CHAPTER 20

Polyvagal Theory and the Social Engagement System

Neurophysiological Bridge Between Connectedness and Health

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The Polyvagal Theory helps us understand how cues of risk and safety, continuously monitored by our nervous system, influence physiological and behavioral states. The theory emphasizes the human quest to calm neural defense systems by detecting features of safety.

S.W. Porges, "Making the World Safe for Our Children"
(Porges 2015)

We wish to thank Dr. Patricia L. Gerbarg for assisting in the preparation of this chapter.

Polyvagal Theory: Neural Mechanisms That Mediate Effects of Mind-Body Treatments

Polyvagal theory is a reconceptualization of how autonomic state and behavior are intertwined (Porges 1995, 2007, 2011). Body practices within complementary, alternative, and integrative medicine (CAIM) involve active behaviors, which exercise neural regulation of the autonomic nervous system and are facilitated by procedures that conform to our quest to feel safe. This quest may be conceptualized as a core biological imperative that underlies the actions of mental, physical, and neurophysiological processes.

Polyvagal theory explains how cues of risk and safety promote states of safety and calmness or states of defense. The theory shows how features of mind-body therapies trigger physiological states that calm neural defense systems, improve mental and physical health, and support feelings of safety and connectedness with others. Polyvagal theory proposes that physiological state is a fundamental part, not a correlate, of emotion and mood. The theory emphasizes a bidirectional link between brain and viscera, which would explain how thoughts and emotions can change our physiological state and how our physiological state influences our thoughts and emotions.

The human nervous system provides two paths to trigger neural mechanisms capable of downregulating defense and enabling states of calmness that support health, spontaneous social behavior, and connectedness. One path is *passive* and does not require conscious awareness (see the subsection "Neuroception" later in the chapter), and the other is *active* and requires *conscious voluntary behaviors* to trigger specific neural mechanisms that change physiological state. Positive patient-therapist interactions recruit the passive pathway (Geller and Porges 2014). This involves the therapist's ability to use positive facial expressions and to speak in a prosodic voice that conveys benevolent feelings of concern toward the patient. The calming of the patient through social engagement is supplemented by the features of the clinical context in which the treatment is delivered, such as a quiet space secure from intrusion, a comfortable chair, or soothing music. Both the animate features of the therapist's engagement and the inanimate features of the clinical context trigger the passive pathway to promote the physiological state associated with feeling safe. Mind-body practices recruit the active pathway by performing voluntary behaviors such as voluntarily regulated breathing practices, movements and postures (e.g., yoga, qigong, tai chi), and vocalizations (e.g., sounds, chants, songs) that exercise the neural circuits that promote neurophysiological states supporting health. These volitional behaviors, which are part of mind-body practices, are directly wired into vagal circuits that efficiently alter the physiological state (see the subsection "Polyvagal Theory: Overview" later in this chapter).

The Role of the Vagus Nerves in Bidirectional Brain-Body Communication

During the phylogenetic transition from ancient reptiles to mammals, the autonomic nervous system changed. In primitive reptiles, the autonomic nervous system regulated bodily organs via two subsystems: the sympathetic nervous system and the parasympathetic nervous system. The sympathetic nervous system provided the neural pathways for visceral changes that support fight-or-flight behaviors. This physiological adjustment to support mobilization was associated with increases in heart rate and inhibition of digestive processes, which required suppression of parasympathetic (i.e., vagal) influences to the heart and the gut. Complementing the sympathetic nervous system, the reptilian parasympathetic nervous system serves two functions. First, when not recruited as a defense system, it supports processes of health, growth, and restoration. Second, when recruited as a defense system, the parasympathetic nervous system reduces metabolic activity by dampening heart rate and respiration, enabling immobilized reptiles to appear inanimate to potential predators. When reptiles are not under threat, the two components of the autonomic nervous system function antagonistically to innervate several of the body organs to coordinate bodily functions. This synergism between the sympathetic and the parasympathetic nervous systems 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. Polyvagal theory considers being safe as a biobehavioral state determined by the nervous system, often independent of awareness and actual threat. Thus, removal of threat may not change physiological state or enable an individual to feel safe.

Most of the neural pathways of the parasympathetic nervous system travel through the vagus nerves, the large tenth cranial nerves that originate in the brain stem and provide a bidirectional connection between visceral organs and the brain. The vagus contains motor fibers that regulate the function of visceral organs and sensory fibers that 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 plausible neural basis for a mind-body science and a brain-body medicine by providing bodily portals of intervention to correct brain dysfunction through peripheral vagal stimulation (e.g., electronic vagal nerve stimulation for treatment of epilepsy or depression) and plausible explanations for exacerbation of physical 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 within physiology and medicine, such as Walter Cannon's homeostasis (Cannon 1932) and Claude Bernard's internal milieu (Bernard 1872).

