Predictors and Consequences of Thought Suppression Ability: A Replication and Extension

Dissertation

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By

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Abstract

Previous research has shown that individual differences in self-regulatory capacity, including resting heart rate variability (HRV), moderate thought suppression success. However, it remains unclear to what extent individual differences in self-regulatory capacity predict thought suppression success under conditions of cognitive load. Furthermore, few studies have investigated whether utilizing thought suppression can impact an individual's perception of their self-regulatory capacity (i.e., self-reports of effortful control). The current study aimed to further explore the relationship between predictors and consequences of thought suppression ability and sought to replicate the findings from previous work. The current study used a standard thought suppression paradigm that included a cognitive load condition in which participants recorded occurrences of a personally relevant intrusive thought over three monitoring periods. Participants also rated their level of effortful control both before and after the thought suppression task. Results were not generally consistent with those found in previous study examining resting HRV and thought suppression ability. Cognitive load did not significant impact the effects of HRV and effortful control on thought suppression ability. Moreover, performance on the thought suppression task did not significantly affect self-reports of effortful control. Reasons for such replication failures are considered and future directions for research on the roles of self-regulatory capacity, cognitive load, and thought suppression ability are discussed.

Dedication

This work is dedicated to my loving wife, Theresa and my wonderful son, Alexander. I cannot thank you enough for your love and willingness to sacrifice.

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I greatly appreciate the continued support of my advisors, Dr. Julian Thayer and Dr. Michael Vasey. Thank you so much for your guidance, both professionally and personally, that you provided me throughout my graduate school career.

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Publications

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Chapter 1: Introduction

One hallmark of psychological health is the ability to control the experience of unwanted and intrusive thoughts. Thought suppression is one of a number of mental control strategies that individuals employ to manage the occurrence of unwanted cognitions. However, many have critiqued the effectiveness of thought suppression as mental control strategy on the basis that it sometimes serves to paradoxically increase the frequency of intrusive thoughts (Wegner, Schneider, Carter, & White, 1987). Moreover, engaging in thought suppression can be counterproductive in other ways, by leading to increases in negative mood and negative appraisals regarding one's self-efficacy (Borton, Markowitz, & Dieterich, 2005; Kelly & Kahn, 1994). Yet, evidence consistently suggests that both clinical and nonclinical samples frequently use thought suppression as a means of controlling the occurrence of unwanted thoughts (Clark & Purdon, 2009; Rachman & Silva, 1977). Given the widespread use of thought suppression and its association with psychopathology, particularly obsessive-compulsive disorder (OCD), posttraumatic stress disorder (PTSD), and depression, it is important to explore how individual differences and circumstantial factors impact the effectiveness of thought suppression. The proposed study will examine the influence of cognitive load and individual differences in self-regulatory capacity on thought control ability assessed via a laboratory based suppression task. An additional aim is to examine whether thought suppression success impacts self-reports of self-regulatory capacity. The proposed study is a replication and extension of previous work (Gillie, Vasey, & Thayer, 2015).

Thought suppression

Can individuals keep a particular thought out of mind? Wegner and colleagues (1987) examined this question in their seminal “white bear” studies. In this paradigm, participants were assigned to either a *suppression* condition in which they tried to not think of a white bear or a *monitor/expression* condition in which they were simply asked to monitor the occurrence of thoughts of white bears. Participants indicated each time they thought of a white bear by ringing a bell. A series of studies using this general paradigm consistently found that participants instructed to not think of a white bear reported more thought intrusions during the suppression period (e.g., an immediate enhancement effect) and a subsequent recovery period (e.g., a post-suppression rebound effect) than those who were not instructed to monitor (Wegner & Erber, 1992; Wegner et al., 1987; Wegner, Schneider, Knutson, & McMahon, 1991). On the basis of these findings, Wegner and colleagues (1987) concluded that thought suppression is an ineffective mental control strategy because it often serves to paradoxically increase occurrences of unwanted thoughts.

Wegner (1994) proposed the ironic process model of mental control to account for the paradoxical consequences that result from thought suppression efforts. Ironic process theory suggests that engaging in thought suppression activates two cognitive mechanisms: 1) an intentional, effortful operating process that seeks distractor thoughts and 2) an automatic monitoring process that searches for occurrences of the to-be-avoided thought. The role of the operating process is to keep the unwanted thought out of conscious awareness by searching for distractor thoughts (anything other than the unwanted thought). The monitoring process serves an ironic function in that it maintains a representation of the unwanted thought at some level of consciousness. Yet, the monitoring process is necessary because it alerts the individual to occurrences of the unwanted thought and thus re-engages the search for distractor thoughts. According to the model, the operating process requires sustained effort and can be voluntarily terminated or disrupted by cognitive load, whereas the monitoring process is automatic and continues after the operating process has abated. The continuation of the monitoring process in the absence of the operating process enhances the individual's awareness of the unwanted material, thereby producing the ironic initial enhancement and post-suppression rebound effects.

Wenzlaff and Wegner (2000) acknowledged that most laboratory based inductions of suppression are contrived because they do not address the fact that that thought suppression, as it exists in the "real world," is often a self-initiated process. However, a number of studies have attempted to induce spontaneous suppression attempts in the laboratory and in doing so, have also provided additional evidence for the enhancement of the paradoxical consequences of suppression (Arndt, Greenberg, Solomon, Pyszczynski, & Simon, 1997; Greenberg, Arndt, Schimel, Pyszczynski, & Solomon, 2001). On the basis of these findings, Wenzlaff and Wegner (2000) concluded, "spontaneous suppression appears to result in the same type of paradoxical effects as does instructed suppression" (pg. 72).

Since the initial experiments of Wegner and colleagues, thought suppression research has greatly expanded. For example, researchers have examined methodological variables that can influence the effects of thought suppression including thought valence and personal relevance, thought assessment techniques, and how suppression is experimentally induced (Merckelbach, Muris, Van den Hout, & de Jong, 1991; Rassin, Muris, Jong, & Bruin, 2005). In addition, there is evidence linking thought suppression to emotion, memory, interpersonal consequences, and psychopathology (for a review see Wenzlaff & Wegner, 2000). As empirical evidence accumulated, researchers began to quantitatively examine the magnitude of thought suppression effects across controlled studies. Abramowitz, Tolin, and Street (2001) conducted the first meta-analysis on this subject, in which they included twenty-eight laboratory studies. The results indicated a small to moderate postsuppression rebound effect ($d_+ = .30$), but there was no evidence of an immediate enhancement effect (Abramowitz et al., 2001). In addition, the magnitude of the rebound effect varied as a function of the method by which thought frequency was measured such that covert methods of data collection (e.g., pressing a key silently) yielded greater effects than obtrusive methods (e.g., ringing a bell, and stream of consciousness) (Abramowitz et al., 2001). A more recent meta-analytic quantitative review showed no overall differences in the recurrence of intrusions due to thought suppression between individuals with and without psychopathology (Magee, Harden, & Teachman, 2012). Overall, there seems to be only partial support for the ironic consequences of thought suppression.

Although a majority of studies have examined how thought suppression impacts intrusive thought frequency, others have investigated its effects on mood state, appraisals of self-concept, and beliefs about thought controllability. A number of studies have found that among both clinical and non clinical samples, suppression of personally relevant (e.g., a loved-one being involved in a car accident) or obsessional thoughts are associated with higher levels of subjective distress and more negative mood state relative to suppression of positive or neutral thoughts (Belloch, Morillo, & Giménez, 2004; Borton et al., 2005; Grisham & Williams, 2009; Najmi, Riemann, & Wegner, 2009; Purdon & Clark, 2001; Rassin, 2001; Roemer & Borkovec, 1994). Thought suppression can also negatively impact an individual's self-concept. For example, after failing to suppress separation-related thoughts, highly avoidant individuals report an increase in the accessibility of negative self-representations and a reduction in the accessibility of positive self-representations (Mikulincer, Dolev, & Shaver, 2004). In another study, participants who suppressed negative self-referent thoughts experienced lower state self-esteem compared to those who did not suppress (Borton et al., 2005). Clark and Purdon (2009) conducted a phenomenological study of control over intrusive thoughts and found that nonclinical samples attributed their failures in thought control to personal failures of willpower or strength. Relatedly, others have shown that experiencing a post-suppression rebound is followed by increased reports of feeling out of control of one's thoughts (Kelly & Kahn, 1994; Tolin, Abramowitz, Hamlin, Foa, & Synodi, 2002). Taken together, these results suggest that the consequences of thought suppression extend well beyond increased occurrences of unwanted thoughts.

Based on these findings, a majority of researchers have concluded that thought suppression and its repercussions are maladaptive. However, a number of studies have provided evidence to the contrary. For example, McLean and Broomfield (2007) had participants suppress a worrisome thought and record their relative success and beliefs about worry controllability over the course of a week. The results showed that those who were asked to suppress reported more success at controlling their chosen worries and found them more controllable and less distressing than the control group (McLean &

Broomfield, 2007). In addition, thought suppression can result in mood improvement. For instance, chronic use of thought suppression predicted *decreases* in levels of depression over a 7-week period, but only during times of lower life stress (Beevers & Meyer, 2004). Others have shown that highly socially anxious individuals report reduced shyness after suppressing thoughts of a recent social interaction (Magee & Zinbarg, 2007). The potential benefits of thought suppression may also include enhanced physiological regulation. Fraley and Shaver (1997) found that avoidant individuals displayed a decrease in physiological activation, as indexed by skin conductance levels, after suppressing thoughts about abandonment. Taken together, such evidence suggests that thought suppression can result in both maladaptive and adaptive outcomes.

Regardless of whether thought suppression incurs negative consequences or not, it remains a widely used mental control strategy. Individuals with obsessive-compulsive disorder (OCD) use suppression as a means of avoiding the unpleasantness associated with experiencing obsessional thoughts and performing compulsive behaviors (Purdon, Rowa, & Antony, 2007). In addition, nonclinical samples occasionally experience intrusive cognitions and frequently use thought suppression as a mental control strategy (Clark & Purdon, 2009; Freeston, Ladouceur, Provencher, & Blais, 1995). Some theorists suggest that suppression efforts are reinforced through immediate distress reduction and removal of the unwanted thought (Rachman & Hodgson, 1980; Salkovskis, 1985). Yet, if thought suppression paradoxically increases occurrences of the unwanted thought and leads to more a more negative mood state and self-appraisals, why do individuals continue to suppress? In light of evidence suggesting that thought suppression is not inevitably counterproductive, one possibility is that some individuals are able to engage in thought suppression and avoid most, if not all of its negative repercussions. To evaluate this hypothesis, it is worth considering whether there are factors that influence thought suppression success.

Predictors of thought suppression success

Individual differences in self-regulatory capacity and one's perceptions regarding such capacity are two factors that can influence thought suppression success. Self-regulatory capacity refers to one's ability to alter one's own emotions, thoughts and behaviors especially to bring them into line with standards such as ideals, values, morals, social expectations, and to support long-term goals (Carver & Scheier, 1982). Individuals regulate themselves by using a broad collection of strategies, most of which are effortful and conscious while some are effortless and automatic (Fujita, 2011; Gyurak, Gross, & Etkin, 2011). Moreover, individuals differ greatly in their ability to self-regulate. Individual differences in self-regulatory ability predict a wide variety of outcomes including physical health, academic and financial success, as well as mental health (Moffitt et al., 2011; Tangney, Baumeister, & Boone, 2004). Thus, one would expect that self-regulatory ability may also predict the extent to which thought suppression is effective.

Indeed, individual differences in self-regulation, indexed through a variety of measures, are associated with thought suppression ability. Brewin and colleagues (2002; 2005) reasoned that if intentional thought suppression is an effortful process that competes for limited resources, those with greater cognitive capacity should be better able to keep unwanted thoughts out of mind relative to those with a more limited capacity. In support of this idea, individuals with higher levels of fluid intelligence and working memory capacity experience fewer intrusions during suppression than their low capacity counterparts (Brewin & Beaton, 2002; Brewin & Smart, 2005). Moreover, increasing working memory capacity by means of an executive function training program leads to improvements in the ability to suppress unwanted thoughts (Bomyea & Amir, 2011). Other performance based measures of self-regulatory capacity, including those that assess inhibitory control, have also been linked to individual differences in thought suppression ability. Inhibitory control is a self-regulatory process that is often defined as the ability to exert control over previously activated cognitive representations (Munakata et al., 2011). Individuals who display greater inhibitory control are more likely to be successful at suppressing unwanted thoughts (Ólafsson et al., 2013; Wessel, Huntjens, & Verwoerd, 2010). Thus, it appears that self-regulatory capacity, assessed via performance based measures, relates to thought control ability.

Self-reports of an individual's self-regulatory capacity also predict the extent to which thought suppression is successful. For example, individuals who rated themselves as having low overall trait self-control were more likely to experience inappropriate sexual thoughts compared to those with high self-control (Gailliot & Baumeister, 2007). Using a mortality salience treatment to induce spontaneous suppression, Gailliot, Schmeichel, & Baumeister (2006) found that participants who reported high levels of self-control generated fewer death-related thoughts and reported less death anxiety compared to those with low levels of self-control. According to the strength model of self-control (Baumeister, Bratslavsky, Muraven, & Tice, 1998), acts of self-regulation deplete an individual's pool of limited resources making subsequent attempts at self-regulation less effective. Researchers have investigated the impact of self-regulatory depletion on the effectiveness of thought suppression. Using various depletion paradigms, researchers have shown that individuals whose self-regulatory resources had been depleted were more likely to experience the ironic consequences of thought suppression (Gailliot & Baumeister, 2007; Gailliot et al., 2006). Interestingly, the act of thought suppression itself can deplete an individual's self-regulatory regulatory resources; those who engaged in thought suppression performed worse on subsequent acts of self-regulation (Burkley, 2008; Muraven, Tice, & Baumeister, 1998; Tyler, 2008).

In summary, individual differences in self-regulatory capacity appear to impact thought suppression ability and its consequences. Evidence suggests that both objective markers and self-reports of self-regulatory capacity predict thought suppression success. However, the extent to which these different measurement modalities relate to one another remains unclear. More generally, different measures of self-regulatory capacity show only moderate overlap (Duckworth & Kern, 2011), suggesting that there may be important differences between measurement modalities in the prediction of thought suppression success. If so, a better understanding of these differences might guide researchers on which measures might be the best predictors of thought suppression success. Furthermore, clarifying this issue could benefit clinical interventions by identifying a specific pathway to modify the effectiveness of thought suppression. A recent study (Gillie et al. 2015) explored the relations among objective markers and self-reports of self-regulatory capacity and thought suppression success. As this study serves as the basis for the current proposal, it is important to understand its rationale, method, and conclusions.

Relations among heart rate variability, effortful control, and thought suppression success

Gillie, Vasey, & Thayer (2015) sought to further explore the link between self-regulatory capacity and mental control by examining the effect of individual differences in heart rate variability (HRV) and self-reported effortful control (EC) on thought suppression ability. Both HRV and self-reports of EC are well-established measures of self-regulatory capacity. Moreover, evidence suggests that HRV and EC are associated with the same control processes thought be involved in the successful suppression of unwanted thoughts. However, evidence also suggests that the two measures are only modestly correlated (Chapman, Woltering, Lamm, & Lewis, 2010; Healy, Treadwell, & Reagan, 2011; Spangler & Friedman, 2015; Sulik, Eisenberg, Silva, Spinrad, & Kupfer, 2013)

HRV represents the beat-to-beat changes in heart rate that result from the interplay between sympathetic and parasympathetic nervous system influences on the heart. Although both branches influence heart rate, evidence suggests that that parasympathetic influence is dominant (Levy, 1990), indicating that the heart is under tonic inhibitory control peripherally via the vagus nerve. Vagal modulation of cardiac activity allows the organism to quickly and flexibly respond to environmental challenges. Moreover, there are direct and indirect pathways by which the prefrontal cortex modulates parasympathetic activity via subcortical circuits (Ter Horst, 1999). Thayer and Lane (2000, 2009) proposed an inhibitory cortical-subcortical circuit that supports physiological, affective, and cognitive regulation, and whose activity can be indexed by vagally mediated HRV. According to this model, higher levels of HRV (i.e. greater vagal tone) at rest are a product of a system in which the prefrontal cortex exerts inhibitory control over subcortical circuits thus allowing the organism to respond to environmental challenges in a controlled and adaptive manner when needed (Thayer & Lane, 2000; 2009). Importantly, individual differences in HRV can be observed during resting baseline periods and appear to be relatively stable over time (Li et al., 2009). Given the relations between prefrontal cortical activity and the vagus nerve, we would expect that those higher in vagally mediated HRV should be better able to respond to demands from the environment, and organize their behavior effectively.

Indeed, a number of studies have found evidence that individual differences in HRV serve as an index of self-regulatory capacity. For instance, those with high HRV show enhanced performance on executive function tasks including those that assess working memory (Hansen, Johnsen, & Thayer, 2003), attention (Johnsen et al., 2003), and motor response control (Krypotos, Jahfari, van Ast, Kindt, & Forstmann, 2011). Moreover, high HRV individuals are better able to maintain their attention and cognitive resources under cognitive load (Hansen, Johnsen, & Thayer, 2009; Park, Vasey, Van Bavel, & Thayer, 2013) and are less susceptible to the depleting effects of self-regulatory challenges (Segerstrom & Nes, 2007). By contrast, those with low HRV are characterized by self-regulatory deficits including poor attentional control, ineffective emotional regulation and behavioral inflexibility (Thayer & Brosschot, 2005). Of particular relevance to the occurrence and control of intrusive thoughts, imaging studies have shown that the brain regions involved efforts to suppress unwanted thoughts, including the dorsolateral prefrontal cortex (DLPFC), medial prefrontal cortex (MPFC), and anterior cingulate cortex (ACC) (Mitchell et al., 2007; Wyland, Kelley, Macrae, Gordon, & Heatherton, 2003) are also part of the inhibitory cortico-subcortical pathway that influences levels of HRV at rest (Thayer, Ahs, Fredrikson, Sollers, & Wager, 2012). Taken together, these findings suggest that individual differences in HRV may impact thought suppression ability.

Another construct that may also impact thought control ability is effortful control. According to Rothbart's model of temperament (1998), individual differences in reactivity and effortful control are two important determinants of behavior. Reactivity refers to the excitability, responsivity, and arousability of behavioral and physiological systems of the organism, whereas effortful control (EC) is a self-regulatory dimension of temperament that reflects one's capacity to voluntarily modulate this underlying reactivity by inhibition of prepotent responses and substitution of more adaptive alternatives (Rothbart, Ellis, Rueda, & Posner, 2003). More specifically, EC has been defined as "the ability to inhibit a dominant response to perform a subdominant response, to detect errors, and to engage in planning" (Rothbart et al., 2003). Individual differences in these self-regulatory abilities appear quite early in childhood and are relatively stable over time. In fact, differences in performance on behavioral tasks that reflect aspects of EC have been observed in children as young as 2.5 years and remain stable across a period of 3 years (Kochanska, Murray, & Harlan, 2000). A variety of paradigms from delay of gratification tasks to Stroop-like spatial conflict tasks have been used to index aspects of EC (Rothbart et al., 2003), but it can also be measured in both children and adults through self-report questionnaires (Ellis & Rothbart, 2001; Evans & Rothbart, 2007). Lastly, individual differences in EC appear to have a neurobiological basis. Parent-reported levels of EC are positively correlated with activity in the anterior cingulate cortex and lateral prefrontal cortex and performance on tasks that require error detection and inhibition of prepotent responses (Chang & Burns, 2005; Rothbart, Ellis, & Posner, 2004). In addition, self-reports of effortful control in adults are related to aspects of executive function including updating/monitoring information in working memory (Bridgett, Oddi, Laake, Murdock, & Bachmann, 2013) In summary, it is clear that individual differences in EC reflect relatively enduring capacities for self-regulation.

In line with previous studies examining the association between self-regulatory capacity and thought suppression success, Gillie, Vasey & Thayer (2015) hypothesized that those with high levels of self-regulatory capacity, as indexed by HRV would exhibit greater declines in intrusions during and following suppression attempts relative to those with low levels of such capacity. Moreover, we examined the interaction between these measures of self-regulatory capacity and spontaneous attempts at suppression in the prediction of intrusive thought frequency. We employed a standard laboratory thought suppression paradigm to test the hypotheses. In this task, participants were asked to track the occurrence of a personally relevant thought (i.e., a loved-one in a car accident) over three monitoring periods: baseline (P1), manipulation (P2), and final monitoring (P3), each lasting a total of five minutes. In addition, participants were randomly assigned to either a suppression condition, in which they received instructions to suppress the target thought during the second period, or a control condition in which they were not given any instructions to suppress. All participants indicated each time they experienced the target thought by pressing a button on the computer keyboard in front of them. Following each 5-minute period participants were asked to rate their current level of distress and efforts to suppress the target thought (0 = ‘not at all distressing’ to 100 = ‘extremely distressing’ and 0 = ‘not at all trying to suppress’ to 100 = ‘trying extremely hard to suppress’, respectively). Variations of this thought suppression task have been successfully employed in a number of recent studies (Grisham & Williams, 2009, 2013; Williams et al., 2009). Resting levels of HRV were obtained during a 5 minute baseline period prior to the start of the thought monitoring periods while self-reports of EC were collected after the task.

The results showed that individuals in both experimental conditions (control and suppress) experienced a similar decline in unwanted thoughts over the course of the experiment on average, indicating a general absence of the paradoxical consequences of thought suppression. HRV at rest was not significantly associated with experimental condition, number of intrusions, suppression effort, or distress during the baseline monitoring period. However, consistent with expectations, the results revealed a significant interaction between experimental condition and resting levels of HRV in the prediction of intrusive thought frequency change from P1 to P2 (β = -1.04, *sr* = -.17, *p* = .01)[1]. Although the same interaction predicting intrusive thought frequency change from P2 to P3 was not significant (β = -.42, *sr* = -.09, *p* = .19), it showed a similar pattern. In other words, among those instructed to suppress, higher levels of HRV were associated with greater declines in intrusions across the monitoring periods while no such relationship was found among those assigned to a free thought control condition; these results are illustrated in Figure 1.

[1] The Condition x HRV interaction also significantly predicted change in intrusions from P1 to P3 (β = -1.03, *sr* = -.15, *p* = .009), such that among those instructed to suppress, higher levels of HRV were associated with greater declines in intrusions. Importantly, after accounting for intrusions experienced during P2, the interaction predicting change in intrusions from P1 to P3 was no longer significant (*sr* = -.07, *p* = .15, suggesting that members of the suppress condition with higher levels of HRV experienced fewer intrusions during P3 because of their success during instructed suppression.

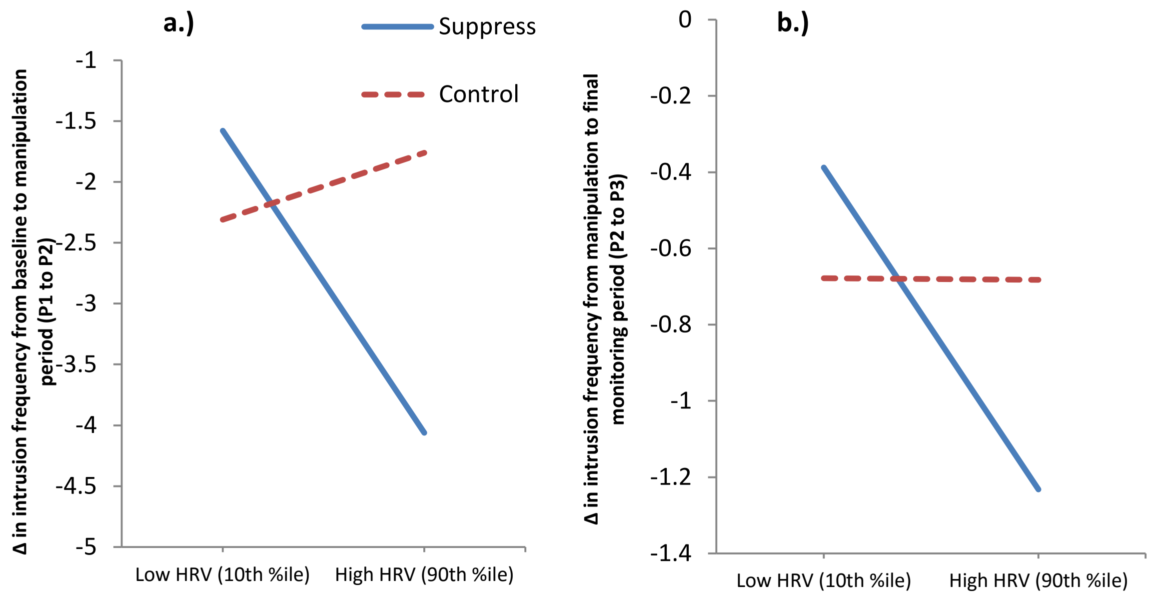

Figure 1. A significant Condition x HRV interaction predicting change in thought frequency from P1 to P2 (a). Negative values reflect *declines* in intrusion frequency. Condition x HRV interaction did not significantly predict change in thought frequency from P2 to P3 (b).

In addition to the effects of instructed thought suppression, the researchers also examined the role of spontaneous suppression. Individuals in both experimental conditions were motivated to suppress for reasons above and beyond the instructions of the experiment as each group reported making efforts to suppress during the manipulation period. Moreover, the vast majority of variance in suppression effort was independent of experimental condition. Therefore, statistically controlling for the influence of experimental condition on self-reports of suppression effort allowed the researchers to assess the effects of spontaneous suppression. The results showed that spontaneous suppression efforts in P2 interacted with resting HRV to predict change in intrusions from P1 to P2 (β = -.47, *sr* = -.16, *p* = .01). As illustrated in Figure 2, when HRV was low, greater spontaneous suppression effort was associated with less decline in intrusions from P1 to P2. In contrast, spontaneous suppression effort was unrelated to change in intrusions at higher levels of HRV (Figure 2). Among those with high HRV, the magnitude of decline in intrusions was similar regardless of their level of spontaneous suppression effort. In summary, these results demonstrate that individual differences in HRV at rest modulate the success of both instructed and spontaneous attempts at thought suppression.

