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PROFESSIONAL ISSUES

HeartMath approach to self-regulation and psychosocial well-being

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The ability to alter one's emotional responses is central to overall well-being and effectively meeting the demands of life. In this article, we discuss the perspective that one's ability to self-regulate the quality of feeling and emotion of one's moment-to-moment experience influences our physiology and the reciprocal interactions between physiological, cognitive, and emotional systems. We outline the bi-directional communication pathways between the heart and brain, and how neural activity in these pathways affect the central processes of cognitive and emotional function and self-regulatory capacity. We discuss how self-induced positive emotions is reflected in the pattern of one's heart's rhythm, which in turn increases the coherence in bodily processes. This shift in the heart rhythm plays an important role in facilitating higher cognitive functions, creating emotional flexibility, and facilitating social connectedness. Over time, this establishes a new inner-baseline reference, resulting in improvements in attention, behaviour, and measures of health and wellness.

Keywords: cognitive performance, emotion, heart coherence, HeartMath, heart rate variability, trauma

Introduction

Most would agree that failures of emotional self-regulation are central to the vast majority of health and social problems that plague modern societies. It also underlies the majority of stress, anxiety, and overwhelm that people experience in their day-to-day lives (Baumeister, 2003; McCraty & Tomasino, 2006). Therefore, the most important strength that the majority of people can benefit from is building the capacity to more effectively self-regulate their emotions, attitudes, and behaviours.

Through our research at the HeartMath Institute, we have come to identify a specific physiological state associated with optimal cognitive functioning and emotional stability. From these studies, we developed the psychophysiological coherence model (Childre & Martin, 1999). The psychophysiological coherence model emphasises the importance of healthy physiological variability within the autonomic nervous system, afferent feedback from the body to the brain, and reciprocal interactions among a hierarchy of nested neural systems that underlie a complex psychophysiological system for maintaining emotional stability and building the capacity to adapt to complex changing environments and social demands.

Goal of this article

In this article, we seek to orient readers to the psychophysiological basis to emotional stress and self-regulation and psychosocial well-being; with special reference to the coherence model informing the HeartMath system and its scientific development and application of various tools and techniques to cope with stress, and build resilience for the inevitable challenges of life. In this context, this article aims to orient readers to the following key aspects of the HeartMath approach:

- As distinct from heart rate, HeartMath heart rate variability (HRV) studies have revealed the importance of heart-rhythm patterns, which reflect emotional states. Important findings were that negative emotions such as anger and anxiety, as well as positive emotions such as peace and happiness, tended to have characteristic HRV "signature" patterns.
- In addition to "top-down" (brain to heart communication), HeartMath research has indicated the vital importance of "bottom-up" (from heart to brain) communication of information for the self-regulation of emotional states, as well as promotion of health and performance.
- Regular practice of scientifically researched tools and techniques facilitates psychophysiological rewiring of a persons' neural apparatuses and the establishment of a new baseline from which to meet life challenges.

Psychophysiological coherence: Its nature and qualities

The concept of psychophysiological coherence is vitally important for understanding optimal functioning. In physics, coherence is used to describe the coupling and degree of synchronisation between different oscillating systems. When coherence is increased in a system that is coupled to other systems, it can pull the other systems into increased synchronisation and more efficient function (McCraty, Atkinson, Tomasino, & Bradley, 2009).

We introduced the term physiological coherence to describe the degree of order, harmony, and stability in the various rhythmic activities within living systems over any given time period (Tiller, McCraty, & Atkinson, 1996). Specifically, heart coherence can be measured by heart rate variability (HRV) analysis wherein a person's heart-rhythm pattern becomes more ordered and sine-wave-like at a frequency of around 0.1 Hertz (1 cycle every 10 seconds).

We use the terms cardiac coherence, physiological coherence, and heart coherence interchangeably to describe the measurement of order, stability, and harmony in the oscillatory outputs of the body's regulatory systems (such as respiration, heart and blood pressure rhythms) during any period of time. A detailed discussion on the nature of cardiac coherence and how it is assessed can be found elsewhere (McCraty et al., 2009; McCraty & Childre, 2010).

An important aspect of the coherence model is the inclusion of cardiovascular afferent neuronal inputs on brainstem, sub-cortical, and cortical structures. These can have significant influences on cognitive function and emotions. We propose that emotional information is conveyed in the patterns of the heart's rhythm, and that these patterns are transmitted to the brain via afferent neural input, which then affects emotional experience, and modulates cognitive function and self-regulatory capacity (McCraty & Zayas, 2014). We emphasise the importance of shifting the internal emotional and physiological baseline reference, which can be considered a type of implicit memory held in the neural architecture that helps organise perception, feelings, and behaviour. Furthermore, we propose that intentional activation of positive emotions plays an important role in increasing cardiac coherence and increasing self-regulatory capacity (McCraty et al., 2009).

Development of mental and emotional self-regulation techniques

The coherence model informed the development of a number of mental and emotional self-regulation techniques. Most of these techniques are designed to be used during a stressful or emotionally-triggering event, or to better prepare for upcoming challenging events (Childre & Martin, 1999). The use of these techniques typically shifts the user's physiology into a more coherent and balanced functional state, which is reflected in the patterns of the heart's rhythm as in the following examples and others to be discussed later in this article.

