UNIVERSITY OF CALIFORNIA,
IRVINE

The Influence of Emotion Regulation Strategies and Goals on Physiological Outcomes

DISSERTATION

To be submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Psychological Science

by

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Dissertation Committee:
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Christie Kaman Fung

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Fung, C.K., Moore, M.M., Karcher, N.R., Kerns, J.G., Martin, E.A., (2017). Emotional word usage in groups at risk for schizophrenia-spectrum disorders: An objective investigation of attention to emotion. *Psychiatry Research, 252,* 29-37.

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RESEARCH EXPERIENCE

2015 – current **Graduate Student Researcher**
Behaviors, Emotions, Affective Neuroscience Laboratory, Advisors: Dr. Elizabeth Martin; Dr. Candice Odgers
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- Design and implement research studies on emotion processing and emotion regulation in social settings for healthy individuals and people at risk for schizophrenia-spectrum disorders
- Program experiments using Qualtrics, Matlab and E-Prime
- Perform data analyses using SPSS, R, STATA and the LIWC
- Supervised undergraduate RAs and post-baccalaureate students on recruitment, study training, data collection, data cleaning and poster presentations
- *Authored 3 publications (see above)*

2013 – 2015 **Project Manager**
Social Psychophysiological Lab, Advisors: Dr. James Gross, Dr. Sylvia Kreibig
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- Oversaw and coordinated different components of the project, including recruitment, administered phone screening, monitored pre-screen surveys, scheduled appointments through emails and SONA, implemented study protocol, compiled data for coding, data analysis and coordinated with other RAs
- Trained participants through an Emotion Regulation and Reappraisal Task by guiding to use appropriate reappraisal strategies while viewing emotionally driven pictures
- Developed a cognitive reappraisal coding system; combined with the training and coordinating of coders for coding qualitative cognitive reappraisal data

- Measured participants' physiological activity including facial electromyography, electrocardiography, impedance cardiography, electrodermal activity, respiration, finger pulse and blood pressure
- Trained and supervised undergraduate RAs for study procedures and data management
- Facilitated a variety of administrative work; prepared project materials, petty cash management;
- conducted literature review
- Prepared a fMRI study and ran subjects through the scanner to measure neural responses during emotion regulation as a second phase of this study - sequences being ran including: 3Plane Loc SSFSE, ASSET Calibration, HOS WB HRBRAIN, T1, T2 and fMRI sequences
- *Developed a qualitative data coding system, prepared and launched a follow-up fMRI study*

2013 **Research Assistant**

Affect Labeling and Exposure Project |UCLA Anxiety Disorders Research Center, Advisors: Dr. Michelle Craske, Andrea N. Niles

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- Led participants with public speaking anxiety disorders through study procedures, including a public speaking behavioral approach task (BAT) and public speaking exposures independently
- Conducted structured interviews to assess and diagnose social anxiety disorder using the Mini International Neuropsychiatric Interview (MINI)
- Measured participants' physiological activity including heart rate and galvanic skin response
- *Awarded the Stanford Prize in Outstanding Undergraduate Research (see below)*

2012 **Summer Research Intern**

Marketing Department|Hong Kong Baptist University,Advisors: Dr. Su Lei, Dr. Candy Lo

- Designed and developed research questionnaires on Qualtrics and Word to examine the relationship between mood and attribution
- Authored questionnaires to test the relationship between perceived quality of service experience and length of perceived time passed during the use of service and the mood
- Facilitated data collection, literature review and completion of research documentation

2011- 2012 **Research Assistant**

Social Impressions Project|Social & Affective Neuroscience Lab, Advisors: Dr. Naomi Eisenberger, Keely Muscatell

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- Developed database for data entry and data analysis
- Led experiments and ran study procedures including computer tasks and questionnaires
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-

Abstract of the Dissertation

The Influence of Emotion Regulation Strategies and Goals on Physiological Outcomes

by

Christie Kaman Fung

Doctor of Philosophy in Psychological Science

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Professor Candice Odgers, Chair

Emotion regulation is an important process for attaining desired emotional states and has been linked to a number of key behavioral and health outcomes. Being able to successfully regulate emotions depends on several factors including the types of strategy used and the goals of regulation. This dissertation extended what is currently known about emotion regulation by examining how cognitive reappraisal, one of the most widely studied and effective strategies used to regulate emotion, influences different physiological outcomes through a meta-analysis. Moderators of the relationships between cognitive reappraisal and physiology were also investigated. The second study of the dissertation further examined how emotion regulation goals, such as regulating with a qualitative regulation goal (i.e., regulate the valence dimension of emotions) or with a quantitative regulation goal (i.e., arousal dimension of emotions), influenced physiological changes through an experimental paradigm. Results from the meta-analysis provided evidence that cognitive reappraisal had a significant effect on eye movement measures. Across the 73 experimental studies analyzed, the use of cognitive reappraisal strategies also had a stronger effect on regulation of negative versus positive emotions. The effect of cognitive reappraisal was also stronger in younger versus older populations. In the second experimental study, results found that compared with a quantitative regulation goal, individuals regulating with a qualitative

