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Effortful control and resiliency exhibit different patterns of cardiac autonomic control☆

Derek P. Spangler, Bruce H. Friedman *

Department of Psychology, Virginia Polytechnic Institute & State University, United States

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ABSTRACT

Effortful control (EC) and ego-resiliency (often shortened to resiliency) may similarly encode adaptability to stress. Differentiation of these traits in terms of autonomic control may highlight each construct's relative mechanisms in stress regulation. In the current study, 84 subjects self-reported levels of EC and resiliency and then were exposed to 3 mental stressors (mental arithmetic, speech preparation, verbal fluency), during which heart rate variability (HRV) was assessed to index cardiac vagal influences. Interbeat intervals (IBIs) were also collected, while pre-ejection period (PEP) and left ventricular ejection time (LVET) were assessed as sympathetic indices. Multiple regression was used to explore the extent to which autonomic control was moderated by each EC and resiliency. Results indicate that EC was related to concordance between IBI and HRV, along with negative emotion. Resiliency was more associated with coherence between IBI and PEP, and with positive emotion. Findings suggest that regulatory processes play a role in EC's adaptability to stress, while resiliency may involve approach motivation in stress control.

1. Introduction

1.1. Individual differences in self-regulation

Self-regulation describes the adaptation of responses to fit a given context or goal, including control over stress and related emotional states that incorporate fear or threat (Matthews et al., 2000; Rueda et al., 2004; Lovallo, 2004). There are a considerable number of traits that similarly describe individual differences in self-regulation, notably *effortful control* (EC) and *ego-resiliency* (Derryberry and Rothbart, 1997; Eisenberg et al., 2000). Although the construct of ego-resiliency emerged from a psychoanalytic milieu, the term is often shortened to "resiliency" in view of the waning impact of this perspective on contemporary psychology (in accordance with Tugade and Fredrickson, 2004). There is uncertainty about the distinctiveness of EC and resiliency, especially in regard to their autonomic nervous system characteristics. In the current study, we investigated how these constructs are each related to cardiac autonomic functioning and subjective emotion during stress, in order to clarify the extent to which they capture unique features of adaptability to stress.

1.1.1. Effortful control

Self-regulation of stress can be studied within the context of temperament; i.e., biologically-driven individual differences that are stable across the lifespan (Rothbart et al., 2004). In Rothbart's model, temperament includes nonconscious reactivity to appetitive and aversive stimuli (Rothbart and Bates, 2006). Voluntary regulation of this reactivity, known as effortful control, describes "the ability to inhibit a dominant response and/or activate a subdominant response, to plan, and to detect errors" (Rothbart and Bates, 2006, p. 129). There is general agreement that the core mechanism of EC is the executive attention system, which involves conscious detection and inhibition of responses, as well as activity in the anterior cingulate (ACC) and lateral prefrontal cortices (Bush et al., 2000; Fan et al., 2005). The attentional mechanisms of EC are often used to voluntarily regulate emotion and stress reactions, as supported by the negative relations of stress and negative affect with EC (Eisenberg et al., 2007; Putnam et al., 2001; Rothbart et al., 2000).

1.1.2. Resiliency

In contrast, resiliency is an individual difference describing the ability to adapt impulse expression to different contexts (Block and Block, 1980). Resiliency describes a specific set of self-regulatory skills that are more narrowly focused than *resilience*, which is a separate construct related to overcoming hardship (Luthar et al., 2000). Resiliency is held to be closely related to EC, in that it refers to "flexible, optimal attempts at coping or regulation" (Eisenberg et al., 2000, p. 139). Similar to EC, resiliency may rely on aspects of executive attention; i.e., it has been shown to relate to differences in attentional flexibility and problem

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* Corresponding author at: Department of Psychology (0436), Virginia Tech, Blacksburg, VA 24061-0436, United States.
E-mail address: bhfriedm@vt.edu (B.H. Friedman).

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solving (Kochanska et al., 2000; Genet and Siemer, 2011). Like EC, resiliency's adaptability is often applied to control stress (Block and Block, 1980). Compared to lower scorers, persons high in resiliency have been shown to better deal with and recover from stress and negative emotion (Klohnen, 1996; Tugade and Fredrickson, 2004).

1.1.3. Differences between EC and resiliency

Although both traits are involved in control of stress, there is evidence that resiliency is distinct from EC, in that resiliency mediates the contributions of EC to adaptive outcomes (Eisenberg et al., 2003, 2007). A possible unique aspect of resiliency is its reliance on motivation, or reactive behavioral inclinations to respond to appetitive stimuli (i.e., goals and rewards) (Elliot and Thrash, 2002). This notion is supported by resiliency's relations to positive emotion, impulsivity, and exploration (Klohnen, 1996; Cumberland-Li et al., 2004; Block and Kremen, 1996). Approach motivation is a reactive aspect of temperament that is somewhat independent to self-regulatory ability captured by EC (Derryberry and Rothbart, 1997). Resilients use positive emotion to recover from distress, but they may also employ more active aspects of approach such that they strive towards positive incentives to "undo" stress (Klohnen, 1996; Fredrickson et al., 2003). In contrast, EC may rely on executive attention for the same outcome. However, no study has contrasted the traits on the basis of top-down regulation and approach during stress. EC and resiliency's differences in this regard may be clarified by assessing their relation to autonomic nervous system characteristics, as is discussed below.

