EXAMINATION OF THE DYNAMIC MULTILEVEL MODEL OF EMOTION REGULATION

A Dissertation

Submitted to the Graduate School

of the University of Notre Dame

in Partial Fulfillment of the Requirements

for the Degree of

Doctor of Philosophy

by

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June 2022

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Abstract

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This dissertation sought to align theoretical accounts of emotion regulation as a process-oriented system with quantitative approaches consistent with this perspective. To achieve the aforementioned, the present study tested aspects of the Dynamic Multilevel Model of Emotion Regulation, which characterizes regulation processes as an emergent feature of the relational interaction between the individual and their surrounding environment (Martinez, Bergeman, Payne & Yoon, invited revision). Mindfulness and Religion/Spirituality (R/S) cognitive reappraisal variants were compared to test assumptions of the explicit-internal strategy categorization of the Dynamic Multilevel Model of Emotion Regulation. Data were drawn from an affect regulation task comprised of negative images from the International Affective Picture System (Lang, Bradley, & Cuthbert, 1997). Participants ($N = 83$, $M_{age} = 21.73 \pm 4.36$) were randomly assigned to the R/S ($n = 28$) or Mindfulness ($n = 26$) intervention groups, or a no-intervention control group ($n = 28$) and instructed to either decrease or maintain their affective response to the images. Heart rate (HR), the dependent variable of interest, was measured throughout the

affect task and interpreted as a physiological index of emotion regulation. Repeated-measures ANOVA were first used to assess whether changes in HR were present across the affect regulation task. Results, however, were not significant and suggested that no differences in HR emerged between regulation and non-regulation trials or when the intervention groups were compared to controls. Multilevel Models employing Satterthwaite approximations were then used to explore within- and between-person differences in HR change. Although HR did not vary across the regulation task and was not significantly different between regulation and non-regulation trials, within-person variation in HR was observed but could not be attributable to the study interventions. Despite the null effects of the interventions on HR, results of the manipulation check revealed that the interventions successfully attenuated self-reported measures of valence, arousal and state-negative affect compared to controls. No significant differences between the R/S and mindfulness interventions were observed, suggesting both cognitive reappraisal variants effectively modulate the emotional experience. In sum, results of the manipulation check suggest that the R/S and mindfulness interventions comparably attenuated the emotional experience compared to no-intervention controls, but exerted no effects on HR between groups. Limitations of the study such as the structure of the data set and sample size are considered, and future directions including longitudinal approaches are discussed.

To Molly Jean.

1993 – 2021

Feminist, nerd, survivor, animal.

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ACKNOWLEDGMENTS

This dissertation would not have been possible without the help of Research Assistants in the Emotion and Stress Physiology lab. I am grateful for all the hard work and time they dedicated to this project. I am especially grateful for Julie Rosta and Jack Harness, who were with me through the very end during a global pandemic. Mentoring the Research Assistants, learning from them, and sharing laughter was one my greatest joys in graduate school. I will forever appreciate having worked alongside such a smart and kind group of students.

Many thanks are also owed to my advisor, Cindy S. Bergeman, for her unwavering support. Cindy is one of my greatest cheerleaders, and believed in me during times where it was difficult to believe in myself. I am especially grateful for her mentorship, and constant encouragement to try things that pushed me beyond my comfort zone. It made me a better scientist, scholar, and person. I am grateful for all that she believed I was capable of accomplishing.

Lastly, many thanks are owed to the National Science Foundation Graduate Research Fellowship Program for their support of me and my research.

CHAPTER 1:

LITERATURE REVIEW

1.1 Overview

This study sought to model emotion regulation as a process-oriented system by conducting analyses in two distinct quantitative frameworks. To date, empirical investigations of emotion regulation have typically relied on examinations focused on change scores, for example, that fail to capture *how* emotion regulation unfolds. Given theoretical accounts of emotion regulation as an iterative, goal-driven process, quantitative approaches that capture within- and between-person variation offers a promising methodological alternative that is consistent with theoretical accounts of emotion regulation. To achieve the aforementioned, the present study tested aspects of the Dynamic Multilevel Model of Emotion Regulation, which characterizes regulation processes as an emergent feature of the relational interaction between the individual and their surrounding environment (Martinez, Bergeman, Payne & Yoon, *invited revision*). Development of the dynamic multilevel model was motivated, in part, to account for the inconsistent effects of cognitive reappraisal on physiological responses by including reappraisal variants. Given evidence suggesting that mindfulness and religion/spiritualty (R/S) may alter emotional and physiological responses to duress via emotion regulation, the present study examined both strategies as reappraisal variants within the Dynamic Multilevel Model of Emotion Regulation. The specific aims of the current study were thus twofold: 1) analyze emotion regulation as a process-oriented system and 2) utilize analytical technique to test assumptions of the explicit-internal strategy categorization of the Dynamic Multilevel Model of Emotion Regulation.

1.1.1 Cognitive Reappraisal and Cardiovascular Reactivity

Despite the recent development of the Extended Process Model (Gross, 2015a, 2015b), the cognitive control of emotions has been extensively examined within the Process Model of emotion regulation (Gross, 1998a, 1998b). A central tenet of the Process Model is that the effects of emotion regulation strategies on affective, cognitive, or social domains differ depending on *when* they are engaged during the emotion-generative process (Gross, 2002). *Antecedent-focused* strategies, such as situation selection, situation modification, attentional deployment, or cognitive change, decrease experiential responding, but have no effect on behavioral and physiological responding (Gross, 2001; Gross, 2002). *Response-focused* strategies, such as suppression or distraction, by contrast, do not alter the emotional experience and instead increase physiological responding due to the increased effort required to modify an ongoing emotional response (Gross, 2001, Gross, 2002). Antecedent strategies such as cognitive reappraisal are therefore associated with adaptive affective and physiological responding because they intervene the emotional response early on (Gross & John, 2003).

Cognitive reappraisal, the most widely studied emotion regulation strategy, refers to changing one's perceptions as a way to alter the emotional experience (Gross, 1998a; Gross, 1998b). Reappraisal is categorized within the cognitive change class of antecedent strategies (Gross 1998a, 1998b). Given reappraisals status as an antecedent strategy that intervenes the emotional response before fully activated, predictions derived from the Process Model purport that reappraisal modulates affective reactivity to duress, but exerts no effects on physiological responding (Gross, 2001). Findings from neuroimaging research, however, indicates that cognitive reappraisal alters peripheral physiological responses, such as heart rate, by attenuating activity in the limbic system (Goldin et al., 2008; Kanske et al., 2011; McRae et al., 2010; Ochsner, Bunge, Gross, & Gabrieli, 2002).

Studies examining the effects of reappraisal on cardiovascular reactivity illuminate how regulation attempts influence physiological correlates of emotional valence in addition to self-reported accounts. Measurements of heart rate, in particular, capture the effects of regulation attempts on the sympathetic and parasympathetic response. Although predictions derived from the Process Model predict reappraisal should exert no effects on heart rate following regulation, close examination of studies examining the effect of cognitive reappraisal on heart rate indicate reappraisal attenuates heart rate in the absence of stress, but has no effect when regulation occurs in the context of physiological stress activation (summarized in Table A1). Egloff, Schmukle, and Burns (2006, study 3), for example, examined how dispositional use of cognitive reappraisal influences the experiential and physiological response to a socially-evaluative speech task. Results of their study revealed reappraisal exerted divergent effects on the experiential and physiological response such that reappraisal reduced the expression of anxiety and negative affect but had no effect on heart rate.

State inductions of reappraisal in the context of acute stress also indicate the antecedent strategy has no effect on cardiovascular reactivity when the cortisol stress response is activated. Findings from the Denson et al. (2004) studies provide particularly robust evidence in support of the Process Model's predictions given their use of experimentally-induced reappraisal efforts in the context of two different stress induction tasks. Consistent with the findings of Egloff et al. (2006, study 3), Denson et al. (2014) found no effects of state use of reappraisal on heart rate in response to a socially-evaluative speech task (study 1) or a physical stressor (study 2). Consistent with the Process Model, empirical research suggest that both trait (Egloff et al., 2006) and state (Denson et al., 2014) reappraisal have no effect on peripheral physiological responses such as heart rate in the context of acute stress.

In the absence of acute stress, however, the effects of reappraisal on cardiovascular reactivity depend on whether trait or state-inductions of reappraisal are examined. Mauss and colleagues (2007) examined whether trait reappraisal modulates cardiovascular reactivity to an anger induction paradigm. Based on self-reported responses to the Emotion Regulation Questionnaire (John & Gross, 2003), participants were divided into high versus low reappraisers to examine whether the extent to which an individual uses the strategy differentially modulates affective and physiological responding during anger provocation. Results of their study indicated that the negative emotional response to the anger provocation was attenuated in the high reappraisal group, but no effects on heart rate were observed. Affect modulation thus emerges as a uniquely sensitive measure responsive to dispositional reappraisal whereas heart rate does not.

Studies employing reappraisal inductions, by contrast, suggest that reappraisal attenuates heart rate reactivity in the absence of acute stress. Compared to a no-instruction control group, Yuan et al. (2015) examined whether conscious or unconscious reappraisal inductions attenuate both the experiential and physiological reaction to a frustrating arithmetic task. The authors observed that participants assigned to a conscious or unconscious reappraisal induction exhibited equally attenuated heart rate compared to the control group. Further, Hofmann et al. (2009) compared the effects of a reappraisal and acceptance strategy to suppression on heart rate responses to an anxiety-inducing task. Similar to the results of Yuan et al. (2015), the authors observed that the reappraisal and acceptance inductions resulted in equally attenuated heart rate responses compared to participants in the suppression group.

Heart rate thus emerges as a physiological index sensitive to reappraisal given a variety of factors. Notably, state use of reappraisal attenuates heart rate reactivity to a variety of negative-emotion inducing tasks in the absence of acute stress (e.g., Denson et al., 2011; Hofmann et al., 2009; Yuan et al., 2015). In the presence of stress, by contrast, trait (e.g., Egloff et al., 2006, study 3) and state reappraisal (e.g., Denson et al, 2014) have no effects on heart rate. The inconsistent findings of reappraisals effect on heart rate may be attributable, in part, to methodological limitations. The Egloff et al. (2006, study 3) and Mauss et al. (2007) studies administered the Emotion Regulation Questionnaire (John & Gross, 2003) after the stress task. Given that the questionnaire is designed to assess trait dimensions of reappraisal and not active use of the strategy, assessment of reappraisal via the Emotion Regulation Questionnaire (John & Gross, 2003) may not have captured whether participants actively utilized reappraisal in the moment. The null effects of reappraisal on heart rate may therefore be attributable to the inappropriate characterization of reappraisal use in real time.

In addition to measurement error, review of the literature suggest reappraisal may not be sufficiently robust to attenuate heart rate when a stressor excites a neuroendocrine stress response from the Hypothalamic-Pituitary-Adrenal (HPA) axis. Evidence in support of this claim is drawn from studies utilizing an acute stressor to excite a cortisol response from the HPA-axis. Denson and colleagues (2014) found no effect of reappraisal on heart rate when utilizing a state induction of reappraisal to regulate the emotional experience to a socially-evaluative or physical stress task. In the absence of stress, however, studies using state inductions of reappraisal to modify the experiential response to a variety of negative-emotion inducing tasks revealed attenuations in cardiac reactivity following reappraisal (Hoffmann et al., 2009; Yuan et al., 2015;). Thus, heart rate emerges as an autonomic nervous system indicator that is sensitive to the effects of cognitive reappraisal. This suggest psychological attempts at modulating emotional valence are sufficiently robust to also modulate physiological indicators of emotional valence as well.