regulation goal reported higher blood pressure. Individuals also displayed significant within person variations in skin conductance and respiratory responses when regulating with a qualitative, but not a quantitative goal. Overall findings from this dissertation demonstrated that both regulation strategies and goals are important for shaping different physiological changes and health. Findings provide insights on several factors that could influence the effect of cognitive reappraisal on different physiology compared with other strategies. For instance, the regulatory goal one has, the types of emotion being regulated, and person characteristics like age. Being the first study to investigate the differential effect of regulatory goals on physiology, results suggest the importance of measuring not just how to move away from current emotions, but also how to arrive at our target emotional states to achieve different physiological outcomes. Results also suggest a new research direction to examine the effect of regulatory goals on not only the physiological, but other components of emotions.

Overview

Emotion comprises different components, including subjective feelings, physiological changes, and behaviors such as facial expression, that correlate with each other. Each component has its own functions and implications. For example, feelings influence our memory and decision-making process, physiology is linked to wellbeing and physical health, and our facial expressions have important communicative and social purposes. Together, emotion is important in different processes that help us adapt to the demands of the physical and social environment effectively. Research has shown that experiencing high levels of negative and/or low levels of positive affect is associated with different physical and psychological health outcomes (e.g., Friedman & Booth-Kewley, 1987; Smith & Christensen, 1996). Over the past few decades, emotion regulation has thus been extensively studied in both children (e.g., Campos, Campos, & Barrett, 1989; Thompson, 1991) and adults literature (e.g., Charles & Carstensen, 2014; Cole et al., 1994; Gross & Muñoz, 1995).

A major focus within the field of emotion regulation has been to investigate the effectiveness of different emotion regulation strategies on emotional and mental health related outcomes. For instance, previous meta-analyses have reported that cognitive reappraisal to be the most effective strategy in terms of producing the largest hedonic change in emotions (Webb et al., 2012), and that it is robustly correlated with positive indicators of mental health (Hu et al., 2014). Previous meta-analyses have provided valuable information on the impact of using cognitive reappraisal strategies by incorporating a comprehensive set of emotional outcomes captured by a wide range of methods (i.e., experiential, behavioral and physiological measures); however, the influence of cognitive reappraisal strategies on specific physiological outcomes, such as heart rate and blood pressure, is still largely unknown. Understanding the effect of

cognitive reappraisal on specific physiological outcomes has important theoretical and practical implications. Specifically, physiological measures that may be influenced by emotion regulation strategies have also been linked to a number of different and important health outcomes. For instance, high blood pressure indicates higher risks of stroke and coronary heart diseases (Stamler, 1991; Willmot et al., 2004) whereas abnormal skin conductance response is associated with acute and chronic stress reaction, as well as present in individuals at risk for and with clinical disorders (Felmingham et al., 2012; Najström & Jansson, 2007; Söder et al., 2020; Ward et al., 1983). To begin filling this important gap in the literature, the first study of this dissertation is a meta-analysis focused on synthesizing what is known about the effect of cognitive reappraisal on specific physiological outcomes. Results both fill an important gap in existing literature and could provide important clues as to how this regulation strategy influences different aspects of health. Ultimately, this type of information could inform the work of mental health practitioners as they evaluate whether to encourage the use of this strategy to promote positive health outcomes in their practice.

As mentioned above that even though emotion regulation has been extensively studied over the past decades, it is not yet clear how one's goal of regulation could influence the effect of cognitive reappraisal on physiology. People are goal-directed human beings and we use goals as reference values to guide and adjust current and future behaviors (Carver & Scheier, 1990). When experiencing emotions, we also adopt emotion goals, such as determining whether to maximize hedonic benefits (i.e., greater pleasure and less pain) or nonhedonic benefits of particular emotions to reach desired emotions (Mauss & Tamir, 2014). Emotion regulation is also a process that would activate one's goal, in which action will be directed to shift current emotions to desired emotions. Therefore, understanding the roles that goals play in emotion

regulation may highlight an important motivational perspective for emotion regulation (Tamir et al., 2020).

