Chapter 7

Compassion in the autonomic nervous system
The role of the vagus nerve

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Compassion in the autonomic nervous system: The role of the vagus nerve

One of the defining characteristics of the human species is our intensely social nature. We spend approximately 70–80% of our waking hours in the presence of others (Burger, 1995; Larson & Csikszentmihalyi, 1978) and healthy social relationships are a primary contributor to well-being and physical health (Cacioppo & Patrick, 2008; Cohen & Wills, 1985). As a consequence of our intense sociality, we care deeply about the welfare of others and when their welfare is threatened it elicits powerful emotional and, we argue, biological responses in us.

Although research has examined how compassion is experienced and expressed, its biological underpinnings in the autonomic nervous system are less well understood. In this chapter we explore the relationship between compassion and the autonomic nervous system. We begin by wrestling with fundamental questions about the definition of compassion and the functions of the autonomic nervous system. We propose that compassion is associated with activity in the parasympathetic branch of the autonomic nervous system, namely the vagus nerve. We review supporting evidence for this claim grounded in theoretical work on the vagus nerve’s role in social engagement and caretaking as well as empirical findings that demonstrate its association with prosociality, social connection, and compassion. We explore whether feeling compassion may activate a larger network of integrated biological systems (autonomic, neural, and hormonal). Finally, we consider the benefits offered by applying psychophysiological methods to the study of compassion and future directions for this work.

Understanding compassion in the autonomic nervous system

As the first chapter notes, there are many approaches to defining compassion. It has been treated as a disposition or attitude toward others (Ricard, 2015; Shiota, Keltner, & John, 2006), an emotion or feeling state (e.g. Goetz, Keltner, & Simon-Thomas, 2010; Stellar & Keltner, 2014), and a cognitive or motivational state...
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(Gilbert & Choden, 2013) and it is likely all of these. Compassion can represent an enduring concern for the welfare of others, but also a momentary response to an instance of suffering. Characterizing compassion as both enduring and momentary raises the question of whether it is possible, with such a broad definition, to find a reliable association with specific physiological measures. We argue that it is, but in order to identify these physiological measures we need to understand the primary functions of the autonomic nervous system.

The autonomic nervous system functions to deploy attention and prepare the body for action. Therefore, when we explore what physiological systems are associated with dispositional and momentary compassion the goal should be to identify what features of compassion are relevant to these two functions of the autonomic nervous system. In other words, what are the attentional and behavioral features of compassion that manifest in reliable autonomic responses? We claim there are two. The first is social attunement, which would require a person to focus their attention on another person rather than on themselves or the broader environment. The second is preparing the body for approach-related affiliative behaviors, more specifically caretaking (e.g. soothing, comforting, or helping or rescuing). These two characteristics of compassion are heavily influenced by perceptions of safety. The autonomic nervous system prioritizes threat detection, which catalyzes a cascade of autonomic changes aimed at self-protection. In the case of compassion we believe it is important that individuals make the distinction that a threat is to another’s well-being and not to the self. If a person feels she is under a direct threat, it will make it harder, though not impossible, to attune to the needs of others and engage in caretaking behaviors. As a result one would expect a person whose defense system is activated (e.g. someone who is chronically anxious or feeling a great deal of momentary distress) to be less compassionate, a point we will return to later. Therefore, it is compassion’s ability to attune us to the needs of others and motivate caretaking behavior that we believe represent recurring themes when examining its autonomic correlates, features, which are present regardless of whether compassion is conceptualized as an enduring trait and a momentary state.

As a cautionary note, there are almost no components of the autonomic nervous system that are exclusively associated with one function, that level of modularity is not how the autonomic nervous system is designed. Therefore, we warn against assuming too strict an association between any one autonomic physiological measure and a phenomenon like compassion. For example, increases in heart rate are characteristic of fear, but also other emotional states like anger (Levenson, 1992), appetitive motivations (Fowles, Fisher, & Tranel, 1982), or exercise. This is because increased heart rate functions to make more resources available for physical mobilization, whatever the reason may be—to flee, to get a reward, or because we are trying to get in shape. If the context is narrowly defined, for example if an experimenter is showing a participant a scary video or someone is walking through a haunted house, one could more confidently claim that in this context greater increases in heart rate correspond to greater fear, but it would be incorrect to say that increased heart
rate always indicates feeling threat, a person could be exercising, enjoying sex, or feel joyful at the news their child has passed their exams. We can be in activated states for both threat and positive reasons. In summary, it is grounded in a conceptualization of compassion as both an enduring and momentary experience defined by social attunement and caretaking that we now turn to its relationship to specific physiological measures in the autonomic nervous system.