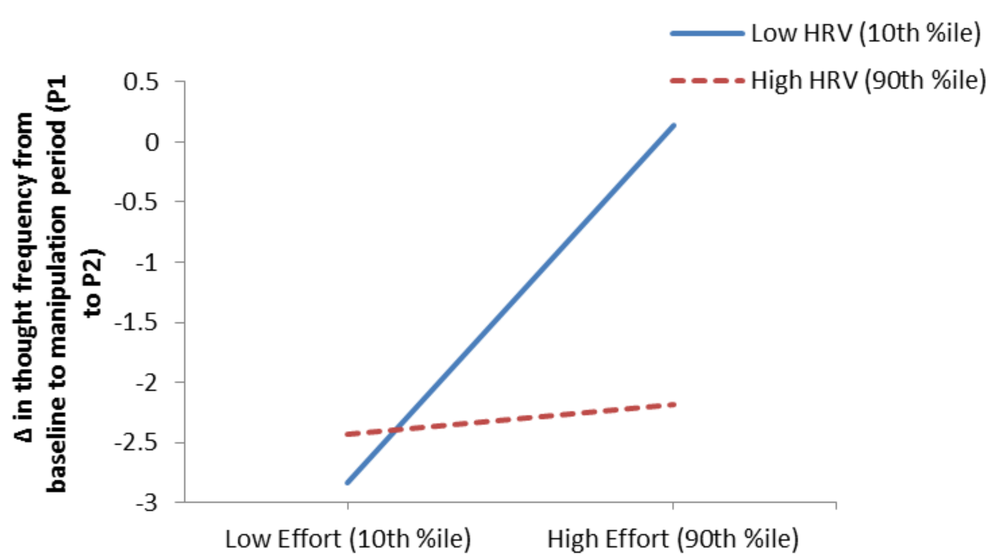

Figure 2. Suppression effort x HRV interaction predicting change in thought frequency from P1 to P2. Negative values reflect *declines* in intrusion frequency

Individual differences in EC were expected to influence thought suppression ability in a similar manner as resting HRV. However, EC was not significantly related to experimental condition, number of intrusions, suppression effort, or distress during the baseline monitoring period. That said, the interaction between experimental condition and EC was in the expected direction both in the prediction of change in intrusions from P1 to P2 (β = -.30, *sr* = -.05, *p* = .46) and P1 to P3 (β = -.60, *sr* = -.09, *p* = .10), though not statistically significant. Moreover, spontaneous suppression efforts did not interact with EC to predict change in intrusions from P1 to P2 (β = -.18, *sr* = -.06, *p* = .32). Thus, in contrast to individual differences in HRV at rest, self-reports of EC did not influence thought suppression ability.

The researchers sought to better understand why EC was not predictive of thought suppression ability. One explanation for these null findings may be the manner in which self-reports of EC were collected. Because the questionnaire measure of EC was administered after participants completed the thought suppression paradigm, it is possible that participants' performance on the task may have influenced self-reports of EC. Because performance on the suppression task was determined by the interaction between experimental condition and HRV, the researchers first examined whether the association between EC and HRV differed across the two experimental conditions. Indeed, the results revealed a non-significant negative correlation between HRV and EC among those in the control condition (*r* = -.14, *p* =.24) and a significant positive correlation among those in the suppression condition (*r* = .32, *p* =.006). Regression analysis controlling for intrusions experienced in P1 confirmed that HRV interacted with experimental condition to predict EC (β = .48, *sr* = .21, *p* = .01), such that among individuals instructed to suppress, those with high levels of HRV reported higher levels of EC relative to those with low HRV (Figure 3).

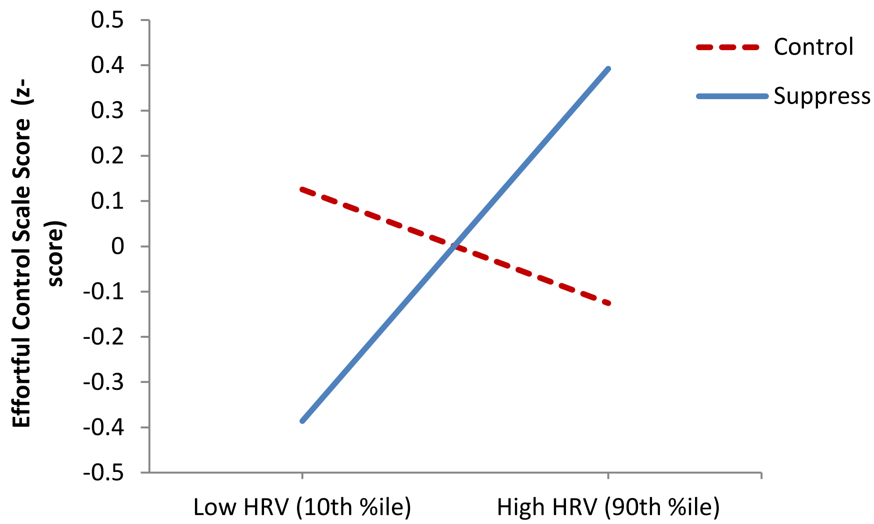

Figure 3**.** Experimental condition by HRV interaction predicting self-reports of EC following the thought suppression task. Note: Positive values reflect higher levels of EC.

The researchers also examined whether reports of EC differed as a function of spontaneous suppression effort and HRV. However, regression analysis controlling for the influence of experimental condition revealed that the HRV by suppression effort interaction term was not significantly significant (β = -.07, *sr* = -.07, *p* = .40).

Having established that experimental condition moderated the effect of resting HRV on EC, the researchers conducted further exploratory analyses aimed at testing whether task performance, assessed via change in intrusions from P1 to P2, mediated this relationship. This amounted to a hypothesis of moderated mediation in which HRV's association with EC was mediated by change in instructions from P1 to P2 and dependent upon experimental condition. As previous results demonstrated that experimental condition interacted with HRV to predict change in thought frequency, experimental condition was considered a moderator of the "a" pathway (Figure 4).

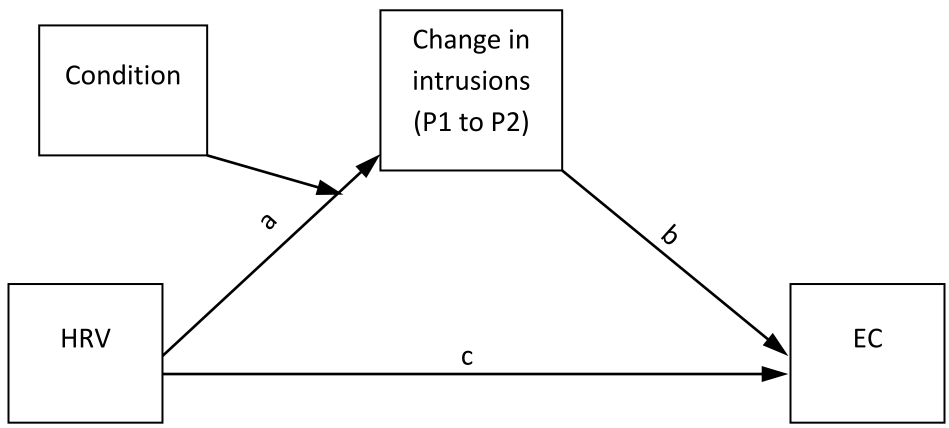

Figure 4. Conceptual diagram of moderated mediation analysis

Analyses were conducted using the PROCESS utility for SPSS (Hayes, 2013) and an estimate of the conditional indirect effect of HRV on EC was assessed via bias corrected bootstrap 95% confidence intervals (based on 5000 bootstrap samples). The results showed that change in intrusion frequency significantly predicted reports of EC (β = -.09, *sr* = -.18, *p* = .007) such that those who experienced less decline in intrusions reported lower levels of EC. However, the conditional indirect effect of HRV on EC was significant only among those in the suppress condition (point estimate = .08, *SE B* = .05, 95% C.I., .006 to .23). The direction of the indirect effect indicates that higher levels of HRV were associated with a greater decline in intrusions which in turn predicted higher levels of EC. Given that the effect of HRV on EC was found in the suppression condition and not the control condition, the results imply a critical role for the degree of thought suppression success. Moreover, the findings are not simply due to overlap in the underlying constructs as the relationship between HRV and EC differed greatly between the experimental conditions. In addition, the questionnaire measure of EC that was used asked participants to estimate how well they can engage in self-regulation *in general*. Thus, the results show that thought suppression ability can influence self-perceptions of an individual's trait-like capacity for self-regulation. It is worth noting that self-perceptions of one's self-regulatory ability have separately been shown to influence thought suppression success (Luciano, Algarabel, Tomás, & Martínez, 2005; Williams et al., 2009). Taken together, these findings suggest a possible reciprocal relationship between thought suppression success and one's perceived regulatory ability.

The effect of cognitive load on thought suppression success

In addition to individual differences in self-regulatory capacity, cognitive load has been shown to influence thought suppression success. According to Wegner's (1994) model, the effortful operating process that is active during suppression attempts serves to keep unwanted thoughts out of mind so long as the individual has sufficient cognitive resources to support it. Introducing a cognitive load during suppression is thought to reduce cognitive resources and interfere with the distraction process, thus making it more difficult for the individual to keep the unwanted thought out of mind. It follows that those who have a greater reserve of cognitive resources and/or are more resistant to the influence of cognitive load should be less susceptible to the ironic consequences of thought suppression.

A number of laboratory investigations have manipulated cognitive load by assigning participants to engage in a working memory task (e.g., remember a 9 digit number). Imposition of this type of cognitive load during suppression has been shown to increase the extent to which paradoxical consequences of thought suppression are experienced. One such study (Wegner & Erber, 1992) examined the joint effects of cognitive load and suppression on the accessibility of unwanted thoughts by requiring some individuals to suppress thoughts of a target word and measuring by reaction times to the suppressed words on a Stroop task. The results showed that participants who were asked to suppress thoughts of a target word produced slower color-naming reaction times, but only under conditions of high cognitive load. These results indicate that suppression and cognitive load increase the accessibility of unwanted thoughts (Wegner & Erber, 1992). Another study examined the relative contributions of both suppression and cognitive load to intrusive thoughts experienced after viewing a traumatic film (Nixon, Cain, Nehmy, & Seymour, 2009). Individuals who were given a cognitive load and asked to suppress thoughts of the film experienced the highest number of intrusions in the following week, suggesting that cognitive load undermines thought suppression ability (Nixon et al., 2009). A number of other investigations have examined the effects of instructed suppression under various conditions of cognitive load (i.e. remember a number ranging from 6 to 9 digits) and found support for the ironic effects of thought suppression (Bryant, Wyzenbeek, & Weinstein, 2011; Mikulincer et al., 2004; Reich & Mather, 2008).

Other studies have examined the effect of cognitive load on intrusive thought frequency in the context of spontaneous suppression. Exposure to reminders of death (i.e., a mortality salience treatment) primes death-related thoughts and fosters spontaneous suppression attempts. Using this paradigm, Arndt and colleagues (1997) found that the addition of a cognitive load impacted spontaneous suppression such that individuals under conditions of low cognitive load were able to suppress successfully, as evidenced by lower levels of death thought accessibility, whereas those under high cognitive load showed higher levels of death thought accessibility (Arndt et al., 1997). Others have replicated these findings and further highlighted the role of cognitive load in increasing death thought accessibility (Greenberg et al., 2001). Thus, attempts at spontaneous suppression under conditions of high cognitive load are likely to be ineffective and counterproductive.

In summary, thought suppression is often viewed as a maladaptive mental control strategy because it sometimes serves to paradoxically increase the frequency of intrusive thoughts. Moreover, engaging in thought suppression can negatively impact an individual's mood and appraisals of thought controllability and self-regulatory capacity. Yet, support for these phenomena is mixed as a number of studies demonstrate that thought suppression success is impacted by both individual differences in self-regulatory capacity and the presence of cognitive load. A consideration of how contextual individual differences influence thought suppression success will lead to a more sophisticated view of suppression as a mental control strategy.

Extending the work of Gillie, Vasey, and Thayer (2015)

One important limitation of Gillie, Vasey & Thayer, (2015) is its lack of a cognitive load manipulation. As discussed previously, cognitive load is thought to undermine mental control efforts by limiting the efficiency of mental processes that support thought suppression success (Wegner, 1994). A number of experimental investigations demonstrate that imposing a cognitive load (i.e., remember a 9-digit number) leads to greater rebound of the suppressed thought relative to suppression in the absence of cognitive load (Arndt et al., 1997; Bryant et al., 2011; Mikulincer et al., 2004; Nixon et al., 2009; Wegner & Erber, 1992). Moreover, in a review of the thought suppression literature, Wenzlaff and Wegner (2000) found that the immediate enhancement and post-suppression rebound effects were observed more often in studies that included a cognitive load task than those that did not. Thus, the lack of ironic effects observed in the previous study (Gillie, Vasey & Thayer, 2015) can likely be attributed to the absence of a cognitive load. In addition, the previous study was unable to examine the joint influence of resting levels of HRV and cognitive load on thought suppression ability. In fact, no study has yet to examine the interaction between cognitive load and self-regulatory capacity in the context of thought suppression ability. Therefore, an important question for the current study is the extent to which individual differences in self-regulatory capacity predict thought suppression success under conditions of cognitive load.

Another limitation of the previous study concerns the extent to which its findings, particularly the unanticipated results involving EC, are replicable. Reproducibility is considered a scientific gold standard as it helps to ensure that research findings are valid and reliable. Moreover, replication is an essential tool for researchers attempting to broaden current theoretical perspectives. Established theories are typically modified only when evidence supporting an alternative perspective accumulates through replication. Along these lines, the results of the previous study begin to expand current perspectives on the predictors and consequences thought suppression by highlighting the roles of resting levels of HRV and self-reported EC. However, it is worth noting that the previous study was not originally designed to test whether self-reports of EC were influenced by thought suppression ability. Although the relation between suppression success and self-reports of EC can be understood conceptually, as thought suppression has been shown to impact other self-reported outcomes including mood and self-appraisals, this finding warrants a more direct test.

The current study

The current study aimed to further explore the relationship between predictors and consequences of thought suppression ability and sought to replicate the findings from previous work (Gillie, Vasey, & Thayer, 2015). As such, I utilized the same standard thought suppression paradigm but with additions of: 1) cognitive load condition and 2) self-reports of EC collected both before and after the thought suppression task.

The first aim of the current study is to replicate the previous findings of Gillie, Vasey, & Thayer (2015). To this end, it was hypothesized that resting levels of HRV would moderate both instructed (i.e., experimental condition) and self-initiated (i.e., spontaneous) attempts at suppression to predict change in intrusive thought frequency across the monitoring periods in the same manner as the previous study. In addition, it was expected that the current study would replicate the unanticipated finding that performance on the thought suppression task (i.e., change in intrusion frequency) influences self-reports of EC. As self-reports of EC will be collected both before and after the thought suppression task, differences in EC post-task that were unpredicted by pre-task EC will serve as a primary outcome measure.

The second aim of the current study is to investigate the interaction between cognitive load and individual differences in HRV in the prediction of change in intrusive thought frequency. Although both cognitive load and HRV have been shown to independently influence suppression ability, they have not yet been jointly examined in the context of instructed or spontaneous thought suppression. Investigating how these factors influence thought suppression ability has the potential to foster integration of multiple lines of research.

Hypotheses

1.) The no load condition will replicate findings from previous study

The current study seeks to replicate the findings of the previous study regarding the predictors of instructed and spontaneous suppression ability. As hypotheses address the replication of previous effects, predictions will be limited to individuals in the *no load* condition.

i.) Instructed suppression

It was expected that resting levels of HRV would interact with experimental condition (i.e., Condition, coded as 0 = control, 1 = suppression) to predict change in intrusive thought frequency from P1 to P2 and P2 to P3. In the previous study, although the Condition x HRV interaction did not significantly predict change in intrusion frequency from P2 to P3, it approached statistical significance and displayed a pattern consistent with expectations. Thus, it was reasonable to expect that the interaction would achieve statistical significance in the current study. Otherwise, the pattern of results was expected to be identical those obtained in the previous study (see Figure 1). Specifically, among individuals instructed to suppress, those with high levels of HRV (90^{th} percentile) were expected to show a greater decline in intrusive thought frequency relative to those with low levels of HRV (10^{th} percentile).

ii.) Spontaneous suppression

It was hypothesized that resting levels of HRV would interact with spontaneous suppression efforts to predict change in intrusive thought frequency from P1 to P2. It was expected that when HRV is low, higher levels of spontaneous suppression effort would be associated with less decline in intrusions relative to those who exert lower levels of effort. In contrast, it was predicted that spontaneous suppression effort would be unrelated to change in intrusions when HRV is high.

2.) Effects of load

Hypotheses regarding the effect of cognitive load on instructed and spontaneous suppression were based upon theory and past findings. Evidence suggests that the immediate enhancement and post-suppression rebound effects of both instructed and spontaneous suppression are more likely to occur under cognitive load (Arndt et al., 1997; Wegner & Zanakos, 1994). However, ironic process theory (Wegner, 1994) suggests that these effects may be contingent upon an individual's capacity to utilize cognitive resources (i.e., self-regulate). For these reasons, the current study reflected separate predictions regarding the Condition x HRV and Suppression Effort x HRV interactions under load vs. no load.

2a.) Effect of load when HRV is low

i.) Instructed suppression

Although the previous study showed that instructed suppression did not produce significant ironic effects on average, the comparison of suppress and control conditions at low levels of HRV suggested that the immediate enhancement (see Figure 5, a) and post-suppression rebound (see Figure 5, b) effects were present to a limited degree.

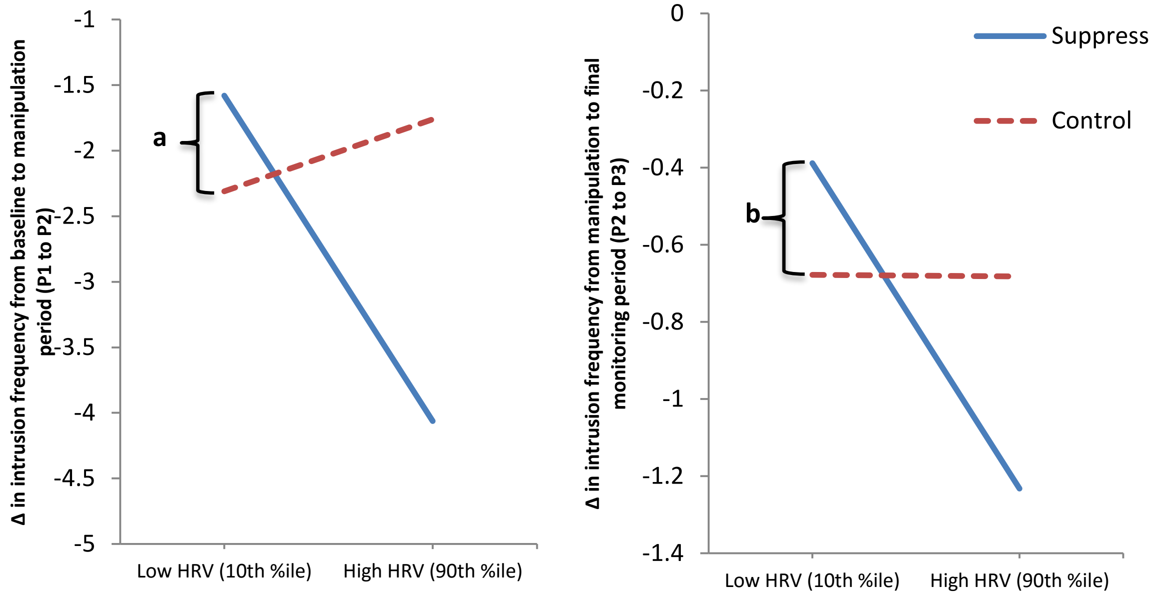

Figure 5. Comparison of suppress and control conditions at low levels of HRV. The pattern of results suggests that immediate enhancement (P1 to P2) and postsuppression rebound (P2 to P3) were present to a limited degree in the previous study.

Therefore, it was expected that the addition of cognitive load would enhance these ironic effects when HRV was low. To test this prediction, the differences between suppress and control groups were compared across conditions of load. As shown in Figure 6, it was expected that the difference between suppress and control conditions under *load* (see "a") would be *greater* than that difference under *no load* (see "b"), such that individuals in the suppress condition would experience, at minimum, less decline and possibly increases in intrusions from P1 to P2 (i.e., immediate enhancement) and from P2 to P3 (post-suppression rebound) relative to those in the control condition.

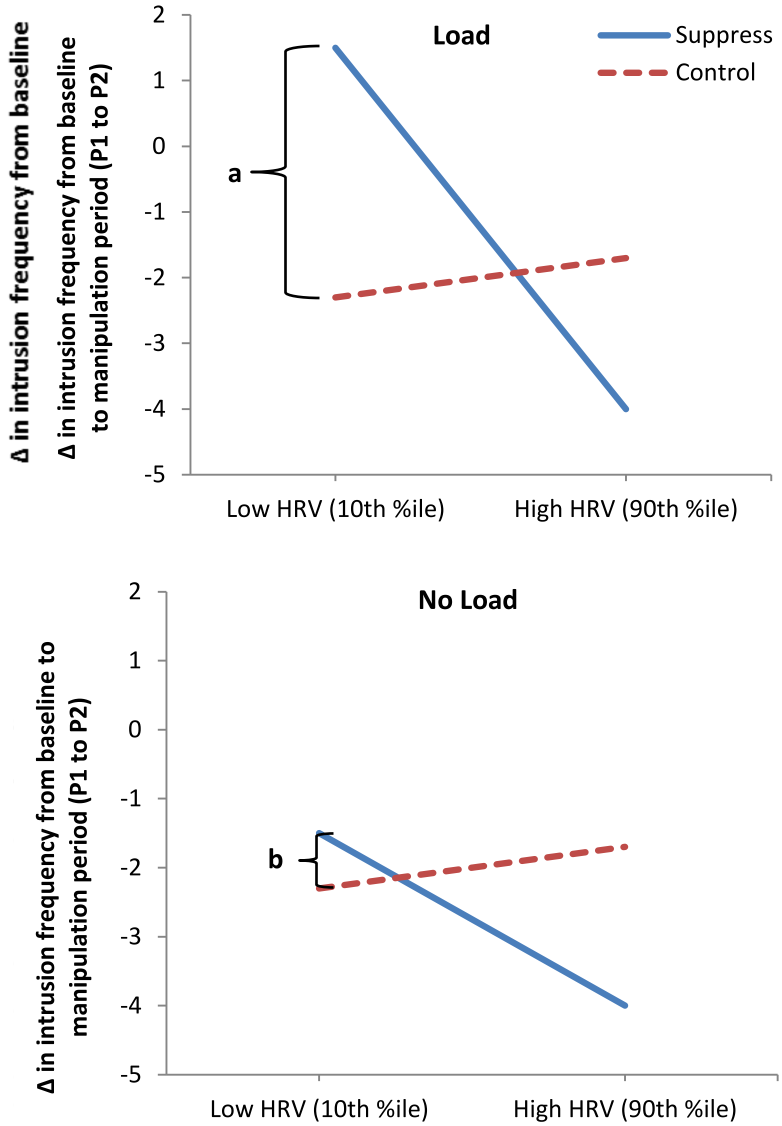

Figure 6. Example of the expected pattern of results regarding the effect of cognitive load on instructed suppression among those with low HRV. A similar pattern of results is expected for change in intrusions from P2 to P3.

ii.) Spontaneous suppression

The addition of cognitive load was also expected to interact with spontaneous suppression efforts when HRV was low. As shown in Figure 7 (No Load), the previous study found that at low HRV, those who reported high levels of suppression effort (90th percentile) experienced less decline in intrusions relative to those who exerted low levels of suppression effort (10th percentile). The current study compared the differences between low and high suppression effort under *load* and under *no load*. As shown in Figure 7, it was hypothesized that the difference between low and high suppression effort under *load* (see "c") would be significantly *greater* than that difference under *no load* (see "d").

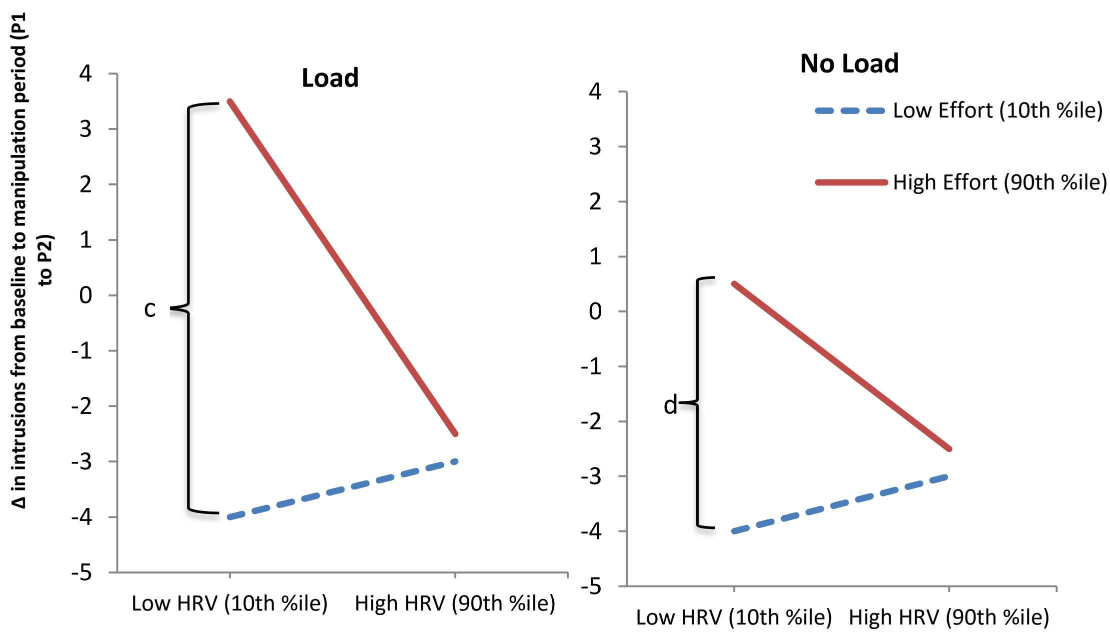

Figure 7. Example of the expected pattern of results regarding the effect of cognitive load on spontaneous suppression at low levels of HRV.

2b.) Effect of load when HRV is high

The current study examined two competing hypotheses regarding the influence of cognitive load on instructed and spontaneous suppression when HRV was high. One possibility was that cognitive load would weaken the association between high HRV and suppression ability. This perspective generated specific predictions for the effects of cognitive load on instructed and spontaneous suppression, which are described in detail below.

i.) Instructed suppression

Cognitive load was expected to undermine the effect of high HRV on instructed suppression. As shown in Figure 8 it was expected that the difference between suppress and control under *no load* (see “a”), in terms of intrusions experienced from P1 to P2 and from P2 to P3, would be significantly *greater* than the difference between suppress and control conditions under *load* (see “b”) such that those in the suppress condition would experience less decline in intrusions than those in the control condition under load relative to no load.

