $B = .38$, $SE = .34$, $t = 2.45$, $p > .05$. $sr^2 = .14$.

condition, the computer program informed participants that their IQ score was 139 and that in relation to other students who have taken the test, their score fell at the 92nd percentile. In the negative feedback condition, participants were told that their score was 91, which fell at the 35th percentile relative to other students. In the neutral condition, participants were given no information regarding their score. For all conditions, at the bottom of the screen, participants were instructed to press the spacebar to continue.

Once participants finished viewing their feedback and pressed the spacebar, a note appeared on the computer screen requesting that they inform the experimenter that they were ready to proceed to the next phase of the study. At this point, the experimenter explained that they would need to re-calibrate the equipment in preparation for the lexical decision PPF test. Participants were therefore instructed to sit still in a comfortable position for a 3-min period. Once again, this time was not for re-calibration, but for actual measurement, and this period constituted the post-feedback EKG measurement. After the second EKG measurement period, participants completed the lexical decision task. They were then probed for suspicion and as in Study 1, the experimenter spent approximately 15 min sensitively debriefing each participant, so that they left the experiment feeling good about their participation.

6.1.3. Physiological recording and data reduction

To prepare for the physiological recording, the experimenter instructed participants to gently abrade the skin just below their elbow on the inside of each arm, and on the inside wrist of their non-dominant arm. The experimenter then affixed disposable silver–silver chloride pre-gelled electrodes to the three abraded locations. The electrode on the wrist served as a ground. The electrode leads were plugged into a BioPac AC amplifier and the EKG signal, sampled at 200 Hz and amplified 500 times, was recorded using Acknowledge software. We derived our composite measures of vagal tone for each participant just as in Study 1, by averaging the standardized scores of the HF HRV and CVI metrics during each of the two recording periods. They correlated quite highly at both time points, *r*s = .92 and .94.

6.2. Results and discussion

In a 3-way (IQ feedback: negative vs. no feedback vs. positive) ANCOVA, we examined our main question—whether this self-esteem relevant feedback would effect changes in vagal tone. A significant effect for IQ feedback emerged, $F(2, 52) = 3.70$, $p < .05$, Cohen's $d = .53$. Vagal tone among those who received positive feedback (*adjusted* $M = .23$, *actual* $M = .13$, $SE = .11$, $SD = .89$) was marginally higher than those who received no feedback at all (*adjusted* $M = -.04$, *actual* $M = -.13$, $SE = .11$, $SD = .93$), $p = .09$, and significantly higher than those who received negative feedback (*adjusted* $M = -.18$, *actual* $M = .01$, $SE = .11$, $SD = 1.13$), $p < .05$. Vagal tone did not significantly differ between those who received negative feedback and no feedback, $p = .34$. The mean among those who received no feedback fell in between the means for those who received positive and negative feedback, albeit closer to the negative feedback condition. In other words, positive feedback appeared to shade participants toward higher vagal tone and negative feedback toward lower vagal tone, though the effects of the self-esteem relevant IQ feedback appeared most clearly when positive and negative feedback were pitted against each other. See Fig. 2 for a visual depiction of the means.

7. Study 3

Together, Studies 1 and 2 provided converging evidence that manipulating self-esteem-relevant feedback affects resting vagal tone. In the next two studies, we examined the relationship between self-esteem and vagal tone more generally—we examined whether people's typical daily self-esteem levels predict individual differences in resting levels of vagal tone. Specifically, participants rated their level of state self-esteem each day for a period of 2 weeks, and did so away from the laboratory, in their own environment. This approach, adapted from Kernis and colleagues (e.g., Kernis, 2005), also allowed us to examine self-esteem stability in conjunction with vagal tone. Self-esteem stability has generally been examined as a moderator of high self-esteem: those with high but stable self-esteem tend to behave and think less defensively than those with high but unstable self-esteem (Kernis, 2005). Consequently, we thought it conceivable that self-esteem level and stability might interact in their relationship with vagal tone—that high stable self-esteem might predict higher levels of vagal tone than high unstable self-esteem. After the 2-week self-esteem rating period, participants came into the laboratory and we recorded 10 min of EKG data to extract vagal tone.