Polyvagal Theory: Overview

Polyvagal theory emphasizes a hierarchical relation among components of the autonomic nervous system that evolved to support adaptive behaviors in response to environmental conditions of safety, danger, and life threat (Porges 2011). The theory is named *polyvagal* to highlight the existence of two vagal circuits: an ancient vagal circuit associated with "immobilization" defense and a phylogenetically newer circuit related to feeling safe and engaging in spontaneous social behavior. The theory articulates two defense systems: 1) the commonly known fight-or-flight system associated

with activation of the sympathetic nervous system and 2) a lesser-known system of immobilization and dissociation associated with activation of a phylogenetically more ancient vagal pathway.

Polyvagal theory describes the neural mechanisms through which physiological states communicate feelings of safety and threat to oneself and to others. Bodily feelings contribute to an individual's capacity either to feel safe and spontaneously engage with others or to feel threatened and recruit defensive strategies. The theory explains how each of three phylogenetic stages, during the development of the vertebrate autonomic nervous system, is associated with a distinct and measurable autonomic subsystem. Each of these three subsystems remains active and is expressed in humans under certain conditions (Porges 2009). The three autonomic subsystems are phylogenetically ordered and behaviorally linked to three global adaptive domains of behavior: 1) social communication (facial expression, vocalization, listening), 2) defensive strategies associated with mobilization (fight-or-flight behaviors), and 3) defensive immobilization (feigning death, vasovagal syncope, behavioral shutdown, dissociation). On the basis of their phylogenetic emergence during the evolution of the vertebrate autonomic nervous system, these neuroanatomically based subsystems form a response hierarchy.

Most of the neural fibers in the vagus are sensory (approximately 80% of the total fibers); however, most scientific interest has been directed to the motor fibers that regulate the visceral organs, including the heart and the gut. Of these motor fibers, only about 15% are myelinated (approximately 3% of the total vagal fibers). Myelin, a fatty coating over the neural fiber, is associated with 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 and other mammals have two functionally distinct vagal circuits. One vagal circuit is phylogenetically older and unmyelinated. It originates in a brain stem area called the dorsal motor nucleus of the vagus. The other vagal circuit is uniquely mammalian and myelinated. It originates in the brain stem area nucleus ambiguus. The phylogenetically older unmyelinated vagal motor pathways are shared with most vertebrates and, when not recruited as a defense system, function to support health, growth, and restoration via neural regulation of subdiaphragmatic organs (internal organs below the diaphragm). The "newer" myelinated vagal motor pathways, found only in mammals, regulate the supradiaphragmatic organs (heart and lungs). This newer vagal circuit, which slows heart rate and supports states of calmness, mediates the physiological state necessary for mind-body treatments to have positive effects.

The Vagal Brake

Through evolution, the primary vagal regulation of the heart shifted in mammals from unmyelinated pathways to include myelinated pathways. Because the nucleus ambiguus is ventral to the dorsal motor nucleus, the regulation of myelinated vagal pathways to the heart is frequently included as part of a ventral vagal complex. The myelinated vagus functions as a brake on the heart's pacemaker, resulting in a substantially slower heart rate than the intrinsic rate of the pacemaker. Thus, the myelinated vagus via rapid inhibition and disinhibition of the pacemaker can quickly calm or mobilize an individual. Consistent with the calming function, the myelinated vagus actively inhibits the influence of the sympathetic nervous system on the heart and dampens hypothalamic-pituitary-adrenal (HPA) axis activity (see Porges 2001). Thus, the vagal brake, by modulating visceral state, enables the individual to rapidly engage and disengage with objects and other individuals and to promote self-soothing behaviors and calm states.

Breathing is the only autonomic function that can be easily controlled voluntarily. Thus, it is an efficient, easily accessible voluntary behavior that regulates the vagal brake by reducing and increasing the influence of the vagus on the heart. Hering (1910) reported that cardioinhibitory vagal pathways had a respiratory rhythm that reflected dynamic adjustments of vagal control of the heart. More recently, this phenomenon was described as a "respiratory gate" by Eckberg (2003), who emphasized enhancement of vagal influences on the heart during exhalation and dampening of vagal cardiac influences during inhalation. Numerous mind-body practices involve shifts in voluntarily regulated breathing patterns (see Chapter 21, "Breathing Techniques in Psychiatric Treatment"). These include changes in the rate and depth of respiration; vocalizations such as sounds (e.g., "om"), chants, and songs; breath holds; and changes in the relative duration of inhalation and expiration, which manipulate the respiratory gate. Other practices, such as meditation, also affect breath patterns. Posture shifts, which trigger baroreceptors (blood pressure receptors) to adjust blood flow to the brain, also recruit systematic changes in vagal regulation of the heart to avoid dizziness and fainting (vasovagal syncope). These manipulations of the vagal brake exercise the inhibitory influence of the vagus on the heart as an efficient calming mechanism.

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

The face-heart connection enabled mammals to detect whether an animal of the same species was in a calm physiological state and "safe" to approach or in a highly mobilized and reactive physiological state during which engagement would be dangerous. The face-heart connection concurrently enabled an individual to signal "safety" through patterns of facial expression and vocal intonation, potentially calming an agitated conspecific to enable formation of a social relationship. When the newer mammalian vagus is optimally functioning in social interactions (inhibiting 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. Thus, it is highly advantageous to become adept at managing social interactions by using the "newer" mammalian vagus rather than the more limited options of recruiting the sympathetic nervous system to support fight-or-flight behaviors or the "older" vagus to support immobilization and death feigning.