Managing stressful, emotionally triggering events

Stressful emotionally triggering events typically affect respiration, blood pressure, and immune system functioning (McCraty & Tomasino, 2006). An effective HearMath management skill called the "Quick Coherence Technique", consists of three sequential steps of heart focus, heart breathing, and heart feeling. Heart focussed breathing ideally occurs at a ten second rhythm (about 5 seconds per in-breath and 5 seconds per out-breath), while cultivating a positive emotion from the heart area.

Preparing for upcoming challenging events

Stressful thoughts, feelings, reactions, and expectancies typically arise before challenging occasions (McCraty & Tomasino, 2006; McCraty & Atkinson, 2012). In such cases Prep-Shift-Reset is a specific practical application of resilience through preparing a calm feeling and/or using any HeartMath tool to consciously shift, reset, and re-stabilise the energy system, sustain coherence, and build resilience throughout the remainder of the day.

Principles of the Physiological Coherence Model

The psychophysiological model of coherence is based on the following five principles, which will be described in turn:

1. There is a bi-directional system whereby the brain sends information to the body through efferent neural networks, and the body communicates with brain centres via sympathetic and vagal afferent inputs to the thalamus, amygdala, and other sub-cortical structures.
2. State-specific emotions are reflected in the patterns of the heart's rhythms, independent of changes in the amount of HRV and heart rate.
3. Through this bi-directional communication network, patterns of the heart's rhythm can significantly influence cognitive performance, self-regulatory capacity, and social connectedness.
4. Resetting emotional and behavioural patterns are facilitated by afferent input from the body, and occurs through positive reinforcement and neuroplasticity of neural networks.
5. Self-induced positive emotions can shift psychophysiological systems into a more globally coherent and harmonious order associated with improved self-regulation, performance, and overall health and well-being.

The body communicates in a bi-directional system

Considerable evidence from clinical, physiological, and anatomical research has identified cortical, subcortical, and brainstem structures involved in physiological regulation (McCraty, 2015; McCraty & Shaffer, 2015; Armour & Ardell, 1994). For the purposes of this discussion, we will focus specifically on cardiovascular regulation. Oppenheimer and Hopkins (1994) mapped a detailed hierarchy of cardiac control structures among the cortex, amygdala, and other subcortical structures; all of which can modify cardiovascular-related neurons in the lower levels of the neural-axis (see Figure 1). They suggest that the amygdala is involved with refined integration of emotional content in higher centres to produce cardiovascular responses that are appropriate for the emotional aspects of the current circumstances. The insular cortex and other centres, such as the orbitofrontal cortex and cingulate gyrus, can overcome emotionally entrained responses by inhibiting or enhancing them. Imbalances between the neurons in the insula, amygdala, and hypothalamus may initiate cardiac rhythm disturbances and arrhythmias. Data suggest that the insular and medial prefrontal cortices are key sites involved in efferent, or descending, neural pathways that modulate the heart's rhythm, particularly during emotionally charged circumstances (Armour & Ardell, 1994).

Physiology textbooks are replete with diagrams that illustrate nervous system pathways from the brain to autonomically innervated organs (Armour & Ardell, 1994). However, many of these illustrations do not complete the communication circuit. They frequently omit the extensive systems of visceral afferent fibres, which carry messages from receptors and ganglia in the body back to the brain. In HeartMath these bottom-up information pathways are as important as the top-down pathways. In fact, the nerve

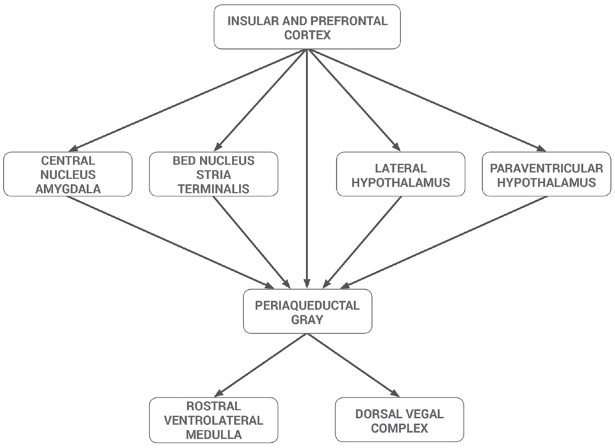

Figure 1. Schematic diagram showing the relationship of the principal descending neural pathways from the insular and prefrontal cortex to subcortical structures and the medulla oblongata. The structures in the medulla represent an interface between incoming afferent information from the heart, lungs and other bodily systems and outgoing efferent neuronal activity (Oppenheimer & Hopkins, 1994).

pathways connecting most organ systems to the brain are composed of as many afferent fibres as there are efferent connections; while in some visceral nerves, such as the abdominal vagus nerve, up to 90% of the fibres are afferent (Cameron, 2002). Due to the important and extensive network of cardiovascular afferent nerves, the heart sends more neural traffic to the brain than the brain sends to the heart. As shown in Figure 2, cardiovascular afferents have connections to numerous brain centres including the thalamus, hypothalamus, and limbic system. As such, cardiovascular-related afferent neural traffic significantly affects activity in the majority of higher brain centres; thereby modulating cognitive processes and emotional experience (McCraty et al., 2009).