7.1. Method

7.1.1. Participants

Twenty-six undergraduate students at the University of Canterbury in New Zealand participated in exchange for course credit and a supermarket voucher worth five New Zealand dollars. The study received ethics approval from the University of Canterbury Human Subjects Committee. Two participants were excluded from the analysis because their EKG recording could not be interpreted due to the participants' excessive movement. This left 24 participants for analyses (we did not ask participants their gender or age).

7.1.2. Materials and procedure

In an initial laboratory session, participants were given a form on which to rate their state self-esteem each day for 14 days. The daily rating consisted of rating one question—adapted from a 1-item self-esteem measure (Robins, Hendin, & Trzesniewski, 2001)—"*Today* I have high self-esteem," which has been validated and correlates highly with the Rosenberg Self-esteem Scale (Robins et al., 2001; Rosenberg, 1979) and closely resembles the Rosenberg Self-esteem Scale in its correlations with a wide variety of personality measures. Participants rated this item using a 10-point scale (where 1 = *not very true of me* and 10 = *very true of me*). The question was repeated on the form 14 times, labeled Day 1 through Day 14. When given this form, participants were also given instructions that defined self-esteem as "a sense that we are of value and that we feel good about ourselves" and explained that though we have a general sense of our self-esteem, research also shows that "our self-esteem from hour to hour, day to day, and week to week, varies for any number of reasons." The instructions requested that participants not think too long about their ratings, that they give their natural, gut response. Further, the instructions explained that if they miss a day they should simply leave that day blank, that making a rating for a prior day would mess up the exercise, and that they would still receive credit for participation even if they missed ratings.

For analyses, we computed self-esteem level by averaging participants' daily ratings ($M = 6.74$, $SD = .85$, *alpha* = .84). In addition, following prior work (e.g., Kernis, Grannemann, & Barclay, 1989), we computed each participant's standard deviation of their ratings to obtain a measure of self-esteem stability ($M = 1.18$, $SD = .41$). This allowed us to additionally examine self-esteem stability and a self-esteem level by stability interaction. The majority of the participants completed all 14 daily ratings. One participant left blank two daily ratings and two participants left blank one daily rating (for these participants with missing values we computed the

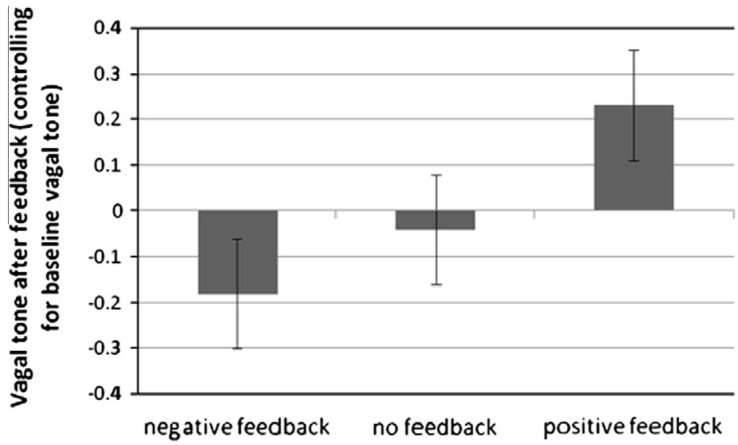

Fig. 2. Study 2: Vagal tone (controlling for baseline vagal tone) as a function of type of feedback. *Note*: Error bars indicate 1 SE above and below the mean.

self-esteem level and self-esteem stability scores based on their existing ratings).

After the 2 week rating period, participants turned in their ratings to a laboratory assistant and were scheduled for individual heart rate recording sessions that occurred over the next 2–5 weeks. In an email reminder, they were asked not to take part in exercise for at least 30 min before the session.

When participants arrived they were greeted by the experimenter who briefly told them that he would be taking their heart rate using a few sensors. The experimenter attached the electrodes to the participants' arms. He told participants that he would take a 10-min recording and that they should get comfortable, put both feet on the ground and their arms on the arm rests of their chair, and try not to move around much during the recording. The experimenter then started the recording and walked around a partition to give the participants privacy. After 10 min, the experimenter returned to stop the recording and debrief participants.