The face-heart system is bidirectional such that the newer myelinated vagal circuit influences social interactions, and positive social interactions influence vagal function to optimize health, dampen stress-related physiological states, and support positive reciprocal social interactions. As individuals change facial expressions, the intonation of their voices, the pattern of breathing, and their posture, they are also changing their physiology through "neural exercises" affecting the influence of the myelinated vagus on the heart and state of mind.

When an individual feels safe, two important features are expressed. First, bodily state is regulated more efficiently to promote growth and restoration (visceral homeostasis). Functionally, 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 HPA axis (e.g., cortisol), and reduce inflammation by modulating immune reactions (e.g., cytokines). Second, through evolution, the brain stem nuclei that regulate the myelinated vagus became integrated with the nuclei that regulate the muscles of the face and head via special visceral efferent pathways. These neuroanatomical developments provide a face-heart connection involving mutual interactions between the vagal influences on 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 and Lewis 2010; Stewart et al. 2013). Social communication, employing the face-heart system for social engagement, provides a mechanism through which individuals can coregulate one another's behavior and physiology.

The Social Engagement System

The phylogenetic origin of 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, the myelinated vagus evolved and was regulated by the nucleus ambiguus. This convergence of neural mechanisms produced an integrated social engagement system with synergistic behavioral (somatomotor) and visceral components, as well as interactions between ingestion, state regulation, and social engagement. The neural pathways originating in several cranial nerves that regulate the striated muscles of the face and head (special visceral efferent pathways) and the myelinated vagal fibers form the neural substrate of the social engagement system (see Porges 1998, 2001, 2003). As illustrated in Figure 20–1, the somatomotor component includes the neural structures involved in social and emotional behaviors. Special visceral efferent nerves innervating striated muscles regulate structures derived from ancient gill arches (Truex and Carpenter 1969). The social engagement system has a motor control component in the cortex (upper motor neurons) that regulates brain stem nuclei (lower motor neurons) to control eyelid opening (looking), facial muscles (emotional expression), middle ear muscles (extracting human voice from background noise), muscles of mastication (ingestion), laryngeal and pharyngeal muscles (e.g., prosody, intonation), and head-turning muscles (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 (the 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 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.

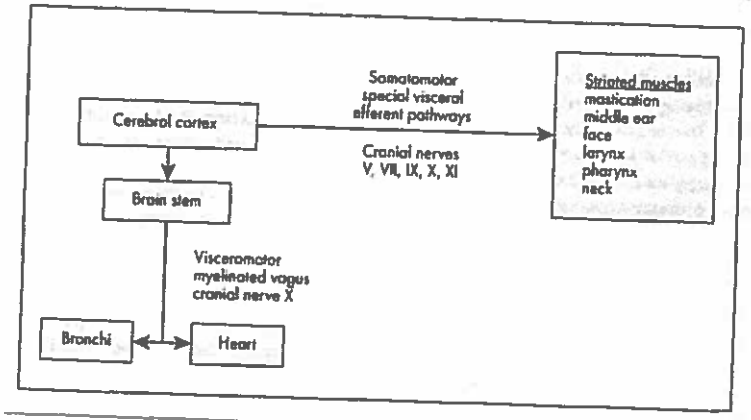

FIGURE 20–1. Motor pathways of the social engagement system.
The social engagement system includes a somatomotor component (special visceral efferent pathways that regulate the striated muscles of the face and head) and a visceromotor component (myelinated vagus that regulates the heart and bronchi).

Afferents from the target organs of the social engagement system, including the muscles of the face and head, provide potent input to the brain stem source nuclei regulating both visceral and somatic components of the social engagement system. Thus, activation of the somatomotor component (e.g., listening, ingestion, lifting eyelids) can influence the visceral state via myelinated vagal efferents to the sinoatrial node (increasing or decreasing the influence of the vagal brake). These changes in visceral state will either promote or impede social engagement behaviors. For example, reducing the influence of the vagal brake promotes mobilization (fight-or-flight behaviors), which impedes expression of social engagement behaviors. Conversely, increasing the influence of the vagal brake promotes spontaneous social engagement behaviors and feelings of safety and trust.

Recruiting Active and Passive Pathways

The pathways defining the social engagement system enable the effects of mind-body practices (e.g., vocalizing, breathing practices, shifting postures, movements) to influ-

ence the physiological state via myelinated pathways within the vagus. Features of the social engagement system are recruited by passive and active pathways. The passive pathway recruits the social engagement system through cues of safety such as a quiet environment, positive and compassionate therapist-patient interactions, prosodic quality (e.g., melodic intonation) of the therapist's vocalizations, and music modulated across frequency bands that overlap with vocal signals of safety used by a mother to calm her infant. Successful therapists, regardless of their orientation, often intuitively manipulate the passive pathway in treatment. In contrast, the active pathway recruits the social engagement system when the patient engages in mind-body practices, such as vocalizations, voluntarily controlled breathing practices, movements, or postures.