Most of the current emotion regulation studies have focused on the absence of the initial emotional state but not the goal, or the end desired state of the regulated emotions when measuring the effectiveness of regulation. For instance, participants would be shown a negative stimulus and asked to regulate their emotions but would not receive further instructions on the target emotional goal after regulation. Without defining this target emotional goal, the end state of the emotional experience could vary, such that participants could not only decrease negative emotions to a neutral state, but also decrease negative emotions and increase positive emotions. Therefore, without specifying a regulation goal, participants could change different dimensions of emotions, e.g., the valence, intensity or both during regulation. Previous studies have suggested that valence and arousal are associated with different physiological systems. For instance, valence and arousal corresponded to facial electromyography and electrodermal activity respectively across stimuli (e.g. Sato et al., 2020). The under-specification of the goal of emotion regulation could therefore be an important moderator that influences the effect of cognitive reappraisal on emotional and physiological outcomes. To test this possibility, the second study of this dissertation examined the effect of setting a regulation goal using an existing dataset from an experimental study, which included a measurement of specific emotion regulation goals (i.e., changing the valence vs. changing the intensity of emotions) and a range of physiological outcomes (e.g., heart rate, blood pressure, skin conductance response). Results from this study fill an important gap in existing literature by testing, within an experimental paradigm how regulation goals influence the relationship between cognitive reappraisal and physiological outcomes.

Though cognitive reappraisal has been shown to be an effective strategy for inducing emotional change, extending this work to examine the nuances in effects within cognitive reappraisal strategies has important theoretical and practical implications. As described in this document, findings from Study 2 suggested that cognitive reappraisal could capture more than one dimension of emotion (i.e., valence and arousal), mental health practitioners could also instruct individuals more specific regulation goals according to individual needs. Further, this dissertation also lays a theoretical foundation for future regulation studies to investigate and explore the effects of different emotion regulation goals in the context of other emotion regulation strategies.

CHAPTER 1: Introduction

Physiological response to emotional stimuli and events is one potential pathway that could explain the link between emotion and health. Not only do we experience emotions on a daily basis, but we also regulate emotions constantly, which in turn is likely to influence our physiological response accordingly. Though some research has investigated how cognitive reappraisal, one of the most widely studied and effective regulation strategies influences physiology, mixed findings have been reported (e.g., Ben-Naim et al., 2013; Butler et al., 2006; Egloff et al., 2006a; Gross, 1998a; Steptoe & Vogele, 1986). Therefore, the true effects of cognitive reappraisal on different physiological outcomes are unknown. The current meta-analysis aims to synthesize existing studies to examine how regulating our emotions through cognitive reappraisal influenced different physiological changes. In this meta-analysis, I first discuss the relation between emotion, physiology and health to review the theoretical foundation for this study. I also present an existing theoretical framework and definitions of emotion regulation, which is an important emotional process that could influence the relation between physiology and health. One specific emotion regulation strategy named cognitive reappraisal and its relation with physiology is also discussed in depth, since it has been shown to be one of the most adaptive strategies and has been associated with a range of beneficial outcomes (Gross, 2015). Next, I elaborate on various challenges in drawing conclusive results related to cognitive reappraisal on physiology. A meta-analytic plan is then detailed, with an aim to address these challenges through synthesizing existing findings. Finally, a set of moderators is described, followed by a description of the methods, results, and conclusion of the meta-analysis.

Emotion and Physiology

Almost a century ago, William James (James, 1884, 1890) proposed that the autonomic nervous system (ANS), which coordinates a network of nerves and organs that regulates largely unconscious bodily functions, is an important component in emotion. James argued for specificity in the ANS, that is, different emotions are associated with different patterns of ANS activity. At the same time, other emotion theorists argued against James' model of specificity and suggested the ANS can only produce one pattern of activation, characterized by a diffuse and undifferentiated state of arousal (Cannon, 1927). More recently, Barrett (2006) also presented some inconsistent results on emotion-specific autonomic patterning (e.g., Cacioppo, Berntson, Klein, & Poehlmann, 1997; Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 2000; Zajonc & McIntosh, 1992). However, meta-analyses on physiological responding in emotion have consistently found evidence for a certain level of autonomic emotion specificity. For instance, a previous review suggested that there was greater activation in several indices of sympathetic activity, including blood volume, cardiac output, left ventricular ejection time, and heart rate during the experience of negative versus positive discrete emotions. At the same time, diastolic blood pressure has been found to be higher during times of anger than in fear, sadness or happiness (Cacioppo et al., 2000).

Though there is relatively less evidence for autonomic specificity in discrete emotions, there is clearer evidence on valence-autonomic patterning, such that negative emotions in general have been associated with stronger physiological responses (see Cacioppo et al., 2000; Taylor, 1991 for reviews). These reviews suggest that finding an unique autonomic pattern for *every* emotion may not be necessary to establish specificity as long as *some* emotions differ in consistent ways, such as negative and positive emotions (Levenson, 1992). It has also been

suggested that some emotions (e.g., calm, contentment) may have more similar types of ANS activation patterns than the others (e.g., calm and anger) for general body protection and behavior preparation purposes, so that nonspecific autonomic activity may be required (Stemmler, 2004). Regardless of whether there are distinctive physiological patterns with emotional experiences, physiological response is still a necessary component that accompanies emotional experiences (Cacioppo et al., 1992).