7.1.3. Physiological recording and data reduction

To prepare for the physiological recording, the experimenter affixed disposable electrodes exactly as in Study 3. The electrode leads were plugged into a BioPac AC amplifier and the EKG signal, sampled at 500 Hz and amplified 500 times, was recorded using Acknowledge software. We derived our composite measure of vagal tone for each participant just as in Studies 1 and 2 by averaging the standardized scores of the HF HRV and CVI metrics. They correlated highly, $r = .97$.

7.2. Results and discussion

To analyze the relationship between self-esteem and vagal tone, we regressed vagal tone calculated from the entire 10-min EKG recording onto self-esteem level, self-esteem stability, and their interaction. An effect for self-esteem level emerged as marginally significant, $Beta = .40$, $SE = .25$, $t = 1.91$, $p = .07$, $sr^2 = .15$. People with higher average levels of self-esteem over the 2-week period exhibited higher levels of cardiac vagal tone. Neither the self-esteem stability effect nor the self-esteem stability by self-esteem level interaction was significant, $ps > .15$.

In addition to this examination of vagal tone extracted from the full 10-min recording, we analyzed vagal tone extracted from the first 2 min of the recording and from the last 2 min. In so far as people adapt to the rather novel laboratory conditions during the recording, vagal tone extracted towards the end might reflect people's general tendencies better than vagal tone extracted from the beginning of the recording period.

To examine this we first regressed vagal tone extracted from the first 2 min onto self-esteem level, self-esteem stability, and their interaction. Contrary to the overall 10-min vagal tone index, no main effect emerged for level of self-esteem, $p > .30$, and no effect emerged for self-esteem stability or the level by stability interaction, $ps > .35$. The same analysis but with vagal tone extracted from the final 2 min, however, revealed a significant main effect for self-esteem level, $Beta = .48$, $SE = .24$, $t = 2.39$, $p < .05$, $sr^2 = .21$, such that those with higher self-esteem exhibited higher vagal tone. See Fig. 3 for a visual representation of this correlation. No other effects were significant, $ps > .15$. Thus, we acquired evidence that people's general levels of state self-esteem predicted people's resting vagal tone levels. The full set of correlations is presented in Table 1.

8. Study 4

In Study 3 we obtained preliminary evidence that daily self-esteem tendencies correlate with resting vagal tone levels. In Study 4 we sought to replicate this effect and also included a mood measure to examine whether, as in Study 1, the effect of self-esteem holds when controlling for people's more general mood.

8.1. Method

8.1.1. Participants

Thirty-six undergraduate students at the University of Canterbury participated in exchange for course credit and for a supermarket voucher worth ten New Zealand dollars. This study received ethics approval from the University of Canterbury Human Subjects Committee. Two participants were excluded from the analysis because of EKG waveform abnormalities. This left 34 participants (9 men, 25 women, mean age = 23.92 years) for analyses.

8.1.2. Materials and procedure

Study 4 was almost identical to Study 3—participants rated their state self-esteem every day for 14 days (again most completed all 14 daily ratings: three participants left two daily ratings blank and three left one daily rating blank) and then came into the laboratory for a 10-min EKG recording. However, after the 10-min EKG recording, participants were given two forms to complete. They first completed a mood measure, the PANAS (Watson et al., 1988), comprised of a negative affect subscale ($M = 1.40$, $SD = .51$, $alpha = .85$) and positive affect subscale ($M = 2.95$, $SD = .64$, $alpha = .81$). After this mood measure, participants completed a demographics form with which we ascertained gender.

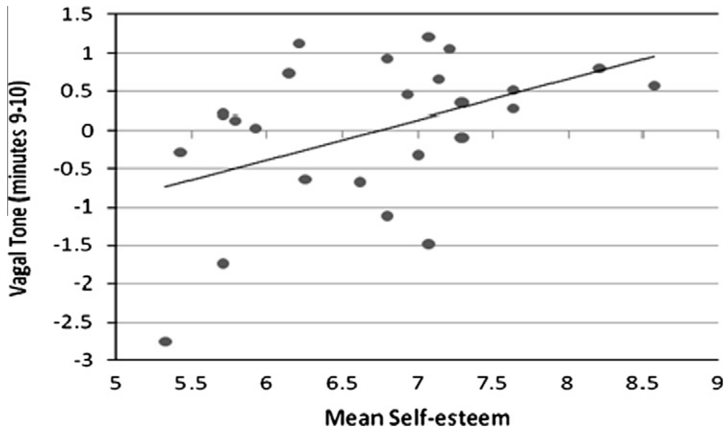

Fig. 3. Study 3: Cardiac vagal tone (extracted from minutes 9–10) as a function of mean self-esteem (average self-esteem rating over the course of 14 consecutive days).