Perhaps the most potent method for influencing the myelinated vagus is through voluntarily controlled breathing practices. Research documents that breathing gates the influence of the myelinated vagus on the heart (see Eckberg 2003). Vagal efferent inhibition of the heart's pacemaker is potentiated during exhalation and dampened during inhalation. Thus, although several therapeutic techniques (e.g., dialectical behavior therapy, cognitive-behavioral therapy) involve slow breathing, calming is a function of breath rate and inhalation-to-exhalation ratio. Techniques that slow breathing and expand the duration of exhalation relative to inhalation enhance the inhibitory effect of the vagus on the heart. This strategy of prolonging exhalation relative to inhalation is embedded in certain breathing practices, chants, and singing. Moreover, as the phrases of vocalizations become longer, breathing becomes slower and deeper. Breathing movements expand from the chest toward the abdomen in order to inhale a sufficient volume of air. With abdominal or belly breathing, the diaphragm must be pushed downward, stimulating vagal afferents and functionally influencing the vagal outflow to the heart. Similarly, modulation of breathing during chants and meditation provides a potent mechanism to regulate and exercise vagal efferent influence on the heart.

Vocalizations, including chanting and singing, and playing a wind instrument may be conceptualized as CAIM treatments that require not only active manipulation of breathing but also recruitment of additional components of the social engagement system. For example, chants require production and monitoring of sounds while regulating breath. Modulation of vocalizations requires the active involvement of laryngeal and pharyngeal nerves (see Figure 20–1) to change pitch and to regulate resonance. Breath is critical because the sounds are produced by controlled expiration passing air at a sufficient velocity across structures in the larynx. Moreover, control of vocalizations requires monitoring of acoustic properties via middle ear structures. Without sufficient neural tone to the middle ear muscles, the sounds of human vocalizations will be lost in the background of low-frequency sounds. Playing a wind instrument could be conceptualized as a CAIM treatment because it involves listening and voluntary control of breathing and of muscles of the face and mouth. Thus, virtually all the neural pathways involved in the social engagement system (see Figure 20–1) are recruited and coordinated with breathing practices, chanting, vocalizing, or playing a wind instrument. This includes regulation of muscles of the mouth, face, neck, middle ear (acoustic monitoring), larynx, and pharynx. Thus, vocalization may

provide an "active pathway" to recruit and exercise several aspects of the social engagement system while promoting a calm state through the ventral vagal pathway.

Mind-body practices may involve voluntary posture shifts, which influence blood pressure receptors known as baroreceptors. Baroreceptors send signals to the brain stem that either increase heart rate by downregulating vagal efferent output (and often stimulating sympathetic output) or decrease heart rate by increasing vagal efferent output. Postures can efficiently shift physiological states, often enabling a visceral feeling of activation (due to transitory withdrawal of the ventral vagus) that is rapidly followed by calming (after reengagement of the ventral vagus). Functionally, voluntary behaviors of breathing, vocalizing, and postures provide a way to regulate and exercise all the neural circuits of the social engagement system. As an individual becomes more proficient in using the active pathway as a neural exercise of autonomic regulation, the autonomic nervous system becomes more resilient. This resilience is manifested in a greater capacity to downregulate defense and to support more flexible, adaptive emotional states, social behaviors, and health.

Consistent with the polyvagal theory, treatments, including CAIM, are optimized during biobehavioral states associated with feeling safe. In this neurophysiological safe state, it is easier to inhibit the neurobiological defense strategies, which may be interfering with the patient's ability to trust and feel safe enough to explore thoughts and feelings in therapy. Thus, treatment is facilitated when the patient is in a physiological state that supports feelings of safety. This can be mediated through the passive pathway, which simultaneously downregulates the involuntary defense subsystems and potentiates the physiological state associated with the evolutionarily newer social engagement system.

Although the provision of a safe, quiet environment is important, it is not always possible. In noisy clinics or emergency departments, or during and after disasters, a quiet environment cannot be achieved. Even when in a quiet office, patients often feel unsafe, anxious, defensive, and inhibited. Nevertheless, certain mind-body practices, particularly slow breathing practices, can be effectively used to shift the patient into a state of mental and physical calmness even under adverse conditions (see Chapter 21). Furthermore, when the instructions for the practices are given in a soft prosodic voice, the passive pathway is activated. In mind-body interventions, breath, posture, and vocalization engage the active pathway as neural exercises of circuits within the social engagement system. By enhancing the efficiency and reliability of pathways inhibiting defense systems, the individual acquires greater feelings of safety such that the body shifts to a neurophysiological state that supports health, growth, and restoration.

To understand how the passive pathway is recruited, it is necessary to understand two additional features of polyvagal theory: dissolution and neuroception. First, through the process of dissolution (see the following subsection, "Dissolution"), 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. The autonomic state that supports calm behavior also has the capacity to actively downregulate reactivity and defense. Thus, it is not sufficient for an in-

dividual to solely refrain from defensive behaviors. He or she also must be in an autonomic state that is incompatible with defensive behaviors. Second, through the process of neuroception (see subsection "Neuroception" 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 support either defense or safe interactions. Neuroception provides clues to how the passive pathway is elicited. Dissolution provides an understanding of emergent properties, related to both resilience and vulnerability, associated with the various autonomic states elicited via neuroception.