Emotion, Physiology and Health

In order to advance our understanding of the relation between physiology and emotion, the important question might *not* be whether there are distinctive biological patterns or pathways to discrete emotions. Instead, it may be more productive to investigate the extent to which our emotions evoke differential physiological responses, as well as the role of these responses in emotional experiences, behaviors and health. A plethora of research has suggested our physiological responses are associated with physical and mental health. For instance, high blood pressure was attributed to hypertension, stroke and coronary heart diseases (Kannel, 1996; Lawes et al., 2008). Health literature has shown that relative to mean blood pressure and diastolic blood pressure, the risk for death from coronary heart disease was the greatest for systolic blood pressure, suggesting systolic blood pressure as the best predictor to risk of cardiovascular death (Lichtenstein et al., 1985; Palaniappan et al., 2002). Several longitudinal studies have shown that hypertension or elevated blood pressure, occurring in either middle or older age, also increased the risk of Alzheimer's disease or other types of dementia (Kivipelto et al., 2001; Posner et al., 2002; Skoog et al., 1996). Interestingly, two studies using a Japanese American and European sample respectively have suggested that other than elevated high systolic pressure, extremely

low diastolic blood pressure was also a correlate of the dementia process (Launer et al., 2000; Qiu et al., 2003).

Apart from using blood pressure, which is a more direct measure of the heart activity as a biomarker to assess risks for cardiovascular diseases, the overall functioning of the ANS is another important health indicator. The ANS has two major branches - the sympathetic nervous system (SNS), which is associated with energy mobilization, and the parasympathetic nervous system (PNS), which is associated with restorative functions. The activities within the two systems are constantly regulated in response to changing environmental demands. Autonomic imbalance, in which one branch of the ANS dominates over the other (e.g., a hyperactive SNS and a hypoactive PNS is typically the case), is associated with a range of health conditions due to excessive energy demands and increased risk of inflammation on one system (Thayer & Sternberg, 2006). Specifically, heart rate variability, resting heart rate, and parasympathetic activity are some physiological indices used to assess autonomic imbalance. Prior research has found that autonomic imbalance is related to the development of cardiovascular diseases, diabetes and Alzheimer's disease (Jankowska et al., 2006; Thayer et al., 2010; Wulsin et al., 2015). Reduced autonomic imbalance, reflected by low heart rate variability, has also been reported in individuals with anxiety and dyspepsia, a condition in which abdominal pain occurs due to indigestion (Friedman, 2007; Friedman & Thayer, 1998; Thayer & Sternberg, 2006). These findings suggest that apart from blood pressure, autonomic balance and flexibility, indicated by physiological assessments such as heart rate variability and heart rate are important health determinants as well. Current literature has also reported a link between electrodermal activity (EDA), which is to pass small external electrical current across the skin to record skin conductance response, and health. Unlike heart rate and heart rate variability, which responds to

the whole ANS activity, EDA provides a relatively direct representation of sympathetic activity (Dawson et al., 2016). Therefore, studies have used skin conductance as an index of sympathetic activity, and suggested skin conductance as an indicator of psychological stress (Lazarus, Speisman, & Mordkoff, 1963) and autonomic arousal (Jacobs et al., 1994). Research has reported that diminished variability in skin conductance responses was observed in individuals with generalized anxiety disorder and panic disorder (Hoehn-Saric, Hazlett, & McLeod, 1993; Hoehn-Saric, McLeod, & Zimmerli, 1991). At the same time, abnormal skin conductance response was displayed in individuals with autism-spectrum disorders (O'Haire et al., 2015) and schizophrenia (Straube, 1979) in response to social stress and attentional stimuli respectively. Further, skin conductance has been suggested as a marker for depression (Ward et al., 1983). Collectively, these studies suggested EDA as another assessment tool to estimate one's psychological health.

Apart from measuring the electrical conductivity in our skin, our facial muscle activities have also been used as indicators for emotional change and health. There has been evidence suggesting associations between emotional experiences and facial expressions (Darwin, 1872; Ekman & Friesen, 1971; Izard, 1994; Levenson et al., 1991). Specifically, facial actions such as the pulling upward of the lip corners would be seen as a sign of positive affect, while pulling downward would be seen as a sign of negative affect. The Facial Action Coding System (FACS: Ekman & Friesen, 1978; Ekman, Friesen, & Hager, 2002) is one of the most widely used measurements to capture those facial actions. FACS involves manually coding on facial expressions that are decomposed into the smallest visually discriminable facial movements, namely action units (Cohn et al., 2007). Using the FACS, it was reported that facial expression of negative emotion, in particular anger, predicted increased grief and poorer perceived health at a

later time (Bonanno & Keltner, 1997). A more recent study also found a link between facial expressions and physiology such that the more fearful expressions individuals displayed in response to stressful tasks, the higher their cardiovascular and cortisol responses to stress (Lerner et al., 2007).