**Compassion and the vagus nerve**

We propose that compassion is associated with greater activity of the vagus nerve, a component of the parasympathetic branch of the autonomic nervous system. The vagus nerve is the tenth cranial nerve, originating in the brain stem and innervating the palate, larynx, and pharynx, as well as the heart and digestive organs (see Figure 7.1). Notably, it innervates the Sinoatrial node of the heart, controlling the frequency with which the heart beats. Without constant vagal innervation the human heart would beat around 100 times per minute rather than the observed range of 60–80 beats per minute. This chronic vagal control over the heart is called vagal tone. Just as each person has a stable resting heart rate, we also have a stable resting vagal tone (although consistent exercise can change both). Therefore, vagal tone varies between individuals and can be interpreted much like a trait or dispositional measure. The vagus nerve also increases or decreases its activation in response to different contexts in a more phasic fashion. This type of vagal activation is often called vagal reactivity. Again, just as a person can show changes in heart rate to a given context, we can also experience changes in vagal activation.

Researchers measure vagal tone and vagal reactivity through the non-invasive indices of respiratory sinus arrhythmia (RSA) and high frequency heart rate variability (HF-HRV). RSA and HF-HRV represent the variability in heart rate as a function of respiration (Berntson, Cacioppo, & Quigley, 1993). In each respiration cycle vagal control over the pace of the heart changes; during inhalation, vagus nerve activity is suppressed, leading to heart rate acceleration, whereas during exhalation, vagus nerve activity increases, resulting in heart rate deceleration. This natural process leads to variation in heart rate, which acts as an index of the current activity of the vagus nerve.

There is converging evidence from theoretical and empirical work for a relationship between compassion, both enduring and momentary experiences, and vagal activation. The Polyvagal Theory offers theoretical support for claims that compassion is related to vagal activation by demonstrating its potential origins in facilitating social connection and engagement, and promoting caretaking and bonding (Porges, 2001, 2007). This argument claims that the myelinated portion of the vagus nerve emerged with the advent of mammals, and particularly attachment, which facilitates proximity seeking, as opposed to disbursement (as for most reptiles) at birth. The capacity to inhibit the fight-flight system and experience soothing and safeness in the context of relating helps facilitate increased sociality, a defining feature for mammals (see Grossman & Taylor, 2007 for a critique of this argument).
According to this theory the vagus nerve can lead to quick changes in heart rate in response to non-threatening contexts, without activation of the more costly sympathetic or hypothalamic-pituitary-adrenal systems. Importantly, vagal activation slows the heart, producing calm states that could encourage affiliation and bonding. In support of this claim the neural origins of the vagus nerve are 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 key signal of engagement; see Kogan et al., 2014; Porges, 2001), orienting the head and gaze toward others, talking and vocalizing, and extracting the human voice from other noises (Porges, 2001). Fundamentally compassion is rooted in social connection and engagement, in particular sensitivity and responsiveness to distress signals (Gilbert, Chapter 1, this volume) as well as affiliation with others (Goetz et al., 2010). Thus greater activity of the vagus nerve, which supports these ends, could accompany compassion.
In addition, this theory ties vagal activation to the most basic form of sociality, caretaking, which also lies at the heart of compassion (Bowlby, 1988; Porges, 2003). Porges argues that the vagus nerve, along with other physiological responses such as the release of oxytocin, may have coopted defensive systems involved in freezing for immobilization during nursing, reproduction, and social bonding more generally. Compassion is also thought to be rooted in caretaking (for a summary of this argument see Gilbert, 2014 and Chapter 3, this volume; Goetz et al., 2010; Narvaez, Chapter 10, this volume; Spikins, Chapter 2, this volume). Human infants have a longer period of vulnerability and require more parental investment than any other species. There is good evidence that strong emotional, cognitive, and physiological systems evolved to help attune parents to the distress of infants and promote caretaking behaviors. In sum, the Polyvagal Theory ties the vagus nerve to two fundamental aspects of compassion: social engagement and caretaking behaviors.