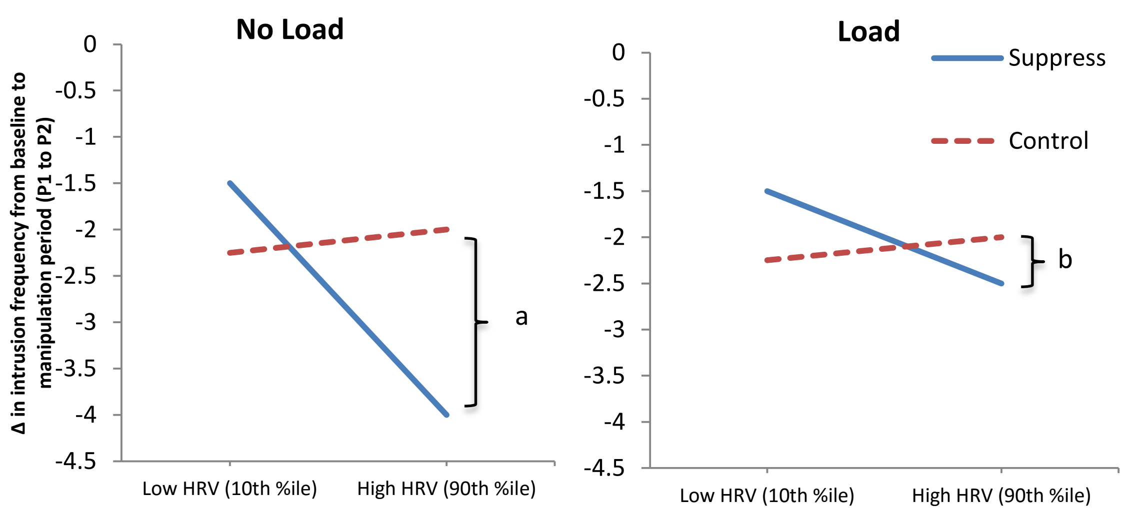

Figure 8. Example of the expected pattern of results regarding the effect of cognitive load on instructed suppression among those with high HRV. A similar pattern of results is expected for change in intrusions from P2 to P3.

ii.) Spontaneous suppression

Cognitive load was expected to diminish the protective effect of high HRV, by reducing the decline in intrusions experienced from P1 to P2 among those exerting high spontaneous suppression efforts. As shown in Figure 9, it was hypothesized that the difference between low and high suppression effort under *load* (see “d”) would be significantly *greater* than the difference between low and high suppression effort under *no load* (see “c”).

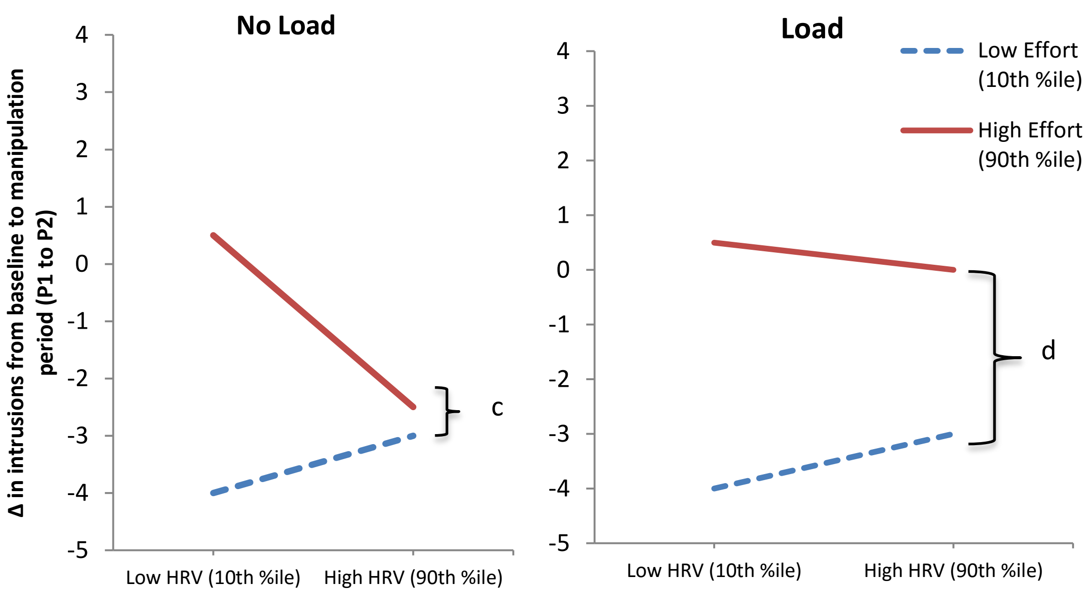

Figure 9. Example of the expected pattern of results regarding the effect of cognitive load on spontaneous suppression among those with high HRV.

If cognitive load impacts those with high HRV in the manners described above, it suggests that the effect of HRV on instructed and spontaneous suppression success is at least partly due to a controlled process that is voluntary, intentional, and able to be disrupted by demands such as cognitive load.

iii.) No effect of cognitive load when HRV is high

Another possibility was that individuals with higher levels of HRV would be unaffected by the addition of a cognitive load. In support of this idea, other studies have shown that high HRV individuals are able to maintain their attention under mental load (Hansen, Johnsen, & Thayer, 2009; Park, Vasey, Van Bavel, & Thayer, 2013) and are less susceptible to the depleting effects of self-regulatory challenges (Segerstrom & Nes, 2007). From this perspective, the simple effect of high HRV on instructed and spontaneous suppression should be similar under load and no load. A series of planned comparisons of simple slope effects was conducted in order to examine this hypothesis. More specifically, I compared the slopes of the regression lines depicting the effect of high HRV on instructed suppression under load vs. no load as well as the slopes of the regression lines depicting the effect of high HRV on high spontaneous suppression effort under load vs. no load. If higher levels of HRV were unaffected by the addition of a cognitive load, it would suggest one of two possibilities: either 1) HRV indexes an automatic self-regulatory process that promotes successful thought suppression and is unaffected by competing processes that accompany cognitive load or 2) the cognitive load was not potent enough to impact the influence of high HRV, leaving individuals with ample self-regulatory capacity for successful thought suppression.

3.) Relations between effortful control and thought suppression

The current study made predictions regarding EC as both a moderator and outcome of thought suppression ability. First, it was expected that self-reports of EC collected *prior* to the start of the task would interact with instructed and spontaneous suppression under load vs. no load in a similar manner as resting levels of HRV. While the pattern of interactions involving EC was expected to be the same as those involving HRV, these interactions should be statistically independent because EC and HRV tend to be only modestly correlated (*r* = .15-.30; Chapman et al., 2010; Healy et al., 2011; Spangler & Friedman, 2015; Sulik et al., 2013).

Second, it was expected that the findings regarding the influence of instructed suppression on self-reports of EC collected following the task would be replicated such that change in EC would occur as a function of performance on the thought suppression task. As it was unclear to what extent cognitive load would impact the association between high HRV and instructed and spontaneous suppression ability, it was difficult to make clear hypotheses regarding change in EC among those in the load condition. Therefore, the following hypotheses were limited to individuals in the no load condition. Specifically, among individuals assigned to the suppression condition, those with high HRV were expected to experience a greater decline in intrusive thoughts and report greater increases in EC relative to those with low HRV. Given that EC was expected to moderate the effects of instructed suppression in the same manner as HRV, it was hypothesized that pre-task EC would also moderate the effect of Condition on differences in EC post-task. Specifically, among those asked to suppress, individuals with high pre-task EC were expected to experience a greater decline in intrusive thoughts and report greater increases in EC relative to those with low pre-task EC. It should be noted that the strong correlation between pre-task and post-task reports of EC may have limited the ability to detect the moderating effect of pre-task EC on change in EC. Thus, a lack of support for this hypothesis should not be taken as evidence that EC does not moderate suppression ability more generally.

4.) Test of a three-way interaction

It is worth mentioning that a three-way interaction will be present if the pattern of the Condition x Load (or alternatively, Suppression Effort x Load) interaction depends upon the level of HRV. Moreover, a significant three-way interaction may not be due to the predicted pattern of differences between the 2-way interactions described previously (i.e., Condition x HRV and Suppression Effort x HRV). Although the three-way interaction will be tested, it is important to note that the hypotheses do not specifically predict nor require a three-way interaction to be statistically significant. Therefore, regardless of whether a three-way significant interaction emerged, I examined the extent to which the patterns of the Condition x HRV and Suppression Effort x HRV interactions under load and no load matched the predicted patterns described previously. To summarize, the critical test for each hypothesis does not depend on the significance of the three-way interaction, but rather the predicted differences between suppression and control conditions and high and low suppression effort at each level of cognitive load within different levels of HRV.

Chapter 2: Methods

Participants

The sample consisted of healthy undergraduate volunteers recruited from the Research Experience Program (REP) participant pool. Participants received credit in partial fulfillment of a course research requirement. Convenience sampling was used to recruit a majority of the participants. However, a subset of the sample (roughly 35 to 40%) was selectively invited to participate in the study on the basis of their responses to screening measures of worry and self-reported EC. This subset consisted of participants who scored in the upper quartile on a measure of chronic worry and either above the median or in the lower quartile of a measure of EC. The purpose of this selective sampling was to better investigate the interaction between EC and chronic worry, a goal that is not directly relevant to the aims of the current study. However, this form of selective sampling likely increased variance in HRV, as high levels of worry have been associated with low levels of resting HRV (Brosschot, Gerin, & Thayer, 2006). Such increased variance in resting HRV and EC likely enhanced the current study's ability to detect the hypothesized interactions of interest.

A total of 308 participants completed both the online and in-person portions of the study protocol. Within this group, experimenters identified 26 individuals who were considered to have put forth questionable effort while completing either the online questionnaires or the thought suppression task and were therefore excluded from the final sample. These participants were identified on the basis of exhibiting particularly unusual behaviors such as completing the online questionnaires in an extremely short amount of time (N= 6), not putting forth suppression effort when explicitly asked to do so (N = 6), falling asleep during the thought suppression task (N = 4), not providing task responses when asked to do so (N = 7), and failure to understand task instructions (N = 3). An additional 2 participants were unable to be included in the final sample to due equipment failure. Moreover, preliminary analyses identified nine extreme observations, in terms of the degree of change of intrusions from P1 to P2 and P2 to P3, with significant influence on model fit (SDR > |3.733|). Although these observations did not display other indications of high influence on the regression equations (DFFITS < |1|; DFBETA < |1|), they were nonetheless removed from analyses due to their extreme and unrealistic values. Thus, the final sample was comprised of 271 individuals.

The mean age for the final sample of 271 participants was 19.50 years (*SD* = 2.10; Range = 18-35 years). A majority of participants were female (N = 164, 60.5%), which is typical of samples drawn from the REP participant pool. Participants were asked to identify their race/ethnicity during the online portion of the experiment and the results are as follows: Caucasian (N = 198, 73.0%), Hispanic/Latino(a) (N = 24, 8.8%), African American (N = 19, 7.4%), Asian/Pacific Islander (N = 17, 6.2%), and Mixed Race/Other (N = 13, 4.7%).

Procedure

The study protocol was comprised of two sessions: 1) an online session in which participants completed electronic questionnaires and 2) an in-person laboratory session in which participants completed the thought suppression task and addition electronic questionnaires. Recruited participants were first provided a description of the study and invited to complete an online series of questionnaires assessing mood, symptoms of anxiety, and effortful control. After completion of the online questionnaires, participants received an email invitation to attend an optional laboratory session for additional credit. Participants were told that they would complete a "thought monitoring task" and additional questionnaires while their heart rate was recorded. To facilitate better attendance, an email reminder was sent to participants one day prior to their scheduled laboratory session. Upon arriving at the laboratory session, participants were reminded of the participation requirements and provided informed consent. A three-electrode setup was attached to participants in order to monitor and record heart rate. Participants were seated in front of a television with a computer keyboard. Participants then completed a 5-minute resting baseline period, followed by the thought suppression task, and electronic questionnaires. The entire laboratory session lasted approximately one hour.

Thought suppression paradigm

Participants completed a thought suppression task in which they were asked to monitor the occurrence of a personally relevant intrusive thought. At the start of the task, a prompt appeared on the screen instructing participants to type in the name of a loved one. After doing so, a subsequent screen embedded the loved-one's name in the following sentence: 'Now imagine that (loved-one's name) has been in a car accident'.

This information was presented on the computer screen for 30 seconds and then participants were informed that this was their ‘target thought’. Prior to entering the laboratory, participants were randomly allocated to one of four experimental conditions: control/load, control/no load, suppression/load, or suppression/no load. For those assigned to the cognitive load condition, a subsequent screen displayed a 9-digit number (249658432) for 25 seconds and instructed the participants to remember the number over the course of the experiment. After receiving these instructions, three 5-minute periods followed. During the first period (baseline), all participants received the baseline monitor instructions. In the second period (manipulation) participants in the suppression condition were instructed to suppress the target thought, while control participants again received the monitor instructions. In the third period (final monitor), all participants received the monitor instructions. The instructions for each of the conditions were originally adapted from Salkovskis and Campbell (1994) and are provided below:

Baseline and monitor condition instructions: *“During the next few minutes, you may think about anything you like. You may think about the accident target thought, but you do not have to. If at any time you think of the accident target thought please press the “X” key for each occurrence. It is important that you continue in the same way for the full duration.”*

Suppression condition instruction: *“During the next few minutes, please record your thoughts as you did before. It is very important that you try as hard as you can to suppress the accident target thought, but be sure to press the “X” key if you do think of the accident target thought. It is important that you continue in the same way for the full duration.”*

All prompts were presented using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002) and key presses indicating the occurrence of the target thought were digitally recorded and not visible or accessible to participants. Following each 5-minute period participants were asked to rate their current level of distress and efforts to suppress the target thought (0 = ‘not at all distressing’ to 100 = ‘extremely distressing’ and 0 = ‘not at all trying to suppress’ to 100 = ‘trying extremely hard to suppress’, respectively). At the end of each period, participants who were assigned to the cognitive load condition entered the 9-digit number using the keyboard.

Measures

Heart rate variability

Heart rate was collected during a 5 minute resting baseline period, prior to the start of the thought suppression paradigm, via a standard three-electrode setup. The electrocardiogram (ECG) signal was sampled at 1000 Hz using a high pass filter of .5 Hz and was passed through Mindware Technology’s BioNex two-slot mainframe (Mindware Technology, Gahanna, OH) to a personal computer. The ECG signal was analyzed offline using Mindware Technology’s HRV 2.51 software. This software provides automated R-peak detection and allows for visual inspection and editing of the ECG signal. Artifact correction was performed for any irregular and ectopic beats. To obtain estimates of HRV, the inter-beat-interval time series was written in a single text file and analyzed using the Kubios HRV analysis package 2.2 (Tarvainen, Lipponen, & Karjalainen, 2009). The Kubios software program provided autoregressive estimates of high frequency power (HF-HRV; 0.15-.40 Hz, ms^2), a measure of parasympathetic nervous system activity. Higher values of HF-HRV indicate a stronger parasympathetic influence on the heart.

Values of HF-HRV were natural log transformed to better approximate a normal distribution. All procedures were conducted in accordance with the recommendations of the Task Force of the European Society of Cardiology and the North American Society of Pacing Electrophysiology (1996).

Questionnaires

Adult Temperament Questionnaire- Effortful Control Subscale (ATQ-EC): The ATQ –EC subscale (Evans & Rothbart, 2007) is a 19-item self-report questionnaire that includes the measurement of three facets of EC, including activation control, inhibition control, and attention control. The items of the ATQ ask participants to rate the extent to which statements are descriptive of themselves on a Likert scale ranging from 0 (extremely untrue of you) to 7 (extremely true of you). The ATQ has been widely used by Rothbart and her colleagues and others in college student and other adult populations (e.g., Evans & Rothbart, 2007). An exploratory factor analysis showed that attentional control, activation control, and inhibitory control subscales all loaded on to a single factor of general effortful control (Evans & Rothbart, 2007). In the current study, the attention control ($\alpha = .70$), and activation control ($\alpha = .70$) subscales demonstrated adequate internal validity, however, the inhibitory control subscale did not ($\alpha = .47$). Importantly, the broadband measure of effortful control formed by of the three subscales (i.e., ATQ-EC) demonstrated adequate internal validity ($\alpha = .75$). The ATQ was administered online, *prior* to the laboratory visit and thought suppression task. Due to scheduling conflicts, 11 participants completed this questionnaire *after* the laboratory visit and thought suppression task. However, removal of these participants from analyses involving EC did not significantly affect the results.

Effortful Control Scale (EC Scale): The EC Scale (Lonigan & Phillips, 2001) is a 24 item scale designed to measure a person's capacity for self-regulation of attention and behavior. This scale yields two subscale scores representing: 1) Persistence/Low Distractibility (12 items) and 2) Impulsivity (12 items). Verstraeten, Vasey, Claes, and Bijttebier (2010) found support for this two-factor structure using confirmatory factory analysis and demonstrated that the EC scale has good psychometric properties. In the current study, the EC Scale demonstrated adequate internal reliability ($\alpha = .86$). The EC scale was administered *after* completion of the thought suppression task.

Data analytic strategy

Correlational analyses were used to examine the relationships among resting levels of HRV, self-reports of EC, and outcomes related to the thought suppression paradigm including intrusion frequency, distress, and suppression effort. Study hypotheses were tested through multiple linear regression (MLR) analyses. Following Aiken & West (1991), all continuous predictors in the regression models were mean-centered through z-transformation (i.e., standardization), which also facilitated interpretation of effects. The primary outcomes for MLR analyses were change in intrusive thought frequency from the baseline to the manipulation (P1 to P2) and manipulation to final monitor (P2 to P3) as well as change in self-reported EC from pre-task to post-task. To assess change in intrusive thought frequency across periods, regression analyses controlled for intrusive thought frequency in the previously occurring period (e.g., P1 intrusions when predicting change from P1 to P2 and P2 intrusions when predicting change from P2 to P3)[2]. Similarly, to assess the joint impact of thought suppression and HF-HRV on EC, analyses predicting post-task levels of EC (e.g., scores on the ECS) controlled for pre task levels of EC (e.g., scores on the ATQ-EC).

Analyses investigated interactions among resting HF-HRV/pre-task EC, experimental condition (Condition; coded as 0 = control, 1 = suppress), and cognitive load (Load; coded as 1 = Load, 2 = No Load) in the prediction of change in intrusive thought frequency. Analyses also investigated these interactions in the context of spontaneous suppression efforts. Lastly, the analyses explored whether HF-HRV interacted with Condition to predict change in EC. Interaction terms were computed using standardized variables and their effects were probed using the PROCESS utility for SPSS (Hayes, 2013). A number of hypotheses were made regarding the effects of HF-HRV x Condition and HF-HRV x Suppression Effort at specific levels of Load. To better understand the pattern of these interaction terms, simple slopes for the predictor were examined at higher (90th percentile) and lower (10th percentile) levels of the moderator. Furthermore, as needed, the Johnson-Neyman technique was implemented for deriving regions of significance, which identifies the range of values of the moderator within which the simple slope of the predictor is significant (see Preacher, Curran, & Bauer, 2006). In the results below, the region of significance was reported in terms of standard deviations from the mean of the moderator.

Regression diagnostics were examined for each analysis to determine if extreme data points were present that might be exerting excessive influence on overall model fit

[2] It should be noted that the pattern of results was identical when P2 and P3 intrusion frequency were substituted as dependent variables instead of these change scores. We report the change score analyses because they clarify the direction of effects.

or on individual beta weights. DFFITS and DFBETA values were used to identify observations with a high degree of influence on the fitted regression models and regression coefficients, respectively, whereas Studentized deleted residuals (SDR) for each case were used to determine unusual values for the response variables. In accordance with recommendations from Cohen, Cohen, &West (2004), data points whose DFFITS and DFBETA values exceeded ±1.0 and/or SDR values that exceeded ±3.77[3] were considered possible outliers

[3] Cohen, Cohen, & West (2004) recommend using the following formula (incorporating a Bonferroni correction for n tests) to identify whether a studentized deleted residual value may indicate the presence of an outlier: $t_{n-p-1}(1 - \alpha/2n)$.

Chapter 3: Results

Preliminary analyses

Means and standard deviations for all variables are shown for the full sample and separately for each experimental group (i.e., Condition/Load) in Table 1 and correlations between primary measures are displayed in Table 2. A 2 (Load) x 2 (Condition) analysis of variance (ANOVA) indicated that the four groups did not differ in terms of HF-HRV [$F(3, 267) = .91$, $p = .43$], ATQ-EC [$F(3, 267) = 1.49$, $p = .21$], baseline intrusion frequency [$F(3, 267) = .31$, $p = .81$], baseline suppression effort [$F(3, 267) = 1.05$, $p = .37$], and baseline distress [$F(3, 267) = 1.42$, $p = .23$]. Furthermore, Condition, Load, and HF-HRV were not significantly associated with any measure of number of intrusions, suppression effort, or distress during the baseline period (all *p*s > .10). However, ATQ-EC was significantly correlated with distress ($r = -.12$, $p = .03$) and suppression effort ($r = -.19$, $p = .001$), but not intrusion frequency ($r = -.07$, $p = .25$) during the baseline period. Additionally, sex (1 = male, 2 = female) was significantly correlated with baseline intrusion frequency ($r = -.11$, $p = .05$), but no other variables. Although sex was not significantly associated with HF-HRV in the current sample, a growing body of evidence suggests that females may demonstrate higher levels of resting HF-HRV than males (Antelmi et al., 2004; Koenig & Thayer, 2016). Therefore, because sex differences in HF-HRV have been demonstrated in other samples and sex was associated with baseline intrusion frequency in the current sample, it was included as a covariate in all analyses.

To determine if participants complied with the task instructions, experimental groups were compared on self-reports of suppression effort from each period. A repeated measures ANOVA with between-subjects factors of Condition (control and suppress) and Load (no load and load) and a within-subjects factor of Time (P1, P2, P3) was conducted to assess self-reports of suppression effort. Results revealed a significant between-subjects effect of Condition [$F(1, 267) = 15.10$, $p < .001$] such that those in the suppression group reported higher levels of suppression effort on average relative to the control group. Additionally, this effect was qualified by a significant Condition x Time interaction [$F(2, 534) = 22.56$, $p < .001$], which indicated that the two levels of Condition showed a different pattern of change in suppression efforts over the course of the three periods. Follow-up tests of these differences indicated that during the manipulation period, participants in the suppression condition reported greater suppression efforts [$F(1, 267) = 42.67$, $p < .001$, $eta^2 = .13$] than those in the control condition. Additionally, there was a nonsignificant trend for those in the suppression group to report higher levels of suppression effort than those in the control conditions during the initial baseline monitoring period [$F(1, 267) = 2.88$, $p = .09$], and the final monitoring period [$F(1, 267) = 2.77$, $p = .09$)].

Replication of previous effects within the No Load condition

The first set of hypotheses in the current study concerned the replication of findings from Gillie, Vasey, & Thayer (2015) regarding resting HF-HRV as a moderator of instructed and spontaneous suppression ability. As this set of hypotheses addressed the replication of previous effects, the subsequent analyses were limited to individuals in the *no load* condition.

No Load: Instructed suppression

Hierarchical MLRs were conducted to predict change in intrusive thought frequency from P1 to P2 and P2 to P3. P1 intrusions were entered as covariate in Step 1 when predicting change in intrusive thought frequency from P1 to P2 and P2 intrusions were controlled for in the same manner when predicting change in intrusive thought frequency from P2 to P3. Analyses examined whether HF-HRV moderated the effect of Condition on change in intrusive thought frequency from P1 to P2 and P2 to P3. HF-HRV and Condition were entered as predictors in Step 2 and the Condition x HF-HRV interaction term was entered in Step 3.

As shown in Table 3, for change from P1 to P2 the MLR analysis revealed a significant main effect for Condition (*sr* = .15, *p* = .04), however this effect was not qualified by a significant Condition x HF-HRV interaction (*sr* = .01, *p* = .83). The pattern of the non-significant interaction is depicted in Figure 10A, which shows the main effect of Condition such that the suppression group experienced less decline in intrusions than those in the control group regardless of their level of HF-HRV. Analyses revealed that the effect of Condition on decline in intrusive thought frequency was similar when HF-HRV was low (i.e., 10^{th} percentile; *B* = 1.01, *p* = .31) and high (i.e., 90^{th} percentile; *B* = 1.33, *p* = .15). Also in contrast to expectations, resting HF-HRV was not significantly associated with change in intrusions in either the suppression condition (simple slope (*B*) = -.33, *p* = .41) or the control condition (simple slope = -.45, *p* = .30). Similarly, for change from P2 to P3, the MLR analysis revealed a main effect for Condition that approached statistical significance (*sr* = .09, *p* = .08) and a non-significant Condition x HF-HRV interaction (*sr* = -.007, *p* = .89). The pattern of this non-significant interaction is depicted in Figure 10B, which illustrates that the suppression group tended to experience less decline in intrusions than those in the control group regardless of their level of HF-HRV. Again, resting HF-HRV was unrelated to change in intrusions in both the suppression condition (simple slope = .02, *p* = .93) and the control condition (simple slope = .07, *p* = .79). Additional analyses revealed that the effect of Condition on decline in intrusive thought frequency was not statistically significant and similar between low (*B* = .75, *p* = .26) and high levels of HF-HRV (*B* = .61, *p* = .31). In both cases, these patterns of results are not generally consistent with those found in the previous study. Thus, the previous results demonstrating HF-HRV's moderating effect on instructed suppression efforts were not replicated in the current study.

