

Vagal pathways: Portals to Compassion

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As contemplative neuroscience emerges as a discipline, research is being conducted to identify the neural pathways that contribute to compassion. Paralleling these scientific explorations, clinicians in mental health disciplines are developing interventions designed to enhance compassion of others and self-compassion (Gilbert, 2009). Limiting these investigations and applications is a lack of a consensus definition of compassion. This ambiguity limits both scientific investigations of the neural pathways determining compassion and the evaluation of compassion based therapies.

Definitions of compassion and the tools used to assess compassion vary within the literature (see Strauss et al., 2016). Compassion has been viewed as an action, a feeling, an emotion, and a temperament. Although common themes may be extracted from the literature, no assessment tool conforms to the standards commonly employed in scientific research (Strauss et al., 2016). Without a consensus definition, researchers investigating compassion lack a toolkit that would foster scientific inquiry and clinicians lack a metric to assess the outcome of compassion based therapies.

In contrast to the frequent definitions of compassion as a psychological construct, this chapter proposes that **compassion is an emergent process dependent on neurophysiological state.** Consistent with this perspective, compassion cannot be investigated as a voluntary behavior or a psychological process independent of physiological state. **Thus, compassion cannot be taught through classic rules of learning, nor can it be indexed by specific neurophysiological processes, behavioral actions, or subjective experiences independent of the bi-directional communication between peripheral physiological state and brain function.** In the proposed model of compassion, physiological state functions as an intervening variable between the person who is suffering and the responses to the person, which are manifested as the subjective experiences and behavioral actions that form operational definitions of compassion.

This chapter proposes that **a physiological state mediated via vagal pathways is a necessary, but not sufficient condition for an individual to experience compassion.** The vagus is a cranial nerve, which provides the major bidirectional (motor and sensory) communication between the brain and the body. The vagus is a major component of the parasympathetic branch of the autonomic nervous system. Functionally, **specific vagal motor pathways have the capacity to inhibit the reactivity of the sympathetic branch of the autonomic nervous system, while vagal sensory pathways provide a major surveillance portal between the body and the brain.** The model emphasizes the dependence of compassion on a vagal mediated state that supports feelings of **safety, which enable feeling one's own bodily responses and respecting the bodily experiences of**

another person. The emphasis on shifting physiological state via vagal mechanisms to experience compassion is consistent with the historic use of rituals in contemplative training.

Since compassion is dependent on a vagal mediated physiological state, it may be separated from other subjective experiences that have a different physiological substrate. For example, although empathy is frequently assumed to be interchangeable with compassion, **the physiological state associated with empathy may differ from the physiological state associated with compassion.** Empathy is operationally defined as feelings someone else's pain. If we deconstruct empathy from a neurobiological perspective, **empathy should be associated with the activation of the sympathetic nervous system.** This would occur, since the autonomic response to pain is characterized by a withdrawal of vagal influences and an activation of the sympathetic nervous system. Thus, from a neurobiological perspective, compassion is not equivalent to empathy.

If compassion is associated with a calm vagal state, it would promote a physiological state associated with safety of self that projects calmness and accepting to the other. Functionally, the vagal pathways a major component of a branch of the autonomic nervous system historically labeled parasympathetic nervous system. An interesting clue is provided in the label, since **'para' is derived from ancient Greek παρά meaning contrary or against.** Thus, the parasympathetic nervous system provides by its name an implicit understanding of the **containment of the defensive reactivity associated with the sympathetic nervous system.** Consistent with this view of containment of defensive reactions, the critical portal to express compassion would be dependent on the capacity to recruit the vagal pathways that actively inhibited sympathetic reactivity and promote a calm physiological state that project a biobehavioral state of safety to others.

The physiological state mediated by the vagus, is not equivalent to compassion. Rather, it is a state that promotes feelings of safety, positive feelings towards other (e.g., Stellar et al., 2015), connectedness, and the potential to respect both the suffering and joy of others. It is through the vagal inhibition of the neurophysiological defenses (HPA-sympathetic responses), that the vagal state functionally contains the biobehavioral reactivity to suffering. **This containment provides opportunities to witness without judgment and to subsequently be helpful in alleviating the suffering.** Brain imaging studies attempting to distinguish empathy and compassion are consistent with the proposed state differences associated with empathy and compassion. Klimecki et al. (2014) suggest that the **excessive sharing of others' negative emotions (i.e., empathy) may be maladaptive and that compassion training dampens empathic distress and strengthens resilience.** Similarly, it has been suggested that empathy involves resonating or mirroring another's emotion in neurophysiological, peripheral physiological, and behavioral domains (for overview see Decety and Ickes 2009).

Functionally compassion, by respecting the individual's capacity to experience pain, allows the individual to have their experiences 'witnessed' by another without hurting the other by empathically sharing their pain and activating the defensive sympathetic nervous system in the other. This allows the pain to be expressed without an anticipation of evaluation and the shame

that emerges from evaluation. Compassion allows and respects the other to ‘own’ their experiences. This respect of other, in itself contributes to the healing process by empowering the other and not subjugating or diminishing the value of the person’s experiences of pain or loss. Compassion functionally allows one, who has lost or is suffering, not to be defensive about the loss and not to experience shame for the loss. If we attempt to fix the problem without successfully expressing compassion, the intervention will disrupt the individual’s process of expression by triggering biobehavioral defense strategies associated with a shift in physiological state characterized by a withdrawal of vagal influences and activation of the sympathetic nervous system. Thus, compassion is dependent on a ‘neural’ platform that enables an individual to maintain and express a physiological state of safety when confronted with the pain and suffering of others.



Vagal states are intertwined with the history of contemplative practices.

Throughout the history of humanity, rituals such as chants, prayers, meditation, dance, and posture have provided the behavioral platform for contemplative practices. A careful investigation of many rituals results in the identification that the rituals are functional exercises of vagal pathways (see Table 1). Although chants, prayers, and meditation have been incorporated into formal religions, the function of these rituals may be different than the narratives upon which religions were based. The narratives are attempts to fulfill the human need to create meaning out of uncertainty and to understand the unknowing mysteries of the human experience in a dynamically changing and challenging world. While this assumption may be consistent with the history of the narratives that form the corpus of formalized religions, the function of rituals may be more closely related to health and personal subjective feelings of connectedness to other and to deity.

