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Affective and Physiological Responses to the Suffering of Others: Compassion and Vagal

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Abstract

Compassion is an affective response to another's suffering and a catalyst of prosocial behavior. In the present studies we explore the peripheral physiological changes associated with the experience of compassion. Guided by longstanding theoretical claims, we propose that compassion is associated with activation in the parasympathetic autonomic nervous system through the vagus nerve. Across four studies, participants witnessed others suffer while we recorded physiological measures including heart rate, respiration, skin conductance, and a measure of vagal activity called respiratory sinus arrhythmia (RSA). Participants exhibited greater RSA during the compassion induction compared to a neutral control (Study 1), another positive emotion (Study 2), and a prosocial emotion lacking appraisals of another person's suffering (Study 3). Greater RSA during the experience of compassion compared to the neutral or control emotion were often accompanied by lower heart rate and respiration, but no differences in skin conductance. In Study 4, increases in RSA during compassion positively predicted an established composite of compassion-related words, continuous self-reports of compassion, and nonverbal displays of compassion. Compassion, a core affective component of empathy and prosociality, increases parasympathetic activity. (180 Words)

Affective and Physiological Responses to Other's Suffering: Compassion and Vagal Activity

Suffering is a defining experience in human social life. The suffering of others evokes strong affective responses in observers. These emotions include feelings of distress, empathic pain, and most prototypically, compassion (Batson, Fultz, & Schoenrade, 1987; Eisenberg et al., 1989; Goetz, Keltner, & Simon-Thomas, 2010). We define compassion as feeling sorrow or concern for the suffering of another person, coupled with the desire to alleviate that suffering (Eisenberg et al., 2004; Haidt, 2003; for definitions of compassion see Goetz et al., 2010).[1] Compassion is elicited in response to observations of different kinds of suffering, including illnesses (Batson, Sager, Garst, & Kang, 1997; Stellar, Manzo, Kraus, & Keltner, 2012), disabilities (Eisenberg et al., 1988), starvation, and poverty (Oveis, Horberg, & Keltner, 2010). Although compassion has negative and distressing antecedents, it is considered a positive emotion that generates positive outcomes and is associated with feelings of warmth, tenderness, and soft-heartedness (Batson et al., 1997; Shaver, Schwartz, Kirson, & O'Connor, 1987). Compassion encourages stronger connection with the sufferer by promoting greater perceptions of similarity (Oveis et al., 2010; Valdesolo & Desteno, 2011) and motivates prosocial behaviors oriented towards the reduction of need and suffering (Eisenberg & Miller, 1987). Evidence suggests that the experience of compassion may benefit well-being and health over the long-term (Kok et al., 2013; Steffen & Masters, 2005). Within these theoretical analyses and findings, compassion is considered a foundational prosocial emotion that motivates caretaking, support giving, and helping behavior (Eisenberg & Miller, 1987; Nussbaum, 2003).

This emerging empirical literature on compassion dovetails with earlier theoretical claims found within evolutionary approaches. There it has been posited that compassion originally evolved to motivate caretaking behavior directed toward offspring (Goetz et al., 2010). In

support of this argument, individuals report strong compassion responses to children (Oveis et al., 2010; Zahn-Waxler, Friedman, & Cummings, 1983) and, in keeping with ideas of inclusive fitness, individuals who are closely related (Cialdini, Brown, Lewis, Luce, & Neuberg, 1997). Batson and colleagues (2005) found that, to some extent, compassion is driven by nurturant tendencies toward strangers, which likely have their roots in motivations to care for offspring. Compassion also has been linked to the security of an individual's attachment style, which itself is a critical part of care-giving behavior (Mikulincer & Shaver, 2005). It is further reasoned within this evolutionary framework that compassion extended to non-kin to encourage sacrifice and generosity, and is a foundation of reciprocally beneficial relationships (Trivers, 1971). Across these relationship contexts, it is thought that compassion in response to suffering, especially emotional suffering, promotes behavioral responses aimed at soothing, calming, or caring for the sufferer.

In keeping with the caretaking origins of compassion and the types of behaviors it motivates, in the present investigation we test the hypothesis that compassion will be accompanied by greater parasympathetic activity than neutral states, or closely related positive and prosocial states. We measure parasympathetic activity via the vagus nerve, which we operationalize as respiratory sinus arrhythmia (RSA). This hypothesis has its precedent in theoretical arguments about the evolution of the vagus nerve (Porges, 2001) and is anticipated by select findings, to which we now turn.

The Vagus Nerve: Anatomy, Measurement, and Function

The vagus nerve, the tenth cranial nerve, is a component of the parasympathetic branch of the autonomic nervous system (Beauchaine, 2001). In contrast to the sympathetic autonomic nervous system, which is associated with high arousal negative states, the parasympathetic

autonomic nervous system (PANS) more generally is thought to be responsible for activities during states of rest. The vagus nerve, one branch of the PANS, extends from the brain stem and innervates major muscles in the larynx, pharynx, and palate, before travelling down to innervate the heart and digestive organs. Recent research suggests the vagus nerve also functions to control immune response by regulating cytokine production (Rosas-Ballina et al., 2011).

Vagal activity is primarily measured through its inhibitory influence upon the sino-atrial node, or pace maker of the heart. In order to obtain a non-invasive index of vagal activity, researchers can gather measures of respiratory sinus arrhythmia (RSA), which quantifies the degree of vagal control over the heart. During inhalation, vagus nerve activity is suppressed, resulting in heart rate acceleration; during exhalation, vagus nerve activity increases, leading to heart rate deceleration. RSA is the variability in heart rate that is specifically associated with the respiration cycle, and thus RSA is thought to be an indicator of vagal activity (Berntson, Cacioppo, & Quigley, 1993).

Compassion and vagal activity: Theoretical claims and suggestive empirical support

A conceptual analysis of compassion and empirical studies of RSA point to three reasons why compassion should be associated with greater RSA. Compassion and RSA both relate to: (1) tendencies towards social connection and engagement with others, (2) prosocial motivations to care for and help others, and (3) the down-regulation of negative emotions like distress, which in the case of compassion are triggered by appraisals of suffering (Batson et al., 1987; Eisenberg et al., 1989). Alongside this appraisal-based analysis that highlights the similarity in the processes underlying compassion and vagal activity, we cite suggestive evidence from physiological studies of compassion and heart rate (e.g. Eisenberg et al., 1991) and research on a closely related emotion, sadness (e.g. Marsh, Beauchaine, & Wiliams, 2008). These findings

lend preliminary although indirect support to the hypothesis tested here, that compassion is associated with greater vagal activity than appropriate comparison conditions.

Compassion is a social emotion that encourages engagement behaviors and approach motivations aimed at enhancing the welfare of the sufferer (Goetz et al., 2010). Theoretical work posits that the myelinated portion of the vagus nerve that originates in the nucleus ambiguus facilitates social engagement (Porges, 2007). Porges's Polyvagal Theory claims that this portion of the vagus nerve emerged during the evolution of mammals, and helps facilitate mammalian affiliative social behaviors (see Porges, 2001, 2007 for analysis of the phylogenetic development of autonomic nervous systems; and Keltner, A. Kogan, P. Piff, & S Saturn, 2014, for a broader summary of prosocial physiology). Specifically, increases in the vagal activity slow the heart, and are argued to produce calm states that would encourage social engagement and bonding with others. Anatomically, the ventral vagus interacts with neural pathways critical to social communication and engagement behaviors. These pathways innervate facial muscles required for emotional expression such as the muscles involved in nodding the head (a behavior strongly associated with perceptions of social engagement with others; see Kogan et al., 2011, 2014), those that orient the head and gaze toward others, the laryngeal and pharyngeal muscles responsible for talking and vocalizing, and the part of the middle ear that extracts the human voice from other sounds in the environment (Porges, 2001).