No Load: Spontaneous suppression

Hierarchical MLR analyses were conducted to examine whether spontaneous suppression effort predicted change in intrusions from P1 to P2 and P2 to P3 either alone or in interaction with HF-HRV. P1 or P2 intrusions, HF-HRV, P2 suppression effort, as well as Condition to control for the influence of the suppression instruction on such suppression effort were entered in Step 1; the Suppression Effort x HF-HRV interaction was entered on Step 2. As shown in Table 4, for change in intrusions from P1 to P2 analyses revealed a significant main effect of spontaneous suppression effort (*sr* = .25, *p* = .001), however, the Suppression Effort x HF-HRV interaction was not significant (*sr* = -.02, *p* = .77). Probing this non-significant interaction as shown in Figure 11A revealed that greater spontaneous suppression effort was associated with less decline in intrusions regardless of level of HF-HRV. Indeed, analyses showed that the effect of spontaneous Suppression Effort was statistically significant and of a similar magnitude at both low (B = 1.21, p = .02) and high (B = .98, p = .04) levels of HF-HRV. In addition, resting HF-HRV was unrelated to change in intrusions at both lower levels of suppression effort (simple slope = -.08, p = .88) and higher levels of suppression effort (simple slope = -.33, p = .46). Of note, this pattern of results differs from those found previously in that the combination of high suppression effort and high HF-HRV was associated with greater intrusion persistence rather than decline in intrusive thought frequency. Additionally, for change from P2 to P3, analyses revealed a significant main effect of spontaneous suppression effort (sr = .13, p = .01) and a nonsignificant Suppression Effort x HF-HRV interaction (sr = .03, p = .57). Figure 11B depicts this nonsignificant interaction and shows that greater spontaneous suppression effort was associated with less decline in intrusions regardless of level of HF-HRV. Exploration of the simple slope effects revealed that spontaneous Suppression Effort was significantly associated with intrusion frequency among those with higher levels of HF-HRV (B = .69, p = .04) but not among those with lower levels of HF-HRV (B = .38, p = .28). Additionally, simple slope analyses indicated that resting HF-HRV showed a negative, but nonsignificant, association with change in intrusions at lower levels of suppression effort (simple slope = -.07, p = .84) and a positive, but nonsignificant, association at higher levels of suppression effort (simple slope = .24, p = .43). Taken together, these results are also not consistent with expectations and with the previous study's results indicating the moderating effect of HF-HRV on spontaneous suppression effort.

Effects of cognitive load on thought suppression success

The second set of hypotheses examined the effects of cognitive load on thought suppression success. Specifically, the subsequent set of analyses examined the differences between suppression and control conditions and high and low suppression effort at different levels of HF-HRV within each level of cognitive load. In each case, the outcome of interest was either change in intrusive thought frequency from either P1 to P2 or P2 to P3. As described previously, separate predictions were made regarding the Condition x HF-HRV and Suppression Effort x HF-HRV interactions under load vs. no load. PROCESS was used to conduct tests of each 2-way interaction (e.g., Condition x HF-HRV and Suppression Effort x HF-HRV) at both levels of Load. The three-way interactions of Condition x Load x HF-HRV and Suppression Effort x Load x HF-HRV were also examined, although it is important to note that this set of hypotheses do not specifically predict nor require a three-way interaction to be statistically significant. Thus, each set of two-way interactions were explored, even in the absence of significant three-way interactions. Indeed, the set of three-way interactions was only examined to aid in interpretation of the lower-order interaction terms that were relevant to the stated hypotheses.

Test of the three-way interactions

As shown in Table 5, the Condition x Load x HF-HRV interaction was not a significant predictor of intrusive thought frequency change from P1 to P2 (sr = .02, p = .61). Additionally, no significant effects of HF-HRV, Condition, Load, or any interaction were observed. The three-way interaction of Condition x Load x HF-HRV was also not a significant predictor of intrusive thought frequency change from P2 to P3 (sr = .009, p =

.83). There were no significant effects of Condition, HF-HRV, or any interaction, however, there was a significant effect of Load (*sr* = .10, *p* = .03) such that the presence of load was associated with less decline in intrusions. The patterns of these non-significant interactions are depicted in Figure 12A (P1 to P2) and Figure 12B (P2 to P3).

As shown in Table 6, the Suppression Effort x Load x HF-HRV interaction was not significant in the prediction of intrusive thought frequency change from P1 to P2 (*sr* = .04, *p* = .34). No significant effects of HF-HRV, Load, or any interaction were observed, although as revealed in previous analyses, there was a significant main effect of Suppression Effort (*sr* = .12, *p* = .01). The Suppression Effort x Load x HF-HRV interaction was not significant in the prediction of intrusive thought frequency change from P2 to P3 (*sr* = .01, *p* = .79). No significant effects of HF-HRV, Suppression Effort, or any interaction were observed, however, there was a significant effect of Load in the same manner as revealed in previous analyses (*sr* = .11, *p* = .02). These effects are illustrated in Figures 13A (P1 to P2) and 13B (P2 to P3). After establishing that no significant three-way interactions were present, separate analyses were conducted to investigate the effects of instructed and spontaneous suppression at varying levels of HRV among those who completed the thought suppression task under cognitive load.

Load Only: Instructed suppression

MLR analyses followed the procedures outlined previously such that Step 1 included the covariates of Sex and P1/P2 intrusions, Step 2 contained the predictors of interest (e.g., HF-HRV and Condition), and Step 3 contained their interaction (HF-HRV x Condition). Table 7 summarizes the regression results for both dependent variables. For change in intrusive thought frequency from P1 to P2, analyses showed a significant association between Sex and intrusions such that females tended to experience less declines in intrusions (*sr* = .15, *p* = .02), however, there were no significant effects of either Condition (*sr* = .08, *p* = .23), HF-HRV (*sr* = -.05, *p* = .43), or HF-HRV x Condition (*sr* = .08, *p* = .26). The pattern of this interaction is depicted in Figure 14A and it is notable in that Condition's association with intrusion frequency was stronger at higher levels of HF-HRV (*B* = 1.18, *p* = .12) than at lower levels of HF-HRV (*B* = -.15, *p* = .83), although neither effect was statistically significant. This interaction was also examined from the perspective of HF-HRV's effect across Conditions. PROCESS revealed that resting HF-HRV showed a positive but nonsignificant, association with change in intrusions within the suppression condition (simple slope = .26, *p* = .43) and a negative, but nonsignificant, association within the control condition (simple slope = -.24, *p* = .42). However, these patterns of results are the opposite of the expectations, as it indicates that among those asked to suppress, those who displayed higher levels of resting HF-HRV experienced less declines in intrusions than those with lower levels of resting HF-HRV. For change in intrusive thought frequency from P2 to P3, analyses showed no significant effects of Sex (*sr* = -.01, *p* = .88), HF-HRV (*sr* = .04, *p* = .64), Condition (*sr* = -.006, *p* = .94), and HF-HFV x Condition (*sr* = -.008, *p* = .92). Figure 14B illustrates the pattern of the interaction and shows that the effect of Condition on decline in intrusive thought frequency was nonsignificant at both low levels of HF-HRV (*B* = .02, *p* = .97) and high levels of HF-HRV (*B* = -.08, *p* = .91). Examination of simple slope effects revealed that resting HF-HRV was unrelated to change in intrusion frequency in both the suppression condition (simple slope = .10, *p* = .75) and the control condition (simple slope = .14, *p* = .64). These results suggest that although the presence of cognitive load appeared to undermine the expected association between high HF-HRV and instructed suppression ability, it did not enhance the ironic effects of suppression among those with low levels of HF-HRV.

Load Only: Spontaneous suppression

Hierarchical MLR analyses were conducted in the same manner as described previously (see "*No Load: Spontaneous suppression*" for details) to examine whether spontaneous suppression effort interacted with HF-HRV to predict change in intrusions from P1 to P2 and P2 to P3. Table 8 summarizes the regression results for both dependent variables. For change in intrusive thought frequency from P1 to P2, analyses showed significant associations between Sex and intrusions and Suppression Effort and intrusions, both in the manners described previously, however, there were no significant effects of either HF-HRV (sr = -.01, p = .84) or HF-HRV x Suppression Effort (sr = .07, p = .29). As illustrated in Figure 15, PROCESS revealed that resting HF-HRV showed a negative but nonsignificant, association with change in intrusions at lower levels of suppression effort (simple slope = -.38, p = .37) and a positive, but nonsignificant, association at higher levels of suppression effort (simple slope = .27, p = .41). In addition, suppression effort was significantly associated with change in intrusive thoughts at high levels of HF-HRV (B = 1.24, p = .002), but not at low levels of HF-HRV (B = .57, p = .13). Indeed, examination of the region of significance for the Suppression Effort effect revealed that it was significant for HF-HRV $\geq$ -1.05 *SD*. Thus, cognitive load appeared to diminish the protective effect of high HF-HRV, by reducing the decline in intrusions among those exerting high spontaneous suppression efforts; no such pattern was observed among those with lower levels of HF-HRV. For change in intrusive thought frequency from P2 to P3, analyses showed no significant effects of Sex (*sr* = -.01, *p* = .87), HF-HRV (*sr* = .04, *p* = .61), Suppression Effort (*sr* = .07, *p* = .37), and HF-HFV x Suppression Effort (*sr* = .02, *p* = .78). Examination of this pattern of results (Figure 15B) indicates that the effect of Suppression Effort was not statistically significant at either lower levels of HF-HRV (*B* = .13, *p* = .73) or higher levels of HF-HRV (*B* = .30, *p* = .45). In addition, PROCESS revealed that resting HF-HRV was unrelated to change in intrusions at both lower levels of suppression effort (simple slope = .02, *p* = .95) and higher levels of suppression effort (simple slope = .19, *p* = .56).

Effortful Control as a moderator of thought suppression ability

The next set of hypotheses made predictions regarding EC as moderator of thought suppression ability. Specifically, it was expected that self-reports of EC collected prior to the start of the task would interact with instructed and spontaneous suppression under load vs. no load in the same manner as resting levels of HRV. Thus, hierarchical MLR analyses were conducted in the same manner described previously with the only change being that EC replaced HF-HRV.

Examination of three-way interactions involving Effortful Control

The Condition x Load x EC interaction was not a significant predictor of intrusive thought frequency change from P1 to P2 (*sr* = -.05, *p* = .35; Table 9). Additionally, no significant effects of EC, Condition, Load, or any interaction were observed. The three-way interaction of Condition x Load x EC was also not a significant predictor of intrusive thought frequency change from P2 to P3 (*sr* = .009, *p* = .83; Table 9). There were no significant effects of Condition, EC, or any interaction, however, there was a significant effect of Load (*sr* = .11, *p* = .02) such that the presence of load was associated with less decline in intrusions. The patterns of these interactions are depicted in Figure 16A (P1 to P2) and Figure 16B (P2 to P3).

The Suppression Effort x Load x EC interaction was not significant in the prediction of intrusive thought frequency change from P1 to P2 (sr = -.001, p = .98; Table 10). No significant effects of EC, Load, or any interaction were observed, although as revealed in previous analyses, there was a significant main effect of Suppression Effort (sr = .13, p = .009; Table 10). The Suppression Effort x Load x EC interaction was not significant in the prediction of intrusive thought frequency change from P2 to P3 (sr = .008, p = .87). No significant effects of EC, Suppression Effort, or any interaction were observed, however, there was a significant effect of Load in the same manner as revealed in previous analyses (sr = .11, p = .02). These effects are illustrated in Figures 17A (P1 to P2) and 17B (P2 to P3). After establishing that no significant three-way interactions were present, separate analyses were conducted to investigate the effects of instructed and spontaneous suppression at varying levels of EC among within the two conditions of cognitive load.

Effortful Control and instructed suppression effects within the No Load condition

As shown in Table 11, for change from P1 to P2 the MLR analysis revealed a significant main effect for Condition (sr = .15, p = .04), however this effect was not qualified by a significant Condition x EC interaction (sr = .06, p = .43). The pattern of the non-significant interaction is depicted in Figure 18A, which shows that Condition's association with intrusion frequency tended to be somewhat stronger at higher levels of EC (B = 1.87, p = .08) than at lower levels of EC (B = .66, p = .44). Additionally, simple slope analyses revealed that EC was not significantly associated with change in intrusions in either the suppression condition (simple slope = .30, p = .45) or the control condition (simple slope = -.17, p = .70). However, these results actually reflect the opposite pattern of expectations, as it indicates that among those asked to suppress, those who displayed higher levels of EC tended to experience less declines in intrusions than those with lower levels of EC. For change from P2 to P3, analyses revealed a main effect for Condition that approached statistical significance (sr = .10, p = .055) and a non-significant Condition x EC interaction (sr = .007, p = .90). The pattern of this non-significant interaction is depicted in Figure 18B, which illustrates that the suppression group tended to experience less decline in intrusions than those in the control group regardless of their level of EC. Indeed, analyses revealed that the effect of Condition on decline in intrusive thought frequency was not statistically significant at both low EC (B = .70, p = .22) and high EC (B = .82, p = .24). Examination of simple slope effects revealed that EC was unrelated to change in intrusion frequency in both the suppression condition (simple slope = -.22, p = .40) and the control condition (simple slope = -.27, p = .36).

Effortful Control and spontaneous suppression effects within the No Load condition

Table 12 displays the results of the MLR analyses for both dependent variables. For change in intrusions from P1 to P2, analyses revealed a significant main effect of spontaneous suppression effort (sr = .27, p = .001), however, there was no significant effect of EC (sr = .04, p = .59) and the Suppression Effort x EC interaction was not significant (sr = .04, p = .57). Probing this non-significant interaction as shown in Figure 19A revealed that greater spontaneous suppression effort was associated with less decline in intrusions regardless of level of EC. Indeed, simple slope analyses showed that the effect of spontaneous Suppression Effort was statistically significant and of a similar magnitude at both low (*B* = .99, *p* = .02) and high (*B* = 1.39, *p* = .01) levels of EC. Examination of the region of significance for the Suppression Effort effect revealed that it was significant for all values of EC ranged between -1.41 *SD* and 2.41 *SD*. In contrast, simple slope analyses indicated that EC showed a negative, but nonsignificant, association with change in intrusions at lower levels of suppression effort (simple slope = -.05, *p* = .91) and a positive, but nonsignificant, association at higher levels of suppression effort (simple slope = .38, *p* = .42). For change from P2 to P3, analyses revealed a significant main effect of spontaneous suppression effort (*sr* = .12, *p* = .03), but nonsignificant effects of EC (*sr* = -.06, *p* = .27) and Suppression Effort x EC (*sr* = -.03, *p* = .49). Figure 19B depicts this nonsignificant interaction and shows that greater spontaneous suppression effort was generally associated with less decline in intrusions regardless of level of EC. However, exploration of the simple effects revealed that Suppression Effort was significantly associated with intrusion frequency at lower levels of EC (*B* = .63, *p* = .02) but not at higher levels of EC (*B* = .30, *p* = .41). Examination of the region of the significance revealed that higher spontaneous suppression effort predicted significantly less decline in intrusions *except* when levels of EC were greater than ≥ .21 *SD* above the mean. Additionally, simple slope analyses revealed that EC was unrelated to change in intrusions at both lower levels of suppression effort (simple slope = -.02, *p* = .93) and higher levels of suppression effort (simple slope = -.38, *p* = .23). Although results examining change in intrusions from P1 to P2 were not consistent with hypotheses, the pattern of results involving change in intrusions from P2 to P3 was somewhat consistent with expectations and with the previous study's findings regarding the moderating effect of HF-HRV on spontaneous suppression effort.

Effortful Control and instructed suppression effects within the Load condition

The results of MLR analyses for predicting change in intrusions from P1 to P2 and P2 to P3 are both summarized in Table 13. For change in intrusive thought frequency from P1 to P2, analyses showed a significant effect of Sex, as described previously, and no significant effects of either Condition (sr = .08, p = .26), EC (sr = .02, p = .77), or EC x Condition (sr = -.04, p = .53). The pattern of these results is depicted in Figure 20A and analyses indicated that Condition's association with intrusion frequency tended to be somewhat stronger at lower levels of EC (B = .90, p = .25) than at high levels of EC (B = .10, p = .89). Additionally, simple slope analyses revealed that EC showed a positive but nonsignificant, association with change in intrusions within the control condition (simple slope = .08, p = .77) and a negative, but nonsignificant, association within the suppression condition (simple slope = -.21, p = .56). For change in intrusive thought frequency from P2 to P3, analyses showed a main effect of EC (sr = -.17, p = .04), such that higher levels of EC were associated with greater declines in intrusion frequency, however, there were no significant effects of Sex (sr = -.06, p = .48), EC (sr = .04, p = .64), Condition (sr = -.01, p = .85), and EC x Condition (sr = .06, p = .44). Figure 20B depicts the pattern of this nonsignificant interaction and simple slope analyses indicated that although EC was significantly negatively associated with change in intrusions in the control condition (simple slope = -.58, p = .04), it was unrelated to intrusion change within the suppression condition (simple slope = -.23, p = .49). Additionally, the effect of Condition on change in intrusion frequency was similar at lower levels of EC (B = -.52, p = .48) and higher levels of EC (B = .40, p = .58). These patterns of results are not generally consistent with expectations and with the previous study's findings regarding the moderating effect of HF-HRV on instructed suppression.

Effortful Control and spontaneous suppression effects within the Load condition

Table 14 summarizes the MLR analyses results for both dependent variables. For change in intrusive thought frequency from P1 to P2, analyses showed significant associations between Sex and intrusions and Suppression Effort and intrusions, both in the manners described previously, however, there were no significant effects of either EC (sr = .04, p = .53) or EC x Suppression Effort (sr = .05, p = .39). As illustrated in Figure 21A, Suppression effort was significantly associated with change in intrusive thoughts at high levels of EC (B = 1.39, p = .001), but not at low levels of EC (B = .66, p = .08). Moreover, examination of the region of significance for the Suppression Effort effect revealed that it was significant for EC ≥ -1.09 *SD*. This nonsignificant interaction was also examined from the perspective of EC's effect within different levels of Suppression Effort. PROCESS revealed that EC showed a nonsignificant negative association with change in intrusions at lower levels of suppression effort (simple slope = -.10, p = .76) and a nonsignificant positive association at higher levels of suppression effort (simple slope = .38, p = .31). Taken together, cognitive load appeared to diminish the hypothesized protective effect of high EC, by reducing the decline in intrusions among those exerting high spontaneous suppression efforts whereas no such pattern was observed among those with lower levels of EC. For change in intrusive thought frequency from P2 to P3, analyses showed a marginally significant effect of EC (sr = -.16, p = .06), but no significant effects of Sex (sr = -.01, p = .87), Suppression Effort (sr = .07, p = .37), and EC x Suppression Effort (sr = .02, p = .78). Figure 21B depicts this nonsignificant interaction and shows that that greater spontaneous suppression effort was generally associated with less decline in intrusions regardless of level of EC. However, exploration of the simple slope effects revealed that spontaneous Suppression Effort was more strongly associated with intrusion frequency when EC was low (B = .29, p = .44) as opposed to high (B = -.002, p = .99). Simple slope analyses revealed that EC was unrelated to change in intrusion frequency at lower levels of suppression effort (simple slope = -.27, p = .43) and higher levels of suppression effort (simple slope = -.57, p = .11) Thus, similar to the results obtained under conditions of no load, results examining change in intrusions from P1 to P2 were not consistent with hypotheses, while the pattern of results involving change in intrusions from P2 to P3 was somewhat consistent with expectations and with the previous study's findings regarding the moderating effect of HF-HRV on spontaneous suppression effort.

Predicting post-task Effortful Control as a function of thought suppression ability

Hierarchical MLR analyses were conducted to examine the extent to which performance on the thought suppression task impacted change in self-reports of EC from pre-task to post-task. The previous study found that HF-HRV interacted with Condition to predict post-task reports of EC, therefore, the current analyses sought to replicate and extend these results by examining change in EC in the full sample and within each load condition. Additionally, given that EC was expected to moderate the effects of suppression in the same manner as HF-HRV, it was hypothesized that pre-task EC would also predict change in EC. Analyses controlled for the influence of Sex, P1 intrusions, and pre-task reports of EC (i.e., ATQ-EC scores) and in each case, post-task reports of

EC (i.e., ECS scores) served as the dependent variable. The results for the full sample and no load and load conditions are summarized within Table 15 and Table 16, respectively.

Within the full sample, the HF-HRV x Condition x Load interaction was not significant, and there were no significant second-order interaction terms nor any significant main effects, other than the association of pre-task EC with post-task EC, which was also present in all subsequent analyses (Table 15); these findings are illustrated in Figure 22A. Similarly, among those who received cognitive load, the HF-HRV x Condition interaction was not significant and no significant main effects were observed (Table 16). Among those who did not receive cognitive load, there was a marginally significant main effect of HF-HRV such that higher HF-HRV was associated with greater post-task increases in EC, however, the HF-HRV x Condition interaction was not significant and no other significant main effects were observed (Table 16). Results from analyses conducted within the Load condition are illustrated in Figure 22B and results from analyses conducted within the No Load condition are illustrated in Figure 22C.

Analyses investigating pre-task EC as predictor of change in EC produced similar results to those analyses involving HF-HRV, described previously, and are summarized in Table 17 and Table 18. Within the full sample, the EC x Condition x Load interaction was not significant, and there were no significant second-order interaction terms nor any significant main effects, other than the association of pre-task EC with post-task EC, which was also present in all subsequent analyses (Table 17); higher levels of pre-task EC were consistently associated with higher levels of post-task EC. The pattern of results for the full sample is illustrated in Figure 23A. Similarly, for both individuals who received cognitive load and those who did not, the EC x Condition interaction was not significant and no significant main effects were observed (Table 18). Results from analyses conducted within the Load condition are illustrated in Figure 23B and results from analyses conducted within the No Load condition are illustrated in Figure 23C.

Chapter 4: Discussion

The first aim of the present study was to replicate the results of previous work (Gillie, Vasey, & Thayer, 2015), which found that individual differences in resting HF-HRV moderated both instructed and spontaneous thought suppression ability and that performance on the thought suppression task influenced self-reports of EC. The second aim of the present study was to extend previous work by investigating whether individual differences in EC (pre-task) predicted change in intrusive thought frequency and exploring the role of cognitive load on moderators of thought suppression ability. Overall, hypotheses regarding each aim received little support.

Overview of results

With regard to the first aim, results from the present study were mostly inconsistent with those obtained in the previous study. Among those in the No Load condition, resting HF-HRV did not significantly moderate the effect of instructed suppression (i.e., the effect of Condition) on change intrusions from either P1 to P2 or P2 to P3. The present results showed that, regardless of resting levels of HF-HRV, individuals asked to suppress tended to experience, on average, *less* decline in intrusions than those in the control condition, whereas the previous results found that those in the suppression condition experienced *greater* decline in intrusions relative to those in the control condition, an effect that was only present at higher levels of resting HF-HRV. Additionally, resting HF-HRV did not significantly moderate the effect of spontaneous suppression (i.e. the effect of Suppression Effort) on change intrusions from either P1 to

P2 or P2 to P3. Consistent with the previous study, the present results showed that higher levels of suppression effort were associated with *less* decline in intrusions across the monitoring periods. However, whereas the previous study found that the effect of suppression effort was unrelated to change in intrusions at higher levels of HF-HRV, the present study showed that greater levels of suppression effort were associated with less decline in intrusions (i.e., less thought suppression success) at higher levels of HF-HRV relative to lower levels of HF-HRV, although this difference was not statistically significant. Lastly, given that HF-HRV was not shown to be a significant moderator of thought suppression, it was not surprising that HF-HRV did not significantly interact with Condition to predict post-task reports of EC. However, the present results did reveal that higher HF-HRV was associated with greater post-task increases in EC, which is consistent with other studies showing a modest positive correlation between resting HF-HRV and EC (Chapman et al., 2010; Healy et al., 2011; Spangler & Friedman, 2015; Sulik et al., 2013).

With regard to the second aim, hypotheses concerning the effects of cognitive load on instructed and spontaneous suppression at low versus high levels of HF-HRV were generally unsupported. Among those with low HF-HRV, it was expected that cognitive load would enhance the ironic effects of suppression, leading to less decline and possibly increases in intrusive thoughts. However, results showed that those with low HF-HRV were not affected by the presence of cognitive load in the hypothesized manner, as the effects of instructed and spontaneous suppression at low HF-HRV were similar across the no load and load conditions. Among those with high HF-HRV, it was expected that cognitive load would either attenuate the effect of high HF-HRV on instructed and spontaneous suppression or have no effect on these relationships. In partial support of the first hypothesis, results showed that for individuals instructed to suppress, there was a non-significant trend such that those who displayed higher levels of HF-HRV tended to experience less decline in intrusions from P1 to P2 than those with lower levels of HF-HRV. These results indicate that, if anything, the cognitive load tended to attenuate the moderating effect of HF-HRV on instructed suppression ability, such that the obtained pattern of results was the opposite of expectations, although it was not statistically significant. In the context of spontaneous suppression, the results were more supportive of the hypothesis that cognitive load would reduce the protective effect of high HF-HRV, as greater suppression effort was significantly associated with less decline in intrusions (P1 to P2) at high levels of HF-HRV, but not low levels of HF-HRV. Again, these results suggest that the presence of cognitive load reduced the moderating effect of HF-HRV to a greater degree than expected, to the point that the protective effect of high HF-HRV on spontaneous suppression efforts was essentially non-existent.

Effortful control was hypothesized to moderate both instructed and spontaneous suppression ability in the same manner as resting HF-HRV, however, results provided limited support for these predictions. Indeed, results regarding EC were, for the most part, similar to those involving HF-HRV. Within the Load condition, EC did not significantly moderate the effect of instructed suppression (i.e., the effect of Condition), however, the association between Condition and intrusion change at P1 to P2 was actually stronger, but not statistically significant, at higher levels of EC. Thus, in contrast to expectations, instructed suppression among those with higher levels of EC tended to be associated with *less* decline in intrusions than those with lower levels of EC.

Additionally, EC did not significantly moderate the effect of spontaneous suppression (i.e. the effect of Suppression Effort) on change intrusions from either P1 to P2 or P2 to P3 among those in the No Load condition. Of note, however, a nonsignificant trend emerged such that the suppression effort was unrelated to intrusion decline from P2 to P3 at higher levels of EC. Thus, the pattern of results involving change in intrusions from P2 to P3 was somewhat consistent with expectations and with the previous study's findings regarding the moderating effect of HF-HRV on spontaneous suppression effort.

Effortful control was also hypothesized to moderate both instructed and spontaneous suppression ability in the same manner as resting HF-HRV under cognitive load. Yet, the results were mostly not consistent with expectations. Within the load condition, EC did not significantly moderate the effect of instructed suppression on change intrusions from either P1 to P2 or P2 to P3. However, when predicting change in intrusions from P2 to P3, there was a main effect of EC such that higher levels of EC were associated with a greater decline in intrusions compared to lower levels of EC. Although such an effect was not specifically hypothesized, it is not entirely unexpected; however, it is unclear why the effect was limited to change in intrusions from P2 to P3. With regard to spontaneous suppression in the Load condition, the moderating effect of EC on suppression effort when predicting intrusion change from P1 to P2 mirrored the pattern of results obtained with HF-HRV described previously, indicating that high EC also offered no protective effect. When predicting intrusion change from P2 to P3, EC displayed the same non-significant moderating effect on spontaneous suppression as observed under No Load, namely, suppression effort was unrelated to intrusion decline from P2 to P3 at higher levels of EC. This pattern of results is generally consistent with expectations and with the previous study's findings regarding the moderating effect of HF-HRV on spontaneous suppression effort.