Table 1
Correlations between Study 3 variables.

Variable	1	2	3	4	5
1. Self-esteem level		−.30	.38	.19	.45*
2. Self-esteem stability			−.04	.04	−.04
3. Vagal tone (full 10 min)				.86*	.91*
4. Vagal tone (first 2 min)					.71*
5. Vagal tone (last 2 min)					

* $p < .05$.

8.1.3. Physiological recording and data reduction

The details of the physiological recording were identical to those in Study 3—the experimenter affixed the electrodes, and the EKG signal was recorded sampling at 500 Hz. We derived our composite measure of vagal tone for each participant by averaging the standardized scores of the HF HRV and CVI metrics. They correlated highly, $r = .95$.

8.2. Results and discussion

As in Study 3, we regressed our composite index of vagal tone onto self-esteem level ($M = 6.68$, $SD = 1.09$, $alpha = .81$), self-esteem stability ($M = 1.56$, $SD = .57$), and their interaction. A significant main effect for self-esteem level emerged, $Beta = .42$, $SE = .16$, $t = 2.35$, $p < .05$, $sr^2 = .15$.[4] People with higher average levels of self-esteem over the 2-week period exhibited higher levels of cardiac vagal tone. Neither the self-esteem stability effect nor the stability by level interaction was significant, $ps > .30$.

In addition, we examined whether this relationship between self-esteem level and vagal tone held when controlling for general levels of negative and positive affect. To do so, we regressed vagal tone simultaneously onto self-esteem level, negative affect, and positive affect. With these mood measures entered into the equation, self-esteem level remained a significant predictor of vagal tone, $p = .05$. Further, negative and positive affect did not predict vagal tone in this analysis, $ps > .40$. Other research, however, has shown a positive relationship between positive affect and vagal tone (Oveis et al., 2009), and though non-significant, our zero-order correlations in Study 4 (see Table 2) do show a similar pattern of data: the positive affect subscale positively correlated with vagal tone ($r = .20$, $p = .26$), while negative affect did not ($r = -.04$, $p = .84$). Perhaps with more power our results would have looked more similar to this prior work. Nevertheless, neither of the broad measures of positive or negative affect appeared to account for the relationship between self-esteem and vagal tone.

As in Study 1, however, we also examined the two items from the PANAS most closely related to self-esteem, those measuring pride and shame. With these two items entered into the regression analysis examining the relationship between self-esteem and vagal tone, the effect of self-esteem level remained significant, $p < .05$. However, the *proud* item also approached significance, $p = .07$, $sr^2 = .08$, while the *ashamed* item hinted at an effect, $p = .13$, $sr^2 = .06$. Thus, the affect items most closely resembling self-esteem—those of pride and shame—related to vagal tone in a manner that somewhat mirrored self-esteem. This would appear consistent with our theorizing, yet in as far as pride and shame are components of self-esteem, these results also suggest that the repeated 1-item self-esteem measure does not fully capture some facets of self-esteem that may relate to vagal tone.

As in the prior study, we also analyzed vagal tone extracted from the first 2 min of the recording and from the last 2 min. First we regressed vagal tone extracted from the first 2 min onto self-esteem level, self-esteem stability, and their interaction. Consistent with Study 3, no main effect emerged for level of self-esteem, $p = .10$, and no effect emerged for self-esteem stability or the level by stability interaction, $ps > .25$. Also consistent with Study 3, the same analysis with vagal tone extracted from the final 2 min revealed a significant main effect for self-esteem level, $Beta = .45$, $SE = .16$, $t = 2.59$, $p < .05$, $sr^2 = .18$, such that those with higher self-esteem exhibited higher vagal tone. See Fig. 4 for a visual representation of this correlation. Effects for self-esteem stability and the level by stability interaction were not significant, $ps > .40$. In sum, we again acquired evidence that people's general levels of state self-esteem predict people's resting vagal tone levels. The full set of correlations is presented in Table 2.