Support for a relationship between compassion and the vagus nerve also comes from empirical work. Recent studies suggest that individuals with higher vagal tone are more compassionate, prosocial, and feel greater social connection with others. Children with higher vagal tone exhibit greater sympathy to another in need (Fabes, Eisenberg, & Eisenbud, 1993). In addition, in one study, adolescents with higher vagal tone showed greater empathic accuracy with their mothers during a conversation (Diamond, Fagundes, & Butterworth, 2012). In adults vagal tone predicts higher scores on the personality trait of agreeableness, which is characterized by a kind, warm, cooperative, and considerate disposition toward others (Oveis et al., 2009). In multiple studies, observers rated those with higher vagal tone as more prosocial (though for adults this relationship was quadratic; Eisenberg et al., 1995; Eisenberg et al., 1996; Kogan et al., 2014). On the other hand, clinical samples defined by deficits in social attunement, such as those with autism, have chronically lower levels of vagal activation than healthy comparison groups (Ming, Julu, Brimacombe, Connor, & Daniels, 2005; Porges, 2007). Finally, in a nine-week longitudinal study where participants reported on their social interactions, those who started the study with higher vagal tone reported greater increases in feelings of connection to others, compared with those who had lower vagal tone (Kok & Fredrickson, 2010). In another study greater vagal tone predicted higher reports of social-support seeking, social integration, and social acceptance (Geisler, Kubiak, Siewert, & Weber, 2013). These studies suggest a potential link between higher vagal tone and a compassionate disposition, but what about momentary experiences of compassion?

Very few studies have measured physiological activity associated with compassion in response to witnessing another suffer, but the little work that has been done in this area appears to converge with findings on dispositional compassion. As mentioned previously, heart rate slows during increased vagal activation. Self-reports and expressive displays of compassion covary with heart rate deceleration (Eisenberg et al., 1991; Stellar, Cohen, Oveis, & Keltner, 2015) and the magnitude of heart rate deceleration distinguishes between those who report more or less compassion toward another’s suffering (Stellar, Manzo, Kraus, & Keltner, 2012).
These findings on heart rate deceleration during compassion could be interpreted to represent increased vagal activation during compassion, which actively slows the heart. However, heart rate is affected by both the parasympathetic and sympathetic systems, so caution must be exercised in interpreting these data, highlighting the importance of measuring vagal activation more directly.

Our lab has found that vagal activation increases during inductions of compassion compared to neutral controls or other positive states such as pride or inspiration (Stellar et al., 2015). These findings generalized across a variety of compassion inductions in which participants watched videos of families of children with cancer, clips of past participants discussing the death of their grandparent, or pictures of individuals who were suffering. In addition, increases in vagal activation during compassion inductions predicted greater ratings of observed compassion by blind coders and greater self-reports of compassion by participants using a continuous self-report measure of emotion. These findings provide initial support that feelings of compassion are accompanied by increases in vagal activation.

While this emergent relationship between compassion and vagal activity is provocative, more work is needed to isolate the active ingredients of compassion that increase vagal activation (i.e. social engagement and activation of caretaking behaviors). In addition, greater attention must be paid to potential moderating factors that may influence the relationship between compassion and increased vagal activation such as the characteristics of the observer (their personal distress in response to seeing another suffer), the sufferer (the nature of that person’s suffering), and the context (the ability to take action).