Lastly, it was predicted that pre-task EC would moderate the effect of Condition on differences in EC post-task, such that among those asked to suppress, individuals with high pre-task EC would experience a greater decline in intrusive thoughts and report greater increases in EC relative to those with low pre-task EC. However, this hypothesis was not supported as EC did not significantly moderate Condition within the full sample and within the Load and No Load conditions. The present results did reveal that higher levels of pre-task EC were consistently associated with higher levels of post-task EC, although it does not appear that this relationship is a function of performance on the thought suppression task, as originally hypothesized.

Given that most hypotheses concerning each aim of the study were mostly unsupported, it is worth considering possible explanations for why such results occurred, beginning with the failure to replicate the results of the previous study.

Explanations for replication failures

Replication failures in psychological science occur frequently, as demonstrated by a recent report in which a collaborative effort among 269 psychologists reported direct replication attempts of 100 experiments and found that under half of them failed to produce a statistically significant effect (Open Science Collaboration, 2015). Yet, these types of endeavors have produced important insights and recommendations that are useful when considering possible reasons for failures to replicate. For example, researchers examining direct replication failures have suggested that unanticipated factors in the sample, setting, or procedure may produce effects that are inconsistent with the original study (Klein et al., 2014). Additionally, those conducting replication studies must also grapple with other possibilities, including whether the original effect size is truly as robust as originally reported and the degree to which the replication study differs with the previously obtained results (Maxwell, Lau, & Howard, 2015). These insights are relevant to the aims and results of the present study and will be discussed in detail below.

In many ways, the present study may be considered a direct replication of Gillie, Vasey, & Thayer (2015). The present study matched the previous study in terms of sample size per condition (N = 135), sample population (undergraduate introductory psychology students), and the semester in which data were collected (spring). Furthermore, the two samples were similar in terms of age and resting level of HF-HRV. Additionally, the thought suppression paradigm used in the present study was identical to the one used in the previous study, other than the addition of a cognitive load condition. However, there are also some notable differences in sample composition/qualities and methodological approaches that may possibly account for discrepant findings between the two studies.

One key set of differences is that individuals in the current study reported both a greater number of intrusions [$t(404) = 2.38$, $p = .01$)] and higher levels of suppression effort [$t(404) = 2.26$, $p = .02$)], at baseline than those in the previous study; the two samples did not differ in initial distress [$t(404) = .22$, $p = .81$)]. Additionally, individuals in the current study reported higher levels of depression [$t(400) = 2.67$, $p = .007$)] , anxiety [$t(400) = 3.01$, $p = .002$)], and stress [$t(400) = 2.09$, $p = .03$)], as assessed by the Depression, Anxiety, and Stress Scales (DASS; Lovibond & Lovibond, 1995), than individuals in the previous study. Of note, higher levels of depression, anxiety, and stress on the DASS have each been positively and often significantly associated with intrusion frequency, suppression effort, and distress. Given that such factors have been strongly associated with the primary outcome of both studies (i.e., change in intrusion frequency), it seems very possible that sample-wise differences in reports of baseline intrusions, suppression effort, and self-reported psychopathology may help to explain failures to replicate the results from the previous study. In addition to differences in self-reports, the current study was composed of a higher female to male ratio than the previous study. A chi-square test of goodness-of-fit, which used expected frequencies of 44 percent female and 56 percent male based on the previous study, determined that the male to female ratio in the current study was different than expectations, such that there were more females and fewer males than expected [χ^2 (1, N = 271) = 27.60, $p < .001$]. However, the implications of such a difference are unclear, as sex was unrelated to number of intrusions, distress, suppression effort, and resting HF-HRV within the no load conditions in both the previous and current studies.

Another set of differences concerns the patterns of intrusions and suppression effort among individuals in the no load condition of the current study and those in the previous study[4]. To examine these patterns, repeated measures ANOVAs with between-subjects factors of Condition (control and suppress) and within-subjects factor of Time (P1, P2, P3) were conducted and compared to results obtained in the previous study. Whereas the previous study found a significant between-subjects effect of Condition such that those in the control group reported more intrusions on average across all periods [*F*

[4] There were no statistical differences in distress between the no load groups in the two samples at any time point.

(1, 133) = 8.10, *p* = .005)], results from the current study showed that the suppression group tended to experience more intrusions across periods, although this effect was not significant [*F* (1, 133) = 1.21, *p* = .27)]; no significant Condition x Time interactions emerged in either sample and the patterns of these effects were comparable. It is unclear why Condition tended to produce an opposite effect in the current study, but it is likely that this finding helps to account for the failure to replicate the moderating effect of HF-HRV. Regarding suppression effort, the current study found a significant between-subjects effect of Condition such that those in the suppression group reported higher levels of suppression effort relative to controls [*F* (1, 133) = 10.18, *p* = .002)] while the previous study did not show a significant between-subjects effect [*F* (1, 133) = .51, *p* = .47)] and found that the suppression group only reported higher levels of suppression effort than the control group at P2. The finding that individuals in the current study exerted greater efforts to suppress than those in the previous study may help to explain the failures to replicate results involving spontaneous suppression. For instance, perhaps the degree of individuals' suppression efforts reached a magnitude in which its effect on intrusions was simply too robust to be moderated by HF-HRV in the same manner that occurred in the previous study when such efforts were of a lesser magnitude.

One potentially important methodological difference is that a subset of the current study's overall sample consisted of participants who scored in the upper quartile on a measure of chronic worry and either above the median or in the lower quartile of a measure of EC. Although this form of selective sampling was though to increase the variance in resting HF-HRV and EC, making it more likely to detect the hypothesized interactions of interest, it is possible that these differences in participant selection could have impacted task performance in other unanticipated ways. To investigate this hypothesis, supplemental analyses were conducted to examine whether self-reported worry interacted with resting HF-HRV and EC to predict instructed and spontaneous thought suppression success. The results showed that all interactions involving worry were nonsignificant when predicting change in intrusive thoughts from P1 to P2 and P2 to P3 (all p values >.27). Thus, although worry did not appear to impact task performance in any significant, detectable manner, it is still worth noting that such selective sampling may have produced other unanticipated and meaningful differences between the previous and present studies. For example, worry may account for the overall higher number of intrusions and greater suppression effort in the current study relative to the previous study, as noted earlier.

Another issue worth examining is whether the original effect size is truly as robust as originally reported and the degree to which the replication study differs with the previously obtained results. Post hoc power analyses using the previous study's sample size and effect size estimate (semi-partial r's = .15 - .17; small) revealed that the previous study achieved an adequate level of power (β = .83) at an alpha error level of .05. However, it is worth considering whether this effect size estimate is of a similar magnitude compared to those reported in the literature. Meta-analyses of controlled experimental studies (Abramowitz et al., 2001; Magee et al., 2012) have examined the paradoxical effects of thought suppression and shown that the overall rebound effects of suppression range from small (Cohen's d = .2) to moderate (Cohen's d = .5). Few studies have examined individual differences in thought suppression ability (i.e., moderators), but among those that have (Brewin & Smart, 2005; Ólafsson et al., 2013; Wessel et al., 2010), the magnitudes of various measures of effect size ranged from small to large. This wide range of effect sizes reported in the literature highlights the difficulty in determining whether the findings from both the previous and present studies are typical or atypical.

Comparing the specific patterns of results obtained in both studies to one another and to those found in the literature may help to resolve inconsistencies and lead to consensus regarding the effects of moderators on thought suppression success. In the previous study, there was a main effect of Condition at average levels of HF-HRV, such that those in the suppression condition showed a greater decline in intrusions than those in the control condition, independent of initial intrusion frequency, whereas to some extent, the opposite pattern was observed in the present study. Although a few studies have found evidence consistent with the former pattern of results (Magee & Teachman, 2012; Mikulincer et al., 2004; Purdon & Clark, 2001), the latter pattern of results is certainly more common, as a large collection of studies, including those examining moderators of suppression ability, have found that those asked to suppress experience a greater frequency of intrusions on average compared to those in the control condition (Beadel, Green, Hosseinbor, & Teachman, 2013; Belloch et al., 2004; Corcoran & Woody, 2009; Grisham & Williams, 2009; Williams et al., 2009). Thus, the relative infrequency of the original study's results perhaps contributed to the replication failures observed in the present study. Furthermore, only a few results in the present study roughly approximated those found in the original study and most analyses found no significant effects. Taken together, these inconsistencies appear to suggest that there may be another moderator of thought suppression ability that is unknown at this time, but perhaps accounts for these different patterns of results. In this regard, it will be important for future research to continue to consider additional individual and situational factors that help to account for inconsistencies among the current and previous studies as well as the larger body of thought suppression studies.

Novel aspects and findings of the present study

Although the present study's hypotheses were largely unsupported, a number of conclusions can be derived from novel aspects of the study's methodology and results. For one, the results revealed that cognitive load appeared to undermine any moderating effects of HF-HRV and EC on thought suppression ability. Indeed, it is notable that those with high HF-HRV and/or high EC seemed to be most negatively affected by the presence of cognitive load whereas load did not enhance the ironic effects of suppression among those with low HF-HRV and/or EC. It is unclear why cognitive load tended to be more impactful at higher rather than lower levels of HF-HRV and EC, however, these results may imply that cognitive load can only negatively impact instructed and spontaneous suppression success for those individuals with self-regulatory resources to lose, whereas those with more limited capacities are unaffected because such resources are already unavailable. These results are consistent with the broader thought suppression literature, which has proposed that suppression is often an intentional and effortful process that requires cognitive resources (Wegner, 1994) that can be undermined by the introduction of cognitive load (Bryant et al., 2011; Mikulincer et al., 2004; Nixon et al., 2009; Wegner & Erber, 1992). Less is known about the degree to which individual differences in resting HF-HRV and self-reported EC predict task performance while under cognitive load. While it is clear that parasympathetically mediated HRV decreases in response to cognitive load and mental effort (Croizet et al., 2004; Luque-Casado, Zabala, Morales, Mateo-March, & Sanabria, 2013; Mukherjee, Yadav, Yung, Zajdel, & Oken, 2012; Taelman, Vandeput, Vlemincx, Spaepen, & Van Huffel, 2011), the role of individual differences in resting HF-HRV in predicting task performance under load is less clear, as some studies have shown that those with high resting HF-HRV are negatively impacted by cognitive load (Spangler, Bell, & Deater-Deckard, 2015), whereas others have shown no detrimental effects of cognitive load (Hansen et al., 2009; Laborde, Furley, & Schempp, 2015; Park et al., 2013). In comparison, broadband measures of EC have not been examined in conjunction with an explicit cognitive load task, but related constructs such as attentional control have consistently been shown to be disrupted by various forms of load (Lavie, Hirst, de Fockert, & Viding, 2004; Lavie, 2010). It is worth noting that researchers are just beginning to investigate the effects of resting HF-HRV and self-reported EC under cognitive load and the present study is the first to do so in the context of a thought suppression paradigm. Thus, while it appears that HF-HRV and EC offer little protection against the detrimental effects of cognitive load, whether these effects are generalizable to a broad range of cognitive control tasks or limited to thought suppression remains unclear.

Another noteworthy finding of the present study is the degree of overlap between the effects of self-reported EC and resting HF-HRV on thought suppression ability. Specifically, there was a trend for individual differences in EC to moderate instructed and spontaneous suppression in a similar manner as resting HF-HRV as originally reported in Gillie, Vasey, & Thayer (2015). Furthermore, resting HF-HRV was significantly positively associated with post-task reports of EC. Other studies have shown that resting levels of HF-HRV and self-reported EC are significantly associated and that the two constructs predict similar outcomes with regard to emotion regulation (Gillie, 2012; Spangler & Friedman, 2015; Sulik et al., 2013) and cognitive control (Chapman et al., 2010; Dinovo, 2009; Healy et al., 2011). Although it may appear that HF-HRV and EC are redundant indexes of self-regulatory capacity, results from the present study as well as previous research, suggests that the actual degree of overlap between these two constructs is modest, indicating that they may reflect different aspects of self-regulation. Indeed, the current study found that HF-HRV and EC were essentially unrelated (r = .04 to .08). Thus, the current findings add to the growing body of evidence which supports the theoretical link between individual differences in EC and resting HF-HRV as conceptually different, but related, indexes of self-regulatory capacity.

Future directions and conclusions

It appears that additional research is needed to establish more definitive conclusions about the roles of resting HF-HRV and EC as moderator of thought suppression ability. Future studies seeking to replicate the results of Gillie, Vasey, & Thayer (2015) should attempt to mimic that study's methodology as close as possible, in order to avoid introducing variance due to methodological differences. Additionally, because failing to account for sampling variability in an original study's effect size estimate can sometimes lead to an underpowered replication study (Maxwell, Lau, & Howard, 2015), researchers should utilize confidence intervals for the population effect size instead of relying on a point estimate of the effect size when determining a replication attempt's sample size (Yuan & Maxwell, 2005). In a similar vein, additional research will likely be needed to clarify the degree to which individual differences in HF-HRV and EC are associated with cognitive control ability under conditions of cognitive load and whether these effects are generalizable to a broad range of cognitive control tasks or limited to thought suppression. Although the present results offer some support for the notion that HF-HRV and EC are similar, but independent, indexes of self-regulatory capacity, further work is needed to specify the ways in which these constructs influence the effectiveness emotional and cognitive regulation strategies, especially those relevant to the development and maintenance of psychopathology. Given the inconsistencies in the broader thought suppression literature, future studies should continue to investigate the degree to which thought suppression success is influenced by moderating factors, including individual differences in self-regulatory capacity. Moreover, researchers would do well to further explore the intrapersonal and interpersonal consequences of thought suppression success and failure.

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Appendix A: Tables

Table 1. Descriptive statistics for primary measures and outcomes

	No Load (N = 135)		Load (N = 136)		
	Control Condition (N = 68)	Suppress Condition (N =67)	Control Condition (N = 68)	Suppress Condition (N = 68)	Total (N = 271)
	M = 24, F = 44	M = 26, F = 41	M = 29, F = 39	M = 28, F = 40	M =107, F = 164
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
lnHF-HRV	6.76 ^{a} (1.0)	6.75 ^{a} (1.1)	6.60 (1.1)	6.49 (1.0)	6.65 (1.0)
P1 Intrusions	7.43^{a} (5.6)	7.42 ^{b} (5.5)	6.99 (5.5)	6.66 (4.8)	7.12 (5.3)
P2 Intrusions	4.69 ^{a} (4.4)	5.87 ^{b} (5.8)	5.01 (4.4)	5.31 (4.4)	5.22 (4.8)
P3 Intrusions	2.99 ^{a} (3.1)	4.25 ^{b} (3.5)	4.13 (4.8)	4.35 (4.5)	3.93 (4.1)
P1 Distress	26.69 ^{a} (22.0)	28.82 ^{a} (23.2)	21.75 (20.5)	28.28 (22.7)	26.38 (22.2)
P2 Distress	19.66 ^{a} (19.4)	20.78 ^{a} (21.1)	15.62 (16.3)	23.85 (21.1)	19.97 (19.8)
P3 Distress	13.44 ^{a} (15.6)	15.40 ^{a} (16.8)	10.43 (13.6)	17.26 (19.6)	14.13 (16.7)
P1 Suppression Effort	51.18 ^{a} (27.2)	56.54 ^{a} (27.2)	49.31 (27.0)	54.97 (25.4)	52.98 (26.7)
P2 Suppression Effort	36.03 ^{a} (28.8)	63.51 ^{b} (29.1)	39.46 (29.6)	57.79 (27.7)	49.14 (30.9)
P3 Suppression Effort	26.57 ^{a} (25.8)	33.00 ^{a} (28.1)	29.43 (29.6)	34.40 (28.9)	30.84 (28.1)
ATQ-EC	80.29 (12.2)	84.21 (13.8)	84.59 (15.1)	83.92 (12.1)	83.25 (13.4)
ECS	71.50 (8.9)	73.49 (9.0)	73.66 (9.0)	73.24 (9.1)	72.97 (9.0)

Note: HF-HRV = natural log transformed high frequency heart rate variability;
ATQ-EC = Adult Temperament Questionnaire-Effortful Control; ECS = Effortful Control Questionnaire

Means with different superscripts differ at $p < .05$.

Table 2. Correlations for primary measures

	1	2	3	4	5	6	7	8	9	10
1. Condition	-									
2. Load	.004	-								
3. Sex	-.01	-.05	-							
4. HF-HRV	-.02	-.09	.04	-						
5. P1 Intrusions	-.01	-.05	-.11	.05	-					
6. P2 Intrusions	.07	-.01	-.02	-.001	.77**	-				
7. P3 Intrusions	.09	.07	-.05	.03	.68**	.77**	-			
8. P1 Distress	.09	-.06	.08	.09	.32**	.29**	.23**	-		
9. P2 Distress	.11	-.01	.09	-.01	.25**	.41**	.30**	.78**	-	
10. P3 Distress	.13*	-.01	.02	.07	.20**	.28**	.33**	.65**	.77**	-
11. P1 Suppression Effort	.10	-.03	-.03	-.02	.22**	.19**	.26**	.42**	.33**	.33**
12. P2 Suppression Effort	.37**	-.01	-.04	-.08	.16**	.33**	.33**	.31**	.43**	.32**
13. P3 Suppression Effort	.10	.03	-.08	.04	.17**	.24**	.35**	.25**	.28**	.37**
14. ATQ-EC	.06	.07	-.06	.04	-.07	-.04	-.12*	-.12*	-.16**	-.09
15. ECS	.04	.05	-.02	.08	-.02	-.003	-.06	-.10	-.10	-.05

Note: N = 271; Condition: 0 = control; 1 = suppress; Load: 1 = no load, 2 = load; Sex: 1 = male; 2 = female; HF-HRV = natural log transformed high frequency heart rate variability; ATQ-EC = Adult Temperament Questionnaire-Effortful Control; ECS = Effortful Control Questionnaire

* p < .05,. ** p < .01

Continued

Table 2. Continued

11	12	13	14
-			
.58**	-		
.53**	.69**	-	
-.20**	-.09	-.06	-
-.19**	-.06	-.02	.69**

* p < .05,. ** p < .01

Table 3. Regression analyses predicting changes thought frequency across the monitoring periods as a function of HF-HRV and instructed suppression within the No Load Condition

	Δ in Thought Frequency – Baseline to Manipulation Period (P1 to P2)				Δ in Thought Frequency – Manipulation to Final Monitoring Period (P2 to P3)			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE*) at Final Step	*sr* at Final Step	Adjusted R^2	ΔR^2	B (*SE*) at Final Step	*sr* at Final Step
Intercept			-3.07**(1.0)				-1.31 (.71)	
Step 1	.18				.57			
Thought frequency (P1or P2)			-1.57**(.28)	-.43**			-2.45** (.18)	-.76**
Sex			.28 (.60)	.03			-.40 (.40)	-.05
Step 2	.22	.03*			.57	.01		
HF-HRV			-.45 (.44)	-.07			.07 (.29)	.02
Condition			1.17* (.58)	.15*			.68 (.39)	-.09
Step 3	.22	.00			.57	.00		
HF-HRV x Condition			.12 (.60)	.01			-.05 (.39)	-.007

Note: *n* =135; change scores were calculated by examining the differences between periods (e.g., P2 – P1) therefore negative values reflect decreases in intrusions; HF-HRV = natural log transformed high frequency heart rate variability; Sex (1 = male; 2 = female); Condition = experimental group (control group = ‘0’, suppression group = ‘1’); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

**p* < .05, ***p* < .01

Table 4. Regression analyses predicting changes in thought frequency across the monitoring periods as a function of HF-HRV and spontaneous suppression effort within the No Load condition

	Δ in Thought Frequency – Baseline to Manipulation Period (P1 to P2)				Δ in Thought Frequency – Manipulation to Final Monitoring Period (P2 to P3)			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE)* at Final Step	*sr* at Final Step	Adjusted R^2	ΔR^2	B (*SE)* at Final Step	*sr* at Final Step
Intercept			-2.72**(1.1)				-1.20 (.70)	
Step 1	.19				.58			
Thought Frequency (P1 or P2)			-1.83**(.28)	-.48**			-2.63** (.19)	-.75**
Sex			.35 (.58)	.04			-.34 (.39)	-.04
Condition			.19 (.63)	.02			.27 (.42)	.03
Step 2	.26	.07*			.59	.01		
HF-HRV			-.21 (.29)	-.05			.09 (.20)	.02
P2 Suppression Effort			1.10** (.31)	.25**			.53** (.22)	.13**
Step 3	.26	.00			.59	.00		
HF-HRV x Suppression Effort			-.09 (.30)	-.02			.11 (.20)	.03

Note: *n* =135; change scores were calculated by examining the differences between periods (e.g., P2 – P1) therefore negative values reflect decreases in intrusions; HF-HRV = natural log transformed high frequency heart rate variability; Sex (1 = male; 2 = female); Condition = experimental group (control group = ‘0’, suppression group = ‘1’); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

*p < .05, **p < .01

Table 5. Regression analyses predicting changes in thought frequency across the monitoring periods as a function of HF-HRV, Load, and instructed suppression

	Δ in Thought Frequency – Baseline to Manipulation Period (P1 to P2)				Δ in Thought Frequency – Manipulation to Final Monitoring Period (P2 to P3)			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE)* at Final Step	*sr* at Final Step	Adjusted R^2	ΔR^2	B (*SE)* at Final Step	*sr* at Final Step
Intercept			-4.33**(1.05)				-2.44** (.89)	
Step 1	.23				.27			
Thought Frequency (P1 or P2)			-1.63** (.18)	-.46**			-1.63** (.16)	-.52**
Sex			.68 (.38)	.09			-.23 (.32)	-.03
Step 2	.24	.02			.28	.01		
HF-HRV			-.70 (.87)	-.04			.06 (.74)	.005
Condition			1.81 (1.17)	.08			.90 (1.00)	.04
Load			.62 (.52)	.06			.93* (.44)	.10*
Step 3	.24	.008			.28	.002		
HF-HRV x Condition			-.22 (1.20)	-.01			-.09 (1.02)	-.005
HF-HRV x Load			.22 (.53)	.02			-.04 (.45)	.006
Condition x Load			-.62 (.74)	-.04			-.41 (.63)	-.03
Step 4	.24	.001			.28	.001		
HF-HRV x Condition x Load			.37 (.74)	.02			.11 (.64)	.009

Note: *n* =271; change scores were calculated by examining the differences between periods (e.g., P2 – P1) therefore negative values reflect decreases in intrusions; HF-HRV = natural log transformed high frequency heart rate variability; Sex (1 = male; 2 = female); Load = presence of cognitive load (no load = ‘1’, load = ‘2’); Condition = experimental group (control group = ‘0’, suppression group = ‘1’); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

**p* < .05, ***p* < .01

Table 6. Regression analyses predicting changes in thought frequency across the monitoring periods as a function of HF-HRV, Load, and spontaneous suppression effort

	Δ in Thought Frequency – Baseline to Manipulation Period (P1 to P2)				Δ in Thought Frequency – Manipulation to Final Monitoring Period (P2 to P3)			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE*) at Final Step	*sr* at Final Step	Adjusted R^2	ΔR^2	B (*SE*) at Final Step	*sr* at Final Step
Intercept			-3.57**(.85)				-2.00** (.75)	
Step 1	.24				.27			
Thought Frequency (P1 or P2)			-1.81** (.18)	-.50**			-1.72** (.16)	-.52**
Sex			.69 (.36)	.09			-.23 (.32)	-.03
Condition			.08 (.38)	.01			.06 (.34)	.01
Step 2	.31	.07**			.29*	.02		
HF-HRV			-.40 (.58)	-.03			.05 (.52)	.006
P2 Suppression Effort			1.37* (.57)	.12*			-.04 (.51)	-.005
Load			.34 (.35)	.04			.72* (.31)	.11*
Step 3	.30	.003			.28	.004		
HF-HRV x Suppression Effort			-.44 (.60)	-.03			.02 (.53)	.002
HF-HRV x Load			.18 (.36)	.02			.07 (.32)	.01
Suppression Effort x Load			-.44 (.60)	-.03			.26 (.31)	.04
Step 4	.30	.002			.28	.001		
HF-HRV x Suppression Effort x Load			.35 (.37)	.04			.08 (.33)	.01

Note: *n* = 271; change scores were calculated by examining the differences between periods (e.g., P2 – P1) therefore negative values reflect decreases in intrusions; HF-HRV = natural log transformed high frequency heart rate variability; Sex (1 = male; 2 = female); Load = presence of cognitive load (no load = ‘1’, load = ‘2’); Condition = experimental group (control group = ‘0’, suppression group = ‘1’); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

*p < .05, **p < .01

Table 7. Regression analyses predicting changes in thought frequency across the monitoring periods as a function of HF-HRV and instructed suppression within the Load condition

	Δ in Thought Frequency – Baseline to Manipulation Period (P1 to P2)				Δ in Thought Frequency – Manipulation to Final Monitoring Period (P2 to P3)			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE)* at Final Step	*sr* at Final Step	Adjusted R^2	ΔR^2	B (*SE)* at Final Step	*sr* at Final Step
Intercept			-3.66** (.81)				-.79 (.77)	
Step 1	.30				.01			
Thought frequency (P1 or P2)			-1.67**(.24)	-.49**			-.50* (.24)	-.17*
Sex			1.04* (.47)	.15*			-.06 (.45)	-.01
Step 2	.30	.006			.004	.01		
HF-HRV			-.24 (.31)	-.05			.14 (.30)	.04
Condition			.55 (.46)	.08			-.03 (.44)	-.006
Step 3	.30	.007			.004	.00		
HF-HRV x Condition			.51 (.45)	.08			-.04 (.44)	-.008

Note: *n* = 136; change scores were calculated by examining the differences between periods (e.g., P2 – P1) therefore negative values reflect decreases in intrusions; HF-HRV = natural log transformed high frequency heart rate variability; Sex (1 = male; 2 = female); Condition = experimental group (control group = ‘0’, suppression group = ‘1’); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

**p* < .05, ***p* < .01

Table 8. Regression analyses predicting changes in thought frequency across the monitoring periods as a function of HF-HRV and spontaneous suppression effort within the Load condition

