Psychophysiological perspectives on emotion regulation

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Several studies have suggested a correlation between heart rate variability (HRV), emotion regulation (ER), and consequent psychopathological conditions. Specifically, recent data seem to support the hypothesis that low-frequency heart rate variability (LF-HRV), an index of sympathetic cardiac control, correlates with worse ER and specific psychopathological dimensions. The present work aims to review the previous findings on these topics and integrate them from two main cornerstones of this perspective: Porges' Polyvagal Theory and Thayer and Lane's Neurovisceral Integration Model, which are necessary to understand these associations better. For this reason, based on these two approaches, we point out that low HRV is associated with emotional dysregulation and transversal psychopathological conditions. This understanding is beneficial as a theoretical ground from which to start for further research studies and as a starting point for new theoretical perspectives useful in clinical practice.

Keywords: heart rate variability ; emotional regulation ; psychopathology ; polyvagal theory ; neurovisceral integration model

1. Introduction

Heart rate variability (HRV) has been increasingly recognized as a useful tool in medical research and psychological investigations as can be considered a transdiagnostic biomarker related with emotion regulation abilities [1]. The autonomic nervous system (ANS) activity, due to the actions of the sympathetic and parasympathetic reactivity, is linked to automatic reactions such as the "fight or flight" responses [2][3], and to emotional responses [4]. The vagus nerve is a major component of the ANS, and it has an essential role in connecting the heart and the brain, supporting their communication during emotional reactions. Porges Polyvagal Theory [5] provides an important explanation of the vagus nerve's role in regulating internal viscera and, again, the communication between the heart and the brain. The vagus nerve originates into two different nuclei of the brainstem: the Dorsal Motor Nucleus of the vagus (DNMX) and the Nucleus ambiguus (NA), ending in the sinoatrial node. However, only NA controls the respiratory sinus arrhythmia (RSA), an index of cardiac vagal modulation associated with emotion regulation (ER).

The DNMX and NA act competitively on the sinoatrial node, adjusting the anabolic parasympathetic activity and the catabolic sympathetic one. In this way, these two branches of the vagus's independent action have different effects on RSA and HRV. The sympathetic nervous system (SNS) innervates the cardio-accelerating center of the heart, the lungs (increased ventilatory rhythm and dilatation of the bronchi), and the non-striated muscles (artery contraction), releasing adrenaline and noradrenaline. On the contrary, the parasympathetic nervous system (PNS), which uses the neurotransmitter acetylcholine (ACh), innervates the cardiomoderator center of the heart, the lungs (slower ventilatoryrhythm and contraction of the bronchi), and the non-striated muscles (artery dilatation), reducing the experience of stress. Notably, these two systems act agonistically on the heart, respectively, through the stellate ganglion (a collection of sympathetic nerves) and the vagus nerve (a parasympathetic nerve). Heart rate variability (HRV) is a beat-to-beat variability [6], consisting of changes, fluctuations in intervals between heartbeats and reflects the autonomic balance, blood pressure, heart, gut, and vascular tone [7]. The Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology [8] divided heart rate (HR) oscillations into different bands, better known as ultra-low-frequency (ULF), very-low-frequency (VLF), low-frequency (LF), and high-frequency (HF). The HF component measures vagal activity, while the LF component is related to both vagal and sympathetic activities, and the LF/HF ratio reflects the cardiac sympathovagal balance [7].

2. Porges Polyvagal Theory and the Neurovisceral Integration Model from Thayer and Lane

Porges [5] claims that in mammals, the vagal tone is high when there are no external demands, no challenging situations coming from the external world, while it is low when there are situations that demand to be active such as during stress exercise and attention. According to Porges, mammals have a brainstem organization characterized by a ventral vagal complex that influences attention, emotion, motion, and communication. The Polyvagal Theory explains three evolutionary phylogenetic stages behind the development of the vagus nerve. These phylogenetic stages follow a hierarchical structure. The dorsal vagal system is the unmyelinated system, and it is considered the most archaic, so phylogenetically the oldest one. This system is associated with processes linked to immobilization (death-feigning), vasovagal syncope, and behavioral shutdown. After the dorsal vagal system, the sympathetic vagal system is described. This system is associated with "fight-flight" responses, so all the mechanisms behave to avoid the threat. The last step of this evolution recognizes the ventral vagal system, which is the newest and myelinated one, and it is associated with behaviors involving social and complex human experience such as communication (facial expression, vocalization, and listening). When this system fails in its functionality, the sympathetic vagal system is engaged by displaying the fight or flight response behavior. If this structure fails, the most ancient structure gets involved through an immobilization response [5][9]. Dyfunctional emotional regulation (ER) comes from a failure in the functionality of the latest structures.