There is substantial evidence that the heart plays a unique role in synchronising the activity in multiple systems of the body, and thus in orchestrating the flow of information throughout the psychophysiological network (McCraty & Childre, 2010; McCraty, Atkinson, Tomasino, & Bradley, 2009). As the most powerful and consistent generator of rhythmic information patterns in the body, and possessing a far more extensive communication system with the brain than other organs, the heart is in continuous communication with the brain and other bodily organs and systems through multiple pathways. These pathways include: neurologically (through the transmission of neural impulses), biochemically (through hormones and neurotransmitters), biophysically (through pressure and sound waves), and energetically (through electromagnetic field interactions). Therefore, the heart is uniquely positioned as a central node in the psychophysiological network and can influence multiple systems and communicate information throughout the whole organism. During a state of heart coherence, entrainment is typically observed between heart rhythms, respiratory rhythms, and blood pressure oscillations. However, other biological oscillators, including very low frequency brain rhythms, craniosacral rhythms, and electrical potentials measured

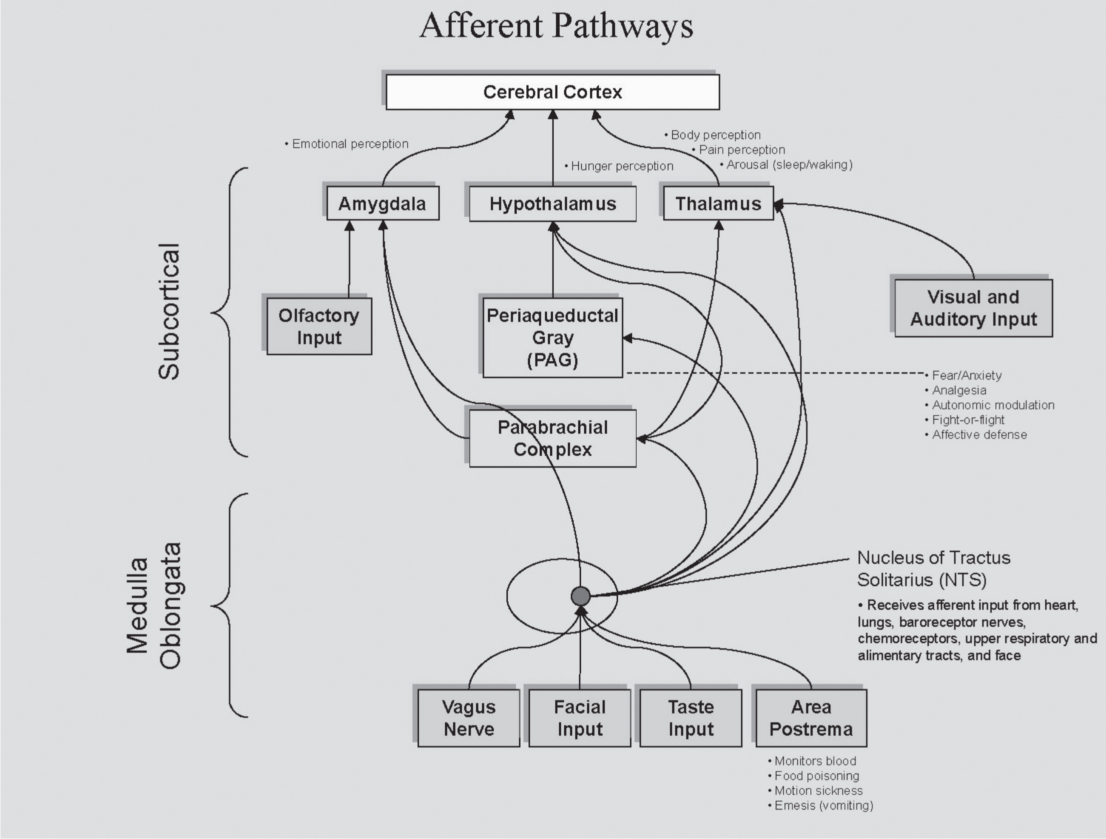

Figure 2. Afferent pathways. Schematic diagram showing the major afferent inputs from the body to the nucleus tractus solitarius, located in the medulla oblongata. Afferent pathways then connect directly to the amygdala, hypothalamus, and thalamus, with information relayed to the cerebral cortex.

across the skin, can also become entrained (Bradley & Pribram, 1998; Tiller et. al., 1996). Thus, the heart effectively acts as the central "conductor" of rhythmic activity in the body: the neural, hormonal, biophysical, and energetic patterns generated by the heart's rhythmic activity provide a global synchronising signal for the system as a whole.

Heart-rhythm patterns reflect emotional states

Many contemporary scientists believe that it is the underlying state of our physiological processes that determines the quality and stability of the feelings and emotions we experience (McCraty, Atkinson, Tomasino, & Bradley (2009). The feelings we label as "positive" actually reflect body states that are coherent, meaning "the regulation of life processes becomes efficient, or even optimal, free-flowing and easy" (Damasio, 2003, p. 131). Accordingly, the feelings we label as "negative" (such as anger, anxiety, and frustration) are examples of incoherent states. For the brain and nervous system to function optimally, the neural activity, which encodes and distributes information, must be stable and function in a coordinated and balanced manner. Furthermore, the various centres within the brain must be able to dynamically synchronise their activity in order for information to be smoothly processed and perceived.