	Δ in Thought Frequency – Baseline to Manipulation Period (P1 to P2)				Δ in Thought Frequency – Manipulation to Final Monitoring Period (P2 to P3)			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE*) at Final Step	*sr* at Final Step	Adjusted R^2	ΔR^2	B (*SE*) at Final Step	*sr* at Final Step
Intercept			-3.36** (.78)				-.79 (.77)	
Step 1	.30				.009			
Thought frequency (P1 or P2)			-1.76**(.23)	-.51**			-.57* (.25)	-.19*
Sex			1.03* (.45)	.15*			-.07 (.45)	-.01
Condition			-.02 (.46)	-.004			-.15 (.46)	-.02
Step 2	.36	.06**			.002	.007		
HF-HRV			-.04 (.22)	-.004			.11 (.22)	.04
P2 Suppression Effort			.90** (.23)	.26**			.22 (.25)	.07
Step 3	.36	.005			.002	.000		
HF-HRV x Suppression Effort			.24 (.22)	.07			.06 (.23)	.02

Note: *n* =136; change scores were calculated by examining the differences between periods (e.g., P2 – P1) therefore negative values reflect decreases in intrusions; HF-HRV = natural log transformed high frequency heart rate variability; Sex (1 = male; 2 = female); Condition = experimental group (control group = ‘0’, suppression group = ‘1’); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

*$p < .05$, **$p < .01$

Table 9. Regression analyses predicting changes in thought frequency across the monitoring periods as a function of EC, Load, and instructed suppression

	Δ in Thought Frequency – Baseline to Manipulation Period (P1 to P2)				Δ in Thought Frequency – Manipulation to Final Monitoring Period (P2 to P3)			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE)* at Final Step	*sr* at Final Step	Adjusted R^2	ΔR^2	B (*SE)* at Final Step	*sr* at Final Step
Intercept			-4.55**(1.09)				-2.39** (.91)	
Step 1	.23				.27			
Thought Frequency (P1 or P2)			-1.61** (.18)	-.45**			-1.66** (.15)	-.53**
Sex			.68 (.39)	.09			-.36 (.32)	-.05
Step 2	.24	.01			.29	.03**		
ATQ-EC			-.44 (.89)	-.02			.17 (.75)	.01
Condition			1.94 (1.19)	.08			1.15 (1.00)	.05
Load			.72 (.53)	.07			1.04* (.44)	.11*
Step 3	.24	.003			.29	.007		
ATQ-EC x Condition			1.22 (1.23)	.05			-.30 (1.02)	-.01
ATQ-EC x Load			.23 (.54)	.02			-.45 (.45)	-.05
Condition x Load			-.70 (.75)	-.05			-.58 (.63)	-.04
Step 4	.24	.002			.29	.001		
ATQ-EC x Condition x Load			-.72 (.77)	-.05			.38 (.64)	.03

Note: *n* = 271; change scores were calculated by examining the differences between periods (e.g., P2 – P1) therefore negative values reflect decreases in intrusions; ATQ-EC = Adult Temperament Questionnaire – Effortful Control subscale; Sex (1 = male; 2 = female); Load = presence of cognitive load (no load = '1', load = '2'); Condition = experimental group (control group = '0', suppression group = '1'); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

**p* < .05, ***p* < .01

Table 10. Regression analyses predicting changes in thought frequency across the monitoring periods as a function of EC, Load, and spontaneous suppression

	Δ in Thought Frequency – Baseline to Manipulation Period (P1 to P2)				Δ in Thought Frequency – Manipulation to Final Monitoring Period (P2 to P3)			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE*) at Final Step	*sr* at Final Step	Adjusted R^2	ΔR^2	B (*SE*) at Final Step	*sr* at Final Step
Intercept			-3.61**(.86)				-1.95** (.75)	
Step 1	.24				.27			
Thought Frequency (P1 or P2)			-1.79** (.18)	-.45**			-1.71** (.16)	-.52**
Sex			.72* (.37)	.09*			-.30 (.32)	-.04
Condition			.02 (.38)	.003			.12 (.34)	.01
Step 2	.31	.07**			.30	.03**		
ATQ-EC			.23 (.58)	.02			.09 (.51)	.01
Suppression Effort			1.51** (.57)	.13**			-.05 (.51)	-.005
Load			.36 (.35)	.05			.73* (.31)	.11*
Step 3	.30	.004			.29	.005		
ATQ-EC x Suppression Effort			.17 (.55)	.01			-.20 (.48)	-.02
ATQ-EC x Load			-.07 (.36)	-.01			-.30 (.32)	-.04
Suppression Effort x Load			-.32 (.36)	-.04			-.21 (.32)	.03
Step 4	.30	.000			.29	.000		
ATQ-EC x Suppression Effort x Load			-.006 (.34)	-.001			.04 (.30)	.008

Note: *n* = 271; change scores were calculated by examining the differences between periods (e.g., P2 – P1) therefore negative values reflect decreases in intrusions; ATQ-EC = Adult Temperament Questionnaire – Effortful Control subscale; Sex (1 = male; 2 = female); Load = presence of cognitive load (no load = ‘1’, load = ‘2’); Condition = experimental group (control group = ‘0’, suppression group = ‘1’); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

**p* < .05, ***p* < .01

Table 11. Regression analyses predicting changes in thought frequency across the monitoring periods as a function of EC and instructed suppression within the No Load Condition

	Δ in Thought Frequency – Baseline to Manipulation Period (P1 to P2)				Δ in Thought Frequency – Manipulation to Final Monitoring Period (P2 to P3)			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE)* at Final Step	*sr* at Final Step	Adjusted R^2	ΔR^2	B (*SE)* at Final Step	*sr* at Final Step
Intercept			-3.10**(1.1)				-1.20 (.70)	
Step 1	.18				.57			
Thought Frequency (P1 or P2)			-1.54**(.28)	-.42**			-2.63** (.19)	-.75**
Sex			.25 (.61)	.03			-.34 (.39)	-.04
Step 2	.21	.02			.58	.01		
ATQ-EC			-.17 (.46)	-.02			.09 (.20)	.02
Condition			1.20* (.59)	.15*			.53** (.22)	.13**
Step 3	.21	.004			.57	.00		
ATQ EC x Condition			.47 (.61)	.06			.11 (.20)	.03

Note: *n* =135; change scores were calculated by examining the differences between periods (e.g., P2 – P1) therefore negative values reflect decreases in intrusions; ATQ-EC = Adult Temperament Questionnaire – Effortful Control subscale; Sex (1 = male; 2 = female); Condition = experimental group (control group = '0', suppression group = '1'); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

*$p < .05$, **$p < .01$

Table 12. Regression analyses predicting changes in thought frequency across the monitoring periods as a function of EC and spontaneous suppression effort within the No Load Condition

	Δ in Thought Frequency – Baseline to Manipulation Period (P1 to P2)				Δ in Thought Frequency – Manipulation to Final Monitoring Period (P2 to P3)			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE)* at Final St p	*sr* at Final Step	Adjusted R^2	ΔR^2	B (*SE)* at Final Step	*sr* at Final Step
Intercept			-2.72**(1.1)				-1.34 (.70)	
Step 1	.19				.58			
Thought Frequency (P1 or P2)			-1.83**(.28)	-.48**			-2.62** (.19)	-.75**
Sex			.35 (.58)	.04			-.30 (.39)	-.04
Condition			.19 (.63)	.02			.36 (.42)	.04
Step 2	.26	.07**			.59	.02*		
ATQ-EC			-.21 (.29)	-.05			-.21 (.19)	-.06
P2 Suppression Effort			1.10** (.31)	.25**			.48* (.22)	.12*
Step 3	.25	.002			.59	.00		
ATQ-EC x Suppression Effort			-.09 (.30)	-.02			-.13 (.19)	-.03

Note: *n* = 135; change scores were calculated by examining the differences between periods (e.g., P2 – P1) therefore negative values reflect decreases in intrusions; ATQ-EC = Adult Temperament Questionnaire – Effortful Control subscale; Sex (1 = male; 2 = female); Condition = experimental group (control group = ‘0’, suppression group = ‘1’); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

*p < .05, **p < .01

Table 13. Regression analyses predicting changes in thought frequency across the monitoring periods as a function of EC and instructed suppression within the Load condition

	Δ in Thought Frequency – Baseline to Manipulation Period (P1 to P2)				Δ in Thought Frequency – Manipulation to Final Monitoring Period (P2 to P3)			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE)* at Final Step	*sr* at Final Step	Adjusted R^2	ΔR^2	B (*SE)* at Final Ste	*sr* at Final Step
Intercept			-3.78** (.85)				-.33 (.80)	
Step 1	.31				.01			
Thought frequency (P1 or P2)			-1.65**(.24)	-.48**			-.56* (.24)	-.20*
Sex			1.12* (.49)	.16*			-.32 (.46)	-.06
Step 2	.32	.006			.03	.02		
ATQ-EC			.08 (.30)	.02			-.08* (.43)	-.17*
Condition			.52 (.46)	.08			-.08 (.43)	-.01
Step 3	.32	.002			.03	.004		
ATQ-EC x Condition			-.30 (.47)	-.04			.34 (.45)	-.06

Note: *n* = 136; change scores were calculated by examining the differences between periods (e.g., P2 – P1) therefore negative values reflect decreases in intrusions; ATQ-EC = Adult Temperament Questionnaire – Effortful Control subscale; Sex (1 = male; 2 = female); Condition = experimental group (control group = '0', suppression group = '1'); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

*p < .05, **p < .01

Table 14. Regression analyses predicting changes in thought frequency across the monitoring periods as a function of EC and spontaneous suppression effort within the Load condition

	Δ in Thought Frequency – Baseline to Manipulation Period (P1 to P2)				Δ in Thought Frequency – Manipulation to Final Monitoring Period (P2 to P3)			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE*) at Final Step	*sr* at Final Step	Adjusted R^2	ΔR^2	B (*SE*) at Final Step	*sr* at Final Step
Intercept			-3.52** (.79)				-.45 (.78)	
Step 1	.30				.009			
Thought frequency (P1 or P2)			-1.72**(.23)	-.50**			-.58* (.24)	-.19*
Sex			1.15* (.46)	.17*			-.24 (.45)	-.04
Condition			-.04 (.46)	-.008			-.12 (.46)	-.02
Step 2	.36	.06**			.02	.03		
ATQ-EC			.14 (.22)	.04			-.43 (.22)	-.16
P2 Suppression Effort			.86** (.24)	.24**			.15 (.25)	.05
Step 3	.36	.003			.02	.002		
ATQ-EC x Suppression Effort			.17 (.20)	.05			-.11 (.20)	-.04

Note: *n* = 136; change scores were calculated by examining the differences between periods (e.g., P2 – P1) therefore negative values reflect decreases in intrusions; ATQ-EC = Adult Temperament Questionnaire – Effortful Control subscale; Sex (1 = male; 2 = female); Condition = experimental group (control group = ‘0’, suppression group = ‘1’); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

**p* < .05, ***p* < .01

Table 15. Regression analyses predicting post-task EC as a function of HF-HRV and instructed thought suppression ability within the full sample

	ECS Total			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE*) at Final Step	*sr* at Final Step
Intercept			-.12 (.25)	
Step 1	.48			
Thought Frequency (P1 or P2)			.02 (.04)	.02
Sex			.03 (.09)	.01
ATQ-EC			.69** (.04)	.67**
Step 2	.48	.003		
HF-HRV			.33 (.20)	.07
Condition			.06 (.28)	.01
Load			.03 (.12)	.01
Step 3	.49	.004		
HF-HRV x Condition			-.14 (.28)	-.02
HF-HRV x Load			-.17 (.12)	-.06
Condition x Load			-.03 (.17)	-.01
Step 4	.49	.000		
HF-HRV x Condition x Load			.07 (.17)	.01

Note: n = 271; ATQ-EC = Adult Temperament Questionnaire – Effortful Control subscale; Sex (1 = male; 2 = female); Load = presence of cognitive load (no load = '1', load = '2'); Condition = experimental group (control group = '0', suppression group = '1'); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

*p < .05, **p < .01

Table 16. Regression analyses predicting post-task Effortful Control as a function of HF-HRV and instructed thought suppression ability across levels of load

	ECS Total (No Load)				ECS Total (Load)			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE*) at Final Step	*sr* at Final Step	Adjusted R^2	ΔR^2	B (*SE*) at Final Step	*sr* at Final Step
Intercept			-.08 (.23)				-.03 (.23)	
Step 1	.48				.45			
Thought frequency (P1 or P2)			.05 (.06)	.05			.003 (.06)	.003
Sex			.03 (.12)	.01			.02 (.13)	.01
ATQ-EC			.69** (.06)	.66**			.68** (.06)	.66**
Step 2	.48	.01			.45	.000		
HF-HRV			.15 (.09)	.10			-.01 (.08)	-.008
Condition			.02 (.12)	.01			-.01. (.12)	-.006
Step 3	.48	.001			.45	.000		
HF-HRV x Condition			-.06 (.12)	-.03			.01 (.12)	.008

Note: ATQ-EC = Adult Temperament Questionnaire – Effortful Control subscale; Sex (1 = male; 2 = female); Condition = experimental group (control group = '0', suppression group = '1'); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

*$p < .05$, **$p < .01$

Table 17. Regression analyses predicting post-task Effortful Control as a function of instructed thought suppression ability within the full sample

	ECS Total			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE)* at Final Step	*sr* at Final Step
Intercept			-.09 (.26)	
Step 1	.000			
Thought Frequency (P1 or P2)			.02 (.04)	.02
Sex			.03 (.09)	.01
Step 2	.47	.47**		
ATQ-EC			.74** (.21)	.15**
Condition			.04 (.28)	.008
Load			.02 (.12)	.009
Step 3	.46	.001		
ATQ-EC x Condition			-.03 (.29)	-.006
ATQ-EC x Load			-.04 (.12)	-.01
Condition x Load			-.03 (.17)	-.008
Step 4	.46	.000		
ATQ-EC x Condition x Load			.05 (.18)	.01

Note: *n* =271; ATQ-EC = Adult Temperament Questionnaire – Effortful Control subscale; Sex (1 = male; 2 = female); Load = presence of cognitive load (no load = '1', load = '2'); Condition = experimental group (control group = '0', suppression group = '1'); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

*$p < .05$, **$p < .01$

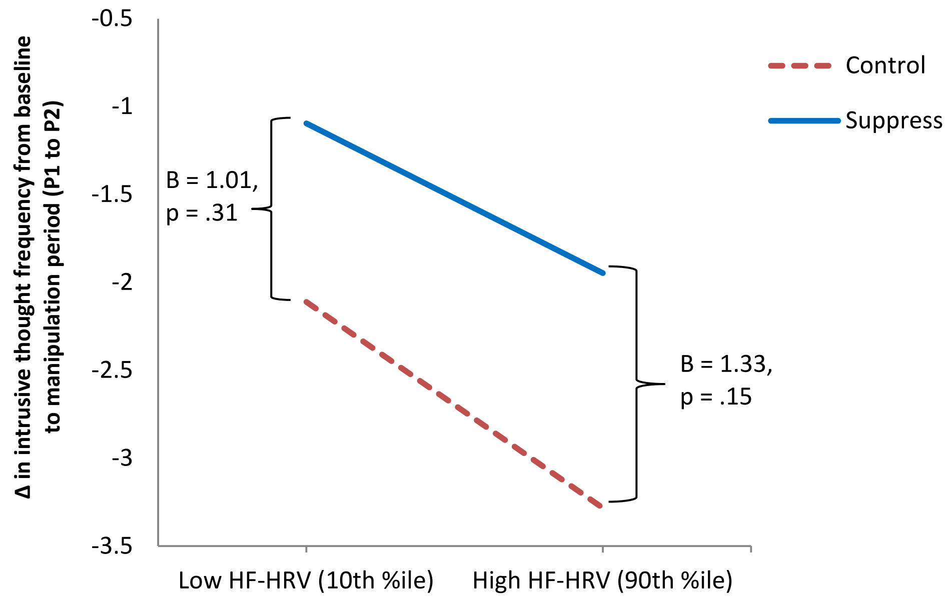
Table 18. Regression analyses predicting post-task Effortful Control as a function of instructed thought suppression ability across levels of load

	ECS Total (No Load)				ECS Total (Load)			
Step/Variables Added	Adjusted R^2	ΔR^2	B (*SE*) at Final Step	*sr* at Final Step	Adjusted R^2	ΔR^2	B (*SE*) at Final Step	*sr* at Final Step
Intercept			-.09 (.23)				-.002 (.23)	
Step 1	.000				.01			
Thought frequency (P1 or P2)			.05 (.06)	.05			-.002 (.06)	-.002
Sex			.05 (.13)	.02			.009 (.13)	-.04
Step 2	.47	.48**			.45	.44**		
ATQ-EC			.69** (.09)	.44**			.64** (.08)	.48**
Condition			.01 (.12)	.009			-.01 (.12)	-.01
Step 3	.47	.000			.45	.001		
ATQ-EC x Condition			.02 (.13)	.01			.08 (.13)	.03

Note: ATQ-EC = Adult Temperament Questionnaire – Effortful Control subscale; Sex (1 = male; 2 = female); Condition = experimental group (control group = ‘0’, suppression group = ‘1’); all non-dichotomous main effect variables were standardized; *sr* = semi-partial correlation coefficient.

*p < .05, **p < .01

Appendix B. Figures



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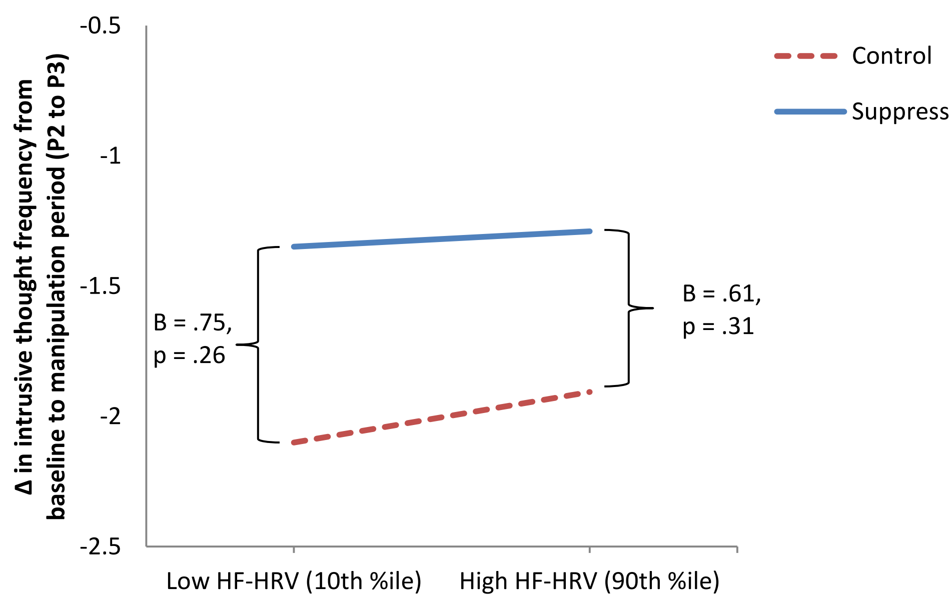

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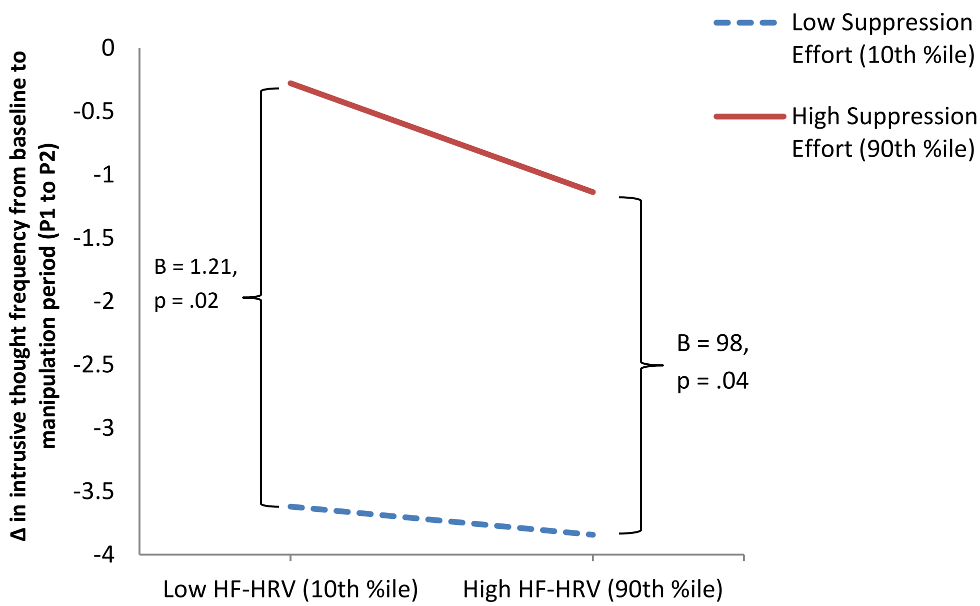
Figure 10. No Load only: Nonsignificant Condition x HF-HRV interaction predicting change in thought frequency from P1 to P2 and from P2 to P3.



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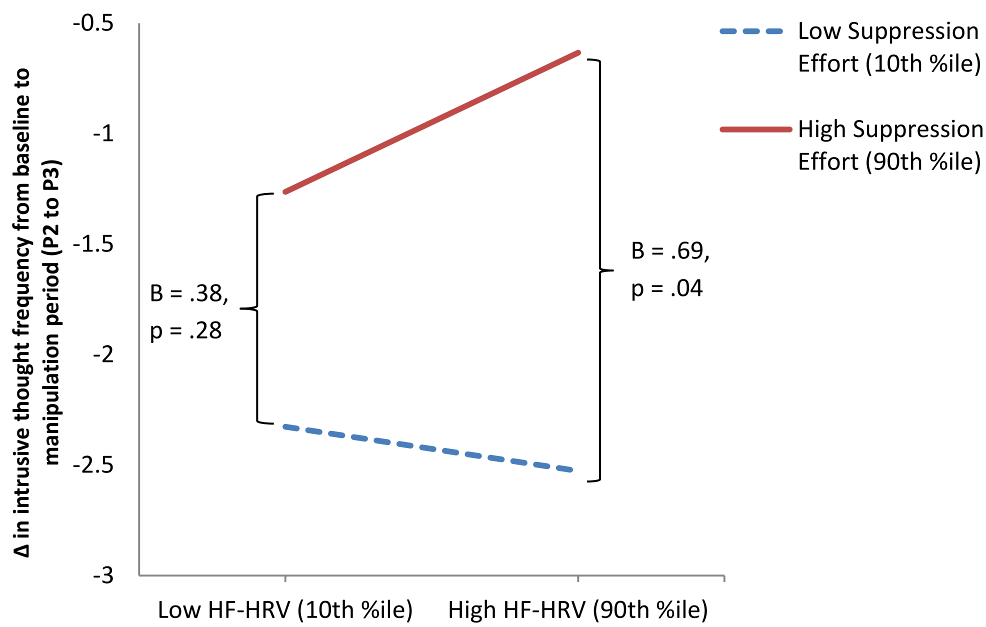

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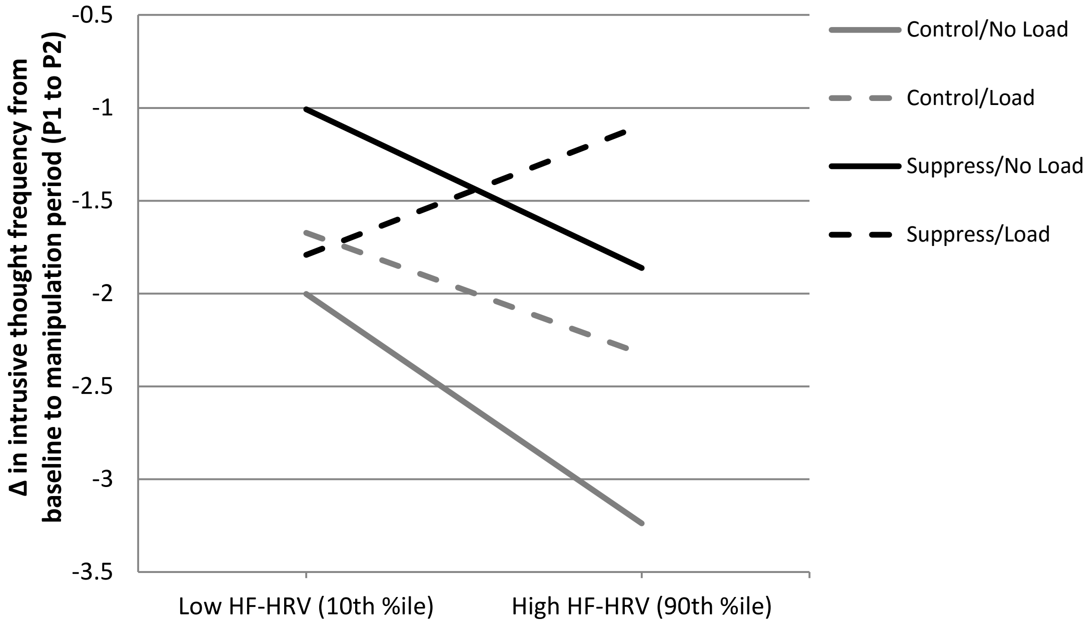
Figure 11. No Load only: Nonsignificant Suppression Effort x HF-HRV interaction predicting change in thought frequency from P1 to P2 and from P2 to P3.