A biological network involved in compassion

In conjunction with greater vagal activation in the autonomic nervous system, individuals feeling compassion also exhibit changes in neural and hormonal systems. We propose that compassion activates an integrated network of biological responses. In the brain, increased activation in the periaqueductual gray (PAG) accompanies the experience of compassion. In one study, PAG activation increased when participants viewed pictures of others suffering; self-reported compassion, in combination with distress, also predicted levels of PAG activation (Simon-Thomas et al., 2012). Though this research suggests PAG activation is part of the experience of compassion, more work is needed to rule out alternative explanations and isolate this relationship.

Compassion has also been associated with the hormone oxytocin (e.g. Barraza & Zak, 2009), though some of these findings are controversial (Nave, Camerer, & McCullough, 2015) and may be moderated by important factors like group membership (De Dreu, 2012). Intranasal delivery of oxytocin increased compassion toward vulnerable targets (Palgi, Klein, & Shamay-Tsoory, 2015), empathic accuracy and emotional empathy especially for observers who are less socially proficient (Bartz et al., 2010; Hurlemann et al., 2010), and prosociality...
Jennifer E. Stellar and Dacher Keltner (Zak, Stanton, & Ahmadi, 2007). Feelings of empathy also increased plasma levels of oxytocin suggesting the relationship may be causal in both directions (Barraza & Zak, 2009).

Importantly, the PAG and oxytocin have anatomical connections with the vagus nerve, suggesting that these systems may communicate with one another. The PAG has important projections to the part of the brain stem where the vagus nerve originates, the dorsal motor nucleus and nucleus ambiguus (Farkas, Jansen, & Loewy, 1997), offering the possibility that the vagus nerve and PAG may communicate directly with one another. In addition, new work has revealed that oxytocin levels are associated with vagal activity. In animal models, oxytocin injections lead to increased vagal activity (McCann & Rogers, 1990) and electrical stimulation of the vagus nerve also increases the release of oxytocin (Stock & Uvnäs-Moberg, 2008). In humans, individuals who were given intranasal oxytocin exhibited greater heart rate variability (a measure of vagal activation) compared to a placebo group (Kemp et al., 2012). Additionally, when fathers were administered oxytocin intranasally, they showed increases in vagal activity during play with their five-month olds compared to controls (Weisman, Zagoory-Sharon, & Feldman, 2012). The anatomical and observed relationships between the vagus nerve, PAG, and oxytocin suggest the potential for an integration of autonomic, neural, and hormonal responses during compassion.

**Implications and future directions**

Psychophysiology is uniquely positioned to offer important insights into compassion. At a broad level, identifying associations between the autonomic nervous system and compassion helps build support for evolutionary claims of a biological basis for altruism. If we have physiological systems that help us attune to the needs of others and promote caring for those in need then we can argue that prosociality may be as deeply embedded as selfishness. More specific to compassion, psychophysiological work can elucidate the process by which dispositional or momentary compassion translates to action. Although we know a great deal about how the body prepares to respond to threats in the environment, we know much less about how it facilitates approach-related behaviors, such as offering comfort, soothing, giving support, or even offering aid (e.g. Batson, Fultz, & Schoenrade, 1987; Eisenberg et al., 1989).

Identifying autonomic responses associated with momentary compassion will also help establish compassion as a discrete emotion. Despite disagreement among affective scientists as to whether compassion represents an emotional state (Ekman, 2016), compassion shows many of the qualities necessary to meet the definition of an emotion. It is universally experienced; it has been documented in a variety of cultures, including pre-historical and pre-industrialized cultures and even in our closest primate ancestors (de Waal, 1996; Eibl-Eibesfeldt, 1989; Hublin, 2009). It has reliable expressions in the form of touch and vocalizations that are universally recognized across
radically different cultures (Cordaro, Keltner, Tshering, Wangchuk, & Flynn, 2016; Hertenstein, Keltner, App, Bulleit, & Jaskolka, 2006). It has clear evolutionary functions including caretaking of offspring (Gilbert, 2014; Goetz et al., 2010; Mikulincer, & Shaver, 2005; Stellar & Keltner, 2014) and promoting reciprocal cooperation among non-kin (Stellar & Keltner, 2014; Trivers, 1971). However, it has not been clear whether compassion evokes reliable physiological changes, which some scholars consider a necessary precondition for claiming a particular state is an emotion (e.g. Ekman, 1992; Lazarus, 1991; Panksepp, 1992).