Notably, emotion regulation research has typically operationalized cognitive reappraisal as attempts to down-regulate affect by cultivating a detached or neutral mood state (e.g., Denson et al., 2014; Erk et al., 2010; Yuan et al., 2015). Scholars have expanded the conceptualization of cognitive reappraisal beyond a detached or neural mood state by identifying alternative reappraisal subtypes (e.g., Driscoll et al., 2009; McRae et al., 2012; Webb et al., 2012). Preliminary findings suggest reappraisal subtypes exert divergent effects on affect and physiological modulation such that reappraising the emotional stimulus or using perspective taking is more effective than reappraising the emotional response (Webb et al., 2012). Consequently, a considerable proportion of studies have examined the effects of only one type of reappraisal strategy (i.e., detached or neutral mood) on affective and physiological reactivity. Variation in cognitive reappraisal subtypes thus offers an additional determinant that modulates emotion regulations' influence on autonomic nervous system modulation.

1.1.2 Religion/Spirituality and Mindfulness as Reappraisal Variants

The present study focused on examining the effects of mindfulness and religion/spiritualty (R/S) on affect and autonomic nervous system modulation within a dynamic system framework. Mindfulness involves cultivating nonjudgmental awareness for the present moment. Mindful practices, such as the body-scan, breathe awareness, and loving-kindness meditations, were popularized in Western medicine following the development of Mindfulness Based Stress Reduction (Kabat-Zinn, 1982), an intervention program originally developed for chronic pain patients. Mindfulness-based interventions have since proliferated, demonstrating clinical effectiveness for the treatment of psychosis (Khoury, Lecomte, Gaudiano, & Paquin, 2013) and smoking cessation (Brewer et al., 2011), for example. As a result, empirically-supported treatments such as Mindfulness Based Cognitive Therapy (Teasdale, Segal, Williams, Ridgeway, Soulsby, & Lau, 2000), Acceptance and Commitment Therapy (Hayes, 2005) and Dialectical Behavior Therapy (Linehan, 1993) include a mindfulness component.

Examining mindfulness as a dynamic regulatory process was motivated, in part, by experimental and theoretical research conceptualizing mindfulness as a variant of cognitive reappraisal. Whereas some scholars characterize mindfulness as an acceptance-based emotion regulation strategy (e.g., Keng, Robins, Smoski, Dagenbach, & Leary, 2013), other groups have proposed mindfulness exerts its effects on wellbeing via cognitive reappraisal (Hözel, Lazar, Gard, Olivier, Vago & Ott, 2011). Consistent with this, Webb et al’s. (2012) taxonomy conceptualizes mindfulness as a cognitive reappraisal strategy that focuses on the non-judgmental reinterpretation of the emotional experience. Empirical research supports the conceptualization of mindfulness as a non-judgmental reappraisal intervention, having demonstrated that brief mindfulness intervention modulates both the affective and cardiovascular response to distressing images (Martinez, Payne, Bergeman, in preparation). How mindfulness unfolds as a self-regulatory process, however, is yet to be understood.

Religion reflects an organized system of beliefs, practices, and symbols that arise out of a community, whereas spirituality refers to a broader concept that individuals define for themselves. As a non-secular alternative to mindfulness, R/S represents a coping resource widely used by the American population (Pew Research Center, 2014) that can enhance well-being (Ano & Vasconcelles, 2005; Jackson & Bergeman, 2011; Tix & Frazier, 1998). The mechanisms underlying the effects of R/S on wellbeing, however, are poorly understood. Traditionally, R/S scholars proposed behavioral (Paloutzian & Park, 2014) or biological pathways (Seeman, Dubin, & Seeman, 2003) to explain the effects of R/S and well-being broadly construed. More contemporaneous thinking, however, champions self-regulation frameworks of R/S (e.g., Koole, McCullough, Kuhl & Roelofsma, 2010; McCullough & Willoughby, 2009). Scholars have proposed self-regulation via emotion regulation, in particular, facilitates the positive effects of R/S on well-being (Aldwin, Park, Jeong & Nath, 2014).

Cross-sectional (e.g., Vishkinl, Bigman, Porat, Solak, Halperin & Tamir, 2016; Whitehead & Bergeman, 2012) research lends preliminary support of R/S enhancing mental health via emotion regulation. Like mindfulness, R/S is thought to promote wellbeing by facilitating cognitive reappraisals (Vishkin et al., 2016; Vishkin, Bloom, & Tamir, 2019) that alter perceptions of control. The integration of religious coping with modern control theories informs this perspective (Joiner, Martinez, Nelson, & Bergeman, *invited revision*), suggesting that R/S reappraisals may enhance feelings of personal control by identifying with powerful others such as God (Rothbaum et al., 1982). Given evidence indicating R/S may influence wellbeing via emotion regulation, the present study utilized dynamic modeling to examine how R/S unfolds as a self-regulatory process that modulates affect and ANS reactivity by altering perceptions of control.

1.2 Dynamic Systems Theory as a Conceptual Framework

Given evidence indicative of regulation strategy subtypes, theoretical models of emotion regulation that account for strategy variation are warranted. It is also critically important that experimental work begin to compare the effects of reappraisal strategy subtypes across varying domains of the emotional and physiological response. Advancements in the development of alternative models of emotion regulation attempt to account for strategy variation by proposing taxonomies that define regulation strategies based on superordinate categories that characterize strategies along continuums of unconscious to conscious deliberation (e.g., Berkman & Lieberman, 2009; Phillips, Ladouceur & Drevets, 2008). Although these frameworks improve upon the Process Model by moving beyond its characterization of emotion regulation as a consciously driven deliberative effort, these frameworks fail to account for additional factors that influence emotion regulation, such as context (Campos, Walle, Dahl & Main, 2011), individual differences (Aldao, 2013), and the affect regulation goal (Tamir, 2009).

Dynamic systems theory provides a conceptual framework that facilities the integration of the many factors (e.g., reappraisal subtypes, individual differences) that influence emotion regulation. Within this conceptual framework, dynamic systems are comprised of nested processes that unfold over time through the interaction of multiple, interacting component parts (Thelen & Smith, 2004). From a dynamic systems view point, emotions are described as a self-regulating system continually working towards maintaining their attractor state (Thompson, 1990). The attractor state, or equilibrium alternatively, represents normative (i.e., undisrupted) functioning of the emotional experience. An advantage of utilizing dynamic systems to describe emotion is the ability to characterize different features of the emotional experience. Order parameters, for example, are inherent to and define the system of interest (Boker, 2002). Examples of order parameters for a model of emotion include emotional lability (i.e., how often mood states fluctuate). Control parameters, by contrast, are external to the system of interest but exert a modulating influence (Boker, 2002). Control parameters may be characterized, for example, by social support or cognitive reappraisal.

Consistent with the view that emotion regulation is best understood as a feature of the broader emotion landscape, principles from dynamic systems theories of emotion (e.g., Lewis, 2002) were adapted to develop the Dynamic Multilevel Model of Emotion Regulation. In brief, this model of emotion regulation employs a conceptual framework of dynamic systems to account for the modulatory effects of context, individual differences, and affect regulation goal (Tamir, 2009) on emotion regulatory efforts. To address theoretical shortcomings related to the disregard for the existence of regulation strategy subtypes, the Dynamic Multilevel Model of Emotion Regulation proposes that regulation strategies can be characterized along a two-dimensional plane that describes the regulation target and degree of conscious deliberation. Whereas traditional conceptualizations of reappraisal may conceive R/S and mindfulness as reappraisal variants, both strategies are subsumed within the dynamic model's higher-order categorization of explicit-internal regulation strategies.

1.2.1 The Dynamic Multilevel Model of Emotion Regulation

Within the Dynamic Multilevel Model of Emotion Regulation, regulation processes are hypothesized to be engaged when the stable equilibrium of the emotional experience is perturbed by some force. Moving from left to right, the image below (i.e., Figure 1.1) depicts disruption of the emotion system and its return back to a pre-stress baseline. The emotion-appraisal stream represents the stable (i.e., undisrupted) equilibrium of the emotional experience prior to the perturbation. Consistent with the first-level valuation system (i.e., World-Perception-Assessment-Action sequence) of the Extended Process model (Gross, 2015a; 2015b), the emotion-appraisal stream enters a trigger phase when a stimulus from the internal (e.g., a distressing thought) or external (e.g., acute stressor like TSST) environment disrupts its equilibrium. The trigger phase transitions to an evaluative phase to assess whether the perceived stimulus is a threat or challenge. Resultantly, the evaluative phase yields a bifurcation point such that typical patterns of emotion are perturbed when a stimulus is evaluated as a threat, and not when it is considered a challenge or opportunity. The Dynamic Multilevel Model of Emotion Regulation (depicted below, Figure 1.2) elucidates the processes engaged following threat perception to return the emotion-appraisal stream back to its pre-stress baseline.

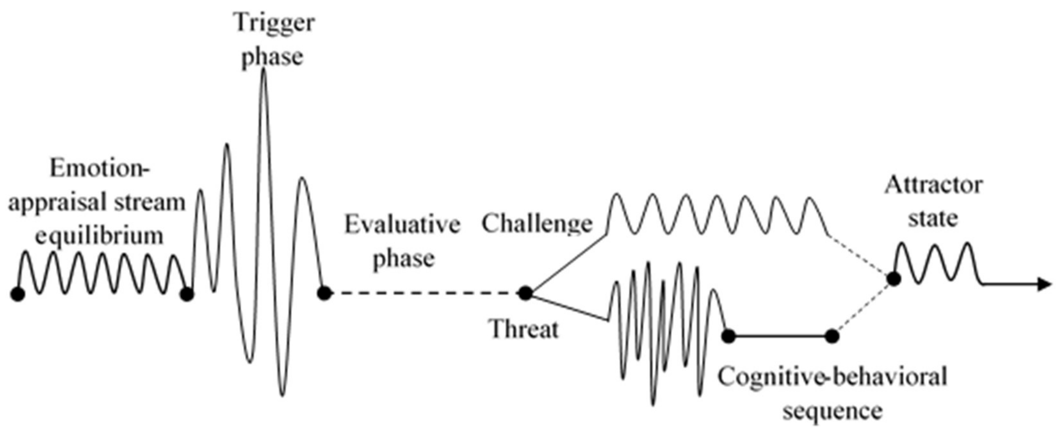

Figure 1.1 Disruption and Re-regulation of the Emotional Experience

On the left side of the model (i.e., Figure 1.2, depicted below), concentric circles depict the dynamic and interrelated associations at each level of the model. Similar to other dynamic models, each level reflects an intrinsic, self-organizing system comprised of many heterogeneous component parts that influence and are influence by other systems (Boker, 2002). At the broadest level, the physical environment (C1: external milieu) is depicted, which includes the social context in which the emotional experience unfolds. The individual (C2: internal milieu) is nested within the external milieu as a visual depiction of their separate, but interrelated association. A bi-directional arrow (A1) illustrates the mutually-influential association between the external and internal milieu by representing how the effect at one level (e.g., C1) cascades onto another (e.g., C2), and vice versa. Similar to the physical environment, the internal milieu is comprised of its own intrinsic features many of which also represent systems (e.g., emotion, cardiovascular functioning, endocrine). Component parts (e.g., personality) at the level of the individual operate as control parameters (i.e., extrinsic features) that modulate the system of interest (i.e., emotion regulation), and vice versa. An example offered by Lewis (2005) describes how the emotion system determines the mood system, which shapes the personality system. Personality features such as neuroticism, in turn, influence the emotion system and so on.