DISSOLUTION

The three circuits defined by polyvagal theory are organized and respond to challenges in a phylogenetically determined hierarchy consistent with the Jacksonian principle of dissolution. Jackson proposed that higher (phylogenetically newer) neural circuits inhibit lower (phylogenetically older) circuits, and "when the higher are suddenly rendered functionless, the lower rise in activity" (Jackson 1882, p. 412). Although Jackson proposed dissolution to explain changes in brain function due to damage and illness, polyvagal theory proposes a similar phylogenetic hierarchical model to describe the sequence of autonomic responses to challenges.

In addition to the myelinated vagal pathway, in order to survive in dangerous and life-threatening situations, the mammalian nervous system retained two more primitive neural circuits to regulate defensive strategies: *fight-flight* and *death-feigning*. It is important to note that social behavior, social communication, and visceral homeostasis are incompatible with neurophysiological states that support defense. In the hierarchy of adaptive responses, the newest circuit is used first; if that circuit fails to provide safety, older circuits are recruited sequentially. Thus, from a polyvagal perspective, the objective of CAIM treatments is to recruit the phylogenetically newest circuit that downregulates defense and uses the social engagement system and the myelinated vagus. Mind-body procedures, via the active pathway, can exercise the social engagement system, including the myelinated vagus. Mind-body practices provide more efficient neural exercises when the individual is in a calm and safe physiological state, wherein the active pathway is not in conflict with adaptive defense reactions elicited through the passive pathway. Thus, understanding how to regulate the passive pathway to maintain a calm physiological state is important for optimizing the effectiveness of CAIM. Neuroception provides insight into mechanisms that enable or disable the passive pathway.

NEUROCEPTION

The nervous system processes sensory information from the environment and from the viscera to evaluate risk continuously. Polyvagal theory proposes that this neural evaluation of risk does not require conscious awareness and functions through neural circuits that are shared with our phylogenetic ancestors. The term *neuroception* (Porges 2004) was introduced to emphasize a neural process, distinct from conscious perceptions or sensations, capable of distinguishing environmental (and visceral) features that indicate safety, danger, or life threat. In safe environments, the autonomic state adaptively dampens sympathetic activation and protects the oxygen-dependent central nervous system, especially the cortex, from the metabolically conservative reactions of the dorsal vagal complex (e.g., vasovagal syncope).

Neuroception mediates both the expression and the disruption of positive social behavior, emotion regulation, and visceral homeostasis (Porges 2004, 2007). Triggered by feature detectors in the brain, neuroception may involve areas of temporal cortex that communicate with the central nucleus of the amygdala and the periaqueductal gray. Accordingly, neuroception is proposed as a mechanism through which limbic reactivity is modulated by temporal cortex responses to biological movements, including voices, faces, and hand gestures. Embedded in the construct of neuroception is the capacity of the nervous system to detect and react to the "intention" of movements and sounds by decoding and interpreting the intuited goal of the movements and sounds of animate and inanimate objects. This process occurs without awareness. Although we are often unaware of the stimuli that trigger neuroceptive responses, we are usually profoundly aware of our body's reactions (e.g., rapid heart rate, shaking, sweating). Thus, the neuroception of familiar individuals and those with appropriately prosodic voices and warm, expressive faces promotes a calm physiological state and a sense of safety that translate into a positive social interaction.

Navigating in a potentially precarious environment, neuroception is involved in regulating the nervous system to perform two important adaptive tasks: 1) assessment of risk and 2) if the environment is safe, inhibition of the more primitive limbic structures involved in defensive fight, flight, or immobilization (e.g., death feigning). Any stimulus that can signal cues of safety through neuroception has the potential to recruit the evolutionarily advanced social engagement system that promotes calm behavioral states and supports prosocial behaviors.

Removing cues of danger is not sufficient for ensuring that everyone feels safe. Many experience quiet spaces as safe and restful, but others become anxious and hypervigilant in anticipation of an undefined intrusion. One method to enable safe feelings is slow, regulated breathing practices, preferably with eyes closed, while sitting or lying in a physically comfortable supported position. Vagal afferent messages from the respiratory system can override anxiety and hypervigilance (see Chapter 21). Another method for attaining a neuroception of safety is to process additional sensory features in the environment, such as acoustic stimulation modulated in the frequency band of a mother's lullaby. Humans are hardwired to be calmed by modulated voices (Porges and Lewis 2010). The acoustic features that calm infants are universal and have been repurposed by composers of classical music (Porges 2010). Composers implicitly understood that they could lull the audience into a state of safety (via neuroception) by constructing melodic themes that duplicate the vocal range of a mother soothing her infant, while limiting the contribution of low-frequency sounds. Similarly, the acoustic structure of liturgical vocal music minimizes low-frequency sounds and emphasizes voices in the range of the nurturing mother calming her infant. In contrast, organs with large pipes generating low-frequency tones do not create a feeling of safety but trigger a feeling of awe. These low tones have acoustic features that overlap with our immobilization reactions to a predator.