Altogether, current literature has provided evidence that specific physiological indices are important indicators for a wide range of physical and psychological health outcomes. Since emotion organizes and coordinates activity within the ANS (e.g., changes in heart rate and blood pressure) and between the ANS and other physiological response systems (e.g., changes between the cardiovascular system, facial expressions, behaviors and subjective emotional experiences) (Levenson, 1992, 2003), it is imperative for researchers to investigate factors or processes that could modulate the coordination between systems for desirable health outcomes.

Current Theoretical Framework of Emotion Regulation

One process that influences this coordination between multiple physiological systems is emotion regulation, which can occur automatically and outside of our conscious awareness (Bargh & Williams, 2007; Mauss, Bunge, & Gross, 2007). Emotion regulatory process involves changes in "emotion dynamics". Emotion dynamics describe a variety of different indices of an emotional episode, for example, latency, rise time, magnitude, duration, and offset of responses in the behavioral, experiential or physiological domains of emotion (Thompson, 1990). Thus, through emotion regulation, people modulate aspects of emotions like valence, arousal or frequency of the emotional experience. The related physiological states and overt behaviors, such as facial expressions, that are associated with the emotional experience are also regulated. It is therefore common for regulation studies to include self-reported emotions, facial expressions and/or physiological measures to assess how emotion regulation influences these systems

simultaneously (e.g., Egloff et al., 2006; Gross, 1998; McRae, Ciesielski, & Gross, 2012; Sheppes, Catran, & Meiran, 2009; Wu, Winkler, Andreatta, Hajcak, & Pauli, 2012).

There have been a number of frameworks to conceptualize the different ways people can regulate their emotions (Koole, 2009; Larsen, 2000; Parkinson & Totterdell, 1999; Thayer & Lane, 2000), but the process model of emotion regulation (Gross, 1998b) has received the most attention thus far. This model builds on the modal model of emotion generation, which specifies a situation-attention-appraisal-response sequence of emotion generation process (Barrett et al., 2007). The process model of emotion regulation treats each step of the sequence in emotion generation as a potential target of regulation. Five families of regulation strategies were suggested based on which emotion-generative process is at the primary impact for regulation. The strategies include situation selection (approaching or avoiding certain situations), situation modification (changing an environment to alter emotions), attentional deployment (turning attention towards or away from stimuli), cognitive reappraisal (reevaluates either the situation or one's capacity to manage the situation), and response-modulation (Gross, 1998b).

Cognitive Reappraisal and Physiology

Extensive research suggested that cognitive reappraisal is an adaptive strategy with beneficial outcomes (Butler et al., 2003; Folkman et al., 1986; Goldin et al., 2012; Gross, 2002; Gross & John, 2003; Haga et al., 2009; McRae et al., 2012). For instance, people who regularly reappraise (high reappraisers) experienced and expressed greater positive emotion and less negative emotion than those who do not reappraise often (low reappraisers) (Mauss, Cook, Cheng, & Gross, 2007). Using reappraisal is associated with better self- and peer-reported interpersonal functioning and wellbeing (Gross & John, 2003). Clinical studies also provided evidence that higher reappraisal ability was associated with less depression but only among

people with high levels of life stress (Troy et al., 2010). Reappraisal is thus a core element in different forms of therapy, including cognitive behavioral therapy (Beck, 2005) and personality disorder treatment (Linehan et al., 1999), which are effective in treating different forms of mood and anxiety disorders.

A potential pathway to explain those beneficial health outcomes could be the more adaptive physiological responses that come along when we cognitively reappraise. Relative to low reappraisers, high reappraisers showed a more adaptive profile of cardiovascular responding, indicated by showing greater cardiac output and ventricular contractility, as well as less peripheral resistance in the heart, after an anger induction (Mauss et al., 2007). Though researchers largely agree that cognitive reappraisal should lead to an overall reduced physiological reactivity (Gross & John, 2003), past research testing the effects of cognitive reappraisal on specific physiological indices have been mixed. For example, reappraisal has been found to reduce cardiovascular arousal, (Ben-Naim et al., 2013), increase cardiovascular arousal, (Butler, Wilhelm, & Gross, 2006; Mauss, et al., 2007), or have no effect on physiological activity (Egloff et al., 2006b; Gross, 1998a; Steptoe & Vogele, 1986). One factor that may account for these mixed findings is that studies have used different physiological measures to define similar constructs and draw similar conclusions. For instance, one study finding a decrease in cardiovascular arousal utilized a composite measure of five cardiovascular variables (cardiac interbeat interval, pulse transmission time to finger, finger pulse amplitude, pulse transmission time to the ear, and pulse amplitude), whereas studies finding no effect on physiology used a combination of cardiovascular and skin conductance measures including finger pulse amplitude, finger temperature, skin conductance level and heart rate.