In support of this claim, resting RSA is positively associated with social engagement and connection with others. Resting RSA positively predicts the frequency of social support seeking, perceptions of social acceptance, and reports of social integration (Geisler, Kubiak, Siewart, & Weber, 2013). Individuals with higher resting RSA at the beginning of a nine-week longitudinal study reported greater social connectedness to others; in this same study, increases in reports of

social connectedness over the course of the study correlated with increases in resting RSA, controlling for RSA at the beginning of the study (Kok & Fredrickson, 2010). Vagal flexibility, defined as higher resting vagal tone and greater vagal withdrawal during a challenging tasks, showed greater empathic accuracy and social sensitivity (Muhtadie, Koslov, Akinola, & Mendes, 2014). Alongside these findings, research with clinical samples demonstrates that individuals diagnosed with autism, characterized by deficits in social communication and engagement with others, show lower baseline RSA compared to healthy controls (Ming, Julu, Brimacombe, Connor, & Daniels, 2005; Porges, 2007). These findings would suggest that greater vagal activity would accompany compassion, an emotion that functions to increase social engagement behaviors.

Empirical studies demonstrate that resting RSA is associated with greater prosocial traits and behaviors, a core component of compassion (e.g. Fabes, Eisenberg & Eisenbud, 1993; Oveis et al., 2009). Resting RSA is positively correlated with dispositional levels of sympathy (Fabes et al., 1993) and self-report measures of the trait agreeableness, a facet of personality associated with a tendency toward compassion and cooperation (Oveis et al., 2009). Individual differences in vagal activity are associated with prosocial traits and observer perceptions of prosociality, though in these studies moderate rather than very high levels of resting vagal activity predict the greatest prosociality (Kogan et al., 2014). In addition, boys in kindergarten through sixth grade with higher RSA were perceived to be more prosocial, as evident in peer ratings (Eisenberg et al., 1996) and teacher ratings (Eisenberg et al., 1995). In specific contexts, higher resting RSA predicts increased prosocial responses. Baseline RSA was associated with children's self-reports of sympathy in response to a film about another child in distress (Fabes et al., 1993). In discussions between mothers and adolescents, adolescents with high resting RSA showed greater

empathy, measured through accuracy in judging their mothers' emotions and shared emotion (Diamond, Fagundes, & Butterworth, 2012). Although these studies measured resting RSA, they provide indirect evidence for claims that participants would experience greater RSA during a key prosocial emotion, compassion.

Compassion also involves appraisals of another's suffering and distress. Compassion may require individuals to down-regulate their own negative emotions and distress, which hinder the experience of compassion (Batson et al., 1987; Eisenberg et al., 1989). Temporary increases in vagal activity have been associated with a calming of the body and regulating of negative affect, quite similar to that theorized to be involved in compassion (e.g. Rockliff, Gilbert, McEwan, Lightman & Glover, 2008). For example, participants instructed to suppress or reappraise their emotional responses while describing a disgusting clip to another participant showed larger increases in RSA compared to those who regulated their responses to a neutral film clip or individuals instructed not to regulate their emotions (Butler, Wilhelm & Gross, 2006). In the still face paradigm, mothers instructed to down regulate their emotional expression while their infants expressed distress showed an increase in RSA compared to a baseline where infants played with a toy (Oppenheimer, Measelle, Laurent, & Ablow, 2013). And finally, participants show greater RSA when doing calming meditation practices compared to a control condition (Ditto, Eclache, & Goldman, 2006; Krygier et al., 2013). Taken together, these results suggest that increases in RSA may be tied to the process of self-soothing or down regulation of negative affect that allows individuals to respond to others' suffering with compassion and approach-related behaviors.

In addition to our conceptual analysis, additional evidence germane to our prediction is found in patterns of heart rate deceleration, which occur during compassion (Eisenberg et al., 1989; Stellar et al., 2012). The vagus nerve functions to inhibit the sino-atrial node of the heart,

so increases in vagal activity often result in measurable decreases in heart rate (Berntson et al. 1993). Eisenberg and colleagues (1991) have documented that subjective reports and expressive displays of compassion covary with heart rate deceleration. Participants induced to feel compassion show decreases in heart rate compared to neutral state inductions, and the magnitude of the physiological response distinguishes between those who reported more or less compassion (Stellar et al., 2012). It is important to note that this evidence must be interpreted carefully because heart rate is affected by both the parasympathetic and sympathetic systems, highlighting the importance of measuring RSA, the focus of the present four studies.

Finally, studies of sadness, an emotion closely related to compassion, further suggest a link between RSA and compassion. In contexts where another person is suffering, we find sadness is correlated highly with compassion ($r = .69$ on average in the four studies presented below). In these cases, sadness is likely part of a larger family of compassion-related emotions that represent concern at the plight of others (e.g., see Goetz et al., 2010). Unlike other negative emotions, which are associated with reduced RSA, sadness shows the opposite pattern of RSA activity (e.g. Marsh et al., 2008). In studies of sadness in which participants watched video clips of vulnerable individuals suffering, participants exhibited greater parasympathetic activity and heart rate deceleration, markedly so during crying (Hendriks, Rottenberg, & Vingerhoets, 2007; Marsh et al., 2008; Rash & Prkachin, 2013; Rottenberg, Wilhelm, Gross, & Gotlib, 2003; Tsai, Levenson & Carstensen, 2000). It is important to note, though, that some researchers have documented reduced RSA during sadness (Rottenberg, Salomon, Gross & Gotlib, 2005) or found no RSA related shifts during the experience of this emotion (Rainville, Bechara, Naqvi, & Damasio, 2006). In many of these studies the stimuli depict others suffering and, in effect, are about other oriented sadness, raising the possibility that compassion may have triggered the

observed changes in vagal activity. Taken together, this theoretical and empirical work lends credence to the hypothesis that the experience of compassion in response to suffering will be associated with greater parasympathetic activity compared to other states.

Present research

In the present research we seek to document whether compassion in response to suffering is associated with greater parasympathetic activity, via the vagus nerve. Our work is guided by conceptualizations of emotions as brief, distinct responses that are centered on core appraisals (Ekman, 1992; Keltner, et al., 2013). We thus ensure that our measurement of vagal activity is tied to the momentary experience of compassion. We measure vagal activity during the presentation of emotion-eliciting stimuli rather than during a baseline or affectively laden task that is not designed to elicit a specific emotion (e.g. public speaking task). We also present our stimuli for short periods, from two to four minutes on average, to capture the rapid onset and brief duration of the typical emotional experience.