\ **Insert Table 1 about here**

The documented positive effects of meditation on mental and physical health (Bohlmeijer et al., 2010; Chiesa & Serretti, 2009; Davidson et al. 2003) have stimulated an interest in contemplative practices as health-related interventions (e.g., Mindfulness Based Stress Reduction). Science is now interfacing with insights derived from historical and often ancient contemplative practices. The accumulated knowledge suggests that meditative practices not only lead to a different perspective of reality that fosters a connectedness with others expressed through feelings of compassion, but also may have positive influences on health. These observations have led to a new discipline of contemplative neuroscience that is targeted towards documenting the shift in neural regulation that occurs during contemplative practices such as meditation.



Contemplative neuroscience has focused on documenting the mechanisms through which meditation ‘heals.’ Thus, contemplative neuroscience assumes directional causality in which mental processes have the capacity to influence and potentially optimize bodily function. This ‘top-down’ model emphasizes mind in the mind-body relationship and assumes that ‘thought’ is

the driving force through which meditation functions effectively. Functionally, the research has emphasized the investigation of mind-brain relationships through imaging and electrophysiological studies of brain circuits of expert meditators (e.g., Lutz et al., 2013). Within contemplative neuroscience investigations of the influences of meditation on the neural regulation of visceral organs has not been emphasized.

The predominant model within contemplative neuroscience, including the study of neural pathways associated with compassion, assumes a directional causality in which mental activity drives brain function. Although this directional causality has been reliably documented (i.e., mental processes reliably influence neural activity), the model is limited because it does not incorporate two intervening variables that may mediate the effectiveness and efficiency of contemplative practices. First, the model does not acknowledge the influence of context on the nervous system. Second, the model does not acknowledge the influence of peripheral physiological state on brain function. Without detailed attention to these two variables the functional impact of contemplative practices on mental and physical health will be unpredictable. In addition, the efficiency of contemplative practices to increase a sense of connectedness and an ability to express compassion may be compromised.

This chapter presents a model in which contemplative practices are conceptualized as methods that require, as a prerequisite, enhanced vagal regulation of biobehavioral states. Functionally, by enhancing vagal regulation these methods efficiently promote health and may enable expansive subjective experiences related to compassion and a universal connectedness. The model proposes that specific voluntary behaviors (e.g., breath, vocalizations, and posture), which characterize ancient rituals and form the core of contemplative practices, have the potential to trigger a physiological state that fosters health and enables subjective experiences that have been the objective of contemplative practices.

The model emphasizes that two well-defined and sequential antecedent conditions are necessary for the beneficial properties of contemplative practices to be experienced. First, the environment in which contemplative practices are performed needs to have physical features that are calming and soothing. Across history and cultures, contemplative practices have been performed in quiet and safe environments. There are specific neurophysiological reasons for this consistency. To survive humans needed to identify danger and distinguish environments and others who were either safe or dangerous. Thus, the human nervous system needed to be sensitive to features that define physical spaces, which may either trigger or dampen defensive physiological reactivity. Second, rituals of chants, prayers, meditation, dance, and posture provide potent stimuli to our nervous system to ‘exercise’ the vagal pathways. These pathways down regulate defense and promote states of calmness and stillness.

In a safe environment, when a person no longer needs to be vigilant in anticipation of danger, the nervous system tends to shift into a qualitatively, and measurably different physiological ‘safe’ state. This ‘safe’ state may function as a ‘neural’ catalyst for subjective feelings of social connectedness and compassion. Without the appropriate contextual cues of safety and without

the body shifting into a 'safe' physiological state, attempts at contemplative practices may be ineffective and even promote defensive feelings focused on self-survival that promote hyper-vigilance and hyper-reactivity. Consistent with this premise, clinicians treating veterans with PTSD have reported situations in which mindfulness techniques have triggered defensiveness.

Polyvagal Theory: Deconstructing ancient rituals from a Polyvagal Perspective

Polyvagal Theory (Porges, 1995, 2011) explains how rituals associated with contemplative practices contribute to bodily feelings of safety, trust, and connectedness. Polyvagal Theory explains how cues of risk and safety, which are continuously monitored by the nervous system, either promote states of safety and calmness or states of vigilance toward sources of potential threat and defense. The theory assumes that mammals are on quest for safety, which when obtained facilitates health and social connectedness. The theory explains how the rituals associated with contemplative practices trigger physiological states that calm neural defense systems and promote feelings of safety that may lead to expressing and feeling compassion.

The human nervous system provides two paths to trigger the neural mechanisms capable of down regulating defense to enable states of calmness that support health and connectedness. One path is passive and does not require conscious awareness (see neuroception below), while the other requires conscious volitional behaviors that trigger specific neural mechanisms that in turn, change physiological state. Spontaneous positive social behavior expressed in facial expressions and vocal intonation is dependent on the former and optimal products of contemplative practices such as meditation and chants are dependent on the latter. Features of voice (i.e., prosody) and facial expression, which characterize the interactions of positive social behavior, provide potent cues to the nervous system that down regulate defense circuits. In contrast to the passive pathway of calming through affiliative social engagement, contemplative training is usually conducted within the context of a 'spiritual' space (e.g., quiet or sometimes with prosodic calming music) that triggers the passive pathway to promote the physiological state associated with feeling safe. Once in a safe state, the individual is instructed to perform voluntary behaviors such as breathing, posture shifts, and vocalizations that functionally exercise the vagal circuit that further promote, reinforce and strengthen states of calmness. These voluntary behaviors, which we observe as rituals, directly tap into and engage vagal circuits that efficiently manipulate physiological state. Thus, enabling rituals to function as neural exercises of vagal pathways.