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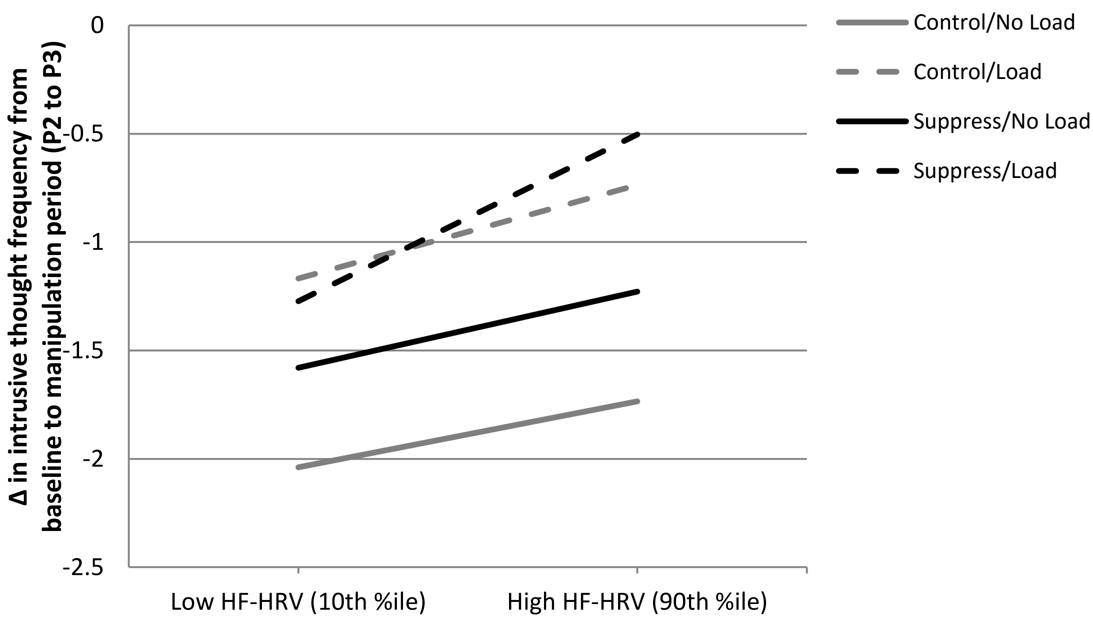
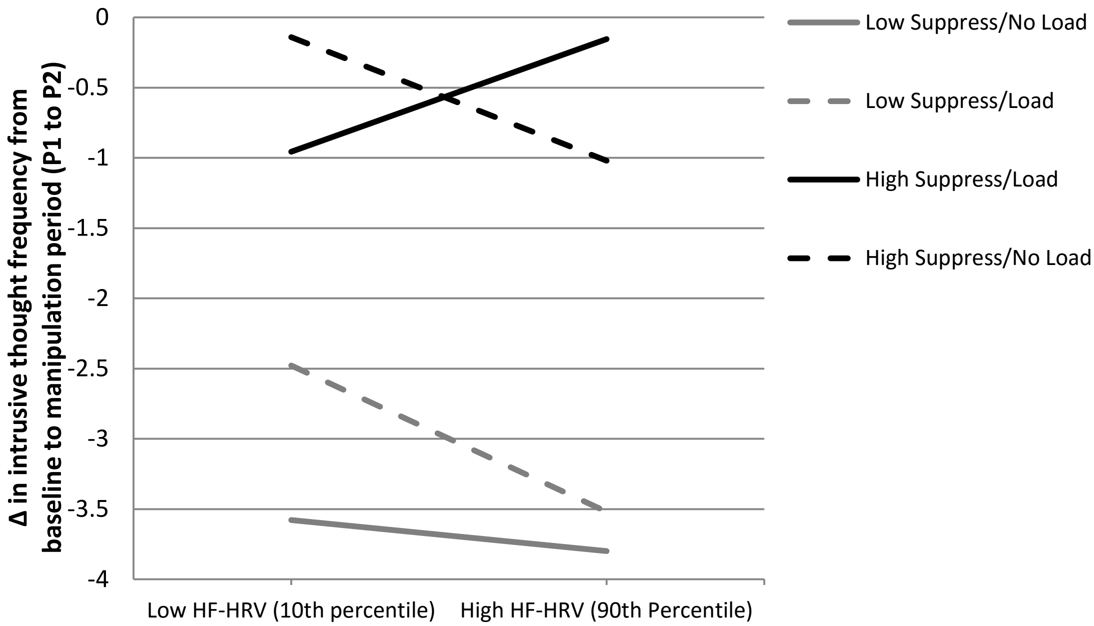


B

Figure 12. Full sample: Nonsignificant Condition x HF-HRV interaction predicting change in thought frequency from P1 to P2 and from P2 to P3.



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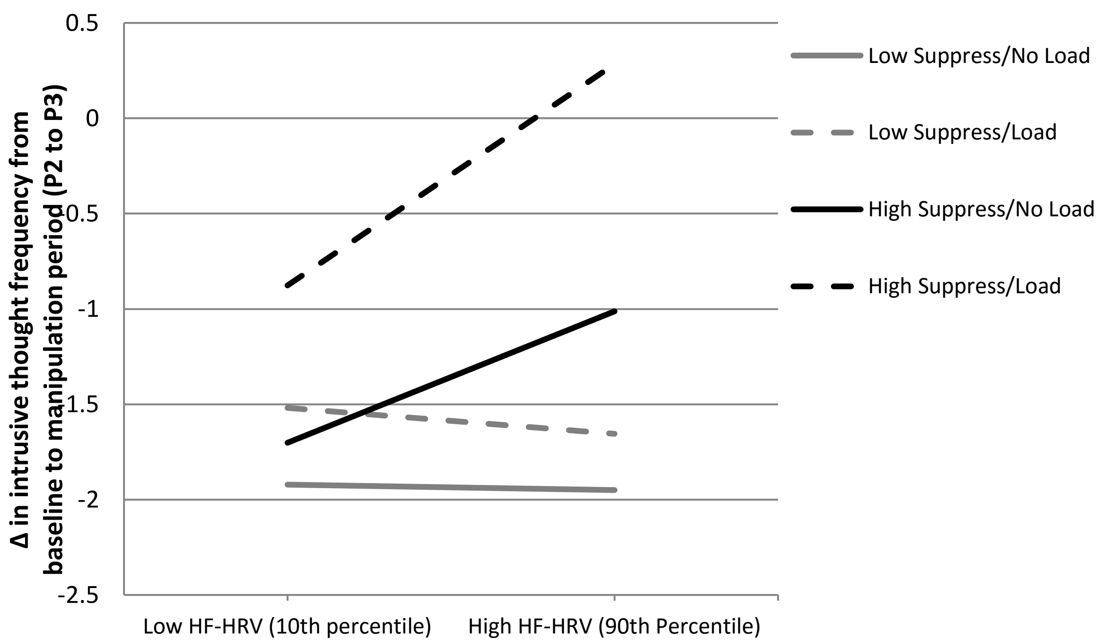

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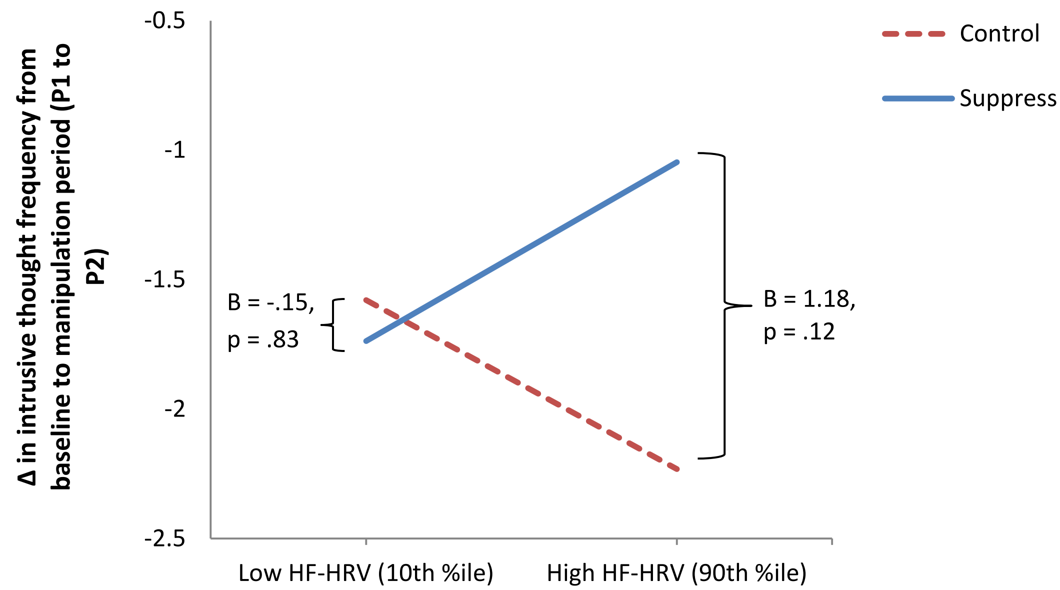
Figure 13. Full sample: Nonsignificant Suppression Effort x HF-HRV interaction predicting change in thought frequency from P1 to P2 and from P2 to P3.



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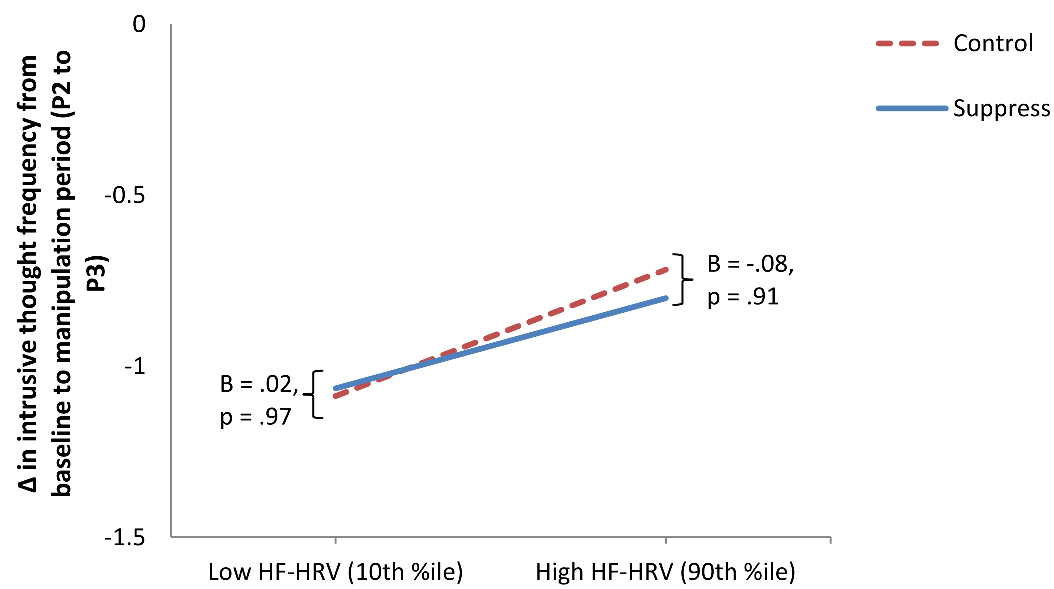

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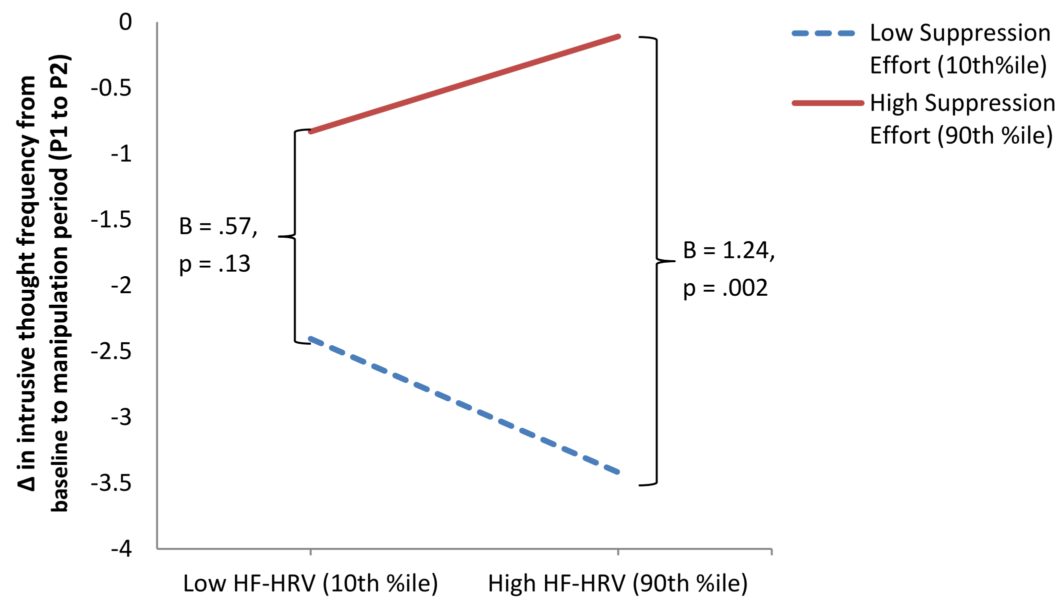
Figure 14. Load only: Nonsignificant Condition x HF-HRV interaction predicting change in thought frequency from P1 to P2 and from P2 to P3.



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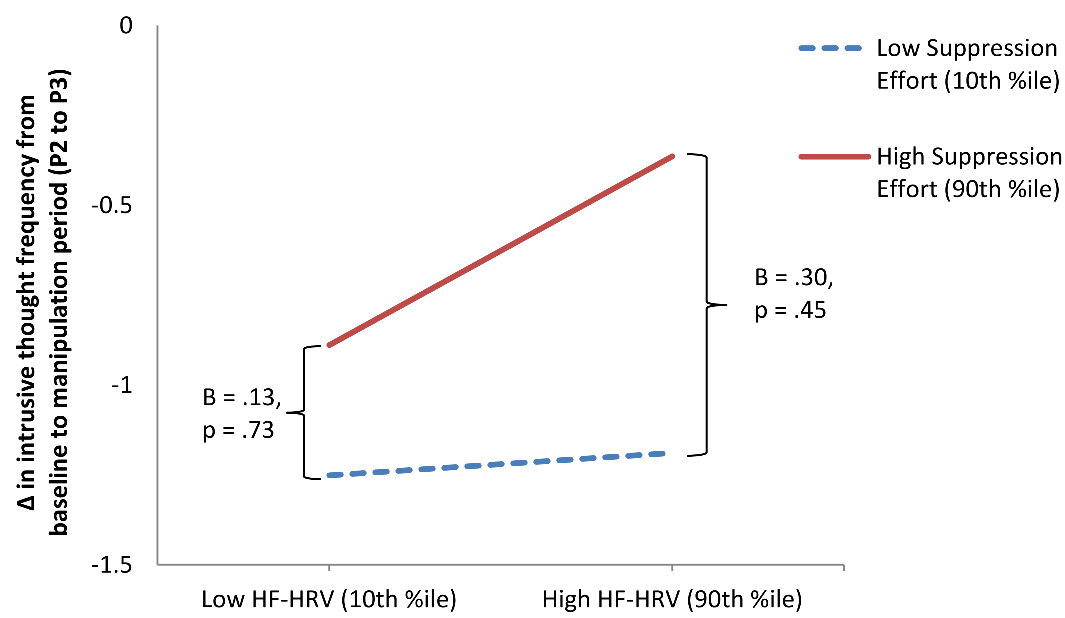

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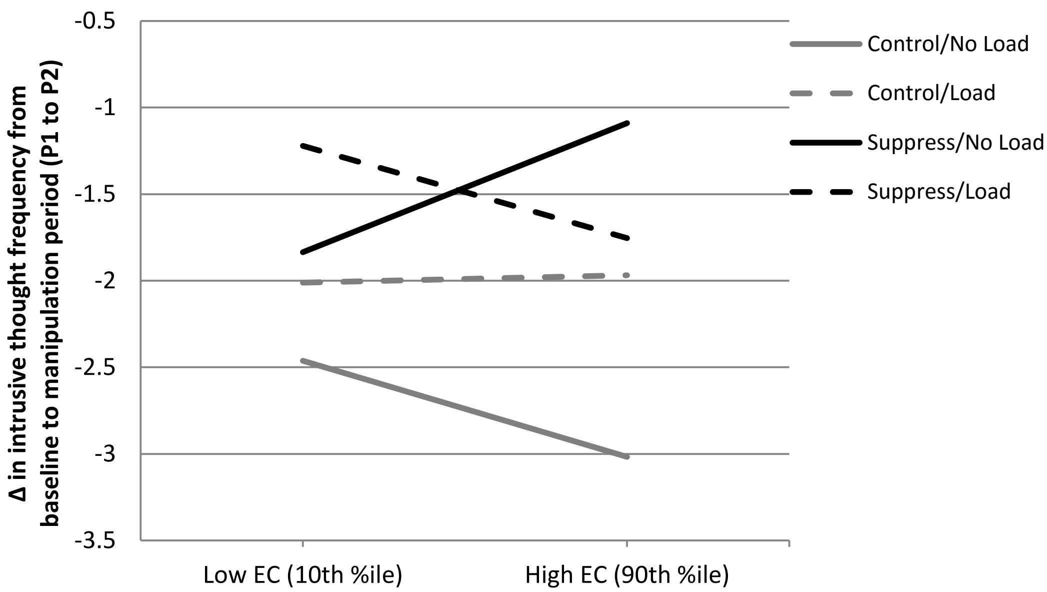
Figure 15. Load only: Nonsignificant Suppression Effort x HF-HRV interaction predicting change in thought frequency from P1 to P2 and from P2 to P3.



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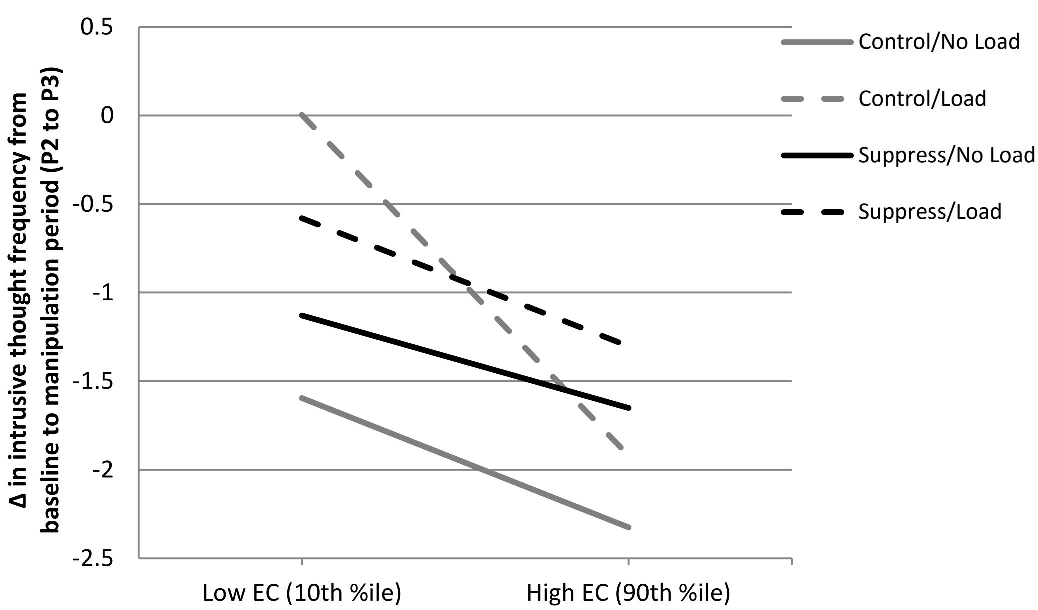

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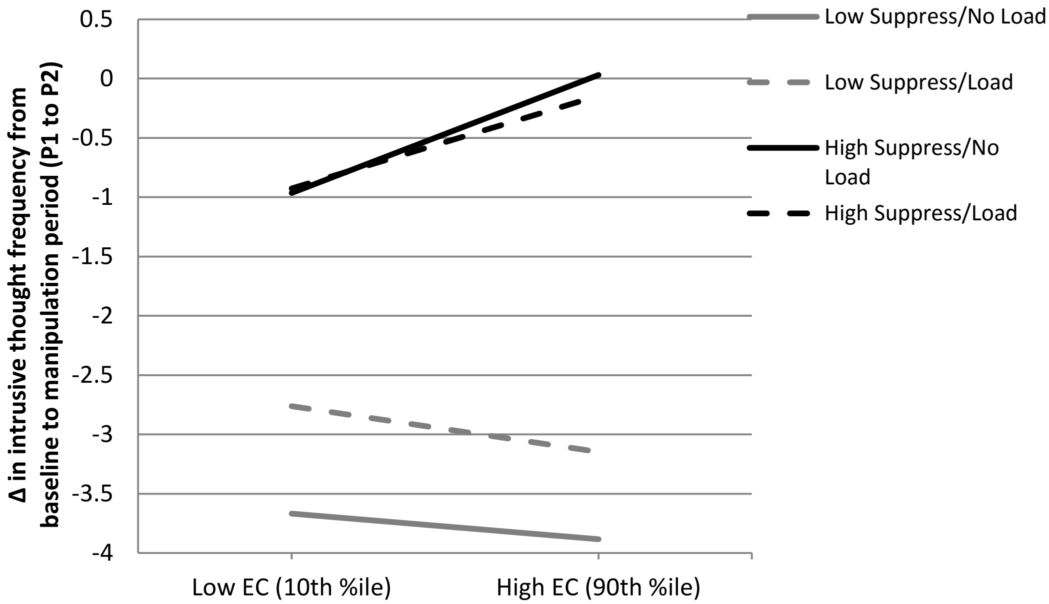
Figure 16. Depiction of Condition x Load x EC interaction predicting change in thought frequency from P1 to P2 and from P2 to P3.



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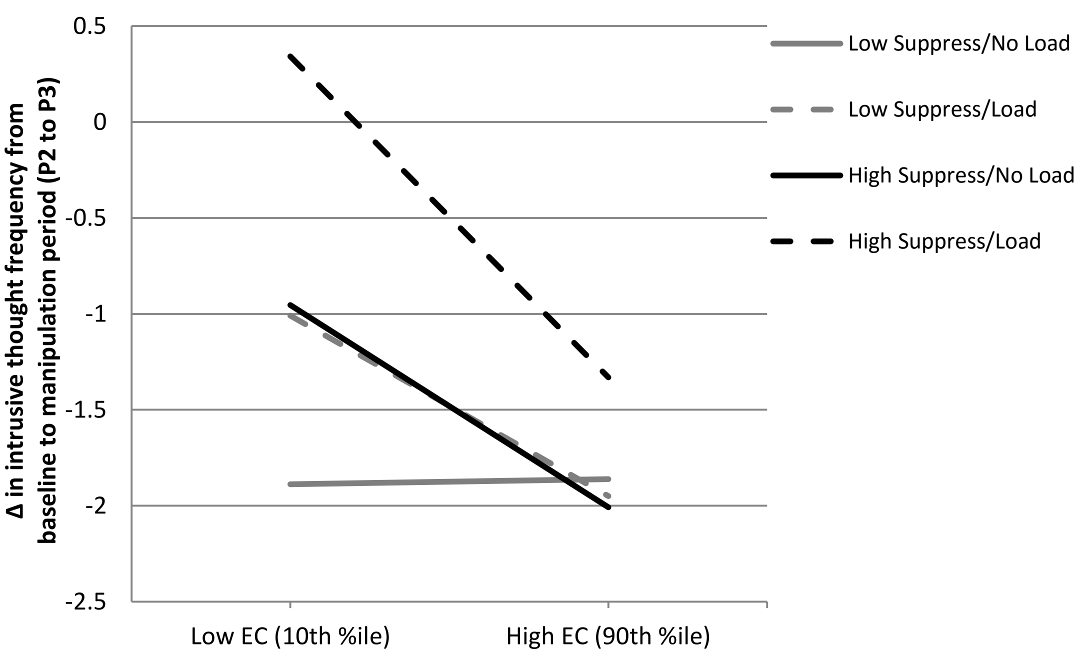
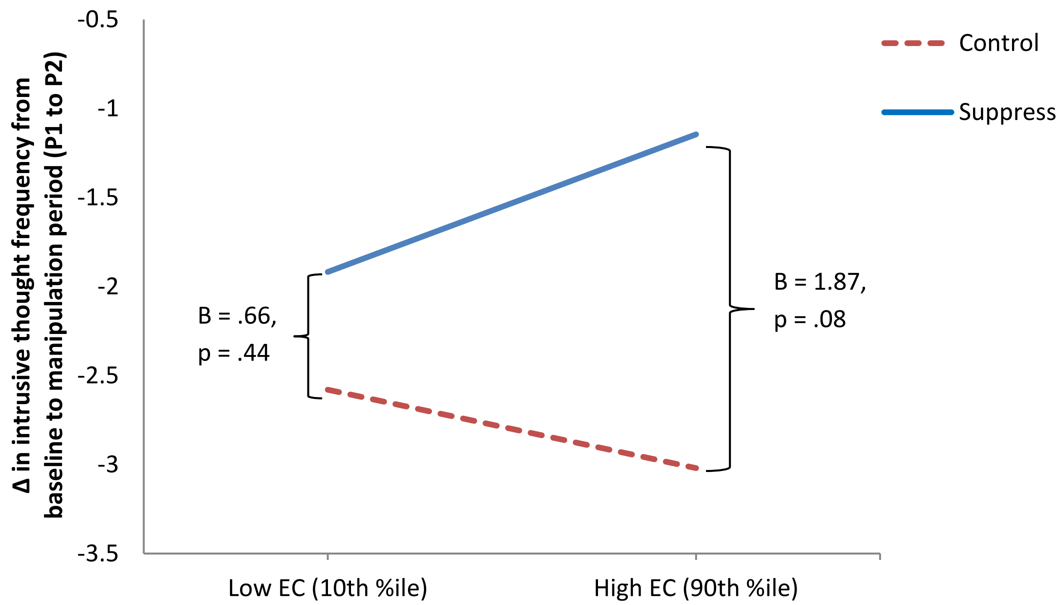
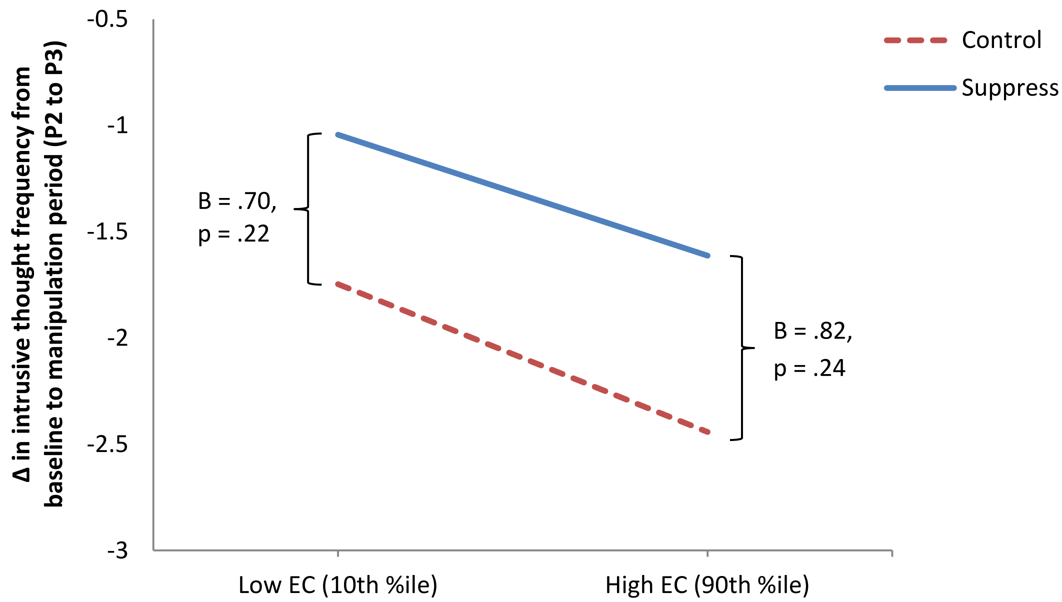


B

Figure 17. Depiction of Suppression Effort x Load x EC interaction predicting change in thought frequency from P1 to P2 and from P2 to P3.