Finally, at the practical level, this work offers researchers a method for assessing compassion that is free from social desirability since autonomic physiology is near impossible to control. Often researchers show individuals videos, photos, or stories of others who are suffering and ask participants how much compassion they feel (e.g. Oveis, Horberg, & Keltner, 2010; Stellar et al., 2012; Stellar et al., 2015). In many studies this method creates a strong demand to report high levels of compassion. In our work we find this demand is particularly powerful for women, who may feel cultural norms dictate that they report high levels of compassion. As a result, our studies and those of other researchers (for a review of this issues see Eisenberg & Lennon, 1983; LaFrance & Banaji, 1992) often find identical physiological responses to suffering among male and female observers, but differences in self-reports.

Future work in psychophysiology can help resolve questions about how to define this complex phenomenon. Notably, this method gives researchers the opportunity to unpack the mixed nature of compassion by exploring it as it unfolds in the body. Compassion combines positive feelings of warmth and tenderness with negative feelings of sadness or distress. The balance between these states is crucial. While a small amount of distress or anxiety is a signal that an individual cares about another’s welfare, and may be necessary to compassion, when too pronounced, distress can overwhelm the more positive aspects of compassion that generate social connection and caretaking (Batson, 1987). In support of this claim research has shown that personal distress in response to another’s suffering is less predictive of prosociality than feelings of compassion (Eisenberg et al., 1989). Physiological indicators in response to another’s suffering like heart rate acceleration or increased cardiac output could signal the balance of affect is tipped toward distress. In addition, better temporal resolution in physiological studies may reveal initial physiological indicators of distress as one becomes aware that another is suffering followed by increased vagal activation as the individual transitions to feeling compassion and social connection to the sufferer. These findings would support arguments that compassion requires a tolerance of distress or perhaps a regulation of one’s own negative feelings when seeing another suffer in order to produce a positive state of social connection (e.g. Stellar et al., 2015). Self-reports do not allow for enough clarity to disentangle the time course of these responses, but psychophysiological studies could help uncover how compassion unfolds over time.
Psychophysiological studies may also be able to differentiate between various responses to another’s suffering that are currently all categorized as compassion. To take an example from Gilbert (Chapter 1, this volume), compassion may be felt when one sees a child trapped in a burning house or for someone who is grieving the loss of a loved one. Although these two types of suffering elicit compassion, they evoke very different behavioral responses that would be served by different physiological patterns of activity. Many studies on compassion focus on witnessing another’s emotional suffering, rather than physical suffering (e.g., injury). Our lab has found that, in response to emotional suffering, individuals report behaviors consistent with giving social support or soothing the sufferer, whereas in response to physical suffering they report behaviors centered on mobilizing to provide emergency aid (e.g., binding a wound, getting help; Stellar et al., in press). While both types of suffering elicit heightened compassion, emotional suffering elicited more sadness, warmth, and tenderness, whereas physical suffering elicited more vicarious distress and anxiety. Unlike emotional suffering, which elicited parasympathetic activation primarily, physical suffering generated co-activation of the parasympathetic sympathetic systems, which would be important to mobilize an individual to act quickly. Despite colloquial usage of the word compassion to describe responses to both emotional and physical suffering, psychophysiological work demonstrates they may be experienced quite differently in the body. In sum, we believe that future psychophysiological studies have the capacity to challenge traditional definitions and offer a more nuanced understanding of compassion.

