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Meta-analysis

Heart rate variability indices as bio-markers of top-down self-regulatory mechanisms: A meta-analytic review☆

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ABSTRACT

Theoretical perspectives posit that heart-rate variability (HRV) reflects self-regulatory capacity and therefore can be employed as a bio-marker of top-down self-regulation (the ability to regulate behavioral, cognitive, and emotional processes). However, existing findings of relations between self-regulation and HRV indices are mixed. To clarify the nature of such relations, we conducted a meta-analysis of 123 studies (N = 14,347) reporting relations between HRV indices and aspects of top-down self-regulation (e.g., executive functioning, emotion regulation, effortful control). A significant, albeit small, effect was observed ($r = 0.09$) such that greater HRV was related to better top-down self-regulation. Differences in relations were negligible across aspects of self-regulation, self-regulation measurement methods, HRV computational techniques, at-risk compared with healthy samples, and the context of HRV measurement. Stronger relations were observed in older relative to younger samples and in published compared to unpublished studies. These findings generally support the notion that HRV indices can tentatively be employed as bio-markers of top-down self-regulation. Conceptual and theoretical implications, and critical gaps in current knowledge to be addressed by future work, are discussed.

Contents

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Heart rate variability (HRV) indices (e.g., respiratory sinus arrhythmia [RSA]), which may reflect the capacity for individuals to modulate cognitive activity, emotion, and behavior to adaptively respond to changing environmental demands, are often considered to be bio-markers of top-down self-regulation based on assertions from two prominent theoretical perspectives, Porges' Polyvagal Perspective (Porges, 1995, 2001, 2007) and Thayer and colleagues' Neurovisceral Integration Perspective (Thayer et al., 2009; Thayer and Lane, 2000). Both perspectives draw upon evidence that prefrontal cortical substrates of top-down self-regulation influence cardiac activity primarily through the parasympathetic nervous system. Given these perspectives, there is considerable interest in relations between HRV indices and aspects of top-down self-regulation (e.g., executive functioning, emotion regulation, self-control, effortful control). However, existing findings of such relations have been mixed. While some studies have observed significant positive associations between HRV indices and other measurement approaches used to assess self-regulation (e.g., Gentzler et al, 2009; Capuana et al., 2014; Hansen et al., 2003), other studies have not observed significant relations (e.g., Blair, 2003; Blankson et al, 2012; Santucci et al., 2008; Gyurak and Ayduk, 2008), and some studies have even observed significant inverse relations (e.g., Sturge-Apple et al., 2016).

Apart from mixed findings in the literature, other conceptually and theoretically important distinctions have been made that warrant consideration and may offer explanations for mixed findings in existing research. For example, while some contend that HRV is a bio-marker of emotion regulation (e.g., Appelhans and Luecken, 2006), others employ HRV as a bio-marker of executive control processes (e.g., Capuana et al., 2014; Hansen et al, 2003), suggesting that HRV may be a bio-marker of a fairly specific top-down self-regulatory process to the exclusion of other top-down self-regulatory processes. To clarify the relation between HRV indices and top-down self-regulation, as well as address key questions of methodological (e.g., are relations between HRV and top-down self-regulation different depending on sample characteristics, such as age or risk status?) and theoretical significance (e.g., are relations stronger when measures of emotion regulation or behavioral regulation are employed?), we conducted a meta-analysis of studies examining relations between HRV and measures of top-down self-regulation.

1. Top-down self-regulation

1.1. Conceptualization

Self-regulation, broadly defined, is a multi-dimensional aspect of temperament involved in the flexible regulation of behavior, emotion, and cognition through means of "top-down" and "bottom-up" neural mechanisms[1] (e.g., Bandura, 1991; Bridgett et al., 2015; Berger et al., 2007). Top-down self-regulation has been differentiated into two subcomponents: emotion regulation and behavioral regulation (Bridgett et al., 2015). These subcomponents have commonalities in terms of conceptual definitions and shared neurobiological substrates; although, some distinct neurobiological mechanisms for each have been reported (for an overview, see Bridgett et al., 2015). More specifically, emotion regulation can be defined as (top-down) regulatory processes that serve to increase or decrease the intensity of an emotion, and/or maintain it as a given situation may dictate (Gross, 2002; Gross and John, 2003; Cole et al., 2004). Emotion regulation consists of processes that are measured at "cognitive" levels (e.g., reappraisal, suppression, rumination; Webb et al., 2012) and behavioral levels (e.g., distraction, self-soothing). Behavioral regulation (i.e., top-down mediated regulatory processes aimed at modulating behavior) consists of several constructs, including executive functioning (Miyake and Friedman, 2012; Miyake et al., 2000), effortful control (Rothbart et al., 2003), and self-control (Gottfredson and Hirschi, 1990).

At the conceptual level, there has been growing recognition in the field that many constructs invoked as being self-regulatory in nature share considerable overlap in regards to their definitions and their underlying neural, physiological, and genetic origins (for discussion and overview, see Beaver et al., 2007; Bridgett et al., 2013; Bridgett et al., 2015; Schmeichel and Tang, 2015;

[1] Importantly, while bottom-up regulatory processes have neurobiological origins in areas related to emotional experience and memory (e.g., amygdala, hippocampus), top-down self-regulatory processes have neurobiological underpinnings in prefrontal cortical brain areas.