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Review

Heart rate variability and self-control—A meta-analysis

Daniela Zahn[a,*], Johanna Adams[a,b], Jeanette Krohn[c], Mario Wenzel[a], Caroline G. Mann[a], Lara K. Gomille[a], Vera Jacobi-Scherbening[a], Thomas Kubiak[a]

[a] Johannes Gutenberg-University Mainz, Health Psychology, Binger Str. 14-16, D-55122 Mainz, Germany
[b] University Medicine, Johannes Gutenberg-University Mainz, Institute for Teachers' Health, University Medical Center of the Johannes Gutenberg-University Mainz, Kupferbergterrasse 17-19, D-55116 Mainz, Germany
[c] Johannes Gutenberg-University Mainz, Personality Psychology and Psychological Assessment, Johannes Gutenberg-University Mainz, Binger Str. 14-16, D-55122 Mainz, Germany

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ABSTRACT

Heart rate variability (HRV) has been suggested as a biological correlate of self-control. Whereas many studies found a relationship between HRV at rest and self-control, effect sizes vary substantially across studies in magnitude and direction. This meta-analysis evaluated the association between HRV at rest and self-control in laboratory tasks, with a particular focus on the identification of moderating factors (task characteristics, methodological aspects of HRV assessment, demographics). Overall, 24 articles with 26 studies and 132 effects ($n = 2317$, mean age = 22.44, range 18.4–57.8) were integrated (random effects model with robust variance estimation). We found a positive average effect of $r = 0.15$, 95% CI [0.088; 0.221], $p < 0.001$ with a moderate heterogeneity ($I^2 = 56.10\%$), but observed evidence of publication bias. Meta-regressions did not reveal significant moderators. Due to the presence of potential publication bias, our results have to be interpreted cautiously.

Contents

* Corresponding author. Tel.: +49 6131 3939168; fax: +49 6131 3939186.
E-mail address: zahn@uni-mainz.de (D. Zahn).

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1. Introduction

Self-control refers to one's capacity to inhibit or modify dominant impulses related to thoughts, behaviors or emotions (de Ridder, Lensvelt-Mulders, Finkenauer, Stok, & Baumeister, 2012) and is considered a key factor for success in goal-oriented behaviors within a wide range of domains including exercising and adopting an active lifestyle, healthy eating, job and school performance (de Ridder et al., 2012). Self-control is also associated with psychological well-being and positive interpersonal relationships (Tangney, Baumeister, & Boone, 2004). The Strength Model of Self-Control (Muraven & Baumeister, 2000) posits that self-control is a limited resource. In turn, self-control research has focused on identifying underlying correlates of self-control, which may reflect self-control capacity on a physiological level. In this line of research, heart rate variability (HRV) has been suggested as a correlate of self-control (Baumeister, Vohs, & Tice, 2007). HRV refers to the beat-to-beat variation in heart rate and reflects the interplay between sympathetic and parasympathetic influences on heart rate (Appelhans & Luecken, 2006). It is assumed that HRV is an indicator of the flexibility of the autonomous nervous system which is necessary to modulate cardiac activity according to changing situational demands arising from changes in physiological as well as psychological states (Appelhans & Luecken, 2006). Based on this notion, HRV has been discussed as an index of physiological and psychological self-regulation (Thayer, Hansen, & Johnsen, 2010). Self-regulation and self-control are closely linked: whereas some researchers refer to the term *self-regulation* to describe automatic regulatory processes and to *self-control* to describe the deliberate regulation of impulses and behaviors, they are often used interchangeably (Baumeister et al., 2007).

Neurovisceral Integration Model (Thayer, Hansen, Saus-Rose, & Johnsen, 2009; Thayer & Lane, 2000) as well as Porges' Polyvagal Theory (Porges, 2001, 2007) provide theoretical frameworks linking HRV to concomitants of self-control such as cognitive and emotional regulation and social engagement. Neurovisceral Integration Model (Thayer et al., 2009; Thayer & Lane, 2000) posits that trait (i.e., at rest) HRV is a proxy for the “inhibitory capacity” of a central autonomic network (CAN) that regulates behavioral, cognitive, and emotional responses (Thayer et al., 2010). The CAN comprises brain regions related to inhibition and executive functions such as the prefrontal cortex and is reciprocally connected with the heart as well as the periphery via parasympathetic and sympathetic neural pathways. Through this neural network, the prefrontal cortex can exert inhibitory control on subcortical structures, thereby enabling the individual to flexibly and adaptively respond to situational demands. Polyvagal Theory (Porges, 2001, 2007) argues that the vagal tone is part of a social engagement system that had been originally developed to regulate flight/fight reactions triggered by sympathetic nervous system. Due to functional connections between vagal outflow and structures related to emotion processing, attention, and communication, the social engagement system enables behavioral responses such as social communication, self-soothing, and the inhibition of physiological arousal (Porges, 2007). Respiratory sinus arrhythmia (RSA), which is closely related to trait HRV, serves an index of tonic vagal tone. According to Porges, RSA indicates an individual's ability to maintain homeostasis and responsiveness to changing demands (Porges, 2001, 2007). In summary, both models assume that higher HRV should reflect a better ability to inhibit dominant impulses and behaviors, which can be considered a key component of automatic regulatory processes (i.e., self-regulation) as well as deliberate regulation (i.e., self-control). Hence, higher HRV may also indicate a better capability for self-control. Whereas many studies hint at a relationship between HRV and concomitants of self-control, the magnitude of the relationship remains still unclear.

In the present study, we aimed at (1) quantifying the magnitude of the association between trait HRV and self-control in laboratory settings in a meta-analysis and (2) evaluating potential moderators of the HRV-self-control connection. In the following sections, we briefly review empirical evidence on the association between self-control and trait HRV and discuss moderators of this relationship.

1.1. HRV and self-control

In the last decades, a considerable amount of empirical evidence has accumulated linking trait HRV and self-control: HRV is associated with a wide range of self-control processes and outcomes, such as addictive behaviors (e.g., Ingjaldsson, Laberg, & Thayer, 2003), binge eating (e.g., Friederich et al., 2006), depression (Rottenberg, 2007), emotion regulation strategies (see Appelhans & Luecken, 2006; for an overview), and cognitive performance (Thayer et al., 2009). The indicators of self-control that have been used in this research may be broadly categorized as outcome-related measures (e.g., addictive behavior, diet), self-report measures of trait self-control, and cognitive and affective processes reflecting self-control. However, there is evidence that these measures show only modest overlap: for example, one meta-analysis found only small to moderate associations between self-reported trait self-control and self-control outcomes such as diet or addictive behavior (de Ridder et al., 2012). In addition, self-report measures are only weakly correlated with performance in self-control tasks assessing basic cognitive processes (Duckworth & Kern, 2011). Outcomes and self-report measures reflect rather distal indicators of self-control, whereas cognitive processes can be considered proximal indicators of self-control, which constitute the basic mechanisms underlying self-control success in a wide range of behavioral domains. The current meta-analysis will focus on the relationship between HRV and basic cognitive processes as assessed by self-control tasks in the laboratory.

1.2. Association between HRV and self-control performance in laboratory tasks

Numerous experimental studies found evidence for positive associations between trait HRV and self-control for a range of cognitive processes including goal setting (Geisler & Kubiak, 2009), working memory and executive function (Hansen, Johnsen, &