Although heart rate changes often occur with emotional state changes, we have found that it is more typically the patterns reflected in the heart's rhythm that change in a state-specific manner, especially during emotions that do not evoke large autonomic nervous system (ANS) activations or inhibitions of parasympathetic outflow. These changes in rhythmic patterns are independent of heart rate; that is, one can have a coherent or incoherent pattern at higher or lower heart rates. Thus, it is the pattern of the rhythm (the ordering of changes in rate over time), rather than the heart rate at any point in time, that reflects more subtle ANS and emotional dynamics, as well as physiological synchronisation (McCraty & Childre, 2010). From a physiological perspective, a coherent heart rhythm is different from the heart rhythm that occurs during the relaxation response, which is associated with a reduced heart rate, but not necessarily a more coherent rhythm.

The nature of the emotional experience appears to be related to the level of coherence of the heart rhythm pattern (McCraty, Atkinson, Tiller, Rein, & Watkins 1995; McCraty et al., 2009). Figure 3 illustrates that emotions typically thought of as positive (such as appreciation and compassion) are related to a more coherent heart rhythm pattern; whereas, emotions that are typically thought of as negative are related to a more incoherent pattern. This suggests that positive emotions have a renewing physiological effect and negative emotions may have a depleting physiological effect.

HRV Waveforms

Evidence suggests that we can identify patterns associated with appreciation versus frustration or anger, for example, by looking at the HRV waveforms. Independent work has verified this by demonstrating a 75% accuracy in detection of discrete emotional states from the HRV signal (Leon, Clarke, Callaghan, & Doctor, 2010). Several studies in healthy subjects, which helped inform the model, showed that during the experience of positive emotions a sine wave-like pattern naturally emerges in the heart's rhythms without any conscious changes in breathing (McCraty et al., 1995, Tiller, et al., 1996). This is likely due to more organised outputs of the subcortical structures involved in processing emotional information described by Pribram an Melges (1969), Oppenheimer and Hopkins (1994), Porges (2007), and Thayer and colleagues (2009) in their Central Autonomic Network model. In this model, the subcortical structures influence the oscillatory output of cardiorespiratory centres in the brain stem (Thayer, Hansen, Saus-Rose, & Johnsen, 2009). In terms of emotional experience, vagal afferent pathways connect to the amygdala via the nucleus tractus solitarius, which synchronises the activity of the central nucleus of the amygdala and the cardiac cycle (Frysinger & Harper, 1990; Zhang, Harper, & Frysinger, 1986). In other words, the heart's afferent neurological signals directly affect activity in the amygdala and associated nuclei, an important emotional processing centre in the brain (Hopkins & Ellenberger, 1994).

For example, resting HRV data obtained from a population of returning soldiers found that those with a diagnosis of posttraumatic stress disorder (PTSD) had both lower levels of HRV and lower levels of coherence than soldiers without PTSD (Ginsberg, Berry, & Powell, 2010). A study that examined pre-deployment heart rate variability as a predictor of post-deployment PTSD

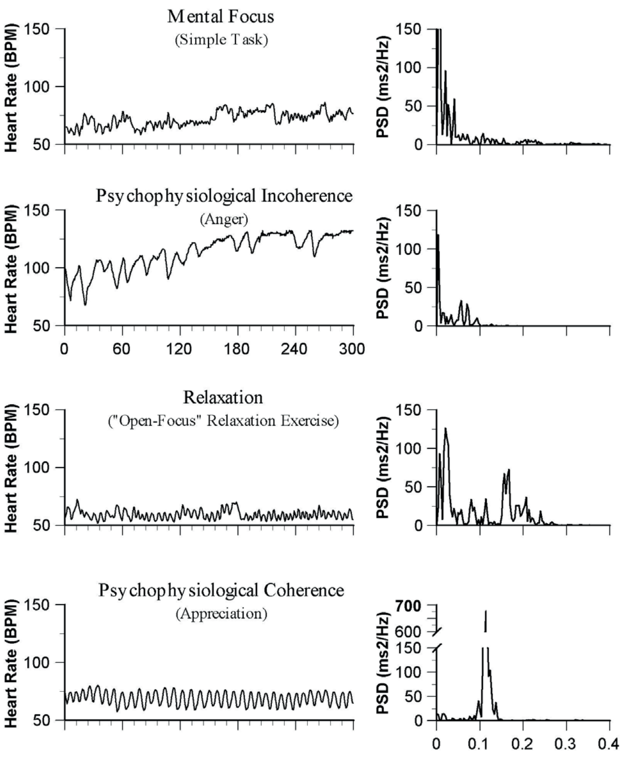

Figure 3. Emotions and heart rhythm patterns. The heart rate tachograms on the left side show patterns in of the heart rate variability (HRV) waveforms typically observed in differing psychological and/or emotional states. The power spectral density (PSD) analysis of the HRV rhythms for each is shown on the left.

symptoms in a population of Army National Guard soldiers, found that lower pre-deployment HRV was a significant predictor of post-deployment PTSD symptoms (Pyne et al., 2016).