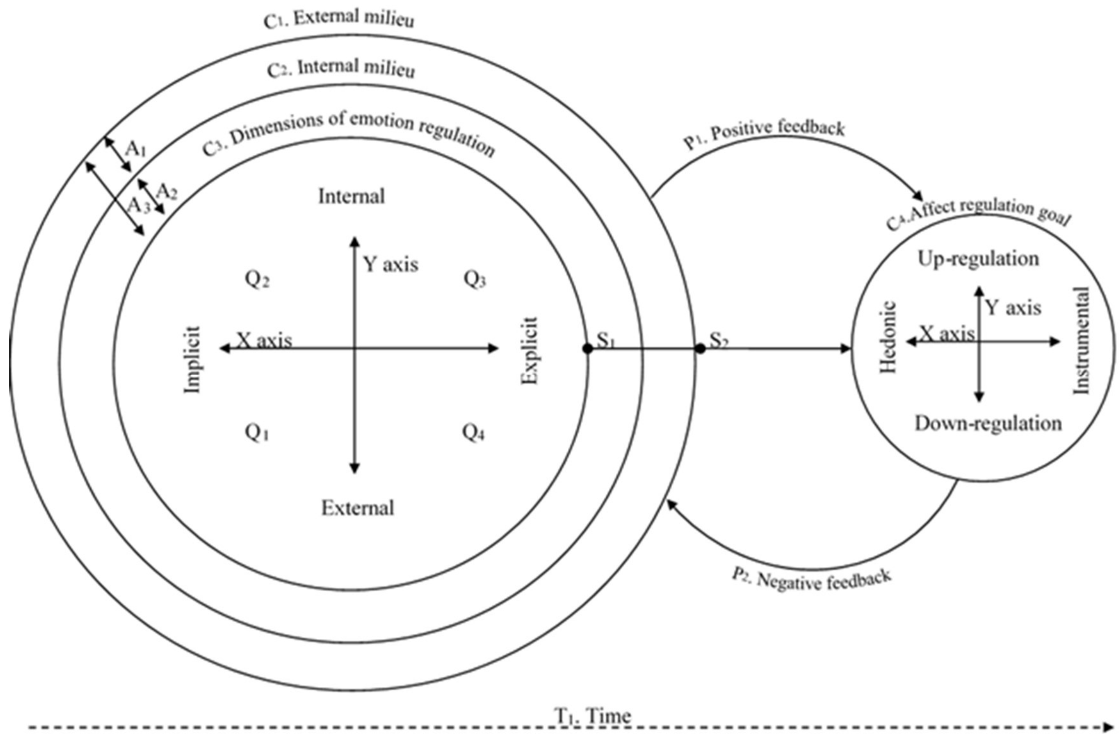

Figure 1.2 Dynamic Multilevel Model of Emotion Regulation

Within the Dynamic Multilevel Model of Emotion Regulation, the emotion regulation system is comprised of experiential and physiological components (C3: dimensions of emotion regulation), and is considered just one of many possible systems (e.g., personality, mood) that define the internal milieu. When threat disrupts normative functioning of the emotional experience, the regulation system operates as the stabilizing force that promotes the coherence and integrity of the emotion system. That is, the regulation system is engaged to return the emotion-appraisal stream back to its stable equilibrium (depicted in Figure 1.1). The emotion regulation system stabilizes the emotional experience by engaging a series of heterogeneous processes that move the system toward its attractor state (i.e., pre-stress baseline). The processes that facilitate regulatory efforts are represented in Figure 1.2 by a two-dimensional space comprised of intersecting continuums. The x-axis represents regulatory efforts that range from implicit (i.e., automatic, unconscious, or spontaneous) to explicit (i.e., deliberative, consciously driven, or effortful). Internal versus external efforts are represented along the y-axis, and capture the regulation target (i.e., the self versus surrounding world, respectively) of the regulation attempt.

Traditional conceptualizations of reappraisal that alter personal relevance (e.g., detached or objective mood) reflect regulation attempts aimed at altering aspects of the internal world or experience. External regulation attempts, by contrast, reframe perceptions of an environmental stimulus (e.g., TSST) as less threatening. Further, the continuums intersect to yield four quadrants that function as descriptive characterizations of how regulatory processes may interact. Beginning at the lower left quadrant (i.e. Q1) and moving in a clockwise direction, the four resulting superordinate, descriptive categories are: implicit-internal, implicit-external, explicit-internal, and explicit-external. Flexibly moving through the four quadrants depending on context and demand promotes adaptive responding to the disruption of the emotional experience. The flexible use of varying regulatory processes is modulated by the internal (A2) and external (A3) environment, which is represented by double-headed arrows. Resultantly, the range in types of processes engaged is restricted by individual and environmental factors.

The right side of the model reflects how emotion regulation system unfolds as a goal-directed process. Emotion regulation processes (i.e., C3) manifest as a cognitive-behavioral sequence (S2) working towards the alignment of current affective states with ideal states. That is, cognitive (e.g., reappraisal) or behavioral (e.g., situation modification) actions serve as the mechanisms by which the system attains the attractor state. Similar to emotion regulation processes, affect regulation goals are represented as a multidimensional phenomenon characterized by a two-dimensional plane. Hedonic or instrumental affective goals are characterized as a continuum along the x-axis of the two-dimensional plane, whereas affective goals to up- or down-regulate the intensity of the emotional response are characterized along the y-axis. The resulting four quadrants thus represent the possible combinations of affect regulation goals to: down-regulate hedonic needs (i.e., attenuate positive affect), up-regulate hedonic needs (i.e., intensify positive affect), up-regulate instrumental needs (i.e., intensify useful emotions), or down-regulate instrumental needs (i.e., attenuate emotions that hinder goal achievements).

Positive (P1) and negative (P2) feedback paths between the multilevel process (C1 – C3) and the affect regulation goal (C4) interact to stabilize the emotional experience. Positive feedback paths signal the maintenance or amplification of regulatory efforts whereas negative feedback paths indicate the attenuation or termination of emotion regulation. Stabilization of the emotion system occurs when the attractor state is reached, such that affective states return to their equilibrium. Positive and negative feedback paths influence regulatory efforts across time (T1), which is decomposed into micro- and macro-level time scales. Micro-level regulation is comprised of successive moments that cohere to form developmental trajectories of emotion regulation at the macro-level. Adaptive responding to an acute disruption (micro-level regulation) thus shapes adaptive functioning of the system at the macro-level over time (Bergeman, Blaxton, & Joiner, in press).

In short, the Dynamic Multilevel Process model represents an effort to characterize the processes involved in regulating emotion dynamics following threat perception. Using dynamical systems as the architectural foundation for the framework, emotion regulation is thus characterized as a dynamic and iterative goal driven-process that involves the up or down regulation of emotions to meet instrumental or hedonic needs through conscious or unconscious processes. Notably, the Dynamic Multilevel Model of Emotion Regulation forgoes the temporal distinction that traditionally define emotion regulation strategies (i.e., antecedent vs. response-based). Consequently, the framework yields a higher-order descriptive taxonomy that categorizes the behavioral or cognitive mechanisms that drive affective change. It is unknown, however, whether this descriptive category better accounts for the divergent effects of regulation strategies compared to other more well-known models. More generally, it also remain unknown whether the Dynamic Multilevel Model of Emotion Regulation offers a valid framework from which testable hypotheses regarding the many factors that influence regulation attempts may be derived. The translation of the Dynamic Multilevel Model of Emotion Regulation into a quantitative dynamic framework offers a promising avenue to begin assessing the validity of the emotion regulation model described herein.

1.3 Study Aims

This study thus sought to advance the application of dynamic systems analyses to the study of emotion regulation by marrying the computational methods of dynamic systems with theoretically aligned models of emotion regulation. To achieve this, assumptions of the Dynamic Multilevel Model of Emotion Regulation were examined using a series of quantitative frameworks. Analyses comparing the control versus intervention groups attempt to illustrate how stressors (such as distressing images) displace the emotion system away from the emotion systems point of equilibrium (i.e., Figure 1), which engages the emotion system to return to its stable resting point (i.e., Figure 2). Analyses comparing the intervention groups during non-regulation and regulation trials examined whether variations in the use of cognitive reappraisal strategies are control parameters that influence functioning of the emotion regulation system. That is, do variations in cognitive reappraisal subtypes influence the frequency or dampening of the emotion systems' disruption and re-regulation? Given that the Dynamic Multilevel Model characterizes regulation strategies along a two-dimensional plane, analyses test assumptions of the explicit-internal categorization. Although mindfulness reframes an emotional experience non-judgmentally, whereas R/S reframes perceptions of control, both strategies were expected to yield similar effects on cardiac reactivity given their characterization as an explicit-internal strategies.

More specifically, the abovementioned was accomplished by first examining whether changes in heart rate (HR) were present across the affect regulation task within a Repeated-measures ANOVA (RM-ANOVA) framework. Two separate RM-ANOVA were conducted to compare: 1) the controls to interventions groups during regulation trials, and 2) the R/S and mindfulness groups during non-regulation and regulation trials. For the RM-ANOVA comparing the control to the intervention groups during regulation trials, a significant *Time*-by-*Group* interaction was expected such that HR would decrease across the task in the intervention groups compared to controls. For the RM-ANOVA comparing the R/S and mindfulness groups during regulation and non-regulation trials, a significant 2-way *Time*-by-*Instruction* interaction was expected such that HR would decrease in the regulation trials compared to non-regulation. Notably, a NS *Group* effect was expected given that the R/S and mindfulness interventions are conceptualized as explicit-internal regulation strategies within the Dynamic Model of Emotion Regulation.

Analyses were then replicated in a Multilevel Model (MLM) framework given that analyses in the RM-ANOVA framework does not capture individual differences in equilibrium levels. Consequently, two-level MLM's were used to examine within- and between-person differences in HR. To parallel the analyses conducted in the RM-ANOVA framework, two separate MLM's were conducted to compare: 1) the controls to interventions groups during regulation trials, and 2) the R/S and mindfulness groups during non-regulation and regulation trials. For the two-level MLM comparing the controls to interventions groups during regulation trials, significant fixed-effects of *Time* and *Group* were expected such that HR would be lower when comparing the R/S and control as well the mindfulness and control group. Notably, significant Level-1 effects of *Time* and *Group* were expected to be significantly associated with within- and between-person variation in HR (i.e., significant tests of the slopes and intercepts for *Time* and *Group*, respectively). For the two-level MLM comparing the intervention groups during regulation and non-regulation trials, significant fixed-effects of *Time* and *Instruction* were expected such that HR would be lower during regulation trials compared to non-regulation. Further, Level-1 effects of *Time* and *Instruction* were expected to be significantly associated with within- and between-person variation in HR (i.e., significant tests of slopes and intercepts for *Time* and *Instruction*, respectively).