9. Meta-analysis of results

In several places we observed results that approached but did not reach significance. It is possible that our studies were underpowered and thus that we might benefit from combining Studies 1 and 2 and combining Studies 3 and 4 to test our key hypotheses, i.e., by conducting two small meta-analyses.

First we examined the two experiments, Studies 1 and 2. Within each study we first converted our vagal tone measures to z-scores and then combined the data from both studies. Controlling for baseline vagal tone, the 3-way (feedback: negative vs. none vs. positive) ANCOVA revealed a significant effect, $F(2, 125) = 5.30$,

[4] We excluded one outlier from this analysis—a participant more than 2.5 standard deviations below the mean for self-esteem level. With this participant included in the analysis, however, the relationship between self-esteem and vagal tone becomes even stronger, $Beta = .59$, $SE = .12$, $t = 3.81$, $p < .001$, $sr^2 = .31$.

Table 2
Correlations between Study 4 variables.

Variable	1	2	3	4	5	6	7	8	9
1. Self-esteem level		−.37*	−.45*	.25	.26	−.39*	.35*	.24	.41*
2. Self-esteem stability			.19	.10	−.14	−.17	.03	.09	−.04
3. Negative affect				−.09	−.12	.68*	−.04	−.06	−.03
4. Positive affect					.68*	−.22	.20	.21	.23
5. Pride						−.11	.34*	.37*	.36*
6. Shame							−.01	−.05	.01
7. Vagal tone (full 10 min)								.90*	.96*
8. Vagal tone (first 2 min)									.78*
9. Vagal tone (last 2 min)									

* $p < .05$.

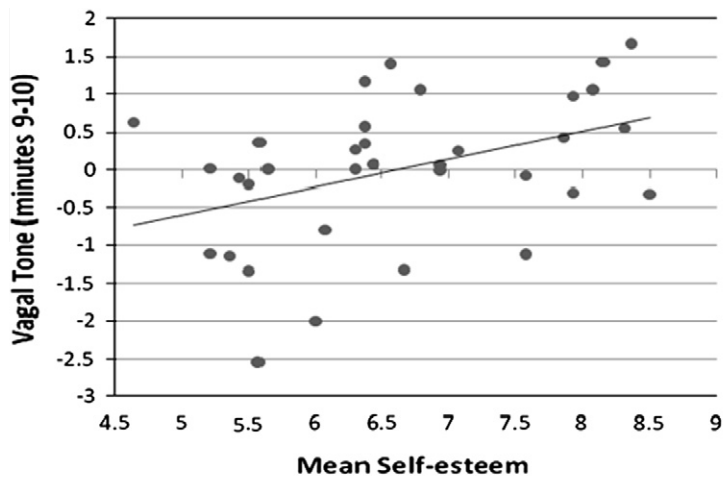

Fig. 4. Study 4: Cardiac vagal tone (extracted from minutes 9–10) as a function of mean self-esteem (average self-esteem rating over the course of 14 consecutive days).

$p < .01$. Positive feedback led to higher vagal tone (*adjusted M* = .14, *SE* = .06, *N* = 54) than negative feedback (*adjusted M* = −.12, *SE* = .06, *N* = 56), $p < .01$, Cohen's $d = .26$). This effect was only marginal in Study 1. As in Study 2, neither positive feedback nor negative feedback differed significantly from no feedback (*adjusted M* = −.04, *SE* = .10, *N* = 19), *p*s of .12 and .45, respectively. In sum, the effect of positive feedback relative to negative feedback clearly emerged with the combining of data. Further, as reported in Study 2, the mean for those who received no feedback fell in between the positive and negative feedback means, though the difference between positive feedback and no feedback was closer to significance than the difference between negative feedback and no feedback.

To meta-analytically examine Studies 3 and 4, within each study we converted our measures of vagal tone, self-esteem level, self-esteem stability, and the level by stability interaction term to z-scores. Then we combined these data ($N = 58$). The effect of self-esteem level on vagal tone calculated from the entire 10-min EKG recording reached significance, *Beta* = .41, *SE* = .13, $t = 3.10$, $p < .01$, $sr^2 = .15$. This effect was only marginal in Study 3. The effect of self-esteem level on vagal tone calculated from the first 2 min of the recording also reached significance, *Beta* = .27, *SE* = .14, $t = 1.99$, $p = .05$, $sr^2 = .07$. This effect did not reach significance in either Studies 3 or 4. The effect of self-esteem level on vagal tone calculated from the last 2 min of the recording was significant, as in Studies 3 and 4, *Beta* = .47, *SE* = .13, $t = 3.62$, $p < .01$, $sr^2 = .19$. As in Studies 3 and 4, neither self-esteem stability nor the level by stability interaction was significant, *ps* > .25. In sum, with more power, the relationship between self-esteem level and vagal tone appeared more clearly than in either Studies 3 or 4 alone.