Information from the heart affects cognitive performance, self-regulatory capacity, and social connectedness

Many therapists, especially those involved in treating patients with trauma, are beginning to understand the critical role played by the afferent neural signals that flow from the body to the brain (Van der Kolk, 1994). For example, somatic-based therapies such as yoga or Tai Chi utilise a similar bottom-up approach that provides afferent feedback from bodily organs to exert a measurable influence on cognitive, perceptual, and emotional processes of the brain.

Cognitive performance

The Laceys, a husband and wife research team, were the first to demonstrate a causal relationship between cardiovascular afferent neuronal activity, affect, and performance capability (Lacey, 1967; Lacey & Lacey, 1970; 1974). The Laceys' observations directly challenged the "arousal" or "activation" theory proposed by Cannon (Cannon, 1927), which asserted that all of the physiological indicators underlying emotion – heart rate, blood pressure, sweating, pupil dilation, narrowing of certain blood vessels, and so on – moved predictably in concert with the brain's response to a given stimulus. Cannon had suggested that when we are aroused, the sympathetic nervous system mobilises us to fight or flight; and in quieter moments, the parasympathetic nervous system relaxes our inner systems for rest and digestion (Cannon, 1927). This theory presumed that autonomic responses increased all together when we were aroused and decreased in unison when we were at rest, and the brain was entirely in control of both these processes. The Laceys noticed that this view of activation as a single dimension only partially matched actual physiological behaviour. Instead, they observed that all physiological responses did not always move together. As their research evolved, they found that the heart, in particular, seemed to have its own peculiar logic that frequently diverged from the direction of other ANS responses.

While the Laceys were conducting their research in psychophysiology, a small group of cardiologists joined forces with a group of neurophysiologists and neuroanatomists to explore areas of mutual interest. This represented the beginning of the new discipline now called neuro-cardiology. One of their early findings is that the heart has a complex neural network that is sufficiently extensive to be characterised as a "brain" in the heart (Armour, 1991, 2008). The heart-brain, as it is commonly called, or intrinsic cardiac nervous system, is an intricate network of complex ganglia, neurotransmitters, proteins and support cells just like those of the brain in the head. The heart-brain's neural circuitry enables it to act independently of the cranial brain to learn, remember, make decisions, and even to feel and sense. Descending activity from the brain in the head via the sympathetic and parasympathetic branches of the ANS is integrated by the heart's intrinsic nervous system, along with signals arising from sensory neurons in the heart that detect pressure, heart rate and rhythm, and hormones. Numerous anatomical and neural recording studies in the field of neuro-cardiology have since shown that the neural communication between the heart and brain is far more complex than was traditionally understood (Armour & Ardell, 1994, Armour & Kember, 2004).

Contributing to this work, Wölk and Velden demonstrated that cardiovascular afferent neuronal activity modulated cortical function through vagal input to the thalamus (Velden & Wölk, 1987; Wölk & Velden, 1987; 1989). Importantly, they found it was the *pattern* and *stability* of the rhythm in the cardiovascular input, as opposed to the rate of neural bursts, which exerted its influence on the thalamus.

Self-regulation

Based on these premises, the heart rhythm coherence hypothesis postulated that the pattern and degree of stability in the beat-to-beat changes in heart rate encodes information that can influence cognitive performance and emotional experience. (McCraty et al., 2009). Several studies have demonstrated that interventions that increase heart rhythm coherence significantly improve cognitive performance (Bradley, McCraty, Atkinson, Tomasino, Daugherty, & Arguelles, 2010; Ginsberg et al., 2010; Lloyd, Brett, & Wesnes, 2010). In a study utilising an odd-ball audio discrimination task with reaction times and error rates as measures of cognitive performance, participants used a technique to induce either a coherence state or a relaxation state for five minutes prior to the experimental protocol. This study found that there was a significant correlation between pre-task cardiac coherence and performance across all participants. Furthermore, in the coherence group, there was a carry-over effect on subsequent performance as compared to the relaxation group. More recently, studies of vagal nerve stimulation have likewise demonstrated improved cognitive processing and memory, likely through its direct effect on limbic structures to encode and store new information (Hassert, Miyashita, & Williams, 2004).

Thayer and Lane (2000) described the same set of neural structures outlined by Oppenheimer and Hopkins, called the central autonomic network (CAN). TheCAN is involved in cognitive, emotional, and autonomic regulation. In their studies, they demonstrated that the amount of vagally-mediated HRV (high-frequency or HF-HRV) is correlated to cognitive performance, memory retrieval, and emotion self-regulation capacity (Gillie, Vasey, & Thayer, 2014; Hansen, Johnsen, & Thayer, 2003; Thayer et al., 2009; Williams, Cash, Rankin, Bernardi, Koenig, & Thayer, 2015). In their model, the CAN links the nucleus of tracus solitarius in the medulla with the insula, prefrontal cortex, amygdala, and hypothalamus through a series of feedback and feed-forward loops. They propose that this network is an integrated system for internal self-regulation by which the brain controls the heart and other internal organs, neuroendocrine and behavioural responses that are critical for goal-directed behaviour, adaptability and sustained health. They suggest that these dynamic connections explain why parasympathetic, vagally mediated HRV is linked to higher-level executive functions and reflects the functional capacity of the brain structures that support working memory and emotional and physiological self-regulation. Others have similarly linked vagally mediated HRV to self-regulatory capacity (Geisler & Kubiak, 2009; Porges 2007; Reynard, Gevirtz, Berlow, Brown, & Boutelle, 2011; Segerstrom & Nes, 2007) and emotional regulation (Appelhans & Luecken, 2006; Geisler, Vennewald, Kubiak, & Weber, 2010).