1.2. Cardiac autonomic control

Cardiac chronotropy describes how quickly the heart beats and is often assessed by the average duration of intervals between consecutive heart beats (interbeat interval, IBI). IBI is inversely related to heart rate and is dually innervated by both branches of the autonomic nervous system; sympathetic and parasympathetic (i.e., vagal) activities tend to shorten and lengthen IBIs, respectively (Berntson et al., 1994).

1.2.1. Cardiac vagal control

Cardiac vagal control (CVC) refers to regulation of cardiac chronotropy by the vagus nerve. One of the most common CVC metrics is obtained through spectral analysis of HRV, yielding spectral power at the frequency of respiration (.12–0.4 Hz; i.e., HF-HRV; Malliani et al., 1991; Task Force of The European Society of Cardiology and the North American Society for Pacing and Electrophysiology, 1996). CVC is held to be a proxy for prefrontal cortex (PFC) inhibition and executive control over automatic threat responses to stress (Thayer et al., 2009). This notion is supported by relations of augmented CVC to state/trait emotion regulation, as well as to increased prefrontal cortex (PFC) activity (for a review, see Appelhans and Luecken, 2006). CVC is often reflected in the extent that vagal withdrawal and recovery modulate cardiac responses during and following stress, respectively (Porges et al., 1996; Bazhenova et al., 2001). Vagal control's role in PFC regulation of stress may indicate that CVC is related to EC, because this trait operates through similar frontal control mechanisms.

1.2.1.1. CVC characteristics of EC and resiliency. EC, whether measured via self-report or laboratory tasks, shows a positive relationship with vagal control across development (Chapman et al., 2010; Eisenberg et al., 2007; Gerardi-Caulton, 2000; Kochanska et al., 2000). To our knowledge, only two studies have identified autonomic correlates of resiliency (Spangler, 1997; Souza et al., 2007). In particular, resilient persons show larger CVC decreases during stress and greater CVC recovery post-stress. It is thus reasonable to speculate that resiliency and EC bear similar relationships to vagal control. However, no study has compared these traits in terms of CVC under stress, in order to clarify their differential relations to top-down regulation.

1.2.2. Cardiac sympathetic control

In contrast, sympathetic cardiac activity can be assessed with systolic time intervals derived from impedance cardiography, such as pre-ejection period (PEP) and left-ventricular ejection-time (LVET) (Ahmed et al., 1972). Lower values of PEP and LVET reflect heightened cardiac sympathetic control (Thayer and Uijtdehaage, 1990). Higher PEP and LVET indicate longer periods between electromechanical and hemodynamic cardiac events, and predict longer IBIs (i.e., slower heart rate). These measures are *inotropic*; i.e., they reflect beta-adrenergic effects on myocardial contractility (Newlin and Levenson, 1979). No unequivocal sympathetic cardiac chronotropic index has been established, but LVET has been shown to reflect more chronotropic function than PEP does (Uijtdehaage and Thayer, 2000).

Beta-adrenergic sympathetic control (i.e., PEP shortening) is thought to index metabolic resource mobilization for goal-directed behavior; i.e., the intensity of effort to attain reward/goals (Wright and Kirby, 2001; Richter and Gendolla, 2009). Although goal-related effort captured by PEP can be a product of self-regulation, it has been particularly linked to reactive approach motivation (Pochon et al., 2002). This notion is supported by consistent relations of PEP to reward value and trait approach (e.g., Brenner et al., 2005; Eubanks et al., 2002). Since resiliency incorporates inclination to reward, it is possible that resiliency is related to effort mobilization; i.e., enhanced cardiac sympathetic control. To the authors' knowledge, the relation between sympathetic control and EC has not been examined.

1.3. Emotion and traits

It is unclear whether achievement-related emotions that have been linked to effort mobilization (e.g., interest, excitement) are implicated in resilients' control of stress, as only low-energy positive states (e.g., pleasure) have been highlighted in this regard (Fredrickson et al., 2000; Kreibig et al., 2010). As such, achievement- and pleasure-related emotions were represented in the present study by excitement and contentment, respectively. Negative emotions linked to stress, like anxiety and frustration, were assessed to help identify unique relations of traits to stress regulation (Lovallo, 2004).

1.4. The present study

The primary aim of this study was to examine if resiliency and EC differ as self-regulatory traits in the context of stress, such that they differentially relate to cardiac autonomic control of stress reactivity and recovery. Vagal control and sympathetic control were compared between EC and resiliency to assess their comparative reliance on top-down regulation and goal-directed effort, respectively. Unlike studies that examine autonomic chronotropic control as reactivity/recovery in HRV and PEP, the current study more directly indexed autonomic control by correlating IBI reactivity/recovery with concurrent fluctuations in autonomic activity (Cacioppo et al., 1994). Large correlations between HF-HRV and IBI changes and between PEP and IBI changes indicate high vagal and sympathetic control, respectively. In a regression approach, trait associations with autonomic control were represented by EC and resiliency's moderation of correlations between autonomic activity and IBI (Levy and Zieske, 1969).

1.4.1. Specific aims

Comparisons between EC and resiliency were made by addressing the following aims: (1) to examine the relation of EC and resiliency with levels of positive and negative emotions during stress; (2) to examine (a) EC's association with CVC of stress reactivity and recovery, as indexed by EC's moderation of IBI–HRV relations and (b) EC's relationship to stress-related sympathetic control, as measured by IBI–PEP and IBI–LVET associations; and (3) to demonstrate resiliency's relations with cardiac (a) vagal and (b) sympathetic control during stress reactivity and recovery, as indexed by resiliency's moderation of IBI–HRV and