The Role of the Vagus in Bidirectional Communication

During the phylogenetic transition from ancient reptiles to mammals, the autonomic nervous system changed. In the ancient reptiles, the autonomic nervous system regulated bodily organs via two subsystems: the sympathetic nervous system and the parasympathetic nervous system. Modern reptiles share these global features. The sympathetic nervous system provided the neural pathways for visceral changes that support defensive fight and flight behaviors. This physiological adjustment to support mobilization for self-preservation was associated with increases in heart rate and an inhibition of digestive process, which required suppression of parasympathetic (i.e., vagal) influences to the heart and the gut.

In the ancient reptiles, the parasympathetic nervous system complemented the function of the sympathetic nervous system by providing reciprocal influences on visceral organs. The reptilian parasympathetic nervous system served two primary adaptive functions: 1) when not recruited as a defense system, it supported processes of health, growth and restoration; and 2) when recruited as a defense system, it reduced metabolic activity by dampening heart rate and respiration, enabling the ‘immobilized’ reptiles to appear inanimate to potential predators (e.g. a “freeze” response). When not under threat, the sympathetic and parasympathetic branches of the autonomic nervous system in reptiles function reciprocally (and frequently antagonistically) to simultaneously innervate the visceral organs that support bodily functions. This synergism between the two branches of the autonomic nervous systems in support of health (not defense) is maintained in mammals, but only when mammals are safe. In this safe state the potential of the autonomic nervous system being recruited in support of defense is greatly reduced.

Most of the neural pathways of the parasympathetic nervous system travel through the vagus nerve. The vagus is a large cranial nerve that originates in the brainstem and connects visceral organs throughout the body with the brain. In contrast to the nerves that emerge from the spinal cord, the vagus connects the brain directly to bodily organs. The vagus contains both motor fibers to influence the function of visceral organs and sensory fibers to provide the brain with continuous information about the status of these organs. The flow of information between body and brain informs specific brain circuits that regulate target organs. Bidirectional communication provides a neural basis for a mind–body science, or a brain–body medicine, by providing plausible portals of intervention to correct brain dysfunction via peripheral vagal stimulation (e.g., vagal nerve stimulation for epilepsy, depression, and PTSD) and plausible explanations for exacerbation of clinical symptoms by psychological stressors, such as stress-related episodes of irritable bowel syndrome. In addition, bidirectional communication between the brain and specific visceral organs provides an anatomical basis for historical concepts of the optimal balance among physiological systems, such as Walter Cannon’s homeostasis (Cannon, 1932) and Claude Bernard’s internal milieu (Bernard, 1872).

Polyvagal theory: Overview.

Polyvagal theory is a reconceptualization of how autonomic state and behavior interface. The theory emphasizes a hierarchical relation among components of the autonomic nervous system that evolved to support adaptive behaviors in response to the particular environmental features of safety, danger, and life threat (Porges, 2011). The theory is named “polyvagal” to emphasize that there are two vagal circuits: an ancient vagal circuit associated with defense (the freeze response) and a phylogenetically newer circuit related to feeling safe and spontaneous affiliative social behavior. The theory articulates two defense systems: (a) the commonly known fight-or-flight system that is associated with activation or the sympathetic nervous system (fight or flight), and (b) a less-known system of immobilization and dissociation that is associated with activation of a phylogenetically more ancient vagal pathway.

The Polyvagal Theory describes the neural mechanisms through which physiological states communicate the experience of safety and contribute to an individual's capacity either to feel safe and spontaneously approach or engage cooperatively with others, to feel threatened and recruit defensive strategies, or to become socially invisible by feigning death. The theory articulates how each of three phylogenetic stages, in the development of the vertebrate autonomic nervous system, is associated with a distinct and measurable autonomic subsystem. In humans, conditions, each of these three subsystems becomes activated and is expressed physiologically under specific conditions (Porges, 2009). The three autonomic subsystems are phylogenetically ordered and behaviorally linked to three general adaptive domains of behavior: (a) social communication (e.g., facial expression, vocalization, listening), (b) defensive strategies associated with mobilization (e.g., fight-or-flight behaviors), and (c) defensive immobilization (e.g., feigning death, vasovagal syncope, behavioral shutdown, and dissociation). Based on their phylogenetic emergence during the evolution of the vertebrate autonomic nervous system, these **neuroanatomically-based subsystems form a response hierarchy.**

The Polyvagal Theory emphasizes the distinct roles of two distinct vagal motor pathways identified in the mammalian autonomic nervous system. The vagus is a cranial nerve that exits the brainstem and provides bidirectional communication between brain and several visceral organs. The vagus conveys (and monitors) the primary parasympathetic influence to the viscera. Most of the neural fibers in the vagus are sensory (i.e., approximately 80%). However, most interest has been directed to the motor fibers that regulate the visceral organs, including the heart and the gut. Of these motor fibers, only approximately 15% are myelinated (i.e., approximately 3% of the total vagal fibers). Myelin, a fatty coating over the neural fiber, enables faster and more tightly regulated neural control circuits. The myelinated vagal pathway to the heart is a rapidly responding component of a neural feedback system, involving brain and heart, which rapidly adjusts heart rate to challenges.

Humans, as well as other mammals, have two functionally distinct vagal circuits. One vagal circuit is phylogenetically older and unmyelinated. It originates in a brainstem area called the dorsal motor nucleus of the vagus. The other vagal circuit is uniquely mammalian and myelinated. The myelinated vagal circuit originates in a brainstem area called the nucleus ambiguus. The phylogenetically older unmyelinated vagal motor pathways are shared with most vertebrates and, in mammals when not recruited as a defense system, function to support health, growth, and restoration via neural regulation of subdiaphragmatic organs (i.e., internal organs below the diaphragm). The phylogenetically "newer" myelinated vagal motor pathways, which are observed in mammals, regulate the supradiaphragmatic organs (e.g., heart and lungs). This newer vagal circuit slows heart rate and supports states of calmness. It is this newer vagal circuit that both mediates the physiological state necessary for compassion and is functionally exercised during rituals associated with contemplative practices.