In this sort of work, it is critical to compare the emotion of interest to conceptually relevant states (Horberg, Oveis, & Keltner, 2011; Keltner & Lerner, 2010; Oveis, Horberg, & Keltner, 2010). This kind of stringent comparison allows for stronger inferences about distinct response profiles of discrete emotions. To ascertain the degree to which compassion is uniquely associated with greater vagal activity, we compare vagal activity during compassion to vagal activity during another positive emotion and a prosocial state lacking in the motivation to care and ameliorate the suffering of others. This pits our hypothesis against two alternatives: that vagal activity is greater during positively valenced states or during prosocial emotions more generally.

In Study 1 we compared RSA during a compassion induction, in which targets discussed the death of their grandfather, to a non-emotional baseline. We aimed, in Study 2, to eliminate the alternative explanation that RSA would be greater during positive emotions more generally by comparing levels of RSA for compassion and pride. In Study 3 we ascertained whether compassion would elicit greater RSA than another prosocial emotion, inspiration. Across the first three studies we assessed the relationship between retrospective self-reports of compassion and differences in RSA between the compassion and comparison inductions. In Study 4, we examined whether changes in RSA from a neutral to compassion induction were associated with an established composite of compassion-related emotions (Batson et al., 1997) reported by participants after the compassion induction as well as continuous self-report measures of compassion and coders' perceptions of participants' verbal and nonverbal expressions of compassion during the compassion induction. Given the literature linking resting RSA with compassion, we also examined whether RSA during our neutral state inductions predicted self-reports of compassion or differences in RSA between emotion conditions or whether RSA during the neutral inductions interacted with differences in RSA between conditions to predict self-reported compassion.

Study 1

Study 1 primarily aimed to demonstrate that: (1) inducing compassion by showing others who are suffering elicits greater RSA than a non-emotional control; and (2) differences in RSA between the compassion and neutral state inductions predict self-reports of compassion. We also explored whether RSA during the non-emotional control predicted any of our measures. We measured and controlled for individual differences in social desirability because self-reports of

compassion are likely to be influenced by self-presentation concerns that could obscure the relationship between the experience of compassion and RSA.

Methods

Participants

Fifty-one (20 male, 31 female) undergraduates from a large west coast university participated in this study for credit in a psychology course.

Procedure

Participants arrived in the lab one at a time, were brought into an experiment room, and physiological sensors were applied. Participants were given fifteen minutes to fill out demographics and a measure of social desirability. This time also allowed participants to acclimate to wearing the physiological recording devices.

For our compassion induction participants watched a four-minute long video of a female student discussing the death of her grandfather. Participants were told the target in the video was a participant from a previous study, but in reality she was a confederate who had memorized a script created by the experimenter. The discussion focused on her grief and how she coped with the news of learning of her grandfather's death. In addition to compassion, participants were asked after viewing the video to report on how much they felt 14 other emotions during the compassion video (afraid/scared, angry, annoyed/irritated, anxious, contempt/disdain, enthusiastic/excited, disgusted/revolted, happy/joyful, inspired/impressed, relaxed/comfortable, sad, surprised/shocked, trust, warmth/tenderness) on a 10-point Likert scale from 1 (*not at all*) to 10 (*as much as I have ever felt*). After 10 minutes of filler tasks for another study, participants then watched another four-minute long video of that student recounting a nature documentary,

which was also created by the experimenter and acted as the neutral, non-emotional comparison condition.

Physiological Measures.

Heart Rate. Electrocardiogram (ECG) recordings were sampled at 1 kHz and were gathered over the entire four minutes of each emotion induction. Sensors were applied to the skin in a Lead II configuration to gather Electrocardiogram (ECG) signals. Physiological signals were collected using the MP 150 data acquisition and analysis systems (Biopac systems, Inc.). ECG signals were converted to beats per minute to obtain heart rate and aggregated to form mean heart rate scores for the entire four minutes and the initial minute and a half of the stimuli introduction. Artifacts in the signal (e.g. due to coughing, sneezing or movement) were corrected manually; this was done to less than 5% of all data files.

Respiration. A respiration belt was place on the torso to assess respiration frequency. Respiration signals were filtered directly as they were recorded with a low pass filter of 1 Hz and high pass filter of .05 Hz. A continuous measure of respiration rate was then obtained by transforming the data through the Biopac data acquisition program to breaths per minute. Respiration rate was then aggregated to form mean values over the four minutes and initial minute and a half of each video.

RSA. RSA was calculated using Biopac's AcqKnowledge 4.0, which uses the peak-to-trough method (Grossman, van Beek, & Wientjes, 1990) to calculate RSA. This method scans the interbeat interval (IBI) channel for the minimum and maximum RR intervals during each respiration cycle. The average data was aggregated to form a mean over the four minutes and the initial minute and a half of the stimulus presentation.

Individual Difference Measures

Social Desirability. The Marlow and Crowne Social Desirability Scale (Crowne & Marlow, 1960) is a 33-item scale where participants respond either true or false, to statements such as, *I have never deliberately said something that hurt someone's feelings* or *there have been times when I was quite jealous of the good fortune of others*. The scale assesses how willing participants are to answer these questions truthfully or whether they will lie in an effort to manage their self-presentation. As a result, participants are given a total score of how susceptible they were to social desirability concerns.

Results and Discussion

To ensure that our compassion stimuli reliably elicited our target emotion, we analyzed subjective reports of participants' emotions. Participants exhibited high levels of compassion in response to the student coping with the death of her grandfather ($M = 7.20$, $SD = 1.61$). Participants reported significantly more compassion than the next two most highly elicited emotions, which were sadness, ($M = 6.29$, $SD = 2.34$), $t(50) = 3.93$, $p < .001$, and warmth/tenderness, ($M = 5.37$, $SD = 2.38$), $t(50) = 7.29$, $p < .001$, which were the only two emotions with average self-reports greater than the midpoint of the scale.

Physiological Reactions. We used a linear mixed model approach, which treated the type of video (neutral or compassion-inducing) as a within-subjects factor. This statistical analysis allowed us to calculate differences in physiological activity within the same person over multiple emotion inductions while controlling for dependencies in the same person's data across time. Linear mixed models also permitted for the inclusion of respiration as a changing covariate, which was important, as respiratory rate was different for each emotion induction. RSA was significantly higher during the compassion condition ($M = 79.06$ ms, $SD = 25.59$) compared to the neutral condition ($M = 69.40$ ms, $SD = 34.30$), $F(1,50) = 7.12$, $p = .01$; $d = .39$. Emotions are

rapid in onset and brief in duration (Ekman, 1992; see figure 1). Therefore, we also examined the

first minute and a half of RSA (the shortest acceptable duration to analyze RSA; Berntson et al.,

1993) because we anticipated participant's reactions to the compassion induction would be the

strongest upon initially encountering the target's suffering. We found our effects were amplified

when we examined this initial 1.5 minutes. RSA was significantly higher in the compassion

condition (M =82.34 ms, SD = 34.02), than the neutral condition (M =70.16 ms, SD = 26.24),

$F(1, 50) = 12.43$, $p = .001$; $d = .51$.[2] Compassion inducing stimuli elicited greater RSA than a

non-emotional condition, and these effects were more pronounced in the initial stages of the

stimulus presentation.