Though these studies provide important information on how cognitive reappraisal influences different overall physiological profiles, researchers need to be careful when interpreting findings and extending work based on results that have relied on using specific physiological indices. As suggested above, physiological measures are associated with different outcomes (e.g., high blood pressure and low heart rate variability are mostly associated with cardiovascular diseases, whereas abnormal skin conductance response are mostly associated with clinical disorders), thus grouping skin conductance and cardiovascular indices into a composite physiological outcome measure could lead to misleading estimates of linkages with both skin conductance- or cardiovascular-related outcomes. Understanding the effects of cognitive reappraisal on more specific physiological measures should generate more accurate estimates of these specific linkages and, in turn, could provide insights on how this regulation strategy influences specific health outcomes via regulation to physiological response pathways. Findings have the potential to benefit both practitioners and researchers by synthesizing what is known about the impact of cognitive reappraisal strategies on physiological indicators that are of high interest to health practitioners and, for researchers, in highlighting what types of physiological assessments may be most productive to focus on in future work. More generally, this meta-analysis integrates and synthesizes prior findings with the aim of estimating and parsing linkages between cognitive reappraisal and specific aspects of physiology.

Though there is not a clear consensus on which specific markers or physiological indices comprise a physiological outcome, the author consulted several sources of information, including books such as the Handbook of Psychophysiology (Cacioppo et al., 2016), Electrodermal Activity in Psychological Research (Prokasy & Raskin, 1973), book chapters such as Measuring Emotion: Behavior, Feeling, and Physiology (Bradley & Lang, 2002), Cardiovascular and

respiratory systems: modeling, analysis, and control (Batzel et al., 2007), as well as journal articles from Psychophysiology to determine which indices are theoretically and empirically supported to be grouped to represent an outcome. Physiological indices that belong to the same domain of physiological outcomes were grouped and separate meta-analyses were performed for each outcome[1], including outcome 1: cardiovascular and respiratory, outcome 2: electrodermal, outcome 3: facial and, outcome 4: eye movement. Separate moderator analyses were also computed for each outcome. A further breakdown of the indices included in their corresponding outcome is presented below.

Cardiovascular and respiratory outcomes.

The cardiovascular system consists of the heart and the vascular network, a distribution system that ensures that blood reaches all tissues of the body (Berntson et al., 2016). This system is under control of the ANS, which innervates organs that exhibit rhythmic processes, such as heartbeat, of which recurrent events can be monitored (Kreibig et al., 2010). Observations of such events may be quantified by rate, for example, as found in the measure of heart rate. It could also be in the measure of heart rate variability or interbeat interval, which both refers to the changes in time between successive heartbeats. Since interactions exist between our bodily systems, heart rate, for example, changes as a function of the respiratory cycle, a phenomenon known as respiratory sinus arrhythmia. This is measured using the maximal difference between

[1] Cardiovascular and respiratory outcome includes heart rate, (low and high frequency) heart rate variability (HRV), heart rate acceleration, interbeat interval, pre-ejection period, respiration depth, respiration rate, finger pulse, finger pulse transmission time, ear pulse, ear transmission time, respiratory sinus arrhythmia, heart rate inertia, cardiac output, total peripheral resistance, heart rate deceleration, respiratory amplitudes; Electrodermal outcome includes skin conductance level, skin conductance response, skin conductance response amplitude, finger temperature, finger temperature slope, skin conductance rise time to peak time; Facial outcome includes electromyography (corrugator, zygomaticus, levator, and orbicularis oculi muscle groups), facial action units (overall and mean levels of orbicularis oculi, zygomaticus major, and pain related muscle activities); Eye movement outcome includes startle eyeblink, (reflexes, responses or amplitude), fixation count.

heart period at inspiration and heart period at expiration. Research has suggested a highly correlated relationship between the cardiovascular and respiratory system. Specifically, a typical functioning respiratory system is characterized by complex breathing variations in respiratory rate and depth, coupled with both heart rate and blood pressure oscillations in continual co-modification (Bruce, 1996). Respiratory activities such as respiration rate and depth has been shown to not only be linked to pulmonary disease (Shaker et al., 1992), but also cardiovascular functioning (Grossman, 1983).

Another measurement in relation to the heart and the vasculature system in the cardiovascular system is blood pressure (BP), reported with a measurement of systolic blood pressure (SBP) and diastolic blood pressure (DBP). Systolic blood pressure is the maximal blood pressure that occurs when the ventricle of the heart contracts while diastolic is the relaxation of the ventricle following the contraction of the heart. Mean arterial pressure is defined as the average arterial pressure during a single cardiac cycle and is used to describe a notional average blood pressure in an individual (Berntson et al., 2016). Related measures with BP are pulse transmission time and pulse amplitude. These two measures utilize plethysmography, a technique to index the blood volume and blood flow transit time of a body structure (Berntson et al., 2016). Research has suggested that finger pulse transit time and finger pulse amplitude can be used to estimate SBP and DBP, and might be a substitute of the more traditional BP measurement (Wang et al., 2014), finger pulse transit time and finger pulse amplitude are therefore also included in the current meta-analysis. These two indices measure blood pressure from a specific body part (i.e., finger) that is much further away from the heart, indicating the pressure pulse received would also be damped out through the travel from the heart to the finger (Berntson et al., 2016).