Vagal brake: A mechanism to contain emotional reactivity

When mammals evolved, the primary vagal regulation of the heart shifted from the unmyelinated pathways originating in the dorsal motor nucleus of the vagus to include myelinated pathways

originating in the nucleus ambiguus. The myelinated vagus provided a mechanism to rapidly and efficiently regulate visceral organs to support behavior, psychological, and physical health. For example, the myelinated vagus functions as an active efficient brake (see Porges et al., 1996), in which rapid inhibition and disinhibition of vagal tone to the heart can rapidly calm or mobilize an individual. Moreover, the myelinated vagus actively counteracts the sympathetic nervous system's influences on the heart and dampens hypothalamic pituitary adrenal (HPA) axis activity (see Porges, 2001). **The vagal brake has the capacity to modulate visceral state, especially the sympathetic nervous system reactions that frequently accompany empathy. Functionally, regulation of the vagal brake contains autonomic reactivity from moving into a range that supports defensive behaviors.** Thus, the vagal brake and enables the individual to rapidly engage and disengage with objects and other individuals, while maintaining a physiological resource that is capable of promoting self-soothing behaviors and calm states. Ancient rituals, employing breath, posture, and vocalizations, actively recruit and exercise the vagal brake to down regulate defensive biases and to enhance positive engagement of others with feelings of compassion.

The Face–Heart Connection: The Emergence of the Social Engagement System

When the individual feels safe, two important features are expressed. First, bodily state is regulated in an efficient manner to promote growth and restoration (e.g., visceral homeostasis). This is accomplished through an increase in the influence of myelinated vagal motor pathways on the cardiac pacemaker to slow heart rate, inhibit the fight-or-flight mechanisms of the sympathetic nervous system, dampen the stress response system of the hypothalamic–pituitary–adrenal axis (e.g., cortisol), and reduce inflammation by modulating immune reactions (e.g., cytokines). **Second, through the process of evolution, the brainstem nuclei that regulate the myelinated vagus became integrated with the nuclei that regulate the muscles of the face and head via special visceral efferent (motor) pathways.** These emergent changes in **neuroanatomy provide a face–heart connection in which there are mutual interactions between the vagal influences to the heart and the neural regulation of the striated muscles of the face and head.** The phylogenetically novel face–heart connection provided mammals with an ability to convey physiological state via facial expression and prosody (intonation of voice), enabling facial expression and voice to calm physiological state (Porges, 2011; Porges & Lewis, 2010; Stewart et al., 2013).

The face–heart connection enables mammals to detect whether a conspecific is in a calm physiological state and ‘safe’ to approach, or is in a highly mobilized and reactive physiological state during which engagement would be dangerous. The face–heart connection concurrently enables an individual to signal ‘safety’ through patterns of facial expression and vocal intonation, and potentially calm an agitated conspecific to form a social relationship. **When the newer mammalian vagus is optimally functioning in social interactions (i.e., inhibiting and containing the sympathetic excitation that promotes fight-or-flight behaviors), emotions are well regulated, vocal prosody is rich, and the autonomic state supports calm spontaneous social engagement behaviors. The face–heart system is bidirectional with the newer myelinated vagal circuit influencing social interactions and positive social interactions influencing vagal function to optimize health, dampen stress-related physiological states, and support growth and restoration.**

Social communication and the ability to co-regulate another, via reciprocal Social Engagement Systems, leads to a sense of connectedness, which is a defining feature of the human experience.

The Polyvagal Theory proposes that physiological state is a fundamental part, and not a correlate, of emotion and mood. The theory emphasizes a bidirectional link between brain and viscera, which would explain both how thoughts can change our physiology, and how physiological state influences our thoughts. Thus, the initiation of contemplative practices is dependent on physiological state and through the mental process defining contemplative practices, influences physiological state. As individuals change their facial expressions, the intonation of their voices, the pattern in which they are breathing, and their posture, they are also changing their physiology primarily through manipulating the function of the myelinated vagus to the heart.

Regulating physiological state through the myelinated vagus is an implicit underlying principle of contemplative practices. However, contemplative practices, by directly exercising the vagal regulation of state, co-opt the need for social interactions to reflexively calm (see neuroception below) and expand the sense of connectedness from a proximal social network to an unbounded sense of oneness. Neurophysiologically, the rituals involved in contemplative practices elicit the same neural circuits that evolved with mammals to signal safety. Through our phylogenetic history these signals were usually emitted by the mother to calm her vulnerable infant. Thus, the metaphor of the mother calming the child is neurophysiologically embedded in contemplative training and practices and is frequently used in various spiritual narratives.

As we learn more about the face-heart connection, we are informed that contemplative practices may recruit this system to obtain states of calmness. This is initially accomplished sequentially, first through the passive pathway detecting features of safety in the context in which contemplative practices are typically experienced, and then through a voluntary pathway (i.e., neural exercises) that use efficient and reliable behavioral manipulations (e.g., breath, vocalization, posture) that we know as rituals.

The Social Engagement System: A system that expresses and acknowledges emotion.

The phylogenic origin of the behaviors associated with the Social Engagement System is intertwined with the phylogeny of the autonomic nervous system. As the muscles of the face and head emerged as social engagement structures, a new component of the autonomic nervous system (i.e., a myelinated vagus) evolved that was regulated by the nucleus ambiguus. This convergence of neural mechanisms produced an integrated Social Engagement System with synergistic behavioral (i.e., somatomotor) and visceral components, as well as interactions among ingestion, state regulation, and social engagement processes. The neural pathways originating in several cranial nerves that regulate the striated muscles of the face and head (i.e., special visceral efferent pathways) and the myelinated vagal fibers form the neural substrate of the Social Engagement System (see Porges, 1998, 2001, 2003).