When measuring RSA, the question of whether respiration rate should be statistically

controlled is debated. Some researchers argue that respiration rate, or changes in respiration rate,

have a negligible impact when measuring RSA (Denver, Reed & Porges, 2007). Others note that

decreases in respiration rate increase RSA, but do not change vagal activity. This claim calls

into question the validity of RSA as an index of vagal activity, and suggests that respiration rate

should be included in all analyses as a covariate (Grossman & Taylor, 2007). Respiration rate

was lower over the entire four minutes of the compassion video (M =18.33, SD = 4.70) compared

to the neutral condition (M =19.33, SD = 4.43), $F(1, 50) = 7.79$, $p = .007$; $d = .40$. We conducted

a mixed model with type of video as a within-subjects factor and respiration rate as a changing

covariate and still found that RSA was significantly higher in the compassion condition

compared to the neutral condition over the entire four minutes, $F(1, 53) = 4.61$, $p = .04$. Within

the first minute and a half of the video there were no significant differences in respiration rate

between the neutral (M =19.23, SD = 3.78) and compassion condition (M =18.18, SD = 4.87),

$F(1, 50) = 2.67$, $p = .11$. Nevertheless, when we treated respiration rate as a covariate we still

observed that RSA was significantly higher in the compassion condition compared to the neutral condition, $F(1, 51) = 9.61$, $p = .003$. Surprisingly, we did not find significant differences in heart rate, which often accompanies compassionate responses, during the compassion condition ($M = 79.11$, $SD = 8.54$) compared to the neutral condition ($M = 78.37$, $SD = 8.31$), $F(1, 50) = 2.80$, $p = .10$. Overall, we found a pattern of greater RSA during the compassion induction compared to a non-emotional control. As we predicted, these effects were more pronounced in the first minute and a half of the video where individuals first encountered the suffering.

We examined whether differences in RSA between the two conditions would predict self-reports of the experience of compassion. We controlled for RSA during the neutral clip to isolate the unique effect of greater RSA in the compassion condition compared to neutral condition on reported compassion, independent of RSA during the neutral clip. Contrary to expectation, differences in RSA between the two conditions (over the entire 4 minutes and the first 1.5 minutes), controlling for respiration rate and RSA during the neutral video, did not predict self-reports of compassion, $\beta's \leq -.11$, $p's \geq .44$. Including social desirability as a covariate did not strengthen these correlations, $\beta's < -.10$, $p's \geq .50$.[3]

Given that past research has found a relationship between resting RSA and compassion, we also tested whether RSA during the neutral video, our closest approximation to resting RSA, predicted self-reported compassion. We found that it did not predict self-reports of compassion, $\beta = -.12$, $p = .44$, nor did it predict differences in RSA from the neutral to the compassion condition, $\beta = -.02$, $p = .88$. RSA during the neutral clip did not interact with our difference score of RSA to predict self-reports of compassion, $\beta = .14$, $p = .30$. Therefore, resting RSA did not predict emotional reports or physiological responses to the compassion clip or interact with differences in RSA to predict emotional responses.

Study 2

Study 1 provided support that compassion in response to suffering elicits greater vagal activity. Study 2 aimed to demonstrate this result is specific to compassion and not positively valenced emotions, more generally. Past work has demonstrated that greater resting RSA is associated with greater positive mood and dispositional optimism (Oveis et al., 2009). Some studies find reductions in RSA in response to positive film clips (e.g. Frazier, Strauss, & Steinhauer, 2004), although others find slight increases or no changes at all (e.g. Demaree, Pu, Robinson, Schmeichel, & Everhart, 2006). In light of these findings, and the aim of this investigation, we chose to compare the influences upon RSA of compassion and pride (for similar rationale, see Oveis et al., 2010). Compassion and pride vary on an important appraisal domain of self- versus other-focus that we believe may be important for vagal activity. Compassion is elicited by suffering, characterized by appraisals of need, vulnerability, and weakness, and promotes motivations to approach, care for, and soothe others. Pride, on the other hand, is a self-focused emotion that centers on appraisals of one's own strength and exceptionalism (Tracy & Robins, 2007). It is elicited when individuals feel responsible for a positive outcome and is characterized by appraisals of personal achievement and feelings of dissimilarity from vulnerable others, promoting a desire to distance oneself from weak others (Oveis et al., 2010). We anticipated that the self-focused and disengaged nature of pride would make this emotion less likely to be associated with higher RSA than a neutral or compassion condition, despite its positive valence. In addition, we used slides to elicit our target emotions to ensure our effects would generalize to other forms of emotionally-evocative stimuli. In Study 2 we also randomized the order of the film clip presentation to account for potential order effects that may have affected the results of Study 1 where the order was not counterbalanced. We

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hypothesized that the experience of compassion would elicit greater RSA than pride or a neutral comparison condition.

Methods

Participants

Eighty-one (19 male, 61 female, 1 decline to state) undergraduates participated in this study for credit in a psychology course.

Procedure

Participants arrived in the lab one at a time and were brought into an experiment room where physiological sensors were applied. Participants were shown three sets of slides (Oveis et al., 2009, 2010) that elicited no emotion, compassion, and pride while they were connected to the physiological recording devices. Each set of slides was 1.5 minutes in duration and the order of presentation of the compassion and pride slides was randomized. Neutral slides showed different shapes and numbers, compassion slides included photographs of individuals who were suffering (starving children, homeless individuals, injured animals, crying babies, etc.), and pride slides included photographs of the students' university and of national symbols. After watching each set of slides participants reported on the intensity of their experience of compassion and pride along with six other emotions (anger, awe, enthusiasm/excitement, fear, sadness, and surprise) on a Likert scale of ranging from 0 (*not at all*) to 10 (*as much as I have ever felt*).

Physiological Measures.

Heart Rate. Electrocardiogram (ECG) recordings from an Ambulatory Monitoring System (VU-AMS, The Netherlands) were gathered by applying sensors to the skin in a Lead II configuration. Recordings were sampled at 1 kHz and were gathered over the 1.5 minutes of the

emotion induction. Artifacts in the signal (e.g. due to coughing, sneezing or movement) were corrected manually; this was done to less than 5% of all data files.

RSA. Vagal activity was computed by using cardiac metric software since we did not have measures of respiration frequency (CMet; Allen, 2002). This analysis is based on Porges' adaptive polynomial filter method, where a series of inter-beat intervals is filtered through a high frequency band. CMet calculates RSA by taking a series of inter-beat intervals and filtering them using a frequency band of 0.12-0.40 Hz (Allen, Chambers, & Towers, 2007). This program offers a validated analysis of RSA that correlates highly with measures from other established programs such as Mxedit, while reducing the effects of potential human error (Allen, 2002). RR intervals from the ECG channel over the 1.5 minutes of each induction were passed through a high frequency spectrum range (.12-.40 Hz) and logged to isolate the activity of the vagus nerve.

Results and Discussion

First, we aimed to establish that our neutral induction was in fact a non-emotional comparison condition. Across all eight emotions participants reported ratings of 1.28 (SD = .80) within a possible range of 0 (*not at all*) to 10 (*as much as I have ever felt*). These findings support the claim that our induction did not elicit any strong emotions.[4] Second, we aimed to establish that our emotion manipulations elicited the target emotions of interest. Participants reported significantly higher levels of compassion towards the compassion eliciting slides (*M* = 6.31, *SD* = 1.83) than the pride slides (*M* = 2.09, *SD* = 2.13), $t(76)= 13.04$, $p < .001$. In addition, the pride slides evoked significantly more pride (*M* = 5.38, *SD* = 2.52) than the compassion slides (*M* = 0.55, *SD* = 1.09), $t(76)= 11.19$, $p < .001$. Compassion was also the highest rated emotion in response to the slides depicting suffering and the only emotion, other than sadness (*M* =6.08, *SD* = 1.74), that was elicited at higher levels than the midpoint of the scale.