Electrodermal outcomes.

There are two forms of sweat glands in our body, which are the apocrine and eccrine glands. The eccrine glands are of researchers' interests as they are responsive to psychologically significant stimuli, such as emotion, arousal, and attention (Dawson et al., 2016). Most psychological studies use the exosomatic measure of electrodermal activity (EDA) to measure the activity of the eccrine sweat glands, which are innervated by the sympathetic nervous system in the ANS (Levenson et al., 2016). As it reflects sympathetic activation and is associated with emotional valence and arousal, EDA is commonly used in emotion research (Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang, Greenwald, Bradley, & Hamm, 1993; see Kreibig, 2010; Mauss & Robinson, 2009 for reviews). However, different aspects of EDA can be obtained, for instance, skin conductance level (SCL, mean levels of EDA) and skin conductance response (SCR, change in skin conductance in presence of identifiable eliciting stimulus), were both used in cognitive reappraisal studies (e.g., SCL: Gross, 1998; McRae et al., 2012; Sheppes et al., 2009; Wolgast, Lundh, & Viborg, 2011; SCR: Demaree, Robinson, Pu, & Allen, 2006; Kim & Hamann, 2012; McRae, Taitano, & Lane, 2010;). One aspect could be more useful than the other depending on the research design and questions. For instance, SCL may be more meaningful if the overall change of psychophysiological processes is of interest, whereas SCR may be necessary if a specific psychophysiological response towards certain stimulus is of interest. Regulation studies have found significant effects of cognitive reappraisal on both SCL and SCR, and studies usually include only either one but not two of these measures. Although changes in arousal and alertness require on average 1 to 3 seconds to occur in both SCL and SCR, only SCR has been found to be correlated with real-time measures of these processes (Lyytinen, Blomberg, & Näätänen, 1992). In addition, previous findings indicated that subjects

might not need to be consciously aware of the significance of the affective stimulus to elicit an SCR (for a review, see Öhman, 2009). SCRs also occur when an affective stimulus activates the appetitive or defensive motivation systems (Lang et al., 1993) and during decision making process that associates with rewards or outcomes (Bechara et al., 1997). Unlike the mixed findings seen in cardiovascular outcomes, the effect of cognitive reappraisal on electrodermal outcomes has been largely robust. However, past research has not examined or directly compared the difference in effects between cardiovascular and electrodermal outcomes. The current meta-analysis would allow us to examine how cardiovascular and electrodermal outcomes would moderate the effect of cognitive reappraisal

Facial movement outcome

Though studies using the Facial Action Coding System (FACS) have shown promising evidence that action units reflect emotion experiences (e.g., Ekman & Friesen, 1971; Kring & Gordon, 1998; Levenson, Carstensen, Friesen, & Ekman, 1991) and is associated with physiological and health outcomes (e.g., Bonanno & Keltner, 1997; Lerner et al., 2007; Rosenberg et al., 2001), it is less useful in detecting subtle facial movements and for assessing differences in intensity. Implementing FACS could also be difficult in cultural studies in which differences in the management of facial expressions, or display rules (Ekman et al., 1969) exist in participants. Emotional experiences and expressions could be masked based on the appropriateness of facial expressions displayed in different situations in different cultures (Matsumoto & Ekman, 1989). Extensive research therefore has adopted a different technique, the facial electromyography (EMG) to measure the production instead of the perception of facial displays. Facial EMG measures muscle activities by detecting and amplifying the voltage changes in muscle fibers when they contract (Tassinary et al., 2016). Larsen and colleagues

(2003) found that negative affect increased activity in the brow region (corrugator supercilii muscle) whereas positive affect increased activity over the cheek region (zygomaticus major muscle. Research has also found that higher zygomaticus activity predicted better treatment outcomes for patients with clinical depression. In addition, reduced zygomaticus major muscle activity was reported in schizophrenia patients compared to healthy participants (Wolf et al., 2006). Since there are evidence for the relationship between emotion, facial expressions and health using both the FACS and facial EMG techniques, the meta-analysis examined how cognitive reappraisal would influence the facial expression outcome with these two methodologies included.

Eye movement outcome

Eyeblink is a measure of startle response, an automatic reaction to attentional and affective characteristics of immediately preceding stimuli (Graham, 1975; Lang et al., 1990). It consists of different components, such as eyelid movement and the eyeblink reflex, which refers to a rapid and intense contraction of the orbicularis muscle (area under the eye) in response to a startling stimulus (Blumenthal et al., 2005). Previous research studies have demonstrated that negative affect amplified startle reactions, whereas positive affect inhibited them, shortly after the onset of an affective stimuli (e.g., Filion et al., 1998; Grillon et al., 1991; Lang et al., 1990; Smith et al., 2005; Vrana et al., 1988). Startle eyeblink measure are most often measured by attaching electrodes over the orbicularis oculi inferior to collect electromyographic activity. Since startle response can be precisely assessed at any time when participants are viewing stimuli, the measure possesses extremely high temporal resolution (Blumenthal et al., 2005). Consequently, when used to assess affective responses to stimuli with short latency, the startle eyeblink measure can reveal responses that are clearly attributable to the automatic processes.