Future work should consider whether feeling compassion reduces physiological stress, promoting better health. Some accounts of the vagus nerve suggest it may be part of a soothing affect system (Rockliff, Gilbert, McEwan, Lightman & Glover, 2008) and that low vagal activation is a marker of threat and stress (Thayer, Åhs, Fredrikson, Sollers, & Wager, 2012). Activation of the vagus nerve reduces heart rate and levels of pro-inflammatory cytokines, an immune marker associated with stress (Johnston & Webster, 2009; Maes et al., 1998; Slavich, Way, Eisenberger, & Taylor, 2010; Steptoe, Willemsen, Natalie, Flower, & Mohamed-Ali, 2001; Tracey, 2002). In one study, when compassion focused imagery led to greater vagal activation, as assessed by heart rate variability, it was associated with reduced cortisol (Rockliff et al., 2008). In addition, decreased vagal function is a risk factor for cardiac disease and mortality (Thayer & Lane, 2007). Some work indicates that compassion is also associated with the release of oxytocin. Oxytocin inhibits the stress-induced activity of the hypothalamic–pituitary–adrenal axis in rats (e.g., Uvnas-Moberg, Ahlenius, Hillegaart, & Alster, 1994). In humans, intranasal oxytocin, especially when combined with social support, suppressed cortisol during a stressful task (Heinrichs, Baumgartner, Kirschbaum, & Ehlert, 2003) and in another study intranasal oxytocin reduced salivary cortisol levels after a conflict between romantic partners (Ditzen et al., 2009). The important inhibitory effects of vagal activation and oxytocin on physiological stress responses (e.g., heart rate, pro-inflammatory cytokines, and cortisol) suggest the potential anxiolytic power of compassion in the body.
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Understanding the physiological changes associated with compassion may also allow researchers to develop novel compassion interventions that are physiologically based. Although emotions typically evoke physiological responses, there is an enduring debate about whether physiological responses may also evoke emotional states (Cannon, 1927; James, 1894; Lange, 1885). This debate raises the question of whether increasing vagal activation can promote compassion. Although no empirical research has addressed this question, there are a variety of possible methods for influencing vagal activation. Most notably, slowing one’s breathing and taking deeper breaths. Many forms of meditation utilize this breathing technique and meditation has been found to increase both vagal activation (Ditto, Eclache, & Goldman, 2006) and compassion (Condon, Desbordes, Miller, & DeSteno, 2013). Future research should examine whether pacing one’s breathing during meditation increases momentary compassion in response to suffering and whether this effect is explained by vagal activation. As technology progresses, alternative methods for increasing vagal activation have emerged. Currently, surgical implantation of a vagus nerve stimulator, which directly activates the vagus nerve by electric stimulation, is being employed for drug-resistant epilepsy (Handforth et al., 1998) and depression (Rush et al., 2000). In both disorders implantation of the vagus nerve stimulator led to increased positive mood and decreased negative mood (Elger, Hoppe, Falkai, Rush, & Elger, 2000; George et al., 2005; Harden et al., 2000), though this work is still nascent. Finally, in the past few months a new company claims they can activate the vagus nerve through an electrical pulse in the ear. Although these technologies may hold promise it remains to be seen whether increases in vagal activation do lead to notable increases in compassion.

Conclusion

In this chapter we have noted that the evolution of care-giving between infant and parent, alliance formation, and other forms of altruism were supported by a range of evolutionary adaptations to the body and brain. Among these was the ability for individuals to operate in close proximity to each other, feel safe (rather than threatened), and physiologically regulate each other. A capacity to pay attention to distress and be motivated to respond to distress is part of this evolution and is the root of our capacities for compassion. Clues to the physiological underpinnings of compassion can be found in the mechanisms and support caring behavior, particularly in the vagal nerve (Porges, 2003).

We have proposed that the higher vagal tone may be associated with more compassionate individuals and that vagal activation may increase activity during momentary experiences of compassion. Theoretical claims that the myelinated portion of the vagus nerve emerged with the advent of mammals has an important autonomic facilitator of social interaction and caretaking, suggest that the vagus nerve would be crucial to encouraging calm approach-related states characteristic of compassion in which individuals could offer support to, soothe, and comfort another in need. Empirical findings also support a relationship between
vagal activity and compassion. This work highlights two essential elements of compassion, such as social attunement and behavioral responses like caregiving, which would be served by activation of particular physiological systems, and offers a new perspective to an enduring debate about the nature of compassion. We believe the ability to detect traces of compassion in our biological systems counters long-held notions that individuals are designed only to be selfish and demonstrates a deeply embedded tendency to be compassionate and concerned with the welfare of others.

References