10. General discussion

Based on evidence that a sense of security increases vagal tone, and that self-esteem provides a sense of security from threat, we hypothesized that levels of self-esteem should impact levels of resting cardiac vagal tone. In four studies we found evidence consistent with this hypothesis. In Study 1 we found that positive self-esteem relevant feedback increased vagal tone relative to negative self-esteem relevant feedback. In Study 2, examining people whose self-esteem was invested in their intelligence, we found that positive intelligence feedback increased vagal tone relative to negative intelligence feedback. In Studies 3 and 4 we utilized a correlational approach and found that people's general levels of self-esteem over the course of a 2-week period positively correlated with resting levels of vagal tone assessed in the laboratory.

Across the four studies, these findings converge on a link between two heavily researched and important variables, one psychological and the other physiological. Self-esteem is one of the most studied variables in psychology (e.g., Greenberg, 2008; Leary et al., 1995; Tajfel & Turner, 1986; Swann et al., 2007). It is associated with a wide range of mental and physical health indicators, plays a substantial role in buffering people from experiencing anxiety and threat, and enhances the ability to cope with stressors. Yet little is known about the basic physiological outcomes of self-esteem. By showing a relationship between self-esteem and a well-researched indicator of parasympathetic functioning—cardiac vagal tone—this work takes an important step toward filling that gap. Further, the parasympathetic system is critical in many ways to the workings of our physical bodies, with numerous implications for physical functioning and health as elaborated on below.

Thus, this work may shed light on an important pathway by which self-esteem affects the quality of physical functioning and health.

10.1. Remaining issues regarding the nature of the self-esteem and vagal tone relationship

The present data do not provide specifics for how tightly self-esteem and vagal tone are intertwined, for example, when they dissociate and what we can infer from changes in vagal tone about changes in self-esteem. In addition, self-esteem is clearly one of a number of factors that affect vagal tone, and clarifying the relationship between self-esteem and vagal tone would entail examining the conditions under which self-esteem and non-self-esteem factors do and do not impact vagal tone. Thus, though a one-to-one correspondence between a physiological measure like vagal tone and a psychological construct like self esteem is unlikely (cf. Cacioppo, Tassinary, & Berntson, 2007), a careful investigation of such factors may determine whether and under what conditions vagal tone might provide an informative index of self-esteem. If under certain circumstances vagal tone were highly correlated with self esteem, this would raise the intriguing possibility that we could infer state self-esteem from a physiological measure that is presumably unbiased by self-report issues (e.g., introspective difficulties, Nisbett & Wison, 1977; impression management concerns, Tedeschi, Schlenker, & Bonoma, 1971).

One possibility for follow-up research that could begin to more precisely uncover how tightly self-esteem and vagal tone are intertwined could assess vagal tone on a daily basis, in conjunction with self-esteem. In Studies 3 and 4, we measured only self-esteem each day. In as far as accruing these multiple measures of self-esteem over a period of time provided a more accurate picture of participants' typical self-esteem levels than merely measuring it on one occasion, measuring vagal tone repeatedly over a period of time should likewise provide a more accurate picture of natural resting vagal tone levels, and in turn allow for more precisely testing the hypothesized relationship. Further, in Studies 3 and 4 we had no guarantee that participants in fact rated their self-esteem daily, as instructed (i.e., it is conceivable that some completed their self-esteem ratings in bulk). Thus, future research more closely monitoring daily self-esteem ratings would rectify this shortcoming. In addition, this daily co-measurement of self-esteem and vagal tone would allow for observing whether, independent of laboratory manipulations, self-esteem and vagal tone rise and fall together, within subjects.