CHAPTER 2:

METHODS

2.1 Design Overview

Data were drawn from a larger study assessing the effects of cognitive reappraisal on affect, physiology and recognition memory. Participants were recruited from the University of Notre Dame community via flyers for financial remuneration at a rate of 10 USD per hour. Given the collection of continuous measurements of cardiac reactivity, the present study is selectively focusing on the heart rate data.

Given that physiological measures were collected, all participants were asked to complete a comprehensive phone screen to exclude participants with any cardiovascular (e.g., congestive heart failure) or endocrine (e.g., Cushing's disease) disorders. During the phone screen, participants were also required to provide verbal consent to the study procedures. That is, participants had the opportunity to decline any further participation when informed that the study may require them to read a biblical excerpt or poem. Furthermore, due to the use of highly arousing negative stimuli, participants were also excluded if they endorsed any depressive symptoms (e.g., loss of interest or pleasure in things previously enjoyed). Inclusion criteria was therefore: men and women 18 – 35 years of age with normal to corrected vision, fluent in English, with no history of cardiovascular, endocrine, or mood disorders. Study procedures were reviewed and approved by the university Institutional Review Board (protocol #17-02-3642).

2.2 Participants

Participants (N = 83) ranged in age from 18 to 34 (Mage = 21.73 ± 4.36), with approximately 65% of the sample comprised of women. Given that the study sample was recruited from a predominantly Catholic university, approximately 56% of the overall study population self-identified as Catholic, which was well distributed across the R/S (n = 28, 50%), mindfulness (n = 26, 58%), and control (n = 28, 62%) groups.

2.3 Stimuli and Apparatus

The emotional response was perturbed by displaying distressing stimuli. The stimuli were selected from The International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1997), a standardized set of static color images based on a dimensional model of emotion. The image set contained scenes depicting mutilations, snakes, pollution, babies, and landscapes among others that can be rated along dimensions of valence and arousal. Images (N = 60) for the regulation task included 40 negative ($M_{valence} = 2.8 \pm .13$), highly arousing ($M_{arousal} = 5.5 \pm .8$) images, and 20 neutral ($M_{valence} = 5.1 \pm .1$) non-arousing ($M_{arousal} = 3.0 \pm .5$) images. Twice as many negative images compared to neutral were selected to facilitate comparisons across various dimensions of the emotional response (i.e., valence, arousal, state negative affect) between regulation versus non-regulation trials.

Stimuli were presented using a blocked design to combat participant fatigue and increase the likelihood of task compliance as it relates to emotion instruction (i.e., Decrease or Maintain). A total of 16 blocks were generated (8 negative blocks, 4 neutral blocks), each comprised of 5 pictures. Negative picture blocks were designed to be equivalent in average valence and arousal ratings. Neutral picture blocks were also equivalent in valence and arousal ratings. Both block presentation across the regulation task, and picture presentation within each block was randomized. Further, each block was preceded by an instruction cue to Decrease or Maintain, followed by a fixation cross with an onscreen presentation of 2000ms. Block presentation included 5 pictures from the same valence category presented onscreen for 5000ms. Following the presentation of each image, participants immediately indicated valence, arousal and state NA ratings. At the end of each picture block, participants reported their state negative affect on a 1 (not negative) to 7 (very negative) rating scale. Finally, 8000ms Rest slides were included between each block to decrease the likelihood of participant fatigue and reduce contamination effects from block to block. During the Rest slides, participants were instructed to “use that time to relax.” The emotion regulation task design is illustrated in Figure 2.1.

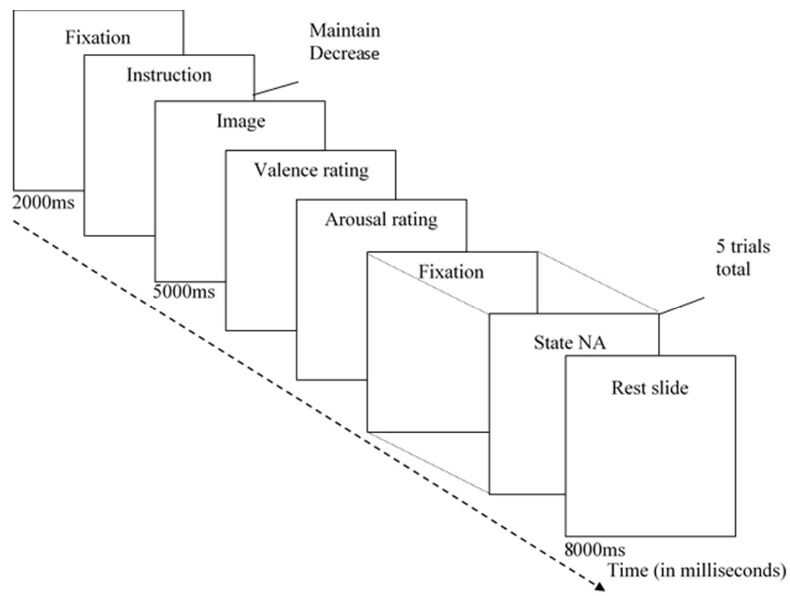

Figure 2.1 Schematic Representation of the Emotion Regulation Task

2.4 Heart rate

Heart rate responses recorded related to the onscreen presentation of IAPS images were used as physiological correlates of the emotional response. Wireless EKG/ECHO electrodes (EL503, Biopac Systems Inc., Goleta CA.) were placed on the ribcage and collarbone for ECG collection of heart rate according to instructions in Tassinary and Cacioppo (2000). A Biopac MP150 data acquisition unit (Biopac Systems Inc., Goleta CA) equipped with a wireless ECG BioNomadix module continuously recorded electrocardiogram data during the regulation task. These data were transformed into averages that were processed using the automated mean analysis feature provided by AcqKnowledge (Biopac Systems Inc., Goleta CA).

2.5 Procedures

Study sessions began between 1300 -1530 hours, and lasted 2.5 hours. Participants gave verbal and written consent upon arrival, and skin was prepared for electrode application. A five-minute baseline of physiology was recorded at 20-minutes, and repeated at 30, 50, 90, and 115 minutes to assess global changes in autonomic reactivity. With the exception of the first affect measurement at 05 minutes into the study, questionnaire administration occurred alongside psychophysiology measurements to also capture global changes in affect.

Participants were randomly assigned to one of the three conditions (i.e., control, R/S, or mindfulness) immediately upon providing baseline psychophysiology measures and questionnaires. During the affect regulation task, the R/S and mindfulness groups were cued to regulate their emotional response (i.e., decrease) to half of the negative images. Details of the regulation excerpts for each condition are provided in Appendix C. During regulation trials, the R/S group was instructed to "*think about the picture in a way that decreases your emotional response"* using the Philippians 4:6-8 excerpt from the Christian Bible (English Standard Version). Matched for theme and length, participants in the mindfulness group were instructed to regulate their emotional response using the poem *The Guest House* by Rumi (Segal and Teasdale, 2018). To combat demand effects, participants were told "*if the reappraisal did not make the image less negative – that's okay. There is no right or wrong answer*." For the remaining negative images as well as neutral images presented during the affect regulation task, the R/S and mindfulness groups were cued to "*respond naturally*" (i.e., maintain). The control group, by contrast, was cued to "respond naturally" to all negative and neutral images presented in the affect regulation task.

Before the regulation task, participants read their assigned passages and became familiar with applying them during practice blocks. During practice blocks, participants viewed two blocks of five negative images not presented elsewhere in the study matched to the regulation task on valence and arousal. In the first block, participants were exposed to non-regulation neutral trials. Participants then viewed a negative picture block preceded by the instruction to regulate their emotional response. For every image, participants reported their reappraisal aloud. Participants in the R/S group (e.g., *Even if this image makes me anxious, it is okay because I carry the peace of God with me*) and mindfulness (e.g., *I recognize I am horrified by this image*, *but I accept that's a feeling I have and I am okay with letting it go*) were provided with example reappraisals. The R/S and mindfulness groups were also provided with corrective feedback. Immediately after the practice blocks, participants completed the 30-minute regulation task.

Following a 20-minute delay, participants completed a yes-no recognition memory task not included in the present study. Psychophysiology and affect data were also collected throughout the remainder of the study to assess global changes in cardiac reactivity or affect. Psychophysiology electrodes were removed after resting-state measures and participants were debriefed and monetarily compensated for their participation.

2.6 Analytic Strategy

Empirical examination of the Dynamic Multilevel Model of Emotion Regulation was achieved by modeling the data in two distinct frameworks: Repeated-measures ANOVA (RM-ANOVA) and Multilevel Modeling (MLM). Analyses were performed in the two frameworks to examine their respective utility in characterizing emotion regulation as a dynamic and iterative process, thus aligning theoretical models of emotion regulation with analytical techniques. Given this, RM-ANOVA's were first used to assess whether changes in HR were present across the affect regulation task. Two-level MLM's employing Satterthwaite approximations were then used to examine within- and between-person differences in HR change. Notably, analyses in each analytic framework were done to: 1) compare the control to the intervention groups during regulation trials, and 2) directly compare the intervention groups during regulation and non-regulation trials1. Details of each analytic approach are provided below.

2.6.1 Step 1: Repeated Measures ANOVA's

Using SAS PROC GLM, a Repeated Measures ANOVA with between-subjects factor Group (3 levels: Mindfulness vs. R/S vs. Control) with within-subjects factor Time (140 observations) examined whether the intervention groups differed in HR patterning over the course of regulation trials compared to controls. Additionally, a Repeated Measures Mixed ANOVA with between-subjects factor Group (2 levels: Mindfulness vs. R/S) and within-subjects factors Instruction (2-levels: decrease vs. maintain) and Time (280 observations) directly compared whether changes in HR differed between the intervention groups during regulation and non-regulation trials. An alpha level of .05 was for used for all statistical tests, pairwise comparisons were adjusted using a Bonferroni correction, and results were reported using the mean difference (MD) and confidence intervals (CI) where appropriate.

2.6.2 Step 2: Two-level Multilevel Modeling

To parallel to the repeated measures ANOVA comparing the intervention groups (i.e., R/S versus mindfulness) to control, a two-level multilevel model nesting time points

(j; Level 1) within individuals (i; Level 2) was specified using the SAS GLM procedure. The Level 1 model, which examined the within-person change of heart rate, was specified as follows:

$$HR_{ij} = \pi_{0i} + \pi_{1i}(Time)_{ij} + \mathrm{e}_{ij}$$

in which HR_{ij} represents heartrate in individual i's time point j predicted by an intercept, π_{0i}, and the slope associated with the main effect of time, π_{1i}. The term e_{it} represents the Level-1 residual, which is the deviation from the predicted HR for individual i in time point j. Notably, the Level-1 model can be conceptualized as the within-subjects model given that the Level-1 model characterizes the study manipulation (i.e., condition assignment to an intervention group versus controls) at the level of individual.