Social connectedness

In concert with an increased capacity for emotional self-regulation, studies have linked vagally-mediated HRV with social functioning and feelings of connectedness (McCraty, 2017). In a study of young adults, vagally-mediated high frequency HRV was positively correlated with engagement coping strategies, and predicted less use of disengagement strategies and less episodes of anger or other negative emotions (Geisler, Kubiak, Siewert, & Weber, 2013). In another study of 114 young couples, resting HF-HRV correlated with marital quality. The authors concluded that the capacity for self-regulation is necessary for adaptive functioning in close relationships. In addition, this study demonstrated that negative marital interactions could reduce a woman's HF-HRV, with potentially adverse health consequences (Smith et al., 2011).

In summary, evidence now clearly demonstrates that afferent signals from the heart significantly influence cortical and limbic activity. Specifically, we now know that afferent messages from the cardiovascular system are not only relayed to the brain stem to exert homeostatic effects on cardiovascular regulation, but also have separate effects on aspects of higher perceptual activity, mental processing, and emotional regulation.

Getting past the past: Resetting behaviour patterns through neuroplasticity

Neuroplasticity refers to the ability of the brain to change continuously throughout life (LeDoux, 1996). The amygdala is the neural centre that coordinates behavioural, immunological, and neuroendocrine responses to environmental inputs. In assessing the external environment, the amygdala scans the inputs (visual, auditory, olfactory, etc.) for emotionally relevant content and compares them with the implicit memories maintained in the neural architecture. In this way, the amygdala makes instantaneous decisions about the familiarity of incoming sensory information. Furthermore, because of its extensive connections to the hypothalamus and other autonomic nervous system centres, the amygdala is able to activate the autonomic nervous system and emotional responses before the higher brain centres receive the sensory information (LeDoux, 1996). In terms of the body's interceptive pathways, if the rhythmic patterns generated by the heart are consistently disordered and incoherent, especially in early life, the amygdala learns to expect disharmony as the familiar pattern, and thus we feel "at home" with incoherence, which can affect learning, creativity, and emotional balance. In other words, we feel "comfortable" with internal incoherence. Based on what has become familiar to the amygdala, the frontal cortex mediates decisions as to what constitutes appropriate behaviour in any given situation (Pribram, 2013; McCraty, 2017). Thus, subconscious emotional memories and associated physiological patterns underlie and affect our perceptions, emotional reactions, thought processes, and behaviour. This means we can easily get "stuck" in unhealthy emotional and behavioural patterns, making it difficult for lasting improvements in emotional experience or behaviours to be sustained. If sustained behaviour change or improved affective states are desired, it is critical to establish a new internal reference that can become the new "familiar".

The afferent inputs from the cardiovascular system to the amygdala are primary contributors in determining emotional experience and in establishing the set point to which all current and future inputs are compared:

> *Cardiovascular feedback constitutes, by the nature of its diffuse afferent organization, a major source of input to the brain's biasing mechanism; it is an input which can do much to determine set-point. Cardiovascular events are repetitiously redundant in the history of the organism leading to stable habituations. Thus, cardiovascular afferent autonomic activity makes up a large share of the stable baseline from which the organism's reactions can take off* (Pribram, 1969, p. 322).

In fact, Pribram went on to show that changes in the pattern of afferent input has to occur for the establishment or resetting of the stable baseline or set-point (Pribram, 2013). The importance of this finding cannot be overstated. What it is saying is that without a change in the inputs from the body to the brain, especially those from the heart, a new baseline cannot be established. This goes a long way towards explaining why what are often called "bottom-up" approaches such as somatic approaches and HRV biofeedback, are often more effective than "top-down" (cognitive) approaches in treating psychological issues, especially in cases of trauma (Kar, 2011; Van der Kolk, 1994).

In the context of this discussion, it is important to note that the heart's rhythmic patterns and the patterns of afferent neurological signals change to a more ordered and stable pattern when one uses heart-focused self-regulation techniques (McCraty & Childre, 2010). Regular practice of these techniques, which include a shift of attentional focus to the centre of the chest (heart area) accompanied by the conscious self-induction of a calm or positive emotional state, reinforces the association (pattern match) between a more coherent rhythm and a calm or positive emotion. Positive feelings then more automatically initiate an increase in cardiac coherence. In turn, increased coherence initiated through heart-focused breathing tends to facilitate the felt experience of a positive emotion. This practice facilitates the re-patterning process through neuroplasticity, which is especially important in situations where there has been sustained exposure to high-risk environments or trauma in the past (McCraty & Zayas, 2014). Through this feed-forward process, new reference patterns are established. Once this new, more energetically efficient, reference pattern is created, the system strives to maintain it. This makes it easier for people to maintain stability and self-directed control during daily activities, even in more challenging situations. Without a shift in the underlying physiological baseline, it is exceedingly difficult to sustain behavioural change, placing people at risk of relapsing into their behaviours informed by their past, more familiar, experiences.