Physiological Reactions. For three participants, physiological responses were not recorded properly, and were excluded from analysis. In a linear mixed models analysis of our main variable of interest, participants showed greater RSA activity while watching the compassion-inducing slides ($M = 6.22$, $SD = 1.05$) compared to the pride inducing slides ($M = 6.05$, $SD = 1.02$), $F(1, 78) = 4.52$, $p = .04$; $d = .39$ (see Figure 1) and the neutral slides ($M = 6.03$, $SD = 1.08$), $F(1, 78) = 5.29$, $p = .02$; $d = .28$. In addition, participants showed lower heart rate while watching the compassion-inducing slides ($M = 77.72$, $SD = 10.96$) compared to the pride-inducing slides ($M = 80.99$, $SD = 11.60$), $F(1, 78) = 33.70$, $p < .001$; $d = .65$, and the neutral slides ($M = 80.07$, $SD = 11.07$), $F(1, 78) = 33.34$, $p < .001$; $d = .67$.

Differences in RSA during the compassion slides, controlling for RSA during the neutral slides, did not predict self-reported compassion, $\beta = -.12$, $p = 35$. In this study, RSA during the neutral video was a significant predictor of self-reports of compassion, $\beta = -.23$, $p = .05$, and differences in RSA from the neutral to the compassion condition, $\beta = -.38$, $p = .001$, but did not interact with differences in RSA to predict self-reports of compassion, $\beta = -.04$, $p = .97$. These results suggest that more trait-like RSA activity during the neutral induction can predict emotion reports and physiological responses to the compassion clip, in keeping with previous studies (e.g., Oveis et al., 2009). Overall, we find that the experience of compassion elicits greater RSA and lower heart rate compared to the experience of pride.

Study 3

In Study 3 we compared RSA during compassion to another prosocial emotion that lacks appraisals of suffering, inspiration. Inspiration, along with compassion, is part of a family of prosocial emotions that promote social engagement (Algoe & Haidt, 2009). Inspiration is typically elicited by artistic and scientific insight, finding a purpose in life, and being around role

models, and generates feelings of transcendence and the urge for self-improvement (Algoe & Haidt, 2009; Thrash & Elliot, 2003). Given that resting levels RSA predict prosocial states it is possible that RSA may be a marker of prosocial emotions more broadly (Oveis et al., 2009; Porges, 2001). No study to date has sought to distinguish which prosocial states RSA is associated with; a comparison of compassion and inspiration represents a theoretically grounded, first step in addressing this conceptual concern. We hypothesized that suffering and the motivation to down-regulate negative emotions and care for the sufferer may be critical to eliciting higher RSA during compassion. Compassion, unlike inspiration, is elicited by the suffering of others, which is theorized to entail the down regulation of distress and negative emotion in order to orient and respond to others' needs (Batson et al., 1987). Down regulation of negative emotions and the soothing affective system appear to be central to increased RSA (e.g. Butler et al., 2006; Van Kleef et al., 2008). Inspiration is not typically elicited by suffering or weak others, but by individuals that demonstrate exceptionalism (Algoe & Haidt, 2009; Thrash & Elliot, 2003). Therefore, it does not typically require any down-regulation of distress, nor is it oriented towards caring for those in need, both reasons to hypothesize that inspiration may not be associated with greater RSA compared to a compassion or neutral condition. An additional reason to compare compassion to inspiration is that the latter state is often reported during compassion, and both emotions are associated with warmth and tenderness, and trigger approach motivations (Algoe & Haidt, 2009). As a result, comparing compassion to inspiration allows us to further isolate the relationship between compassion and RSA.

We also collected an additional physiological measure, skin conductance level (SCL). SCL has been shown to index general emotional arousal (Cuthbert, Bradley, & Lang, 1996), stress (Dawson, Schell, & Filion, 2000), and perceptions of threat (Mathews, Richards, &

Eysenck, 1989). SCL is a purely sympathetic measure and will allow us to monitor sympathetic

arousal during our compassion inductions, enabling us to solidify our claim that compassion is

associated with greater parasympathetic activity compared to a neutral state and identify whether

our compassion inductions are evoking stress, threat, or other forms of negative emotional

arousal. We predicted RSA would be higher during the compassion-inducing film clip than the

neutral clip or inspiration film clips, but that SCL would show no differences across conditions.

Methods

Participants

Seventy-four (33 male, 41 female) undergraduates participated in this study for credit in a

psychology course.

Procedure

Participants arrived in the lab individually, were seated in front of a computer, and

physiological sensors were applied. Participants filled out demographics information on the

computer and then watched three two-minute long videos, which were meant to elicit

compassion, inspiration, or provide a non-emotional control. These videos were presented in

random order and were separated by approximately 2-3 minutes of filler or distraction tasks

where participants had to write as many words as possible that started with a particular letter, in

addition to answering questions. As part of the compassion induction, participants were shown a

video of children and their families who attend St. Jude's hospital where their children were

receiving treatment for cancer. This video primarily covered footage of the parents discussing

when they learned their child had cancer, the chemotherapy sessions that the children attended,

and the outcomes of the cancer treatment. This compassion induction has been validated to

successfully elicit compassion (Stellar et al., 2012). In the inspiration video, participants were

shown a man carrying a sign saying free hugs and giving hugs to strangers on the street set to inspirational music. The neutral condition consisted of an instructional video on how to build a fence. In addition to compassion, participants were asked to list how much they experienced the same emotions as Study 1 from 1 (*not at all*) to 10 (*as much as I have ever felt*) after each video.

Physiological Measures.

Electrocardiogram (ECG) sensors were applied in a Lead II configuration, a respiration belt was placed on the participant's torso to measure the rate of inhalation and exhalation, and SCL was measured by passing a constant voltage (0.5 V) between disposable snap electrodes that were pre-gelled with isotonic gel and placed on the palmar surface approximately an inch apart. ECG and respiration data were gathered and cleaned for artifacts using the same methods as Study 1, and heart rate, respiration rate, and RSA were then calculated. Physiological measures were gathered over the entire length of the emotion induction. In addition, continuous measures of unfiltered SCL signals were averaged over the entire two minutes of each video.

Results and Discussion

There were significant differences in self-reports of compassion in response to the different conditions, $F(2,142) = 225.10$, $p < .001$, such that participants reported greater compassion during the compassion condition compared to the neutral condition $F(1,71) = 469.22$, $p < .001$, and the inspiration condition, $F(1, 72) = 65.11$, $p < .001$. However, other prosocial emotions such as warmth/tenderness, inspiration, and trust were more strongly elicited in the inspiration condition (see table 1 for emotion comparisons).