In the two-level model, Level-1 coefficients become the outcome variables in the Level-2 model. Given this, the Level-2 model was formulated by predicting the Level-1 random effects including the intercept, π_{0i}, and the slope for time, π_{1i}. The 3-level condition variable was included as a Level-2 predictor represented by $Dummy1_i$ and $Dummy2_i$ in which the control group served as the reference group. The Level-2 model, which examined whether the intervention groups differed from controls, was specified as follows:

$$\pi_{0i} = \beta_{00} + \beta_{01}Dummy1_i + \beta_{02}Dummy2_i + r_{0i}$$

$$\pi_{1i} = \beta_{10} + \beta_{11}Dummy1_i + \beta_{12}Dummy2_i + r_{1i}$$

In which π_{0i} characterizes an individuals heart rate at the start of the affect regulation task, and π_{1i} is the slope describing an individuals rate of change in heart rate across the regulation task. Given that the Level-2 condition predictor was 3-level, β_{00} is the mean intercept representing average heart rate at the start of the regulation trials for negative stimuli in the entire study sample. β_{10} is the mean slope representing the average rate of change in heart rate across regulation trials for negative stimuli in the entire sample. Further, β_{01} represents the average difference between R/S intervention and control group, whereas β_{02} represents the average difference between the mindfulness intervention and the control group. Lastly, r_{0i} and r_{1i} are the residuals for the Level-2 model, which characterize the extent to which an individual deviates from the fixed effects (i.e., condition average). In contrast to the Level-1 models characterization of within-subjects effect, the Level-2 model reflects between-subject differences given that it examines the effects of condition assignment on heart rate.

Direct comparisons of the intervention groups (i.e., R/S versus mindfulness) also involved fitting a two-level multilevel model in SAS Proc GLM, nesting time points (*j*; Level 1) within individuals (*i*; Level 2). The Level-1 model, which examined the within-person variation of heat rate, was specified as follows:

$$HR_{ij} = \pi_{0i} + \pi_{1i}(Time)_{ij} + \pi_{2i}(Instruction)_{ij} + \pi_{3i}(InstructionXtime)_{ij} + \mathrm{e}_{ij}$$

in which HR_{ij} represents heartrate in individual i's time point *j* predicted by an intercept, π_{0i}, and the slope associated with the main effect of time, π_{1i}. Additionally, $Instruction_{ij}$ (i.e., interpreted as emotion regulation) is a dummy variable coded as 0 and 1, and was included as a time varying predictor (i.e., decrease versus maintain). An $InstructionXtime$, π_{3i}, interaction effect was also included to examine whether individuals changed in their ability to regulate to the distressing stimuli over time (that is, did attempts to regulate affect change over time such that individuals improved or worsened). Lastly, the term e_{ij} represents the Level-1 residual, which is the deviation from the predicted HR for individual *i* in time point *j.* Similar to the two-level model comparing intervention groups to controls, the Level-1 model directly comparing the intervention groups can be conceptualized as the within-subjects model given. The models differ, however, in that the Level-1 model comparing R/S to mindfulness characterizes the study manipulation to regulate affect or passively view the stimuli at the level of individual.

The Level-2 model was formulated by predicting the Level-1 random effects including intercept, π_{0i}, the slope for time, π_{1i}, the slope for instruction, π_{2i}, and the slope for the *Instruction*X*time* interaction, π_{3i}. The Level-1 predictor, *Instruction*, was dummy coded as 0 and 1 to represent task instructions to maintain (i.e., no regulation) or decrease (i.e., regulate) affect, respectively. $Condition_i$, the unique Level-2 predictor, was also coded as a 0 and 1 dummy variable to represent the R/S or mindfulness groups, respectively. The Level-2 model, which examined the effects of condition assignment (i.e., R/S versus mindfulness) on Level-1 random effects, was specified as follows:

$$\pi_{0i} = \beta_{00} + \beta_{01}Condition_i + r_{0i}$$

$$\pi_{1i} = \beta_{10} + \beta_{11}Condition_i + r_{1i}$$

$$\pi_{2i} = \beta_{20} + \beta_{21}Condition_i + r_{2i}$$

$$\pi_{3i} = \beta_{30} + \beta_{31}Condition_i + r_{3i}$$

In which π_{0i} characterizes individual i's heart rate at the start of the affect regulation task if instruction at the first time point for individual i is 0, and π_{1i} is the slope describing individual i's rate of change in heart rate when instruction ij is 0. π_{2i} is the parameter representing the main effects of instruction (i.e., decrease versus maintain) on heart rate for individual *i,* whereas π_{3i} characterizes the *Instruction*x*Time* interaction effect for individual *i*. β_{00}, by contrast, is the mean intercept representing average heart rate at the start of the study task if instruction at the first time point is 0 (i.e., maintain) for those who are in the 0 (i.e., R/S) condition. β_{10} is the mean slope representing the average rate of change in heart rate when instruction_ij is 0 for the entire sample. The β_{20} and β_{30} regression coefficients describe the average difference in the intercepts and the rates of change when instruction_ij is 1 (i.e., decrease) compared to when instruction_ij is 0 (i.e., maintain) for those who are in the 0 condition, respectively. Further, β_{01} represents the main effect of condition (i.e., R/S versus mindfulness) on heart rate at the start of the regulation task if instruction at the first time point for individual i is 0. β_{21} denotes the cross-level *Condition*X*instruction* interaction, whereas β_{31} represents the cross-level *Condition*X*instruction*X*time* interaction effect. Lastly, r_{0i}, r_{1i}, r_{2i} and r_{3i} are the residuals for the Level-2 model, which characterize the extent to which an individual deviates from the fixed effects (i.e., condition averages). In contrast to the Level-1 models characterization of within-subjects effect, the Level-2 model reflects between-subject differences given that it examines the effects of the study manipulation (i.e., decreases versus maintain) on heart rate associated with the Condition (i.e., R/S versus mindfulness).

CHAPTER 3:

RESULTS

3.1 Arousal Manipulation check

Prior to examining differences in HR, the efficacy of the reappraisal interventions was investigated by testing whether the intervention groups (i.e., R/S or mindfulness) self-reported lower levels of valence, arousal, and state NA during the affect regulation task compared to controls. As expected, results of the one-way MANOVA with between-subjects factor Group (3 levels: Control, R/S, mindfulness) on negative images revealed a significant main effect of Group ($F(6, 154) = 5.31$, $p = .001$, $\eta^2_{partial} = .171$) for arousal ($F(2, 79) = 13.15$, $p = .001$, $\eta^2_{partial} = .25$) and valence ($F(2, 79) = 14.13$, $p = .001$, $\eta^2_{partial} = .26$). The main effect of Group for NA was also significant ($F(2, 79) = 3.02$, $p = .05$, $\eta^2_{partial} = .07$). Findings suggest that compared to the control condition, the interventions successfully mitigated the experience of unpleasantness, agitation, and overall negative mood elicited by the negative stimuli (Table 3.1).

TABLE 3.1

DESCRIPTIVE STATISTICS FOR AFFECT INDICES (N = 82)

		Control	**R/S**	**Mindfulness**
Valence	View	5.307 (.514)	5.43 (.49)	5.15 (.44)
	Decrease	.	4.63 (.58)	4.76 (.51)
Arousal	View	4.958 (.513)	5.07 (.53)	4.93 (.46)
	Decrease	.	4.23 (.61)	4.40 (.44)
Negative affect	View	4.669 (.902)	4.81 (.79)	4.81 (.67)
	Decrease	.	4.14 (.89)	4.38 (.52)

Note: Values represent means and standard deviations within parentheses

Additionally, a two-way MANOVA with between subjects factor Group (2 levels: R/S or Mindfulness) and within-subjects factor Instruction (2 levels: decrease versus maintain) examined whether the intervention groups reported significantly lower levels of valence, arousal, and state NA during the regulation trials of the affect task compared to passive viewing trials. As expected, results of the MANOVA revealed a significant main effect of Instruction ($F(3, 50) = 34.39$, $p = .001$, $\eta^2_{partial} = .67$) for valence ($F(1, 52) = 72.75$, $p = .001$, $\eta^2_{partial} = .583$), arousal ($F(1, 52) = 93.85$, $p = .001$, $\eta^2_{partial} = .64$), and NA ($F(1, 52) = 30.00$, $p = .001$, $\eta^2_{partial} = .37$). Pairwise comparisons indicated that the experience of unpleasantness and agitation was significantly lower in the regulation trials compared to passive viewing. Further, negative mood was also significantly lower in the regulation trials following the use of either intervention compared to passive viewing. All other Group ($F(3, 50) = .93$, $p = .44$, $\eta^2_{partial} = .05$) or Group-by-Instruction interaction effects ($F(3, 50) = 2.76$, $p = .052$, $\eta^2_{partial} = .14$) were not significant, indicating that the R/S and mindfulness interventions comparably attenuated valence, arousal, and NA during the regulation trials of the affect task (see Table 2.1).

3.2 Characterizing Changes in Heart Rate via Repeated Measures ANOVA Modeling

Given that the manipulation check indicated the interventions successfully attenuated the experience of negative emotions, follow up analyses examined whether changes in heart rate similarly emerged. To achieve this, a Repeated Measures ANOVA with between-subjects factor Group (3 levels: Mindfulness vs. R/S vs. Control) and within-subjects factor Time (280 observations) examined whether the intervention groups differed in HR patterning over the course of the affect regulation task compared to controls. Results revealed that the main effects of Time ($F(1, 53.8) = 0.41$, $p = 0.52$) and Group ($F(2, 59.1) = 0.78$, $p = 0.46$) were not significant. The Group-by-Instruction interaction was not significant ($F(2, 53.3) = 2.02$, $p = 0.14$) as well. Findings indicate that although the interventions significantly mitigated negative emotional reactivity compared to controls, no effects on heart rate were exerted.

Although no significant differences in heart rate were observed when comparing the intervention groups to control, a Repeated Measures ANOVA with between-subjects factor Group (2 levels: Mindfulness vs. R/S) and within-subjects factors Instruction (2-levels: decrease vs. maintain) and Time (280 observations) examined whether differences in HR emerged when the intervention groups were directly compared between regulation and non-regulation trials. Consistent with the null effects observed when comparing the interventions to control, results revealed that the main effects of Group (F(1, 35.1) = 0.00, p = .97) and Instruction (F(1, 8532) = 2.72, p = 0.10) were not significant. Further, the Group-by-Instruction (F(1, 8532) = 0.06, p = 0.80), Time-by-Instruction (F(1, 8963) = 0.55, p = 0.46), and Group-by-Instruction-by-Time interaction (F(1, 8963) = 0.59, p = 0.44) effects were also not significant. Table 3.2 includes descriptive statistic characterizing heart rate during the affect task, and the results of both Repeated Measures ANOVA's are summarized in Table 3.3.