Re-patterning with tools of emotional self-regulation: HeartMath Interventions

The psychophysiological model of coherence has been used to help guide the development of simple techniques such as Quick Coherence Technique and Prep-Shift-Reset that have already been mentioned. These interventions allow people to quickly self-induce a physiological shift to a more coherent state in the moment stress or depleting thoughts and emotions that are occurring. This approach takes advantage of the concurrent change in afferent neuronal input to the brain, which is associated with increased self-regulatory capacity and thus the ability to more successfully handle the demands and challenges of life with more ease and composure. Consequently, there is a greater experience of social connectedness, harmony, balance and physical, emotional and psychosocial well-being.

The HeartMath self-regulation techniques and assistive technologies provide a systematic process for self-regulating thoughts, emotions, and behaviours and increasing physiological coherence (Childre & Martin 1999; Childre & Rozman 2003, 2005). Many of the self-regulation techniques are specifically designed to enable people to intervene in the moment they start to experience stress reactions or unproductive thoughts or emotions. Skill acquisition of the tools and techniques are often supported by heart rhythm coherence feedback technology. With practice, one is able to use one of the techniques to shift into a more coherent physiological state before, during, and after challenging or adverse situations; thus optimising mental clarity and emotional composure and stability. As previously discussed, in this state, most people are able to more quickly find their "centre," gain new perspectives, and counter ineffective and maladaptive thoughts, feelings, and behaviours.

Effectively instating a new internal reference first involves increased self-awareness and recognising triggers, reactions, and recurring emotional undercurrents (fear, negative projection, insecurity, worry, etc.). Once one is more aware, the next step is learning how to consciously self-regulate and increasingly replace these feelings with more neutral or positive attitudes and perceptions.

Heart -Focused Breathing

The first step in most of the techniques is called Heart-Focused Breathing, which includes putting one's attention in the centre of the chest (area of the heart) and imagining the breath is flowing in and out of that area while breathing a little slower and deeper than usual. Conscious regulation of one's respiration at a 10-second rhythm (0.1Hz) increases cardiac coherence and starts the process of shifting into a more coherent state (McCraty & Zayas, 2014). In challenging situations, or after a strong emotion has been triggered, Heart-Focused Breathing is often the step that most people can remember and find that it "helps take the intensity out" or "turn down the volume" of the reaction. As we have conscious control over breathing and can easily slow the rate and increase the depth of the breathing rhythm (McCraty & Zayas, 2014), we can take advantage of this physiological mechanism to modulate efferent vagal activity and affect heart rate. This, in turn, increases vagal afferent nerve traffic and increases the coherence in the patterns of vagal afferent nerve traffic, which influences the neural systems involved in regulating sympathetic outflow, informing emotional experience, and synchronising neural structures underlying cognitive processes (McCraty et al., 2009).

While rhythmic breathing methods are an effective way to increase heart rhythm coherence, cognitively-directed paced breathing is difficult for many people to maintain for more than about a minute before it becomes uncomfortable and distracting (Alabdulgader, 2012). Use of these emotional self-regulation techniques can also lead to state-specific increases in HRV and vagal activity, even in the absence of paced breathing (McCraty et al., 1995, Tiller et al., 1996) and overtime can lead to a shift in the baseline reference patterns (Bradley et al., 2010).

In a study of high school students who practiced HeartMath self-regulation techniques over a three month period, their resting HRV was significantly increased and the pattern of the HRV was significantly more coherent. These improvements in resting HRV coherence were positively correlated with increased test scores and improved behaviours, suggesting that the practice of the self-regulation skills induces a more coherent heart rhythm that is processed by cortical and sub-cortical networks to influence cognition, affect, and behaviour (Bradley et al., 2010).

Outcome studies conducted in laboratory, clinical, educational, and organisational settings with diverse populations have shown sustained reductions in stress and improvements in many dimensions of health, well-being, and performance (McCraty & Zayas, 2014). For example, a randomised controlled trial of 38 middle school students with a diagnosis of attention deficit hyperactivity disorder (ADHD), demonstrated that the students had a wide range of improvements in cognitive functions such as short and long-term memory, ability to focus, and improved behaviours both at home and in school (Lloyd, 2010). A study of 41 fighter pilots engaging in flight simulator tasks found a significant correlation between higher levels of performance and heart rhythm coherence as well as lower levels of frustration (Li, Chiu, Kuo, & Wu, 2013).

Preventing depleting thoughts and emotions

Numerous studies have demonstrated that regular practice of HeartMath self-regulation techniques has demonstrated improvements in levels of perceived stress, as well as objective health measures (McCraty & Zayas, 2014). A study of correctional officers reporting high work stress showed significant reductions in systolic and diastolic blood pressure, total cholesterol, fasting glucose, overall stress, anger, fatigue and hostility (McCraty, Atkinson, Lipsenthal, & Arguelles, 2009). In another study, police officers experienced reductions in stress, negative emotions, depression, and increased peacefulness and vitality as compared to a control group. In the qualitative aspect of the study, officers reported improved family relations, better communication, and cooperation at work (McCraty & Atkinson, 2012; Weltman, Lamon, Freedy, & Chartrand, 2014).