Insert Figure 1 about here

As illustrated in Figure 1, the somatomotor component includes the neural structures involved in social and emotional behaviors. Special visceral efferent nerves innervate striated muscles, which regulate the structures derived during embryology from the ancient gill arches (Truex and Carpenter, 1969). **The Social Engagement System has a control component in the cortex (i.e., upper motor neurons) that regulates brainstem nuclei (i.e., lower motor neurons) to control eyelid opening (i.e., looking), facial muscles (e.g., emotional expression), middle ear muscles (e.g., extracting human voice from background noise), muscles of mastication (e.g., ingestion), laryngeal and pharyngeal muscles (e.g., prosody and intonation), and head turning muscles (e.g., social gesture and orientation).** Collectively, these muscles function both as determinants of engagement with the social environment and as filters that limit social stimuli. The neural pathway involved in raising the eyelids (i.e., facial nerve) also tenses the stapedius muscle in the middle ear, which facilitates hearing human voice. Thus, the neural mechanisms for making eye contact are shared with those needed to listen to human voice. As a cluster, poor eye gaze, difficulties extracting of human voice from background sounds, blunted facial expression, minimal head gesture, limited vocal prosody, and poor state regulation are common features of individuals with autism and other psychiatric disorders.

Afferents from the target organs of the Social Engagement System, including the muscles of the face and head, provide potent input to the source nuclei in the brainstem regulating both the visceral and somatic components of the Social Engagement System. Thus, activation of the somatomotor component (e.g., listening, ingestion, lifting eyelids) could trigger visceral changes that would support social engagement, while modulation of visceral state, depending on whether there is an increase or decrease in the influence of the myelinated vagal efferents on the sinoatrial node (i.e., increasing or decreasing the influence of the vagal brake), would either promote or impede social engagement behaviors. For example, stimulation of visceral states that promote mobilization (i.e., fight or flight behaviors) will impede the ability to express social engagement behaviors.

Contemplative practices and the Social Engagement System

The pathways defining the Social Engagement System enable many of the processes associated with contemplative practices (e.g., listening, chanting, breathing, shifting posture during prayer, and facial expressivity) to influence physiological state via a myelinated branch of the vagus. The passive pathway recruits the Social Engagement System (including the myelinated ventral vagus) through the cues of safety, such as a quiet environment and the presentation prosodic vocalizations (e.g., chants) in the frequency band that would overlap with the vocal signals of safety that a mother uses to signal safety to her infant. In male dominated religious practices, where females are not available to provide the vocal signals of safety, female-like voices are produced by boy choirs and, historically, by castrato soloists to promote feelings of spirituality.

Shifts in breathing pattern are perhaps the most accessible potent manipulations of the output of the myelinated vagus. Research documents that respiration gates the influence of the vagus on the heart (see Eckberg, 2003). **The vagal inhibition of the heart's pacemaker is potentiated**

during exhalation and dampened during inhalation. Thus, both the duration of exhalation and the inhalation/exhalation ratio are critical in manipulating the functional ‘calming’ of the vagus on the heart. Rituals such as chants require extending the duration of the exhalation relative to the inhalation. Moreover, as the phrases of the chants become longer, the parameters of breathing spontaneously adjust to provide a sufficient volume of air, and breathing movements expand from the chest towards the abdomen. With abdominal or belly breathing the diaphragm is actively pushed downward. This action stimulates vagal afferents, which functionally influence the vagal outflow to the heart. As described in Table 1, the manipulation of breathing during chants and meditation provide a potent mechanism to regulate vagal efferent activity. Thus, in these rituals, breathing strategies optimize and exercise the vagal influence on the heart.

Chants and other forms of vocalizations are frequent features of contemplative practices. These processes require active manipulation of not only of breathing, but also recruit additional components of the Social Engagement System. For example, chants require the production and the monitoring of sounds, while regulating breath. The modulation of vocalizations requires the active involvement of neural regulation of laryngeal and pharyngeal muscles (see Figure 1) to change pitch and to regulate resonance. Breath is critical, since the acoustic features of vocalizations are a product of a controlled expiration, which passes air at a sufficient velocity across structures in the larynx to produce sounds.

Successful social communication via vocalizations requires rapid adjustments in both the production and detection of vocalizations. This process requires a complex feedback loop that informs brain areas of acoustic properties conveying cues of safety or danger (see neuroception below). The cues result in dynamic adjustments in the transfer function of middle ear structures via cranial nerves to enhance or dampen the loudness of sounds within the frequency band in which social communication occurs. Without sufficient neural tone to the middle ear muscles, the sounds of human vocalizations will be lost in the low frequency background noise that characterizes our environment.

Virtually all the neural pathways involved in the Social Engagement System (see Figure 1) are recruited and coordinated while chanting. This would include the regulation of muscles of the mouth, face, neck, middle ear, larynx, and pharynx. Thus, chanting may provide an efficient ‘active pathway’ to recruit and exercise several features of the Social Engagement System, while promoting a calm state through the myelinated ventral vagal pathway.

Rituals often involve voluntary posture shifts. Posture shifts influence blood pressure receptors known as baroreceptors. Baroreceptors send signals to the brainstem that will either increase heart rate by down regulating vagal efferent output (and often stimulate sympathetic output) or decrease heart rate by increasing vagal efferent output. Manipulating posture functions as an efficient voluntary method to shift physiological state, often enabling a visceral feeling of activation (due to a transitory withdrawal of the myelinated ventral vagus) that is rapidly followed by calming (due to a re-engagement of the myelinated ventral vagus).

Functionally, rituals provide, as a complementary alternative to social engagement behaviors, an opportunity to use voluntary behaviors to regulate and exercise several neural pathways involved in the Social Engagement System. As an individual becomes more proficient with the rituals, the autonomic nervous system becomes more resilient and exhibits a greater capacity to down regulate defense and to support states that promote health, social behavior, and compassion.

Consistent with the Polyvagal Theory, effective contemplative practices can only occur during states experienced as safe. Only in safe states are neurobiological defense strategies inhibited and emotional reactivity contained. Thus, a key to successful contemplative training would be to conduct contemplative exercises in an environment that supports feelings of safety. This step is mediated through the ‘passive’ pathway, which simultaneously down-regulates the involuntary defense subsystems and potentiates the physiological state associated with the evolutionarily newer Social Engagement System. Functionally, during contemplative training, the rituals involving breath, posture, and vocalizations provide, through an active pathway, “neural” exercises of circuits involving structures described in the Social Engagement System. As these neural exercises enhance the efficiency and reliability of the neural pathways inhibiting defense systems, the individual acquires a greater accessibility to feelings of safety, openness, and connectedness, which are explored during contemplative practices and are antecedent states for compassion.