In most situations, the passive pathway is activated during social interactions by prosodic vocalizations, gestures, and facial expressions. Violations of a "neural expectancy" for reciprocal interactions can shift the physiological state from calmness to defensiveness that would, by disrupting homeostasis, interfere with healing processes (see Geller and Porges 2014). The reciprocal behaviors and intersubjective experiences that define therapeutic interactions may greatly influence a patient's physiological state and thereby contribute to treatment outcomes. In addition to physiological state shifts in response to the interactions between social engagement systems of the patient and the therapist, neuroception monitors features of the *context* in which treatment is delivered. Polyvagal theory helps identify optimal contexts for delivering CAIM. Contexts that enable the individual to reduce hypervigilance and maintain a state of calmness provide 1) protection from others when one is in a physically vulnerable state (e.g., supine or eyes closed) and 2) reduction of sensory cues of danger by attenuating low- and high-frequency sounds associated with danger and by limiting distracting visual cues. Such contexts are characteristic of traditional forms of psychotherapy and psychoanalysis in which the therapist uses a warm prosodic voice to regulate the state of the patient even when the patient is unable to make direct eye contact.

Visceral cues as triggers of defense. Potent visceral feedback from organs below the diaphragm often occurs during illness and injury. Unlike specifically localized sensory feedback through spinal nerves, for example, when our gut is distended, our brain interprets *interoceptive* signals through vagal afferent pathways from subdiaphragmatic organs as generalized. It is often difficult to identify the precise origin of visceral signals (Craig 2002; Porges 1993). During illness, injury, inflammation, or any serious challenge to the normal "homeostatic" function of a visceral organ, signals travel from the organ through vagal sensory fibers to a brain stem area, the nucleus of the solitary tract. This nucleus contributes to central regulation of autonomic state and the function of visceral organs. As the primary sensory nucleus of the vagus, the nucleus of the solitary tract sends information to higher brain centers and vagal "motor" nuclei (nucleus ambiguus and dorsal nucleus of the vagus) to selectively modulate specific target organs.

When using *mobilization* as a defense (fight-or-flight behaviors), vagal afferent pathways, via the nucleus of the solitary tract, impact the nucleus ambiguus, enabling sympathetic activation by turning off the inhibitory action of the myelinated ventral vagal pathway on the heart (i.e., withdrawing the vagal brake) (Porges et al. 1996). However, when using *immobilization* as a defense, vagal sensory pathways, via the nucleus of the solitary tract, activate the dorsal nucleus of the vagus. Thus, trauma inflicted directly on the subdiaphragmatic area (via surgery, birthing, rape, illness, or injury) may trigger dorsal vagal responses (e.g., immobilization with fear) that are manifested psychologically as depression or dissociation, behaviorally as fatigue, and medically as problems in blood pressure regulation, fainting (vasovagal syncope), fibromyalgia, or digestive disorders, including irritable bowel syndrome. With higher-level defensive strategies, the social engagement system and the ventral vagus (e.g., vagal brake) are downregulated, and physiological states do not support health,

growth, and restoration. Mind-body practices can be used to enhance physiological resilience and to optimize homeostasis by strengthening higher-level neural systems and reducing dependence on lower-level defense systems.

Potential discrepancies between feelings and cognitions. *Neuroception* refers to those neural processes involved in risk evaluation that are not conscious. Functionally, this can lead to discrepancies between conscious perceptions and feelings. We may be aware of how we feel, but we may not be aware of the antecedent features in the environment that trigger the neuroceptive processes that change our physiological state and form the neural substrate of our feelings. For example, lowering pitch and reducing prosody may trigger a neuroceptive response similar to a fear response to a predator. The words may be benign, but the tonal qualities of voice may trigger a physiological state that supports aggressive behaviors (Pell et al. 2015). During such states, higher brain processes attempt to make sense of discrepancies between feelings and cognitions. In most situations, feelings take priority because the feelings are wired into our brain's adaptive survival strategies. In contrast, hostile words delivered via melodic vocalizations may have less negative effect.

Once feelings are driving defenses, higher brain structures build a cohesive personal narrative that justifies being defensive. When we are in these physiologically vulnerable states, our attempts to engage socially may be aggressive, and we may misinterpret the social cues of others as aggressive. In vulnerable people, even subtle behavioral changes, such as mild exercise or walking, may reduce the calming influence of the vagal brake and put the individual into a state in which the social engagement behaviors of others may be misinterpreted as aggressive. Pausing to breathe slowly (at 4.5–6 breaths per minute) can rapidly calm such defensive reactions, providing time for higher cognitive processes and social engagement to take effect. This technique is embedded in therapeutic strategies such as cognitive-behavioral therapy and dialectical behavior therapy.