According to Porges [10], communications between the peripheral organs and the brain allows mammalians to reach homeostatic balance. Neuroception, a term coined by Porges to describe the mechanism by which our brain can detect dangerous environmental stimuli by analyzing the information coming from our senses through body scanning, supports this communication between the brain and peripheral organs. In fact, the homeostatic balance is interrupted by a threat that our brain detects (consciously or unconsciously).

The Polyvagal Theory [11] provides a plausible explanation for the correlation between atypical autonomic regulation (e.g., reduced vagal influence on the heart) and psychiatric and behavioral disorders, outlining a complex framework of human thinking and behavior.

Beauchaine and Thayer [12] highlight the validity of respiratory sinus arrhythmia (RSA), an index for parasympathetic activity, and a transdiagnostic biomarker of emotional dysregulation and concurrent psychopathology in humans. The stress degree-level of an organism can be detected by measuring RSA, which is estimated by heart rate variability (HRV) that registers increased heart rate during inspiration and a decrease during expiration.

In line with the Research Domain Criteria (RDoC) project for the re-conceptualization of psychopathology [13][14][15][16], Beauchaine and Thayer claim that, in order to address knowledge on psychopathological transdiagnostic mechanisms, it is necessary to use psychophysiological measures. Thayer and Lane [17][18] introduced the neurovisceral integrated model of the heart-brain activity, where HRV is an index of integrity or not of the neural network involved in emotion-cognition interactions. In this model, HRV is both related to attentional and affect regulation, and this model improves understanding of the role of the central autonomic network (CAN), already pointed out by Benarroch [19]. They concluded that it is an integrated component of a complex regulation system by which the brain controls visceromotor, neuroendocrine, and behavioral responses, which are essential for goal-directed behavior and human adaptability. There are several regions of the central nervous system (CNS) such as the anterior cingulated, insular, orbitofrontal, and ventromedial prefrontal cortices together with the central nucleus of the amygdala (CeA), the paraventricular and related nuclei of the hypothalamus, the periaqueductal gray matter, the parabrachial nucleus, the nucleus of the solitary tract (NTS), the nucleus ambiguus (NA), the ventrolateral and ventromedial medulla, and the medullary tegmented field that are included in the CAN. These regions are reciprocally interconnected, and this interconnection leads the information flowing bidirectionally between lower and higher brain levels. According to this model, prefrontal-subcortical inhibitory circuits linked to self-regulation are connected with the heart through the functionality of the vagus nerve [20].

3. Emotion regulation abilities and Heart Rate Variability

Accumulating evidence confirms that HRV can be used as an index of self-regulation [21]. In fact, functional and adaptive top-down and bottom-up cognitive processes seem to associate with higher resting HRV, while maladaptive cognitive responses and hyper-vigilant responses are associated with lower resting HR, leading to impairment in emotion regulation abilities [20]. Individual differences in regulation ability are associated with greater baseline HRV [18][22]. This is also confirmed by both task-related HRV [21], and phasic increases in HRV in response to emotion-inducing situations that are associated with better and effective emotion regulation [23]. By contrast, low HRV is associated with emotion dysregulation, and emotion dysregulation is associated with many if not all psychopathologies [24][25][26].

Porges [23] has been one of the first in underlining the relationship between low HRV and emotional dysregulation visible in behaviors characterized by anxiety and rigid attentional threat processing. A meta-analysis by Zahn et al. [27] confirmed a clear relationship between low HRV and worse self-control over dysfunctional thoughts, impulses, behaviors, and emotions [28]. Low HRV is also associated with specific diagnostic categories, such as panic disorder [29][30], schizophrenia [31], borderline personality disorder [32], attention deficit hyperactivity disorder (ADHD) [33], neuroticism [34], and major depression [35].

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