The processes and mechanisms involved in exercising the ‘active’ pathway are explained above. To understand how the ‘passive’ pathway is recruited, it is necessary to understand two additional features of the Polyvagal Theory: dissolution and neuroception. First, through the process of ‘dissolution’ (see below), the theory describes autonomic reactivity as a phylogenetically organized response hierarchy in which evolutionarily newer circuits inhibit older circuits. Dissolution explains how specific autonomic states have the capacity to support either defensive or calm behaviors. Moreover, the autonomic state that supports calm behavior also has the capacity to actively down-regulate reactivity and defense. Thus, it is not sufficient for an individual to solely abstain from defensive behaviors. The individual must also be in an autonomic state that is incompatible with defensive behaviors. Second, through the process of ‘neuroception’ (see below), context can influence autonomic state. Neuroception is a complex neural process that evaluates risk in the environment independent of cognitive awareness. Neuroception detects risk from sensory patterns in the environment and reflexively shifts autonomic state to either support defense or safe interactions. Neuroception provides the clues to understand how the passive pathway is elicited. Dissolution provides an understanding of the emergent hierarchical relationship among the components of the autonomic nervous system that are related to resilience and vulnerability.

Dissolution

The three circuits defined by the Polyvagal Theory are organized and respond to challenges in a phylogenetically determined hierarchy consistent with the Jacksonian principle of dissolution. Jackson proposed that in the brain, higher (i.e., phylogenetically newer) neural circuits inhibit lower (i.e., phylogenetically older) neural circuits and “when the higher are suddenly rendered

functionless, the lower rise in activity'' (Jackson 1884). Although Jackson proposed dissolution to explain changes in brain function due to damage and illness, Polyvagal Theory proposes a similar phylogenetically ordered hierarchical model to describe the sequence of autonomic response strategies to challenges.

The human nervous system, similar to that of other mammals, evolved not solely to survive in safe environments but also to promote survival in dangerous and life-threatening contexts. To accomplish this adaptive flexibility, the mammalian autonomic nervous system, in addition to the myelinated vagal pathway that is integrated into the Social Engagement System, retained two more primitive neural circuits to regulate defensive strategies (i.e., fight–flight and death-feigning behaviors). **It is important to note that social behavior, social communication, and visceral homeostasis are incompatible with the neurophysiological states that support defense.** Thus, via evolution, the human nervous system retains three neural circuits, consistent with the Jacksonian principle of dissolution, that are in a **phylogenetically organized hierarchy**. In this **hierarchy of adaptive responses**, the newest circuit is used first; if that circuit fails to provide safety, the older circuits are recruited sequentially. From a contemplative practice perspective, it is necessary to recruit the phylogenetically newest circuit that down regulates defense and involves the Social Engagement System and the myelinated vagus.

As described above, via the active pathway, rituals exercise the integrated Social Engagement System including the myelinated vagus. However, before rituals can function as efficient neural exercises, the individual must be in a calm and safe physiological state. Only in this state is the active pathway available and not in conflict with adaptive defense reactions. Thus, an understanding of how to regulate the passive pathway to maintain a calm physiological state is the initial and most critical step leading to subjective experiences related to compassion and a universal connectedness. Neuroception provides the insight into the mechanisms that enable or disable the passive pathway.

Neuroception

To effectively switch from defensive to social engagement strategies, the mammalian nervous system needs to perform two important adaptive tasks: (1) assess risk, and (2) if the environment is safe, inhibit the more primitive limbic structures involved in fight, flight, or immobilization (e.g., death feigning) behaviors. **Any stimulus that has the potential for signaling cues of safety has the potential to recruit an evolutionarily more advanced neural circuit that promotes calm behavioral states and supports the prosocial behaviors of the Social Engagement System.**

The nervous system, through the processing of sensory information from the environment and from the viscera, continuously evaluates risk. Polyvagal Theory proposes that the neural evaluation of risk does not require conscious awareness and functions through neural circuits that are shared with our phylogenetic ancestors. Thus, the term neuroception (Porges 2004) was introduced to emphasize a neural process, distinct from perception, which is capable of distinguishing environmental (and visceral) features that are safe, dangerous, or life-threatening. In safe environments, autonomic state is adaptively regulated to dampen sympathetic activation

and to protect the oxygen-dependent central nervous system, especially the cortex, from the metabolically conservative reactions of the dorsal vagal complex (e.g., fainting).

Neuroception mediates both the expression and the disruption of positive social behavior, emotion regulation, and visceral homeostasis (Porges 2007, Porges 2004). **Neuroception might be triggered by feature detectors involving areas of temporal cortex that communicate with the central nucleus of the amygdala and the periaqueductal gray, since limbic reactivity is modulated by temporal cortex responses to biological movements including voices, faces, and hand gestures (Ghazanfar, 2005; Pelphey et al., 2005). Embedded in the construct of neuroception is the capacity of the nervous system to react to the ‘intention’ of these movements and sounds.** ←

Neuroception functionally decodes and interprets the assumed goal of movements and sounds of animate and inanimate objects. This process occurs without awareness. **Although we are often unaware of the stimuli that trigger different neuroceptive responses, we are aware of our body’s reactions.** Thus, the neuroception of familiar individuals and individuals with appropriately prosodic voices and warm, expressive faces translates into a positive social interaction promoting a sense of safety.

In most situations the ‘passive pathway’ is activated during social interactions by identifiable social engagement features including prosodic vocalizations, gestures, and facial expressions. However, within the proposed model, the passive pathway is recruited via exposure to the physical characteristics of the context in which contemplative training will occur. History helps identify and describe optimal contexts. Contemplative training and practice often occur in structures with physical features that functionally remove background sounds. This contextual feature is similar to silent retreats, in which the passive triggering of “safety” is shifted from social interactions to context. In the silent retreat the removal of distracters, including the inhibition of potential social engagement via voice, enables the body to move from either a state of hypervigilance or a state of reciprocal interaction to a state of calmness.