TABLE 3.2

DESCRIPTIVE STATISTICS FOR HEARTRATE (N = 62)

			Control	**R/S**	**Mindfulness**
Heartrate	Negative	View	74.33 (11.23)	69.31 (12.29)	69.14 (10.74)
		Decrease	.	69.77 (13.15)	69.51 (10.98)
	Neutral	View	75.44 (11.25)	70.15 (13.00)	70.23 (11.64)

Note: Values represent means and standard deviations within parentheses

TABLE 3.3

ANOVA RESULTS FOR HEARTRATE

	Heart rate		
Control versus Intervention during regulation (N = 62)	df	F	p
Group	2, 59.1	0.78	0.46
Time	1, 53.8	0.41	0.52
Time X Group	2, 53.3	2.02	0.14
Mindfulness versus Religion/Spirituality (N = 37)			
Group	1, 35.1	0.00	0.97
Instruction	1, 8532	2.72	0.10
Time	1, 34.9	1.77	0.19
Time x Instruction	1, 8963	0.55	0.46
Time X Group	1, 34.9	0.47	0.50
Group X Instruction	1, 8532	0.06	0.80
Time x Group x Instruction	1, 8963	0.59	0.44

Note: Entries degrees of freedom (df), F-test (F), and significance values (p). Values based on SAS PROC Mixed; Satterthwaite degrees of freedom, *Statistically significant, $p < .05$

3.3 Characterizing Changes in Heart Rate via Multilevel Modeling

Despite the null findings using the ANOVA framework, analyses in MLM were completed to assess whether the framework offers a more nuanced understanding of the interventions effects on HR. Thus, to examine the Repeated Measures ANOVA with between-subjects factor Group and within-subjects factor c*Time* in a MLM framework, an unconditional means model was first conducted to examine changes in heart rate across conditions. Following this, the effects of the Level-1 c*Time* predictor and the Level-2 Group predictor (dummy coded as 1 and 0) were sequentially examined. As a result of examining each predictor in a step-wise progression, a total of four MLM's were conducted.

The Repeated Measures Mixed ANOVA with between-subjects factor *Group* (2 levels: Mindfulness vs. R/S) and within-subjects factors *Instruction* (2-levels: decrease vs. maintain) and *Time* (240 observations) was similarly replicated in a MLM framework, beginning with an unconditional means model examining changes in heart rate across condition and instruction. Five models were then sequentially fit by examining the *cTime* and *Instruction* Level-1 predictors and the *Condition* Level-2 predictor in a stepwise manner.

3.3.1 Intervention versus Controls in MLM

The unconditional means model was used to estimate average heart rate in the population, deviations from that predicted HR (i.e., intercept for r_{0i}), as well as deviations from the predicted HR within individuals (i.e., within-person residual, e_{ij}). Results from significance testing of the covariance parameter estimates, which estimates the random effects portion of the model, revealed that individuals differed in their average heart rate (β_{00} = 95.71 (17.24) , p < . 0001), and that heart rate varied within individuals (e_{ij} = 48.57 (0.64), p < . 0001).

Given that the unconditional means model results in a baseline model for which more complex models can be compared, the second model included $Dummy1_i$ (i.e., differences between R/S and control) and $Dummy2_i$ (i.e., differences between mindfulness and control) Level-2 predictors to represent the 3-level group variable. Given that the Level-2 predictor is dummy coded, interpretation of the fixed effects indicate that heart rate in the entire sample was π_{0i} = 71.40 (1.24). Further, HR in the R/S group did not significantly differ from controls as indicated by the non-significant tests of the fixed effect (β_{01} = -4.54 (2.88), p = 0.12). Similarly, HR in the mindfulness group did not significantly differ from controls as indicated by the non-significant tests of the fixed effect (β_{01} = -4.57 (3.04), p = 0.14). Tests of the fixed effects thus indicate that HR in the R/S group differed from controls by -4.54 BPM whereas HR in the mindfulness group differed from controls by -4.57 BPM, which were not significantly different. Further, interpretation of the covariance parameter indicated that individuals significantly differed in their average heart (β_{00} = 95.71 (17.24), p < .0001), and that the variation differed within individuals (e_{ij} =48.57 (0.64), p < .0001), but that the observed variation is not due to the effects of the R/S or mindfulness interventions. Further, comparisons of model fit statistics indicate that inclusion of the Level-2 *Condition* predictor (Model 2 AIC =79, 389.2) did not improve the model (Model 1 AIC =79, 388.3).

Model-3 only included the Level-1 time-varying covariate, *cTime* (π_{1i}) to examine whether changes in heart rate vary across the affect regulation task, and if the relationship between time and heart rate also varies within-individuals. Results of the tests of the fixed effects indicate that heart rate at the start of the affect regulation task was π_{0i} = 70.88 (1.27), but tests of the fixed effects for *cTime* were not significant (π_{1i} = 0.004 (0.004), p = 0.36), indicating there is no relationship between *cTime* and heart rate across regulation trials. Results of the significance testing for the covariance parameter estimates indicated that individuals varied in average heart rate even after controlling for the effects of the *cTime* (β_{00} =98.75 (17.93), p < .0001), and that the slopes were also significantly variable (β_{10} =0.001 (0.000), p < .0001). There was not, however, any significant covariance between the intercepts and slopes (-0.08 (0.04), p = .06). The inclusion of *cTime*, however, did improve model fit (Model 3 AIC = 79, 094.9) compared to Model 2 with only the Level-2 predictor (Model 2 AIC = 79, 389.2) and the Unconditional Means Model (Model 1 AIC = 79, 388.3).

The final model, Model-4, was specified as the full model by including both the Level-1 and Level-2 predictors as well as the corresponding interaction effects. The model, however, did not converge when the random effects for the *cTime*-by-*Dummy1 or cTime-by-Dummy2* interaction effects were specified. The model also did not converge when including the random effects for *Dummy1* and *Dummy2* predictors. Given this, only random effects for *cTime* (i.e., π_{1i}) were specified. Results indicated that although the inclusion of the main and corresponding interaction effects improved model fit (Model 5 AIC = 79, 096.4), the main effects of *cTime* (π_{1i} =0.01 (0.01), p = 0.14), *Dummy1* (β_{01} =-3.72 (2.97), p = .22), and *Dummy2* (β_{02}= -2.51 (3.13), p = 0.43) were not significant. Further, the *cTime*-by-*Dummy1* (β_{11} = -0.002 (0.01), p = 0.86), *cTime*-by-*Dummy2* (β_{11} = -0.02 (0.01), p = 0.06) interaction effects were not significant. Interpretation of the covariance parameter estimates reveals that individuals varied in average heart rate even after controlling for the effects of the *cTime* (β_{00} = 96.21 (17.48), p < .0001), and that the slopes were also significantly variable (β_{10} = 0.001 (0.000), p = .0001) but significant covariance between the intercepts and slopes (-0.08 (0.04), p = 0.06) was not observed. Results of the Full Model suggests that although individuals differed in their observed heart rate across regulation trials for negative images, and that significant variation in heart rate was also observed in individuals, it was not attributable to the effects of *cTime* or the study interventions. The results of each model are summarized in Table 3.4.

TABLE 3.4

ESTIMATES FROM TWO-LEVEL MULTILEVEL MODELS PREDICTING HEARTRATE COMPARING INTERVENTIONS TO CONTROL (N = 62)

	Model 1	Model 2	Model 3	Model 4
Fixed effects				
$\pi_{0i}(Intercept)$	71.40 (1.24)	74.33 (2.04)	70.88 (1.27)	72.95 (2.10)
$\beta_{01}(Dummy1)$		-4.54 (2.88)		-3.72 (2.97)
$\beta_{02}(Dummy2)$		-4.57 (3.04)		-2.51 (3.13)
$\pi_{1i}(Time)$			0.004 (0.004)	0.01 (0.01)
β_{11} $(Dummy1xTime)$				-0.002 (0.01)
β_{12} $(Dummy2xTime)$				-0.02 (0.01)
Covariance Parameter Estimates				
e_{ij} Level -1 Residual variance	48.57 (0.64)	48.57 (0.64)	46.74 (0.61)	46.74 (0.61)
β_{00} Level 2 intercept	95.71 (17.24)	90.96 (16.39)	98.75 (17.93)	96.21 (17.48)
β_{10} Level 2 Slope			0.001 (0.00)	0.001 (0.000)
σ_{01} Level 2 covariance			-0.08 (0.04)	-0.08 (0.04)
Model fit				
AIC	79, 388.3	79, 389.2	79, 094.9	79, 096.4
BIC	79, 394.7	79, 399.8	79, 107.6	79, 117.7

Note: *Statistically significant, $p < .05$; values based on SAS PROC Mixed. Entries show parameter estimates with standard errors in parentheses. Estimation Method = ML; Kenward-Rodgers degrees of freedom

3.3.2 R/S versus Mindfulness in MLM

The unconditional means model was used to estimate average heart rate in the population, deviations from that predicted HR (i.e., intercept for r_{0i}), as well as deviations from the predicted HR within individuals (i.e., within-person residual, e_{ij}).

Results from significance testing of the covariance parameter estimates reveal that individuals differ in their average heart rate (β_{00} = 90.77 (21.15), p < . 0001), and that heart rate varies within individuals (e_{ij} = 61.01 (0.85), p < . 0001).

Using the results of unconditional means model as a baseline model for which more complex models can be compared, the second model included one Level-2 predictor, *Group* (i.e., β_{01}). Given that the Level-2 predictor is dummy coded as 0 and 1, interpretation of the fixed effects indicate that heart rate in the R/S group (i.e., coded as 0) is π_{0i} = 70.53(4.85). Further, HR in the R/S group did not significantly differ from that of the Mindfulness group as indicated by the non-significant tests of the fixed effect (β_{01} = -0.52 (3.14), p = 0.87). That is, heartrate in the mindfulness condition differs from R/S by -0.52, which is not significantly different. Notably, interpretation of the covariance parameter estimates revealed that including the Level-2 condition variable did not reduce either variance component. Individuals significantly differed in their average heart (β_{00} = 90.70 (21.14, p < .0001), and variation differed within individuals (e_{ij} = 61.01 (0.85), p < .0001), but it is not due to the effects of the R/S or mindfulness interventions. Further, comparisons of model fit statics indicated that inclusion of the Level-2 *Group* predictor (Model 2 AIC = 72, 180.4) did not improve the model (Model 1 AIC = 72. 178.4).

Model-3 only included the Level-1 time-varying covariate, *cTime* (π_{1i}) to examine whether variations in heart rate varied across the affect regulation task, and if the relationship between time and heart rate also varied within-individuals. Results of the tests of the fixed effects indicated that heart rate at the start of the affect regulation task was π_{0i} = 69.48 (1.66), however tests of the fixed effect for *cTime* were not significant (π_{1i} = 0.002 (0.002), p = 0.41), indicating that there is no relationship between *cTime* and heart rate across the affect regulation task. Results of the significance testing for the covariance parameter estimates revealed that individuals varied in average heart rate even after controlling for the effects of the *cTime* (β_{00} = 101.45 (23.78), $p < .0001$), and that the slopes were also significantly variable (β_{10} = 0.0002 (0.0001), $p < .0001$). There was not, however, any significant covariance between the intercepts and slopes (-0.05 (0.03), $p = .06$). The inclusion of *cTime*, however, did improve model fit (Model 3 AIC = 72, 012.6) compared to Model 2 which included the Level-2 predictor *Group* (Model 2 AIC = 72, 180.4) and the Unconditional Means Model (Model 1 AIC = 72. 178.4).