Physiological Reactions. Physiology data from one participant's session did not record properly, three participants had too many artifacts in their HR during the neutral condition to clean, and two participants had too many artifacts in their HR during the inspiration condition to

clean and therefore we do not have RSA values for these participants during these video

presentations. In this study RSA was not normally distributed. Therefore we performed a log

transformation when measuring it as dependent variable. Participants showed greater RSA in the

compassion condition compared to the neutral, $F(1,71) = 6.63$, $p = .01$; $d = .39$, and inspiration

conditions, $F(1,70) = 23.67$, $p < .001$; $d = .67$ (see Figure 2).[5] Participants also showed reduced

respiration rate during the compassion condition ($M = 18.21$, $SD = 3.45$) compared to the neutral

($M = 19.06$, $SD = 5.03$), $F(1,71) = 12.02$, $p = .001$; $d = .42$, and inspiration conditions ($M = 19.24$,

$SD = 3.46$), $F(1,72) = 20.68$, $p < .001$; $d = .52$. We found that RSA was still greater in the

compassion condition compared to the inspiration condition when entering respiration rate into

the model as a changing covariate, $F(1,71) = 12.02$, $p = .001$, but was no longer significantly

greater than the neutral condition, $F(1,74) = 2.23$, $p = .14$. Heart rate was also significantly lower

in the compassion condition ($M = 73.42$, $SD = 9.41$) compared to the neutral ($M = 75.71$, $SD = 9.85$), $F(1,71) = 41.57$, $p < .001$; $d = .81$, and inspiration conditions ($M = 74.83$, $SD = 9.43$),

$F(1,70) = 21.13$, $p < .001$; $d = .72$. There were no significant differences in SCL between the

compassion and the neutral, $F(1,70) = 0.06$, $p = .80$, or inspiration conditions, $F(1,70) = 0.06$, $p = .81$.

Greater RSA during the compassion video compared to the neutral video, controlling for

RSA during the neutral video, did not predict participants' self reports of compassion $\beta = .03$, $p = .83$. RSA during the neutral video did not predict self-reports of compassion, $\beta = .13$, $p = .31$,

differences in RSA between the compassion and neutral conditions, $\beta = -.07$, $p = .56$, nor did it

interact with differences scores of RSA to predict self-reports of compassion, $\beta = 0.06$, $p = .71$.

Participants showed greater RSA, lower respiration rate, and lower HR in the compassion

condition compared to the neutral or inspiration condition, but no differences in SCL. These

findings replicate the results from Study 1 and 2 suggesting that RSA is greater during the experience of compassion compared to two different positive emotions, pride and inspiration. Across the first three studies we used a variety of different stimuli, including videos of other students, slides, and films, which suggest that our results are not bound by the nature of the stimulus, but more tightly tied to compassion.

Study 4

Three studies have demonstrated that compassion-inducing stimuli are associated with greater RSA, whereas pride-inducing and inspiration evoking stimuli are not. However, the previous studies did not yield a robust relationship between RSA and participant's self-reports of compassion. This lack of covariation between peripheral physiology and subjective experience is commonly observed in research of this kind, in particular when reports of emotion are retrospective and removed from the emotion-eliciting stimulus, as in our first three studies (Bonanno & Keltner, 2004; see Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005 for a review). Evidence related to the linkage between the experience of compassion and increased RSA is important to our general argument, and motivated Study 4.

In Study 4, therefore, we turned to new methods to examine the compassion-RSA association. First, we broadened the items participants used to report on their emotional experience to include emotion words that have been previously associated with empathic concern, a state closely resembling compassion (Batson et al., 1997). Our previous studies had relied on single item reports of emotions, which may not capture the full subjective experience. Second, we introduced more "on line" approaches to assessing subjective emotion adapted from previous studies of emotions and physiological responses (Levenson & Gottman, 1983). Retrospective reports of emotion may not capture the more spontaneous experience of emotion,

because they suffer from biases such as duration neglect, and are often derived from averaging the peak and end emotional intensity of the experience (Fredrickson & Kahneman, 1993; Levine & Safer, 2002). These biases may be particularly problematic when attempting to establish a relationship with contemporaneous physiological responses. We relied on a technique pioneered by Levenson and Gottman (1983) wherein participants re-watch an emotional stimulus a second time while continuously rating with a rating dial the emotions they experienced in the original encounter with the stimulus. Third, we coded participants' expressive behavior, to ascertain whether RSA might covary with compassion-related responses, measured through nonverbal displays and verbal cues (Eisenberg et al., 1989; Kogan et al., 2014). By expanding the self-report items, relying on continuous measures of subjective emotion, and capturing expressions of compassion, we are in a much better position of documenting compassion-RSA associations than in our first three studies, which relied in single-item, retrospective self-reports.

Participants

Ninety-four participants (26 male, 68 female) undergraduates participated in this study for credit in a psychology course.

Procedure

Participants arrived in the lab individually and were seated at a computer station in front of a mounted video camera. They were connected to the MP 150 data acquisition and analysis systems (Biopac systems, Inc.) through sensors applied to their skin in the same configuration as Study 3.

After providing information about demographics, participants first watched a neutral film clip followed immediately by a compassion-inducing clip. These clips were the same as those used in Study 3. After the compassion-inducing video participants reported how much they felt

the target emotion of compassion in addition to three other compassion-related states, including *moved, warmth/tenderness*, and *softhearted* from 1 (*not at all*) to 10 (*as much as I have ever felt*). These four emotions showed high reliability ($\alpha = .87$). They were embedded within ten other emotions including *afraid, annoyed, angry, anxious, awe, contempt, disgust, inspired, sad*, and *wonder*. The experimenter then asked participants to summarize the video clip and discuss their reaction to it out loud, while the experimenter waited outside. Participants were given as much time as they wished to provide this summary.

The experimenter told participants they would be watching the same compassion-inducing video a second time, but that they would continuously report how much compassion they felt during their original viewing of the clip using a hand held sliding scale. Participants were asked to re-watch the video while making ratings of their compassion. We did not ask participants to make these rating the first time they watched the video because the movements entailed in making such ratings can introduce artifacts into physiological signals, and can interfere with participants' spontaneous responses to the emotional stimulus in the first viewing (Levenson & Gottman, 1983). Participants used a sliding scale device (TSD115 Variable Assessment Transducer by Biopac Systems), which provides continuous subjective responses to stimuli. The labels on the device were modified to range from 1 (*I do not feel compassion at all*) to 10 (*I feel compassion very strongly*). Once participants reported they were comfortable using the scale without looking at it they placed it in their lap and watched the video, moving the scale in accordance with their levels of compassion. Upon finishing the task they called the experimenter back into the room and they were debriefed and released.

Physiological Measures

Heart rate, respiration rate, SCL, and RSA were gathered in the same manner as Study 3. Continuous recordings of these measures were averaged over the entire length of the neutral and compassion film clips. Five participants produced physiology files with too many errors to use and were removed from all analyses leaving a total sample of 89 participants.

Verbal and Nonverbal expressions of Compassion

Two independent coders, blind to the RSA levels of the participants, watched videos of the participants watching the compassion clip and discussing their reactions to the clip. The camera was oriented so that the videos of participants displayed their torso and head. Raters were instructed to answer two questions, *How much do you think this person felt compassion/sympathy?* and *How much do you think this person felt anxiety/distress?*, on 4-point Likert scales, *0* (*not at all*), *1* (*a little*), *2* (*moderately*), or *3* (*very strongly*; for a similar coding system see Oveis et al., 2009).