Historically, structures subjectively experienced as safe were often constructed with heavy durable materials such as stone (e.g., ancient temples). **The fortress attribute supports contemplative practices through two domains: 1) protection from others when in the physically vulnerable state associated with contemplative practices; and 2) reduction of sensory cues of danger by attenuating low frequency sounds associated with predator and limiting distracting visual cues.** In addition, the stone surfaces provided an acoustic environment in which vocalizations could be heard without effort and the acoustic characteristics are enhanced by echoes that may resonate with parts of the body. As vocalizations became ritual chants (e.g., Gregorian and Buddhist chants) the harmonics of the chants would echo through the space and the acoustic energy would be interpreted as spiritual and healing. Physical features of these sanctuaries promote, through a passive pathway, feelings of safety and were often the contexts in which contemplative practices were taught and expressed. Thus, contemplative practices to be functional and to have positive outcomes, must be conducted during physiological states in which the autonomic nervous system is not supporting defense and in a context that do not elicit a neuroception of danger or life threat.

Regulating Autonomic State through passive and active pathways

Within Polyvagal Theory, social safeness is dependent on recruiting the ventral vagal pathways to foster a calm physiological state and maintain physiological and behavioral resilience.

Consistent with compassion-focused therapy (Gilbert, 2009), the recruitment of a social safeness system is a prerequisite for experiencing or expressing compassion. Neuroception describes the 'passive' pathway to recruit this state. Neuroception is the initial step to feel safe in a safe environment. A neuroception of safety shifts biobehavioral state by increasing the influence of both the ventral vagus on the heart and the special visceral efferent pathways regulating the striated muscles of the face and head described in the Social Engagement System.

To experience a state of safety, the contextual cues in the environment have to elicit, via neuroception, the ventral vagal pathways that actively down-regulate autonomic defense systems mediated by the sympathetic nervous system and the dorsal vagus. Feeling safe requires two complementary features. First states of hypervigilance are reduced by removing cues of distraction and potential predators. In general, the focus is on auditory and visual cues, since our nervous system is hardwired to interpret the intentionality of movements and sounds. Low frequency sounds are hardwired cues of predator and potential life threat. High frequency sounds are hardwired cues of danger (see Porges & Lewis, 2010). Since our nervous system continuously attempts to interpret the intention of movements, removal of visual distracters enables individuals to shift from hypervigilance to calmness.

Removal of cues of danger is not sufficient for everyone to feel safe. Some people experience quiet space as restful and spiritual, while others become anxious and hypervigilant. To insure a neuroception of safety, the individual must process additional sensory features in the environment. This is most reliably accomplished through the use of acoustic stimulation that is modulated in the frequency band of a mother's lullaby. Functionally, humans are hardwired to be calmed by the modulation of the human voice (Porges & Lewis, 2010).

The acoustic features for calming infants are universal and have been repurposed by classical composers in music (Porges, 2008). Composers implicitly understood that they could lull the audience into a state of safety (i.e., via neuroception) by constructing melodic themes that duplicated the vocal range of a mother soothing her infant, while limiting the contribution of instruments that contributed low frequency sounds. The acoustic structure of liturgical vocal music follows a similar convention by minimizing low frequency sounds and emphasizing voices in the range of the nurturing mother calming her infant.

A large pipe organ, generating low frequency tones, triggers a feeling of awe and not safety. The low tones of an organ have acoustic features that overlap with our hardwired reactions of immobilization to predator. Thus, loud low tones from a pipe organ could potentially disrupt the passive pathway and interfere with the state of safety required to experience compassion and a connectedness with other. However the presentation of low frequency tones within a confined environment may trigger a sense of submission that could be associated with psychological feelings of surrendering to a deity.

Once the passive pathway effectively shifts physiological state, the second step can be initiated. The second step, exercising the vagal brake, recruits the 'active' (voluntary) pathway through rituals requiring manipulations of breath, posture, and vocalizations. These manipulations of the vagal brake exercise the inhibitory influence of the vagus on the heart as an efficient calming mechanism. Neurophysiologically, the vagus functions as a brake on the heart's pacemaker resulting in the heart beating at a rate substantially slower than the intrinsic rate of the pacemaker.

Breathing is an efficient and easily accessible voluntary behavior to systematically reduce and increase the influence of the vagus on the heart. More than a hundred years ago, Hering (1910) reported that the cardioinhibitory vagal pathways had a respiratory rhythm that reflected the dynamic adjustment of the vagal control of the heart. Further articulation of this phenomenon was summarized as a "respiratory gate" by Eckberg (2003), who emphasized the enhancement of the vagal influences on the heart during exhalation and the dampening of vagal influences on the heart during inhalation. Many rituals require breathing pattern shifts. Perhaps, the most obvious are chants and other forms of vocalizations, which manipulate the respiratory gate by expanding the duration of exhalation and reducing the duration of inspiration. Other rituals involving prayer and meditation may also influence vagal regulation through posture shifts, which trigger baroreceptors (blood pressure receptors) to adjust blood flow to the brain. This process involves systematic changes in vagal regulation of the heart to avoid dizziness and fainting (e.g., vasovagal syncope).

Insert Table 2 about here

As described in Table 2, Polyvagal Theory explains how the manipulation of vagal pathways are involved in the foundational processes upon which contemplative training and practice are based. These processes require two pathways (passive and active) to regulate autonomic state and lead to a physiological state, which would enable feelings of safety and compassion to be felt and expressed. Involving the two pathways to regulate physiological state is a prerequisite for effective contemplative practices (e.g., meditation). The two pathways function sequentially. Thus, once in a physiological state that supports feelings of safety, successful training would result in a resilient autonomic nervous system that would acknowledge without mirroring the emotional reactivity and pain often expressed by those who are suffering.