Model-4 included the Level-1 predictor *Instruction* (i.e., π_{2i}), to examine whether variations in heart rate varied between the regulation and non-regulations trials, and if the relationship between *Instruction* and heart rate also varied within-individuals. Given that the Level-1 predictor is dummy coded as 0 and 1, interpretation of the fixed effects indicated that heart rate during the non-regulation (i.e., maintain trials coded as 0) is π_{0i} = 69.59(1.54). Further, HR in the maintain trials did not significantly differ from heart rate in the regulation trials as indicated by the non-significant tests of the fixed effect (π_{2i} = 0.37 (0.32), $p = 0.26$). That is, heartrate in the decrease trials differed from heart rate in the maintain trials by 0.37 BPM, which is not significantly different. Further, interpretation of the covariance parameter estimates reveals that individuals vary in average heart rate even after controlling for the effects of the *Instruction* (β_{20} = 88.12 (20.58), $p < .0001$), and that the slopes are also significantly variable (β_{30} = 3.02 (0.90), $p = .0004$). Similar to Model-3, however, significant covariance between the intercepts and slopes (1.89 (3.06), $p = .53$) was not observed. Notably, including *Instruction* did not improve model fit (Model 4 AIC = 72, 103.8) compared to the previously specified models.

The final model, Model-5, was specified as the full model by including both the Level-1 and Level-2 predictors as well as the corresponding interaction effects. The model, however, did not converge when the random effects for the *cTime*-by-*Instruction* interaction effect were specified. Given this, only random effects for *cTime* (i.e., π_{1i}) and *Instruction* (i.e., π_{2i}) were specified. Results indicate that although the inclusion of the main and corresponding interaction effects improved model fit (Model 5 AIC = 71, 966), the main effects of *cTime* (π_{1i} = 0.01 (0.01), p = 0.18), *Group* (β_{01} = 0.29 (3.32), p = .92), and *Instruction* (π_{2i} = 1.50 (1.31), p = 0.25) were not significant. Further, the *cTime*-by-*Group* (-0.004 (0.01), p = 0.37), *cTime*-by-*Instruction* (π_{3i} = -0.005 (0.01), p = 0.42), and *Group*-by-*Instruction* (β_{21} = -0.38 (0.86), p = 0.66) interaction effects were not significant as was the *Time*-by-*Group* -by-*Instruction* (β_{31} = 0.001(0.004), p = 0.84) three-way interaction. Interpretation of the covariance parameter estimates reveals that individuals varied in average heart rate even after controlling for the effects of the *cTime* (β_{00} = 99.37 (23.35), $p < .0001$), and that the slopes were also significantly variable (β_{10} = 0.0001 (0.0001), p = .0001) but covariance between the intercepts and slopes (-0.05 (0.03), p = 0.06) was not observed. After controlling for the effects of *Instruction*, however, no significant variations in individual heart rate (β_{20} = 0.56 (3.08), p = 0.85) were observed. Significant differences in slopes (β_{30} = 2.59 (0.823), $p < .0001$), however, were present. Results of the Full Model indicate that although individuals differed in their observed heart rate across the regulation task, and that significant variation in heart rate was also observed within individuals, it was not attributable to the effects of *cTime* or the study interventions of *Group* assignment or *Instruction* to regulate or maintain the affective response to distressing stimuli. The results of each model in Table 3.5.

TABLE 3.5

ESTIMATES FROM TWO-LEVEL MULTILEVEL MODELS PREDICTING HEARTRATE COMPARING INTERVENTION GROUPS DURING REGULATION AND NON-REGULATIONS TRIALS (N=37)

	Model 1	Model 2	Model 3	Model 4	Model 5
Fixed effects					
π_{0i} $(Intercept)$	69.78 (1.57)	70.53 (4.85)	69.48 (1.66)	69.59 (1.55)	68.54 (5.12)
$\beta_{01}(Condition)$		-0.52 (3.14)			0.30 (3.32)
$\pi_{1i}(Time)$			0.002 (0.003)		0.011 (0.008)
$\pi_{2i}(Instruction)$				0.37 (0.32)	1.50 (1.30)
$\pi_{3i}(InstructionxTime)$					-0.01 (0.01)
$\beta_{11}(TimexCondition)$					-0.004 (0.01)
β_{21} $(ConditionxInstruction)$					-0.38 (0.86)
β_{31} $(ConditionxInstructionxTime)$					0.001 (0.004)
Covariance Parameter Estimates					
e_{ij} Level -1 Residual variance	61.01 (0.85)	61.01 (0.85)	59.58 (0.83)	60.22 (0.84)	58.93 (0.82)
β_{00} Level 2 intercept	90.77 (21.15)	90.70 (21.14)	101.45 (23.78)	88.12 (20.58)	99.38 (23.35)
β_{10} Level 2 Slope			0.0002 (0.000)	3.03 (0.90)	0.00 (0.00)
σ_{01} Level 2 covariance			-0.05 (0.03)	1.89 (3.06)	-0.05 (0.03)
β_{20} Level 2 Intercept					0.56 (3.08)
β_{30} Level 2 Slope					2.59 (0.823)
σ_{23} Level 2 Covariance					0.002 (0.005)

TABLE 3.5 (CONTINUED)

Model fit					
AIC	721783.4	72180.4	72012.6	72103.8	71966.2
BIC	72183.3	72186.9	72022.3	72113.4	71990.3

Note: *Statistically significant, $p < .05$; values based on SAS PROC Mixed. Entries show parameter estimates with standard errors in parentheses. Estimation Method = ML; Kenward-Rodgers degrees of freedom

CHAPTER 4:

DISCUSSION

In review, this study sought to examine emotion regulation as a process-oriented system. To achieve this, repeated measures ANOVA and MLM frameworks were utilized to capture how emotion regulation processes unfold to regulate the emotional experience. Notably, these analyses were used to examine aspects of the Dynamic Multilevel Model of Emotion Regulation (Martinez, Bergeman, Payne & Yoon, invited revision). Specific aims of this dissertation therefore were to examine how the emotion system is disrupted following perturbation, and whether control parameters such as strategy variation modulate the effects of the emotion regulation system on the emotion system. To achieve this, analyses were performed in two steps to examine the utility of each approach in aligning theoretical models of emotion regulation with analytical techniques.

Repeated Measures ANOVA's were first used to assess whether changes in heart rate across the task were present. The first series of ANOVA's comparing the intervention to control groups indicated that HR patterning over the course of the affect regulation task did not differ between groups. Although no significant differences in heart rate were observed when comparing the intervention groups to control, repeated measures ANOVA were also used to examine whether differences in HR emerged when the intervention groups were directly compared between regulation and non-regulation trials. Consistent with the null effects observed when comparing the interventions to control, no differences in HR patterning emerged when comparing the intervention groups during regulation and non-regulation trials.

Although results of the repeated measures ANOVA did not support differences in HR patterning over the course of the regulation task, analyses were replicated in a two-level MLM framework due to the exploratory nature of the study. Given that each predictor was examined in a step-wise progression, four MLM's comparing controls to the interventions groups were conducted. Similar to the null effects observed using the repeated measures framework, results of the MLM's indicated that HR patterning did not differ over the course of the regulation task, or between the intervention and control groups. Direct comparisons of the R/S and mindfulness conditions was also performed sequentially, and resulted in five MLMs. Analyses directly comparing the intervention groups similarly revealed that HR did not vary across the regulation task, and was not significantly different between regulation and non-regulation trials. In short, results in the MLM framework were similar to those observed in the repeated measures ANOVA modeling such that no significant differences in HR were observed across time, between groups, or during regulation and non-regulation trials.

The ability to utilize the MLM framework, however, allowed for a more nuanced examination of HR changes over time by estimating random effects. Consequently, covariance parameter estimates were generated for each model to examine the within- and between-person variation in heart rate. The MLM's were thus able to characterize between- and within-person differences such that within-person variation in HR was observed. Given that the main effects of time and group were not significant, however, the within-person variation could not be attributable to time or the study interventions. Similar variation was observed when directly comparing the R/S and mindfulness groups such that individuals differed in their observed heart rate, and that significant variation in heart rate is also observed in individuals. However, this variation could not be attributed to time, condition, or instruction.

When considered against the broader landscape of the emotion regulation literature, the current results are more generally consistent with the reported mixed findings. For example, reappraisal has been shown to effectively attenuate HR during anxiety inducing situations (Hofmann et al. 2009) and a frustrating arithmetic task (Yuan et al., 2015). When reappraisal is utilized to mitigate distress in response to a laboratory stressor, however, it has no effect on physiological responses such as HR (Denson et al., 2004; Egloff et al., 2006, study 3). Further, no associations between self-reported measures of cognitive reappraisal use and HR have also been demonstrated by John and Gross (2003). Taken together, broader review of the literature on HR and reappraisal reveals mixed findings such that no effects of reappraisal on HR are observed in response to laboratory stressors or when correlating it to dispositional measures of reappraisal.

Although there is support in the literature for reappraisal attenuating HR during emotionally arousing tasks (e.g., Hofmann et al. 2009, Yuan et al., 2015), it is possible that in the current study acute use of a reappraisal intervention exerted divergent effects on affective and physiological reactivity to the distressing images. In support of this, results of the manipulation check indicated that the R/S and mindfulness interventions were effective at attenuating self-reported levels of valence (i.e., unpleasantness) and arousal (i.e., agitation). Direct comparisons of the intervention groups similarly revealed that the experience of unpleasantness and agitation was significantly lower in the regulation trials compared to passive viewing. Further, negative mood was also significantly lower in the regulation trials following the use of either intervention compared to passive viewing. Given that the manipulation check indicated that the interventions successfully attenuated the experience of negative emotions, but had no effect on HR, it is possible that acute use of the reappraisal strategy is not robust enough to regulate cardiac reactivity to distressing images.

Although the affect data was not the primary variable of interest, the significant effects of the interventions in attenuating valence, arousal, and negative mood lends some support for the conceptualization of emotion as a process-oriented system that attempts to regulate itself following perturbation by stressors such as distressing images (i.e., Figure 1). Given that the affect data was not collected continuously, however, attempts to characterize re-regulation (i.e., Figure 2), cannot be parameterized as a dynamic, unfolding process. Thus, although there is some indication stressors perturb the experiential domain (i.e., valence or arousal), findings do not illuminate how the emotion regulation process is engaged to help stabilize the emotion system. Future research equipped with the possibility to continuously assess affect is critical to this endeavor, and enables the opportunity of testing affect-related hypotheses derived from the Dynamic Multilevel Model of Emotion Regulation.

It is also worth noting that analyses examining the affect data did not reveal significant group-differences between the R/S and mindfulness groups. Although hypotheses regarding group comparisons between the R/S and mindfulness groups were expected to be null regarding their effects on HR specifically, the non-significant group differences on indices of valence, arousal and negative mood may be interpreted as modest support for the internal-explicit dimension (i.e., C3). The inclusion of R/S and mindfulness as reappraisal variants offered a unique opportunity to assess the strategies' comparable efficacy as reappraisal techniques, and determine whether their comparable effects are attributable to their higher-order classification as consciously-driven regulation attempts that reframe the internal experience. The current study, however, did not assess how either intervention was implemented. The absence of significant differences may therefore indicate that their comparable effects are attributable to their deliberative reframing of the internal experience, but the specific mechanism by which R/S and mindfulness modulate affect may be distinct (i.e., reframing perceptions of control versus non-judgmental reframe of emotional experience, respectively).

Findings regarding the manipulation check should be interpreted cautiously and not overstated given that demand effects could explain the significant influence of reappraisal on self-reported affect but not HR. Indeed, participants were explicitly instructed to decrease their emotional response to the images. Although efforts were made to minimize the presence of demand effects by informing participants there were no right or wrong answers, it is possible that participants provided lower affect ratings when presented with the decrease cue to meet the transparent expectations of the affect task.