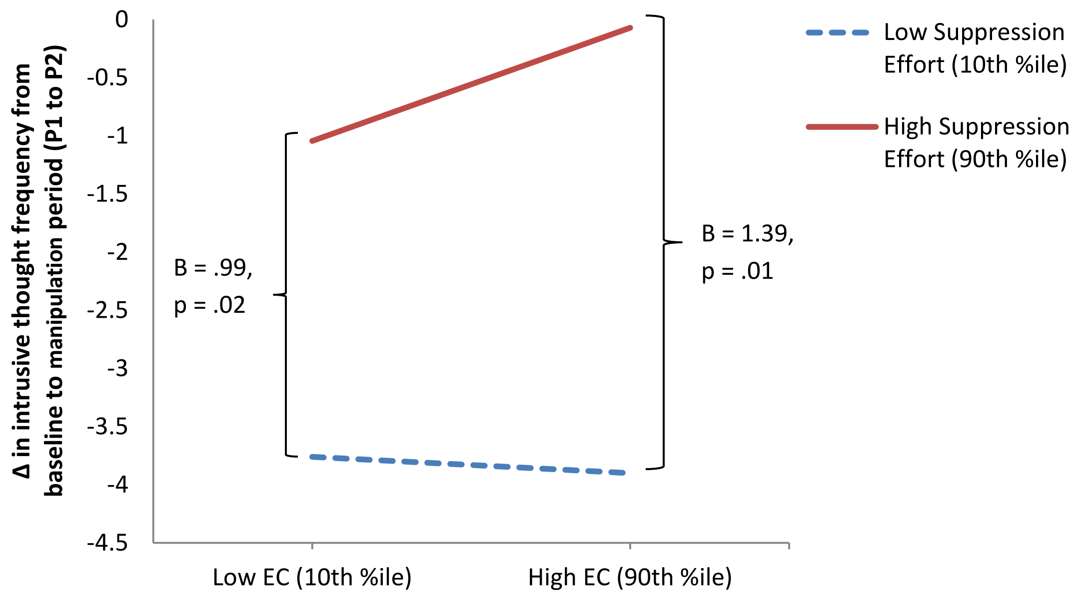


A

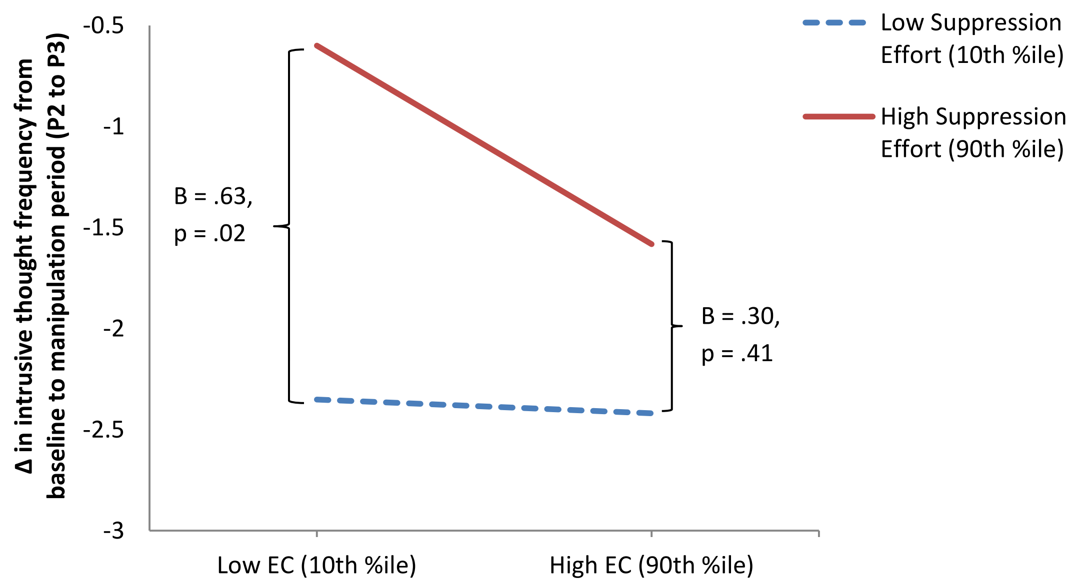


B

Figure 18. No Load only: Nonsignificant Condition x EC interaction predicting change in thought frequency from P1 to P2 and from P2 to P3.

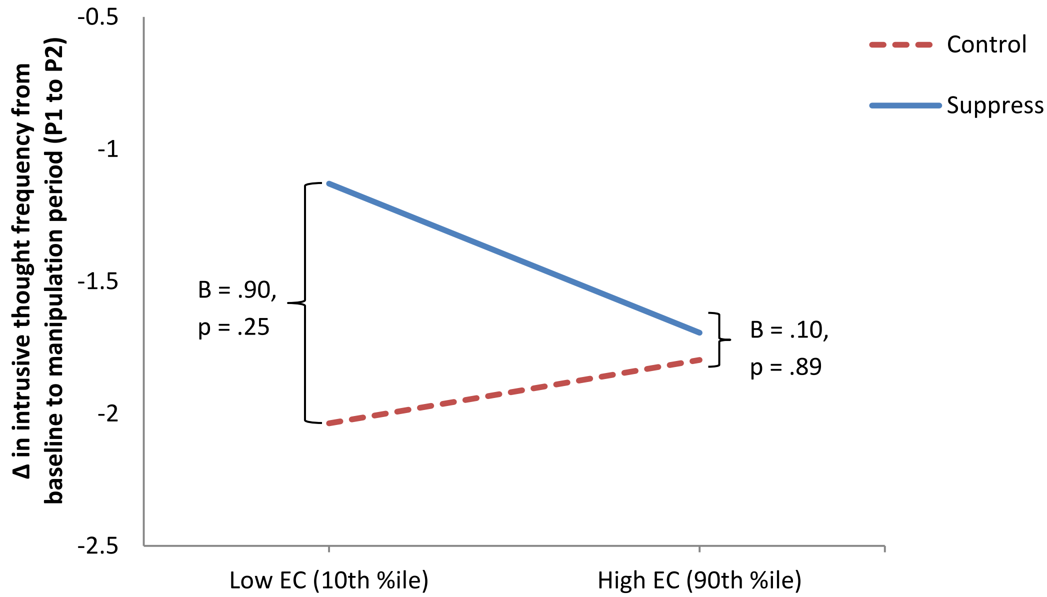


A

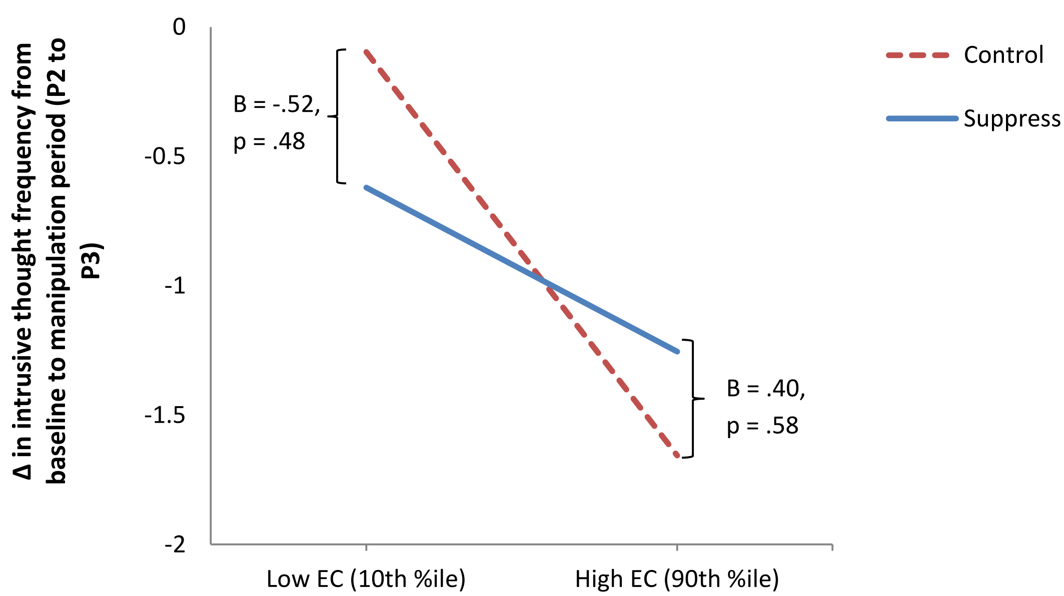


B

Figure 19. No Load only: Nonsignificant Suppression Effort x EC interaction predicting change in thought frequency from P1 to P2 and from P2 to P3.

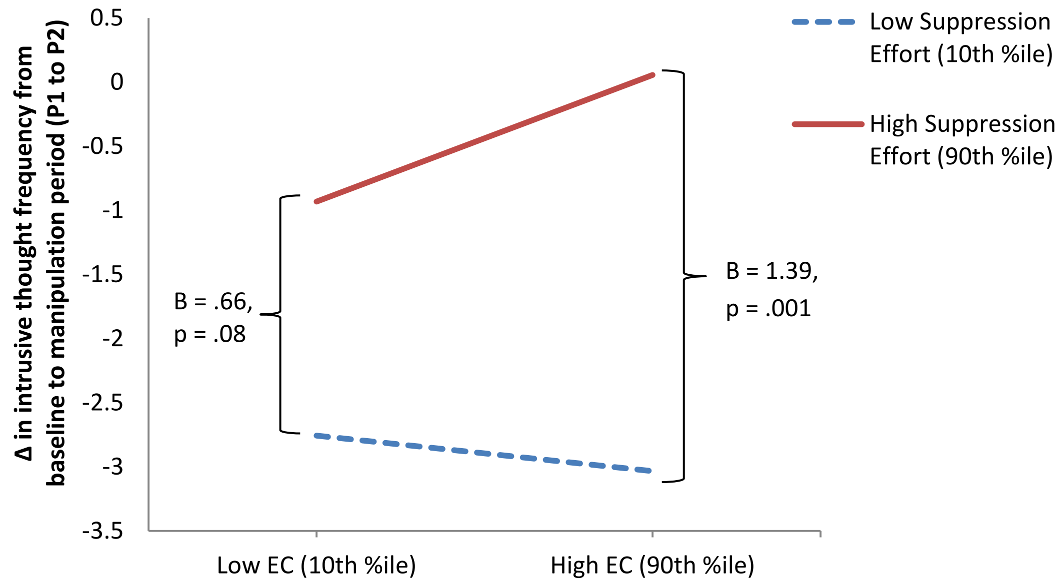


A

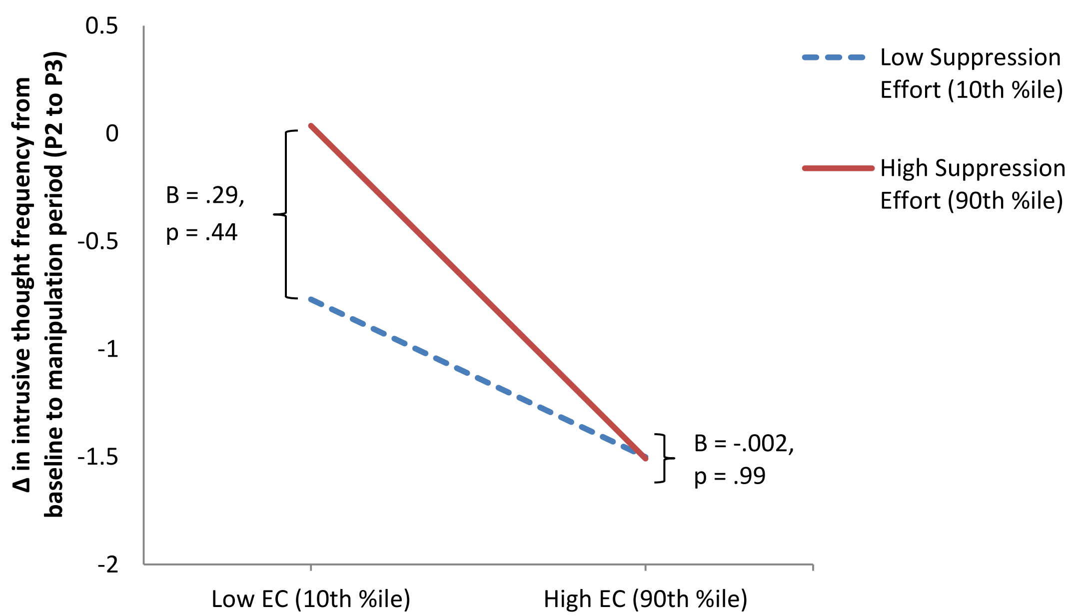


B

Figure 20. Load only: Nonsignificant Condition x EC interaction predicting change in thought frequency from P1 to P2 and from P2 to P3.

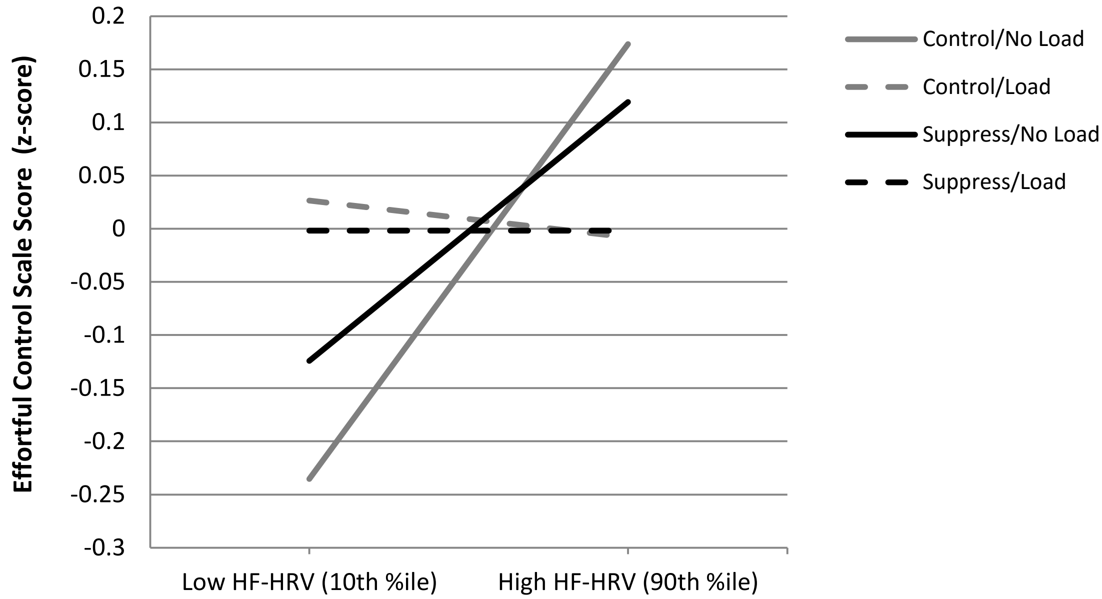


A

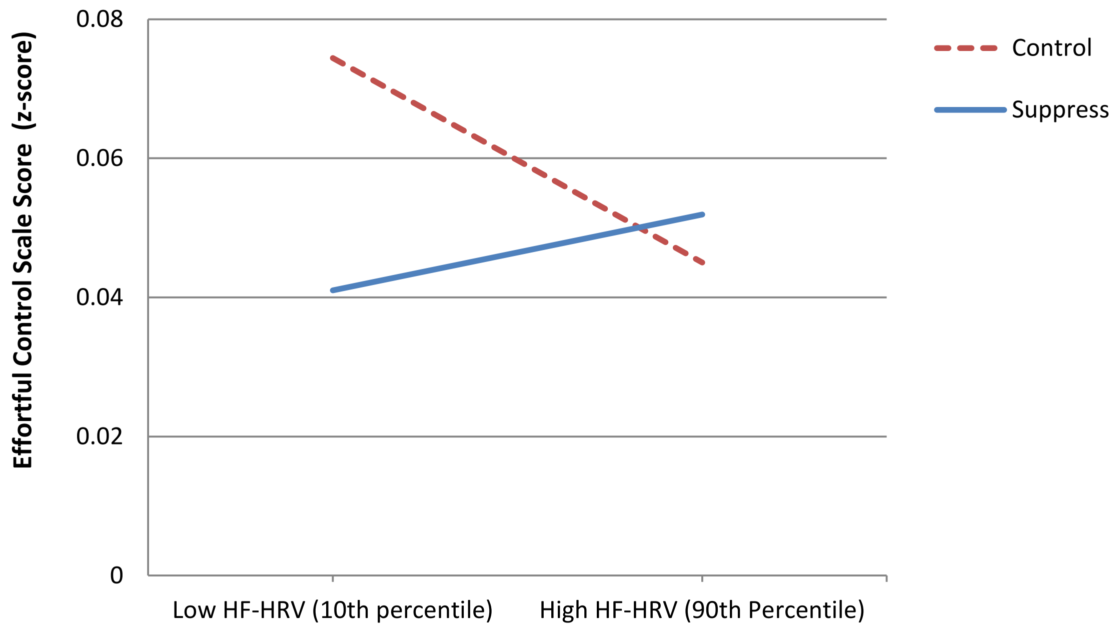


B

Figure 21. Load only: Nonsignificant Suppression Effort x EC interaction predicting change in thought frequency from P1 to P2 and from P2 to P3.



A

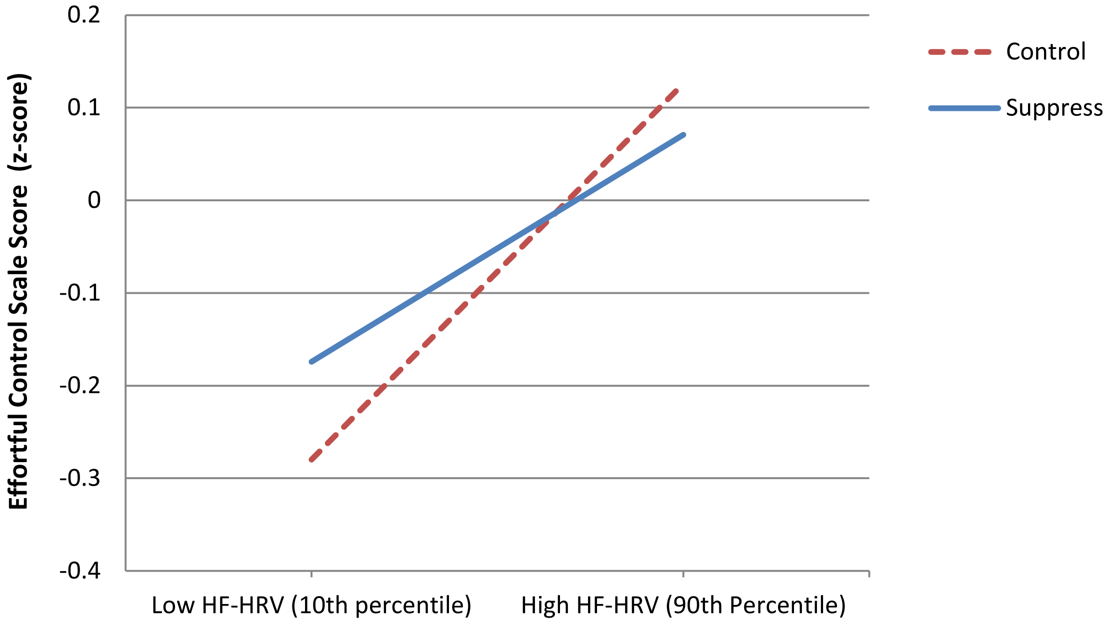


B

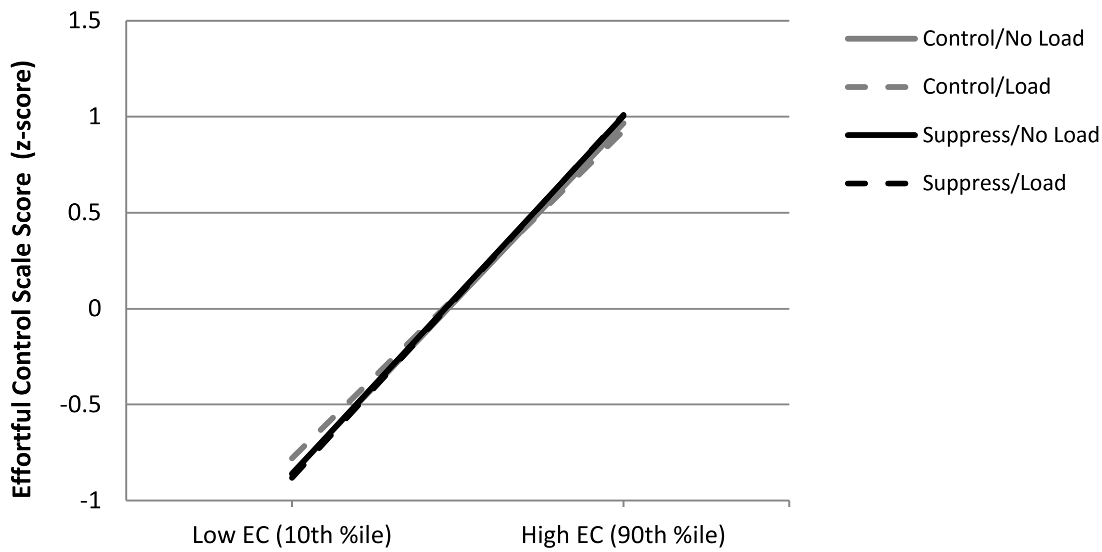
Figure 22. Nonsignificant Condition x HF-HRV interaction predicting change in self-reported ECin the full sample (A), Load condition (B), and No Load condition (C).

Continued

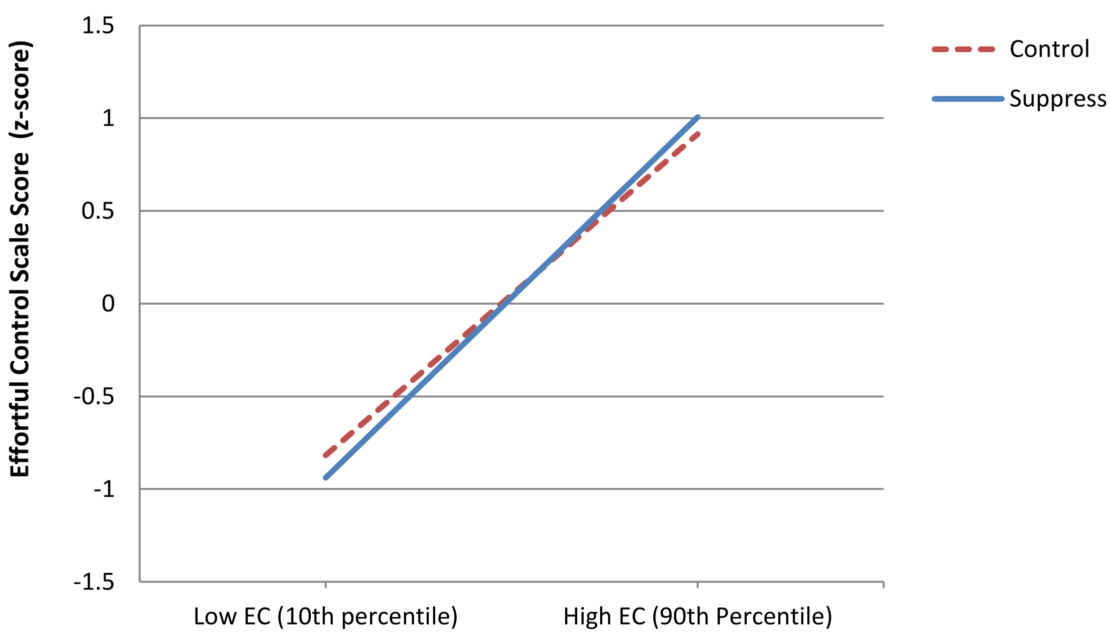
Figure 22 continued



C



A

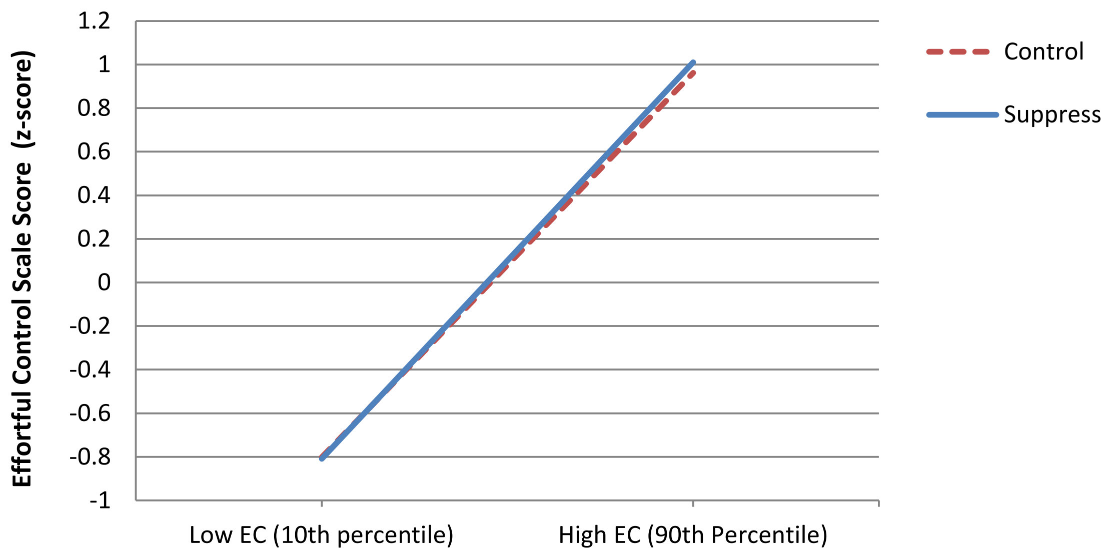


B

Figure 23. Nonsignificant Condition x EC interaction predicting change in self-reported EC in the full sample (A), Load condition (B), and No Load condition (C).

Continued

Figure 23 continued



C