Coders were trained to look for facial and body expressions associated with compassion, including: furrowing in the center of the brow, eyebrows pulled down flat and forward, lower face relaxed with the mouth sometimes opened or frowning, head and body oriented forward and vocalizations typically associated with sympathy (Eisenberg et al., 1989; Goetz et al., 2010). Coders were instructed to provide ratings of participants' distress based on a different set of behaviors: the tightening of one's lips or biting of the lip and eyebrows that were lowered and pulled forward. In addition, coders were allowed to use verbal cues of compassion when making their ratings. Coders demonstrated acceptable reliability in their perception of participant's compassion (α's $\geq$ .81) and distress (α's $\geq$ .66) while participants watch the video and discussed it.

Results and Discussion

As in Study 3, participants reported high levels of compassion in response to the compassion-inducing film clip ($M =7.37$, $SD = 1.59$). The compassion composite ($M = 6.66$, $SD = 1.78$) made up of warmth/tenderness ($M = 6.26$, $SD = 2.13$), moved ($M = 6.66$, $SD = 2.27$), and softhearted ($M = 6.38$, $SD = 2.35$) also received high ratings among participants.

Physiological Reactions. One participant was removed from the analyses of RSA because he/she had an RSA value during the compassion clip that was more than three standard deviations from the mean, and two participants were removed from the heart rate analyses for this reason. RSA measures were not normally distributed, so we performed a log transformation to improve the normality of the distribution when measuring RSA as a dependent variable. A linear mixed models analysis revealed significantly higher RSA in response to the compassion video ($M =94.41$, $SD = 48.18$) compared to the neutral video ($M =87.83$, $SD =43.47$), $F(1, 88) = 6.91$, $p = .010$; $d = .27$.[5] There were significant differences in respiration rate between conditions, $F(1,87) = 4.80$, $p =.03$; $d = .23$, with lower respiration rate in response to the compassion video ($M =16.51$, $SD = 3.51$) compared to the neutral video ($M =16.99$, $SD = 3.45$). Differences in RSA remained significant when controlling for respiration rate, $F(1, 81) = 6.19$, $p =.02$. There were also differences in heart rate across the conditions, $F(1, 86) = 12.61$, $p = .001$; $d = .37$. In the compassion condition ($M =74.68$, $SD = 12.00$) participants showed significantly slower heart rate compared to the neutral condition ($M =75.80$, $SD =12.45$). There were no significant changes in SCL between the neutral ($M =9.64$, $SD =5.93$) and compassion conditions ($M =9.94$, $SD = 6.05$), $F(1, 88) = 1.55$, $p =.22$. Overall, results suggest the compassion video was associated with increased RSA and reduced HR and respiration rate, but not changes in SCL.

In the following analyses we examine how RSA during the compassion clip predicts our self-report and behavioral measures. In these analyses, we controlled for RSA during the neutral

condition and changes in respiration rate.[6] Increases in RSA during the compassion-inducing clip

did not predict self-reports of the single item, retrospective report of compassion gathered after

the viewing of the video, in keeping with findings from our initial studies, β =.12, p = .29. RSA

during the neutral video was a predictor of self-reports of compassion, β=.32, p = .004, although

it did not predict changes in RSA, β= -.07, p = .52, nor did it interact with changes in RSA to

predict self-reported compassion, β = .02, p = .87. Notably, increases in RSA did predict our

compassion composite of emotions, β =.22, p =.05 (see table 2 for all measures of emotion).

During the continuous rating task, five participants did not follow the instructions

therefore did not generate useable data. Data from participants' continuous rating of compassion

during the compassion video were aggregated over the entire film clip to create a mean

continuous compassion rating (M =6.37, SD = 1.56). There was a sizeable and significant

correlation between this continuous measure of compassion and the retrospective reports of at

the end of the clip, r =.53, p < .001. Increases in RSA during the viewing of the compassion

video predicted mean continuous compassion rating when re-watching the compassion video, β

=.26, p = .03. These results suggest that increases in RSA predict reports of compassion

composites and more continuous measures of compassions.

Coded displays of compassion were calculated by averaging coders' ratings of

participants' compassion during the video and while discussing it. Increases in RSA during the

compassion video predicted coders' ratings of the participant's outward displays of compassion,

β =.24, p =.04. As expected, increases in RSA did not significantly predict coders' perceptions of

the participants' distress, β =-.13, p =.26 (see Table 2).

Taken together, the results find that increases in RSA during the compassion clip were

significantly associated with three measures of compassion: compassion using a validated

composite of compassion-related words, continuous online ratings of compassion, and observed behavioral expressions of compassion.

General Discussion

The present investigation demonstrates that compassion, when encountering the suffering of others, leads to markedly greater vagal activity compared to neutral or other emotional states. Across four studies we find that compassion-inducing stimuli, but not those that induce pride (Study 2) or inspiration (Study 3), were reliably associated with greater RSA. Greater RSA in response to suffering was also accompanied by lower HR and respiration rate in the majority of our studies, but was not associated with differences in SCL. Greater RSA in the compassion compared to the neutral condition and RSA during the neutral condition both failed to consistently predict single-item self-reports of compassion across our four studies. However, in Study 4 increases in RSA while encountering suffering predicted a self-report composite of compassion-focused emotions, continuous ratings of compassion during the stimulus presentation, and increased nonverbal and verbal expressions of compassion but not distress, as rated by naïve observers.

These findings add to a growing line of work supporting the claim that compassion is a distinct emotion (Gilbert, 2013; Goetz et al., 2010; Oveis et al., 2010). Compassion evolved to promote caretaking and reciprocal altruism, which are critical to human survival, suggesting this emotion should be a universally experienced (Goetz et al., 2010; Trivers, 1971). Instances of compassion have even been identified in chimpanzees, a closely related species that also has elaborate caretaking systems (de Waal, 1996). Compassion has its own unique expression through touch (Hertenstein, Keltner, App, Bulleit, & Jaskolka, 2006) and vocalization (Simon-Thomas, Keltner, Sauter, Sinicropi-Yao, & Abramson, 2009), which distinguish it from closely

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related emotions, such as love, sadness, and gratitude. In addition, past work has identified regions of the brain, specifically the Periaqueductal Grey (PAG), that are uniquely associated with the experience of compassion (Simon-Thomas et al., 2012). The present investigation's findings build upon these recent discoveries, offering the first evidence pointing to neurophysiological correlates of compassion in the autonomic nervous system.

The degree to which specific emotions are associated with unique physiological responses has been a source of debate since William James made the case for this possibility in the late nineteenth century, and is germane to the evidence from the present investigation (James, 1884). Empirical support for such autonomic specificity has been mixed (Levenson, 2003; Mauss et al., 2005). However, advances in the measurement of physiological responses point to promising means by which emotion-specific physiological responses can be documented. For instance, pro-inflammatory cytokines may be related to specific submissive emotions such as, shame, guilt, and fear (Dickerson, Kemeny, Aziz, Kim & Fahey, 2004; Moons, Eisenberger & Taylor, 2010), cortisol has been linked specifically to the experience of anger (Moons et al., 2010), and the blush, resulting from increased blood flow to the subcutaneous capillaries of the head, and is readily associated with embarrassment (Cutlip & Leary, 1993; Shearn, Bergman, Hill, Abel, & Hinds, 1990). We provide additional support for the claim that, as researchers begin to employ a greater number of physiological measures, physiological profiles of distinct emotions may emerge.