Other studies have shown the use of these self-regulation techniques increases HF-HRV (Tiller et al., 1996) and results in significant reductions in cortisol and increases in Dehydroepiandrosterone (DHEA) over a 30-day period (McCraty, Barrios-Choplin, Rozman, Atkinson, & Watkins, 1998). Additionally, studies showed significantly lower blood pressure and stress measures in a population with a diagnosis of hypertension (Alabdulgader, 2012; McCraty, Atkinson, & Tomasino, 2003). A controlled study of pastors found significant improvements in stress and well-being measures with an overall decrease in health care costs of $585 per participant, while the control group had a 9% increase in health care costs. The largest reduction in costs was related to reductions in medications for hypertension (Bedell & Kaszkin-Bettag, 2010).

New evidence suggests that increased emotional capacity and HF-HRV also predict treatment response in patients with PTSD (Soder, Wardle, Schmitz, Lane, Green, & Vujanovic, 2019). Indeed, this is supported by a prior HeartMath research study of veterans with PTSD, which found that relatively brief periods of using an HRV coherence biofeedback device combined with practicing a HeartMath self-regulation technique resulted in increased cardiac coherence. This correlated with significant improvements in the ability to self-regulate and improvements in a wide range of cognitive functions (Ginsberg et al., 2010). In another study of returning veterans with chronic pain, the treatment group showed marked and statistically significant increases in coherence (191%) along with significant reductions in pain ratings (36%), stress perception (16%), negative emotions (49%), and physical activity limitations (42%; Berry, Chapple, Ginsberg, Gleichauf, Meyer, & Nagpal, 2014). Understanding these relationships between physiological baselines as they relate to heart rate variability is essential to developing effective treatment modalities for individuals experiencing PTSD.

HRV coherence biofeedback devices

In addition to HeartMath self-regulation techniques, HRV coherence biofeedback is often utilised to support self-regulation skill acquisition in clinical, educational, corporate, law enforcement, and military settings (McCraty & Zayas, 2014; McCraty & Nila, 2017; McCraty & Atkinson, 2012; Bradley, McCray, Atkinson, Tomasino, Daugherty, & Arguelles, 2010). Several systems that assess the degree of coherence in the user's heart rhythms are available. The majority of these systems, such as the emWavePro, or Inner Balance for iOS devices (HeartMath Inc), Relaxing Rhythms (Wild Divine), and Stress Resilience Training System (Ease Interactive), use a non-invasive earlobe or finger pulse sensor to measure heartrate, display the user's heart rhythm and HRV pattern, and provide feedback on their level of coherence.

Future research directions

HeartMath research carried out in African settings (e.g. Edwards, 2018, 2019; Hlongwane et al., 2018) has examined the efficacy of Ubuntu type HeartMath interventions in facilitating social coherence and spirit at work. Initial exploratory research employed a mixed method, within subjects, pre-test and post-test, outcome evaluative design. Five experiential themes, which emerged from participants' qualitative data included consciousness transformations, psychophysiological coherence, Ubuntu meanings, social coherence facilitation and spirit at work facilitation (Edwards, 2018, 2019). From an empirical perspective, further studies are needed on social coherence, applying community action research. Phenomenological studies could explicate experiential meanings of moral consciousness in Africanist settings.

Various studies of continuous HRV monitoring have indicated that the human ANS synchronises with resonant frequencies produced by geomagnetic field-line resonances and Schumann resonances (Edwards, 2019; McCraty, Atkinson, Tomasino & Bradley, 2009; McCraty et al., 2018). Results indicated that synchronisation (positive correlation) between participants' HRV and magnetic field activity was significantly higher on the day of the Heart Lock-In than any other day. Interdisciplinary studies are needed on synchronisation between heart rate variability and geomagnetic activity, which has been associated with better health conditions (Alabdulgader, McCraty, Atkinson, Dobyns, Vainoras, Ragulskis, & Stolc, 2018; Edwards, 2015).

Conclusion

The psychophysiological coherence model is an established model based on bi-directional communication between the brain and the body, and emphasises the important connection between heart rhythm patterns and central neural networks responsible for cognitive processing and emotional regulation. The coherence model has informed the development of practical tools and techniques for increasing self-regulatory capacity and vagal activity in a wide range of populations. Numerous studies have provided evidence that coherence training, consisting of intentional activation of positive and calming emotions paired with HRV coherence feedback, facilitates significant improvements in measures of cognition, emotional self-regulation, social connection, health, and wellness. Cardiac coherence is a critical tool in resetting adaptive response patterns through a shift in the physiological baseline reference to a healthier, more sustainable pattern, in support of the body's optimal function.

Authors' note

Dr Elbers and Dr McCraty are employed by the HeartMath Institute which is a non-profit research centre supported by grants, donations, and some fees for service activities such as providing self-regulation trainings, sales of books and heart rhythm coherence technologies, all of which is focused on services to education, service members, veterans, and non-profit social services agencies. The HeartMath Institute does not manufacture any devices, and if and when they are included in research projects or resold, are purchased from the manufacturer in the same way as any other organisation.

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