Regardless of an individual's age, the social engagement system is vulnerable to environmental cues of danger and life threat. Even with the removal of danger cues, the social engagement system may remain dormant unless it is appropriately stimulated with safety cues during critical developmental stages. Research with infants of depressed mothers (Tronick and Reck 2009) illustrates that a lack of opportunity for reciprocal interactions changes the emotional and social profile and trajectory of the infant. For the social engagement system to function, the cues of interaction that are processed by both the visual (facial expressions, gestures) and the auditory (prosodic vocalizations) systems are critical. This redundancy of sensory domains (visual and auditory) enables cues of safety to regulate the child, even if one of these sensory systems is damaged. Although gentle tactile cues may communicate safety, they are often preceded by prosodic voice or warm facial expressions. Without the antecedent vocal and facial signaling of safety, even gentle touch may trigger a neuroceptive state of danger, and the child may recoil from the touch.

The emergence of the social engagement system provides humans with the opportunity to use social behavior to coregulate physiological state and to reciprocally experience a state of safety. During this mutually shared state of feeling safe, the

expansive capacities of the human experience can be optimized. The social engagement system functions as a bidirectional conduit between sensory cues from others and the motor systems that express our thoughts and feelings. Although this conduit of connectedness can efficiently downregulate defensive states through potent features of voice and face, it is vulnerable to diffuse and potent sensory stimuli coming from our bodily organs. Thus, engagement behaviors may be relatively inefficient in calming when directed at an individual who is in a physiological state of defense. Under these conditions, facial expressions and syntax may be misinterpreted and, instead of calming, may elicit aggression. Nevertheless, the auditory channel may be more accessible in regulating state. The prepotent influence of a mother's voice in calming a fussy infant shows this effect. A mother's smile alone is unlikely to soothe the child.

Social behavior, including patient-therapist interactions, is supported by biological components that were repurposed or co-opted through mammalian evolution, thereby enabling mutually adaptive coregulation in which individuals optimized one another's physiological states. The phylogenetic shifts in the autonomic nervous system may explain how neuroception triggers states that support either coregulation or defense. Clinically, we observe that past trauma often leads to biased neuroception that detects risk when there is no risk. In the short term, biased neuroception is protective by minimizing exposure to potential predators. In the long term, this hyperdefensiveness makes it difficult for individuals to fulfill their biological imperative to connect, which would enable them to coregulate and to develop enduring social relationships.

Oxytocin and Vasopressin: The Neurochemistry Underlying Polyvagal States

Coregulation is not entirely neural because it includes behavioral features and biochemical changes. Throughout the life span of mammals, the neuropeptide oxytocin plays a prominent role in the biochemistry of social relationships. In mammals, oxytocin is involved in reproduction by helping expel the large-headed newborn from the uterus, expressing milk, and establishing a selective and lasting bond between mother and offspring (Carter 2014). Mammals depend on their mothers' milk for some time after birth. Human mothers form a strong and lasting bond with their newborns immediately after birth during the time that is essential for nourishment and survival of the infant; however, women who give birth by cesarean delivery without going through labor, or who opt not to breast-feed, still form strong emotional bonds with their children. Furthermore, fathers, grandparents, and adoptive parents also form lifelong attachments to children. Preliminary evidence suggests that the mere presence of an infant increases the release of oxytocin in adults (Feldman 2012; Kenkel et al. 2012). The infant's gaze triggers neurophysiological events (social engagement system and oxytocin) that support the strong social bonds that we interpret as love and

trust. Research supporting the role of oxytocin in the establishment and maintenance of strong social bonds has, until recently, been based on parental behavior (Feldman 2012) or social behaviors in animals (Carter 1998; Kenkel et al. 2012). However, recent human studies documented that administration of intranasal oxytocin facilitated social behaviors, including eye contact and social cognition (Meyer-Lindenberg et al. 2011). This convergence between physiological state (release of oxytocin and an optimized neural regulation of the autonomic nervous system) and social behavior provides a plausible mechanism whereby social behaviors optimize physiological state and promote feelings of trust and love. Moreover, this convergence emphasizes the bidirectionality between social behavior and physiological state. For example, calm physiological states promote spontaneous social engagement behaviors, and social engagement behaviors can lead to calm physiological states. From a CAIM perspective, the clinical environment provides a "social" portal through which the therapist can calm and optimize the patient's physiological state by improving regulation of the autonomic nervous system and prosocial hormones (e.g., oxytocin).

Just as the activation of the social engagement system is not the equivalent of trust and love, neither is oxytocin the molecular equivalent of trust and love. Both are components of a complex, interactive neural system that allows the body to adapt and coregulate even during highly emotive and challenging situations. The mechanisms for reciprocal social interactions involve extensive neural networks throughout the brain and autonomic nervous system that are dynamic and constantly changing during the life span. The properties of oxytocin are neither predetermined nor fixed. Other hormones and epigenetic factors regulate oxytocin's cellular receptors. These receptors change and adapt in response to life experiences. Both the oxytocin system and the experience of safe social interactions change over time (Carter et al. 2009).