These results raise interesting implications for whether greater parasympathetic activity during compassion may yield health benefits, or mediate the emerging literature documenting health benefits associated with compassion and prosocial behavior (Brown et al., 2009; Ludwig & Kabat Zinn, 2008). Researchers have theorized that compassion may yield neurophysiological

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benefits such as increased activity in the left frontal lobes and enhanced immune function

(Davidson, 2002). Practices that incorporate compassion such as particular types of meditation

and mindfulness lead to reduced physiological signs of stress to negative situations, levels of

pain, as well as obesity and bulimia (for a review see Ludwig & Kabat Zinn, 2008). Compassion

in response to suffering, especially in contrast to distress, may provide temporary boosts in vagal

activity that compound over time to provide health benefits. The vagus nerve inhibits the HPA

axis and helps regulate the immune response (Borovikova et al., 2000; Bueno et al., 1989). In

some studies vagal activity is used as a marker of positive health, these studies establish that

psychological experiences, such as repeated practices of loving-kindness mediation, can affect

chronic vagal activity over time (Kok et al., 2013). Future work should examine whether health

benefits associated with compassion may be vagally-mediated.

Across these studies our methodological choices create some important limitations, and

must be borne in mind when interpreting the results from the present investigation. First, we

chose to use a neutral activity as our comparison condition instead of a passive resting baseline.

Relying on a neutral activity has distinct advantages: as in the compassion induction condition, it

engages participants in similar attentional activities. Our reliance on the neutral activity control,

though, has disadvantages: RSA may be lower when watching any type of video and the neutral

condition did not immediately precede the compassion condition in our first three studies. We

demonstrate greater RSA in the compassion condition compared to the neutral condition, but

only in Study 4 can we claim that RSA increased during compassion. A second limitation to the

studies presented here is that in Study 1 we did not counterbalance the order of our film clips,

though subsequent studies found similar results when randomizing stimuli presentation. Third,

our results were designed to test traditional notions about the relationship between emotion and

physiology, which claim that emotions promote changes in the autonomic system in order to prepare the body for different behaviors (Levenson, 1992). We demonstrate that inductions of compassion reliably elicit greater RSA across four studies. However, we did not design studies that would allow us to address the reverse direction of causality, whether increases in RSA can also elicit increases in compassion. A few studies have found support for the claim that physiology can shape emotional experience (e.g. Gray, Harrison, Wiens, & Critchley, 2007). Thus, it is possible that there is a bidirectional relationship between RSA and compassion. Future work could identify whether increases in RSA increase the propensity to experience compassion by manipulating RSA through an unrelated task and measuring resulting changes in reports of compassion.

The results from the present investigation must also be interpreted within the context of what has been learned about RSA and emotion regulation (Beauchaine, 2001; Butler et al., 2006). One notable difference between the compassion and comparison conditions is the presence of suffering and the need to down regulate negative emotions like distress. Given this, an alternative interpretation of our results is that individual differences in RSA between conditions may actually represent a more trait-like tendency to regulate one's emotions that is merely activated during compassion. Support for this claim comes from research that demonstrates individual differences in vagal flexibility, assessed through RSA withdrawal to challenging situations, are associated with better regulation in children (Thompson, Lewis & Calkins, 2008). In adults, research linking emotion regulation and RSA activity is mounting, but is not definitive, with some studies finding a relationship (Butler et al., 2006), while others do not (Demaree, Pu, Robinson, Schmeichel, & Evarhart, 2006). Additionally, research has yet to demonstrate that compassion results from a trait-like tendency to down regulate negative

emotions like distress, or that this tendency is associated with greater RSA during compassion. In our work, we have not found individual differences in emotion regulation to be associated with compassion or greater RSA during compassion inductions.[7] This argument and evidence raises doubts about the cogence of this alternative interpretation of our results, but it still merits more systematic investigation. We suggest that emotion regulation during compassion may be a potential mechanism explaining the link between compassion and greater RSA. Unfortunately, within these studies we do not include a comparison condition that would elicit emotion regulation. Future studies should directly test whether compassion elicits increases in RSA by encouraging individuals to regulate their distress.

Conclusion

Compassion is at the core of moral systems and fundamental to prosociality. Long the focus of philosophy and those writing within ethical and spiritual traditions (e.g., Armstrong, 2006), it is only recently that science has begun to map the different responses associated with compassion. The findings of the present investigation suggest that compassion engages a branch of the autonomic nervous system that is old in mammalian evolution and involved in social engagement and caregiving. These findings would suggest that compassion has an old evolutionary past, one anticipated long ago by Charles Darwin (1872): [sympathy] "will have been increased through natural selection; for those communities, which included the greatest number of the most sympathetic members, would flourish best, and rear the greatest number of offspring." The present data are part of an emerging interest in the physiological bases of compassion, and the broader interest in the origins and functions of this emotion.

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Footnote

[1] Batson typically uses the term empathic concern, which refers to a composite of emotions (sympathy, compassion, moved, and soft-hearted) and Eisenberg uses the term sympathy. We believe that these terms represent the same construct as compassion (see Stellar & Keltner, 2013 for a review). Therefore, we use the term compassion to refer to sympathy and empathic concern.

[2] We also examined differences in RSA between conditions using repeated measures and found our results in this and all subsequent studies exhibited the same pattern of significance as when analyzed using linear mixed models, $F's \geq 3.85, p's \geq 05$.

[3] In this study differences in RSA negatively predicted reports of disgust, $\beta's = -.42, p = .003$. Across all four studies no other emotions were predicted by RSA besides the target emotions when correcting for testing multiple relationships using a family-wise Bonferroni correction ($p < .007$). Therefore we do not believe that RSA reliably predicts the experiences of other discrete emotions in response to suffering.

[4] In a pilot sample (n = 26), participants recruited from Amazon Mechanical Turk, rated each neutral slide from 1 (*not neutral at all*) to 5 (*completely neutral*). Participants reported that these slides were almost completely neutral ($M = 4.24, SD = .69$).

[5] Analyses comparing RSA between conditions controlling for respiration showed the same pattern of significance when using RSA values that were not log transformed, $F's \geq 6.08, p's \leq .02; d's \geq .19$ in Studies 3 and 4.

[6] When performing regressions predicting our self-report and observed measures of compassion from differences in RSA between conditions we do not log transform RSA. Past work suggests that independent variables should not be transformed as a non-normal distribution of the independent variable does not violate the assumptions of regressions and that transforming this variable can reduce the spread of the data making it more difficult to assess relationships between variables (McClelland, & Judd, 1993). We find that our effects hold for the rating dial when log transforming differences in RSA, $\beta = .25, p = .03$, but our composite self report, $\beta = .16, p = .17$, and coded measure reduces in significance, $\beta = .17, p = .16$.

[7] We examined additional data in which, we employed a similar compassion induction and found that, as in the present research, it was associated with greater RSA during compassion relative to a neutral condition (n = 78). This additional data also included a measure of individual differences in emotion regulation (the Emotion Regulation Questionnaire, Gross & John, 2003). We found no relationship between individual differences in emotion regulation tendencies (assessed through the reappraisal and suppression subscales) and differences in RSA from the compassion to neutral induction, $\beta \leq .13, p \geq .21$. We also found no relationship between ERQ and self-reports of compassion, $\beta \leq .15, p \geq .11$.