If the passive pathway does not enable the person to be in a calm ventral vagal state, then the active pathway, rather than being an enabler of compassion, may trigger defensiveness. If an individual engages in the active pathway in a vulnerable physiological state (during either down regulated ventral vagal influences or up regulated sympathetic influences), then exercising the vagal brake may create a transitory state of vulnerability. This would occur when the 'neural exercises' associated with the active pathway withdraw the vagal brake (e.g., during inspiration while meditating or chanting) and trigger a sympathetic excitation sufficient to support fight/flight behaviors.

Summary

In this chapter a multistep sequential model is proposed that would optimize the effects of contemplative training leading to a greater capacity to feel and express compassion. The model includes: 1) a ‘passive’ pathway that is elicited by feeling safe in an environment that provides sensory cues that, via neuroception, down regulate defense, 2) an ‘active’ pathway that is implement via voluntary behaviors (i.e., neural exercises of the vagal brake) capable of establishing a ‘calm’ neural platform (i.e., ventral vagal state) that would functionally optimize contemplative practices, 3) extensive contemplative training, and 4) the emergent properties of contemplative practices including the capacity to experience and express compassion.

The objective of this chapter is to propose that the capacity to experience and express compassion is dependent on a physiological state mediated by myelinated vagal pathways originating in brainstem. Thus, within this model, the capacity to experience and express compassion is predicated on successful implementation of antecedent steps that recruit and exercise the vagal brake. Underlying this objective are several plausible assumptions and testable hypotheses: 1) Autonomic state is critical to experiencing and expressing compassion; 2) The ‘passive’ pathway, through neuroception, can recruit ventral vagal pathways and features of the Social Engagement System to shift autonomic state sufficiently to facilitate the effectiveness of rituals, as neural exercises, in enhancing autonomic regulation; 3) The ‘active’ pathway, through the efficient use of rituals, exercises vagal regulation of autonomic state to optimize health and resilience; and 4) The efficient use of rituals promotes a physiological state in which the outcomes of contemplative training are optimized. Thus, an appreciation of physiological state, as an important prerequisite for compassion, may result in more efficient and positive outcomes of practices, including compassion-focused therapy, leading to enhanced compassion.

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Figure Caption

Figure 1. **The Social Engagement System.** The Social Engagement System consists of a somatomotor component (i.e., special visceral efferent pathways that regulate the striated muscles of the face and head) and a visceromotor component (i.e., the myelinated vagus that regulates the heart and bronchi). Solid blocks indicate the somatomotor component. Dashed blocks indicate the visceromotor component.

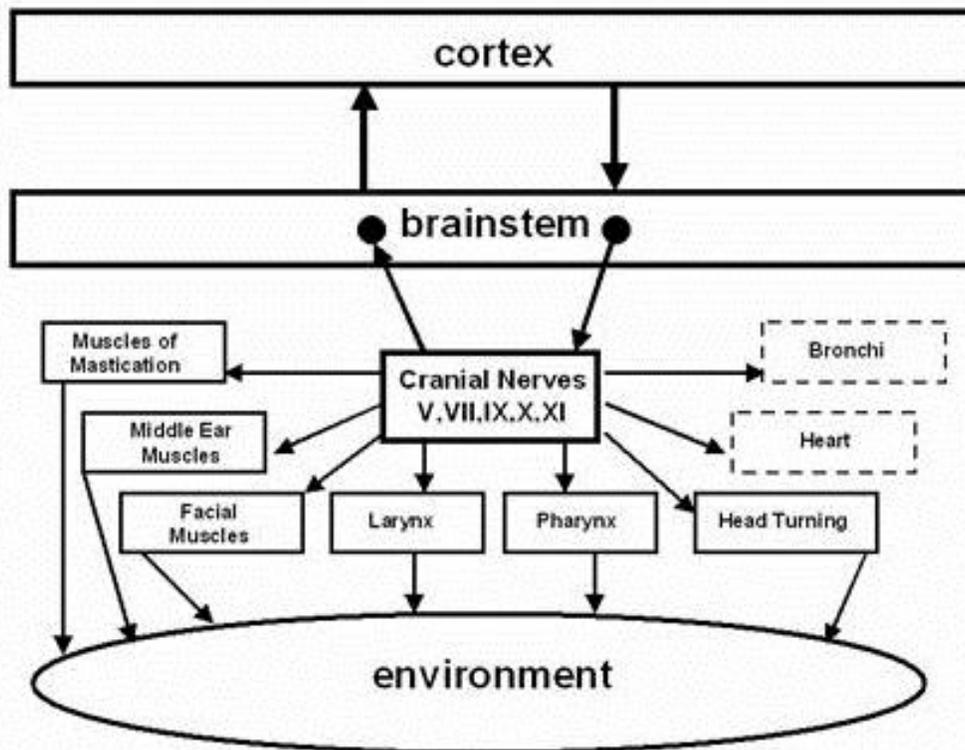


Table 1. The physiology of rituals.

The Physiology of Rituals

Ritual	Vagal Mechanism
Chants (vocalizations)	<ul style="list-style-type: none">• Laryngeal nerves• Pharyngeal nerves• Respiration (long exhalation and deep abdominal inhalation enhance vagal 'brake')
Meditation (breath)	<ul style="list-style-type: none">• Respiration (long exhalation and deep abdominal inhalation enhance the vagal 'brake')
Prayer (posture)	<ul style="list-style-type: none">• Carotid baroreceptors (vagal contribution to blood pressure regulation)

Table 2. Steps to Compassion

Steps to Compassion

Step	Polyvagal Process
1. Experience safe context (recruit passive pathway)	<ul style="list-style-type: none"> • Neuroception of safety <ul style="list-style-type: none"> • Remove predator cues • Add acoustic cues of a loving mother
2. Perform Rituals (recruit active pathway)	<ul style="list-style-type: none"> • Exercise vagal brake to enhance autonomic flexibility and resilience
3. Contemplative training (e.g., meditation)	<ul style="list-style-type: none"> • Mental exercises involving brain functions that are dependent on maintaining 'ventral' vagal state
4. Experiencing compassion and a sense of oneness	<ul style="list-style-type: none"> • Emergent property of higher brain processes, while maintaining a 'ventral' vagal state