Studies have attempted to combat demand effects by allowing participants to spontaneously engage in reappraisal (Yuan et al., 2015), which has been shown to exert mitigating effects on HR. Future research would benefit from utilizing ambiguous cues (e.g., regulate) to circumvent demand effects. Comparisons could then be made examining spontaneous (i.e., implicit) versus instructed (i.e., explicit) regulation attempts to disentangle whether the aforementioned strategies exert divergent effects across the mood, cognitive, or physiological domains.

4.1 Limitations and Future Directions

Although heart rate reflects a physiological correlate of emotional valence, and is more generally indicative of emotion regulation attempts, heart rate variability (HRV) is traditionally utilized as an physiological correlate of emotion regulation (Holzman & Bridgett, 2017). The current study design, however, precluded the use of HRV as physiological index of emotion regulation. Given that the null findings may have been attributable to the use of HR as the dependent variable of interest, exploratory analyses on respiration rate were also conducted. Analyses examining the effects of reappraisal on respiration rate were similarly conducted in the RM-ANOVA and MLM framework, but were also not significant. Limitations regarding the data set should thus be noted as additional explanation of the null findings.

In addition to the relatively small sample size, characteristics of the affect regulation task may not have allowed for sufficient variability in HR to emerge. First, it is possible that although the images were emotionally arousing enough to perturb the emotional experience, it is possible that the pictures were not sufficiently upsetting to activate a physiological response such as HR. Secondly, the affect task utilized a block design. Although block designs are commonly utilized in the emotion regulation literature, it may not have been suited for the current aims of the study given its emphasis on time-varying variability. As an alternative, the use of an affect regulation task that varies by valence image-to-image may elicit sufficient variability to detect changes across time and between groups.

Further, the dataset was comprised of predominantly White, college-educated young adults. It is thus important to utilize a more heterogenous study sample to examine what additional factors may contribute to the variability observed herein. Although gender was examined as an additional factor of interest, it was not significantly associated with HR2. Future research should perform similar analyses using a community sample, or more generally, a diverse dataset better represented by a range in age, socioeconomic and education status. The use of a heterogeneous sample will also enable examination of hypotheses derived from the Dynamic Multilevel Model of Emotion Regulation regarding the modulatory effects of other internal systems (e.g., personality) on the emotion regulation system.

The greatest limitation to the present study, however, was the inability to characterize the effects of HR over the course of time by generating frequency and dampening parameters. Modeling the present data in two distinct analytical frameworks (i.e., Repeated-Measures ANOVA and two-level Multilevel Models), did not reveal any significant variations in HR over time. As a result, it was not possible to generate parameters for time such as zeta, ζ , (i.e., damping, Boker, 2012) or eta, η, (i.e., frequency of oscillations, Boker, 2001). Notably, previous attempts to characterize emotion regulation as a dynamic system have done so by parametrizing intensity, rate of change, and acceleration (Chow, Ram, Boker, Fujita, & Clore, 2005). One drawback, however, is that the aforementioned parameterization of emotion regulation did not capture individual differences in equilibrium levels. This study attempted to address this short-coming by modeling both within- and between- person differences in HR, but was unable to observe significant differences. Future work in this area would benefit from modeling emotion regulation as involving an equilibrium state (e.g., mood) around which a person varies above or below (Bergemen & Deboeck, 2014).

4.2 Concluding Remarks

Nevertheless, this dissertation modestly attempted to better characterize the emotion regulation as a process-oriented system. Much work remains to fully understand how emotion regulation processes unfold, and whether differences in the regulation process vary by affect goal, strategy type, the individual, and their surrounding context. A combination of experimental and naturalistic studies will be critical to examine the remaining three quadrants of regulation strategies, and whether their effects vary by affect goal (i.e., hedonic versus instrumental) or attempts to up- versus down-regulate the emotional experience. Longitudinal research presents a particularly promising avenue to inform the developmental trajectory of the emotion regulation system by illuminating how successive moments of regulation influence overall functioning of the system.

APPENDIX A:

TABLES

TABLE A.1

MODULATORY EFFECTS OF COGNITIVE REAPPRAISAL ON HEARTRATE

Study	Sample size	Stressor	Reappraisal manipulation	Reappraisal instruction	Relevant results
Denson et al. (2014; study 1)	N = 90 (n_{women} = 47, M_{age} = 20)	TSST	Reappraisal induction	Develop neutral and objective attitude about performance, and to view themselves as emotionally detached in third-person	NS differences between reappraisal and no-intervention control group on HR
Denson et al. (2014; study 2)	N = 94 (n_{women} = 52, M_{age} = 22)	CPT	Reappraisal induction	Develop neutral and objective attitude about performance, and to view themselves as emotionally detached in third-person	NS differences between reappraisal and no-intervention control group on HR
Egloff et al. (2006, study 3)	N = 80 (n_{women} = 59, M_{age} = 23)	TSST	Self-report via ERQ	NA	NS associations observed between heart rate and reappraisal subscale
Hofmann et al. (2009)	N = 193 (n_{women} = 111, M_{age} = 19)	Modified TSST	Reappraisal induction	Reappraisal group instructed to task realistic perspective; acceptance group instructed to fully feel feelings and not alter them	Compared to suppression group, reappraisal group had lower HR; NS HR differences between acceptance and reappraisal groups
Mauss et al. (2007)	N = 67 (n_{women} = 67, M_{age} = 21)	NA; anger provocation	Self-report via ERQ	NA	NS differences between high- versus low-reappraisal groups on HR
Yuan et al. (2015)	N = 60 (n_{women} = 25, M_{age} = 21)	NA; frustration task	Reappraisal induction	Unconscious reappraisal group completed jumbled word task; conscious reappraisal group instructed to adopt neutral attitude	Compared to no-interventions controls, conscious and unconscious reappraisal group had lower HR; NS HR differences between reappraisal groups

Notes. ERQ = Emotion Regulation Questionnaire; TSST = Trier Social Stress Test; CPT = Cold Pressor Test; NS = not significant findings; NA = not applicable

TABLE A.2

DESCRIPTIVE STATISTICS FOR RESPIRATION RATE DURING AFFECT REGULATION TASK

			Control	**R/S**	**Mindfulness**
Respiration	Negative	View	16.047 (4.05)	16.688 (3.59)	17.677 (6.51)
		Decrease	.	16.174 (3.77)	17.094 (6.61)
	Neutral	View	15.735 (4.09)	16.600 (3.58)	17.074 (6.90)

Note: Values represent means and standard deviations within parentheses

TABLE A.3

REPEATED MEASURES ANOVA FOR RESPIRATION RATE

	Respiration rate		
Control versus Intervention during regulation (N = 62)	df	F	p
Time	1, 56.3	1.37	0.25
Time x Group	2, 55.3	0.47	0.63
Mindfulness versus Religion/Spirituality (N = 37)			
Group	1, 35.1	0.44	0.51
Instruction	1, 9150	2.03	0.15
Time	1, 35.2	0.14	0.71
Time x Instruction	1, 9723	1.48	0.22
Time X Group	1, 35.2	0.03	0.87
Group X Instruction	1, 9150	0.00	0.97
Time x Group x Instruction	1, 9723	0.22	0.64

Note: Entries degrees of freedom (DF), F-test (F), and significance values (p). Values based on SAS PROC GLM; Satterthwaite degrees of freedom,
*Statistically significant, $p < .05$

TABLE A.4

ESTIMATES FROM TWO-LEVEL MULTLEVEL MODELS PREDICTING RESPIRATION RATE COMPARING INTERVENTIONS TO CONTROLS (N = 62)

	Model 1	Model 2	Model 3	Model 4
Fixed effects				
$\pi_{0i}(Intercept)$	16.34 (0.45)	16.05 (0.77)	16.60 (0.49)	16.62 (0.83)
$\beta_{01}(Dummy1)$		0.13 (1.07)		-0.444 (1.16)
$\beta_{02}(Dummy2)$		0.83 (1.13)		0.41 (1.23)
$\pi_{1i}(Time)$			-0.002 (0.001)	-0.004 (0.003)
β_{11} $(Dummy1xTime)$				0.004 (0.004)
β_{12} $(Dummy2xTime)$				0.002 (0.004)
Covariance Parameter Estimates				
e_{ij} Level -1 Residual variance	12.41 (0.16)	12.41 (0.16)	11.86 (0.16)	11.85 (0.16)
β_{00} Level 2 intercept	12.46 (2.27)	12.33 (2.25)	14.42 (2.66)	14.30 (2.64)
β_{10} Level 2 Slope			0.0002 (0.000)	0.0001 (0.000)
σ_{01} Level 2 covariance			-0.02 (0.007)	-0.02 (0.007)
Model fit				
AIC	61, 804.7	61, 814.1	61, 447.9	61, 454.5

TABLE A.4 (CONTINUED)

BIC	61, 817.1	61, 824.8	61, 460.6	61, 475.7

Note: *Statistically significant, $p < .05$; values based on SAS PROC Mixed. Entries show parameter estimates with standard errors in parentheses. Estimation Method = ML; Kenward-Rodgers degrees of freedom

TABLE A.5

ESTIMATES FROM TWO-LEVEL MULTILEVEL MODELS PREDICTING RESPIRATION RATE COMPARING INTERVENTIONS GROUPS DURING REGULATION AND NON-REGULATION TRIALS (N=37)

	Model 1	Model 2	Model 3	Model 4	Model 5
Fixed effects					
π_{0i} $(Intercept)$	15.47 (0.64)	14.14 (2.00)	15.53 (0.64)	15.65 (0.60)	14.22 (1.98)
$\beta_{01}(Condition)$		0.92 (1.27)			0.97 (1.28)
$\pi_{1i}(Time)$			-0.000 (0.000)		0.002 (0.004)
$\pi_{2i}(Instruction)$				-0.34 (0.15)	-0.49 (0.68)
$\pi_{3i}(InstructionxTime)$					-0.002 (0.003)
Time-by-Condition					-0.001 (0.002)
β_{21} $(ConditionxInstruction)$					0.24 (0.45)
β_{31} $(ConditionxInstructionxTime)$					0.0003 (0.002)
Covariance Parameter Estimates					
e_{ij} Level -1 Residual variance	12.61 (0.17)	12.61 (0.18)	12.42 (0.17)	12.40 (0.17)	12.18 (0.17)
β_{00} Level 2 intercept	15.00 (3.49)	14.79 (3.44)	15.17 (3.57)	13.40 (3.13)	14.70 (3.50)

TABLE A.5 (CONTINUED)

β_{10} Level 2 Slope			0.000 (8.31)	0.71 (0.21)	0.000 (0.000)
σ_{01} Level 2 covariance			-0.002 (0.004)	1.45 (0.61)	-0.01 (0.005)
β_{20} Level 2 Intercept					2.22 (0.79)
β_{30} Level 2 Slope					0.96 (0.27)
σ_{23} Level 2 Covariance					-0.002 (0.001)
Model fit					
AIC	55, 327.8	55, 329.3	55, 238.9	55, 214.5	55, 112.9
BIC	55, 332.6	55, 335.7	55, 248.6	55, 224.2	55, 137.1

Note: *Statistically significant, $p < .05$; values based on SAS PROC Mixed. Entries show parameter estimates with standard errors in parentheses.
Estimation Method = ML; Kenward-Rodgers degrees of freedom

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