Future research might also address an important limitation of the present work—that we assessed individual differences in self-esteem with only one type of self-esteem measure, albeit with multiple assessments. The self-esteem literature is rife with various ways to assess self-esteem, and the various approaches to measuring self-esteem often suggest that self-esteem is not a simple construct but one with different facets. For example, research shows that the implications of implicit self-esteem measures can differ from explicit measures (e.g., Spalding & Hardin, 2000), that the degree of disconnect between implicit and explicit facets may be important (Jordan, Spencer, Zanna, Hoshino-Browne, & Correll, 2003), and that the contingencies of self-esteem (e.g., whether self-esteem is based on extrinsic or intrinsic factors) as well as the stability of self-esteem make a difference beyond level of self-esteem (e.g., Kernis, 2005; Schimel, Arndt, Pyszczynski, & Greenberg, 2001). In the present work we examined stability of self-esteem, as well as pride and shame, but beyond this much more work is needed to understand the full nature of self-esteem's relationship with vagal tone.

Along similar lines, the interplay of self-esteem and other closely related constructs should be explored. For example, given the noted relationship between attachment security and vagal tone (Diamond & Hicks, 2005), it is conceivable that self-esteem is particularly predictive of vagal tone when taking into consideration this developmental aspect. Other work shows a strong relationship between neuroticism and self-esteem (Watson et al., 2002), and so likewise, assessing the relationship of both these constructs to vagal tone in the same study would help build a more nuanced understanding of the self-esteem and vagal tone link. Further, neuroticism has been linked to physical health issues (e.g., Mroczek, Spiro, & Turiano, 2009), and so perhaps vagal tone would be useful for understanding this link too.

Another future extension of this work could address the possibility that the causal arrow also runs from vagal tone to self-esteem, i.e., that cardiac vagal tone influences self-esteem. The autonomic nervous system sends information or feedback from the periphery to the central nervous system—the vagus travels not only from the brain to the heart but from the heart back to the brain. Thus, it is plausible that cardiac vagal tone can affect our cognitive processes, perhaps including those involved in self-esteem. Indeed, research is examining the effects of stimulating these afferent vagal fibers (those that travel from the periphery to the brain) to treat depression (e.g., George et al., 2000).

10.2. Health implications

The evidence we have collected has implications for the effects of self-esteem on physical health. A small but growing body of work suggests a causal role of self-esteem-related constructs in physical health outcomes. For example, affirming important aspects of people's sense of self has predicted decreased physical symptoms of breast cancer (Creswell et al., 2007), and increases in self-esteem have predicted fewer general physical health problems among undergraduates (Stinson et al., 2008). Similarly, research suggests vagal tone can play a causal role in physical health outcomes. For example, higher vagal tone appears to predict the development and/or progression of cardiovascular disease and auto-immune diseases (e.g., Masi et al., 2007; Thayer & Lane, 2007; Yien et al., 1997). Thus, given an effect of self-esteem on vagal tone presented here, vagal tone may be worth investigating as a mediator of effects of self-esteem on physical health and disease.

There are two broad possibilities for how this could occur. First, it may be that vagal tone mediates the effect of self-esteem on health by dampening sympathetic and inflammatory immune responses that when chronically active deteriorate the body (e.g., Bueno et al., 1989; Czura & Tracey, 2005; Krantz & Manuck, 1984; Levy, 1990; McEwen, 1998; Sapolsky, 1994). Second, in addition to this potential pathway from vagal tone to disease via down-regulating sympathetic and inflammation responses, vagal tone may have a more direct effect on physical health. Lower activity of the vagus generally means less resting and restoration of the body (e.g., Costanzo, 2002), which should eventually leave people vulnerable to injury and disease. The more we know about the details of these pathways between psychological health and physical health, of course, the better position we will be in to develop ways to intervene and promote physical wellbeing.

10.3. Conclusion

To sum up, evidence from these studies shows that experimentally manipulated changes in self-esteem can influence cardiac vagal tone, and that people's self-esteem tendencies over a somewhat extended period of time co-vary with resting cardiac vagal tone levels. Certainly more work is necessary to uncover the exact nature of this psychological–physiological relationship, but the current data—the first to explicitly link self-esteem to vagal tone—broadens our understanding of both the physiology of self-esteem and the psychology of cardiac vagal tone, and should inform and generate future research exploring the implications of self-esteem for our physiology and physical health.

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