Oxytocin often interacts with a related peptide, vasopressin. The neural circuits regulated by oxytocin and vasopressin are sometimes redundant. Both neuropeptides are implicated in behaviors that require social engagement by either males or females, such as huddling over an infant (Kenkel et al. 2012). Regulation of the social engagement system, oxytocin, and vasopressin occurs in the brain stem. Interactions among these systems are documented by the presence of receptors for oxytocin and vasopressin in the brain stem source nuclei of the afferent vagal circuit and both efferent vagal circuits (Porges 2001). Research in several mammalian species documented the critical role of oxytocin and vasopressin in the establishment of selective social bonds, parenting, and mate protection. These studies linked oxytocin and vasopressin to the biological imperative of connectedness. Oxytocin and vasopressin potentiate the dynamic behaviors expressed via the social engagement system. These neuropeptides regulate crucial visceral feelings expressed through the autonomic nervous system, which we associate with trusting, loving relationships.

Central vasopressin is associated with the polyvagal state of mobilization. The effects of vasopressin are associated with an increase in sympathetic excitation and, in most cases, with a decrease in the influence of the myelinated vagus via pathways originating in the nucleus ambiguus. Central vasopressin raises the set point of the baroreceptor reflex (a circuit regulating blood pressure), enabling heart rate and blood pressure to rise to higher levels in support of movement, without a reflexive

downregulation (Porges 2001). This biobehavioral state supports vigilance and defensive behaviors needed to guard self (Ferris 2008), partner, or territory (Carter 1998).

Peripheral vasopressin acts on a different system. Peripheral vasopressin may support immobilization and death feigning through the dorsal vagus shutdown response described in the polyvagal theory. Peripheral vasopressin also increases the magnitude of the baroreceptor reflex, which immediately decreases heart rate and may cause fainting such that the individual appears to be dead or inanimate. This involuntary response is a primitive biological reflex that we inherited from our reptilian ancestors. Perhaps most relevant to mind-body practices, oxytocin is associated with immobility without fear. This includes relaxed physiological states and postures that enable birth, breast-feeding, and consensual sexual behavior.

Although oxytocin is not essential for parenting, the increase of oxytocin associated with birth and lactation may enable a woman to be less anxious around her newborn and express loving feelings (Carter and Altemus 1997). When oxytocin is absent (e.g., because of a mutation in the oxytocin gene), vasopressin may stimulate the oxytocin receptor, with consequences similar to those of oxytocin. The dynamic interaction between oxytocin and vasopressin is essential for complex social behaviors (e.g., parenting). In humans and other socially monogamous mammals such as the prairie vole, the intricate molecular dance between oxytocin and vasopressin fine-tunes the coexistence of calm caregiving with protective aggression.

Summary

Polyvagal theory provides an innovative model that links the mechanisms mediating feelings of safety to social behavior and health. It helps us understand how cues of risk and safety, continuously monitored by our nervous system (neuroception), influence physiological and behavioral states. As illustrated in Table 20–1, neuroception of environmental cues triggers different physiological states to adapt to features of safety, danger, and life threat. Each biobehavioral state has a neurophysiological profile involving a specific autonomic pathway and neuropeptide that in combination support different clusters of adaptive behaviors. Neurophysiological circuits, disrupted during stress and trauma, impair our abilities to feel connected and to coregulate. The human quest to calm neural defense systems by detecting features of safety is initiated at birth when the infant is dependent on the mother for soothing and nurture and continues throughout the life span with needs for trusting relationships. This innate quest for a safe relationship can be facilitated by mind-body practices that regulate physiological state and by aspects of patient-therapist interaction. Polyvagal theory provides a plausible explanation for how mind-body treatments use both passive (via neuroception) and active (via neural exercises) pathways to enhance homeostatic function, emotion regulation, and social engagement.

TABLE 20–1. Neuroception of environmental conditions

Safety	Danger	Life threat
Parasympathetic system: myelinated vagus	Sympathetic system	Parasympathetic system: unmyelinated vagus
↑ Heart rate variability	↓ Heart rate variability	↓ Heart rate variability
↑ Body awareness	↓ Body awareness	↓ Body awareness
↑ Social engagement	↓ Social engagement	↓ Social engagement
Immobilization without fear	Mobilization	Immobilization with fear
Flexible and adaptive	Approach or withdrawal	Death-feign, collapse
Bond, connect, love, intimacy, soothing, healing, cooperative	Emotion dysregulation, hypervigilance, overactivity	Disconnect, dissociate
↑ Oxytocin	↑ Central vasopressin	↑Peripheral vasopressin?

Note. The polyvagal theory postulates three levels of autonomic response to perceived environmental conditions.

KEY POINTS

- Polyvagal theory emphasizes bidirectional communication between brain and viscera, which would explain how thoughts and emotions affect physiological states, how physiological states influence thoughts and emotions, and how mind-body practices affect physiological state, thoughts, and emotions.
- The therapist's use of positive facial expressions and prosodic voice conveys benevolent feelings of concern toward the patient and recruits the passive neuroceptive pathway.
- Mind-body practices recruit the active pathway through voluntary behaviors that are directly wired into vagal circuits, promoting neurophysiological states that support health.
- The peripheral vagal system provides portals of intervention for correcting dysfunctions of the central and autonomic nervous systems.
- Specific mind-body treatments may recruit the phylogenetically newest circuits to downregulate defense and favor use of the social engagement system and myelinated vagus.

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