Other than startle responses, researchers have also included visual gaze measures, such as fixation number or count, as well as fixation duration as some other eye movement metrics, since they are also simultaneously affected when viewing stimuli. For instance, participants in general spent longer fixation times on negative than positive stimuli (Charles et al., 2003), but positive traits might moderate this effect. Specifically, higher trait levels of hope and optimism were associated with less fixation time to dysphoric and threatening information (Kelberer et al., 2018), whereas people with higher trait of happiness spent longer time attending to positive stimuli (Raila et al., 2015). Visual gaze measures were often assessed using eye-tracking technique, which was suggested to provide accurate results in sustained visual attention even when one's behavioral reaction time to stimuli is impaired (e.g., Iacono, 1981). Both abnormal startle and visual gaze responses have been suggested as markers for different psychopathology in clinical studies, including anxiety disorders (e.g., Grillon et al., 1998; Reeb-Sutherland et al., 2009), schizophrenia-spectrum disorders (e.g., Cadenhead et al., 2000; see Clementz & Sweeney, 1990 for a review), and depression (Alghowinem et al., 2013; Emslie, 1990). With evidence showing a relationship between emotion, eye movement and health outcomes, the meta-analysis examined how cognitive reappraisal would influence the eye movement outcome with startle and visual gaze responses included.

Proposed Moderators of the Influence of Cognitive Reappraisal on Overall Physiology

Types of emotion regulation strategies. Emotion theorists have argued emotions involve coordinated changes across experiential, behavioral, and physiological response systems to facilitate our response to environmental demands (e.g., Ekman, 1992; Izard, 1977). However, existing empirical findings about the coherence of systems have been mixed. (e.g., Bradley & Lang, 2000; Edelmann & Baker, 2002; Ekman, Davidson, & Friesen, 1990; Mauss, Wilhelm, &

Gross, 2004). The current meta-analysis investigates whether the process of emotion regulation disrupts this coherence. Specifically, the types of emotion regulation strategies could create different experiential, behavioral, and physiological changes. One potential reason is that different regulation strategies modulate different stages of the emotion-generative process, which are associated with different experiences. For instance, cognitive reappraisal and attentional deployment are antecedent-focused regulation strategies that occur early in the emotion-generative process. The goal of cognitive reappraisal is to modify how one appraises a situation, whereas attentional deployment aims to shift one's attention to the significance of the situation to alter the experiential, behavioral and physiological responses. On the other hand, expressive suppression is a response-focused modulation strategy, which occurs late in the emotion-generative process, such that experiential, behavioral, or physiological responses would have already been initiated when participants are instructed to suppress. This form of regulation usually targets ongoing experiences with the goal of inhabitation (Gross, 1998b). The conscious process of inhibiting emotional experience and expressions by suppression would create more changes in facial expressions (i.e., showing fewer facial expressions) but the already activated physiological arousal is hypothesized to be more difficult to change. I therefore hypothesized that physiological responses would be different depending on the types of emotion regulation strategies.

Emotion regulation studies have compared the effect of cognitive reappraisal on different outcomes with different strategies. For example, one could use expressive suppression, which is consciously inhibiting one's own emotionally expressive behavior while emotionally aroused (e.g., Butler et al., 2003, 2006; Denson, Moulds, & Grisham, 2012), distancing, distraction or attentional deployment, which involves shifting or changing one's attention away from the

emotionally salient aspects of an emotion-eliciting event (e.g., Davis, Quiñones-Camacho, & Buss, 2016; Thiruchselvam et al., 2011; Urry, 2010). Another strategy is rumination, which refers to having repetitive thoughts around a common theme, without the immediate environmental demands for those thoughts (Martin & Tesser, 1996). Acceptance, an approach seen in Acceptance and Commitment Therapy (ACT: Hayes, 2004) to accept one's emotions has also been studied in the emotion regulation literature (e.g., Hofmann, Heering, Sawyer, & Asnaani, 2009). All these studies also included a control condition without any presentation of regulation instruction. A previous meta-analysis suggested that relative to attentional deployment, distraction, and expressive suppression, cognitive reappraisal was the most effective strategy for emotional change (Webb et al., 2012b). Further, cognitive reappraisal is suggested to have lower physiological cost than expressive suppression (see Gross, 2002 for a review). Consistent with these previous research findings, I hypothesized that the effect of cognitive reappraisal would be larger comparing to all the other types of regulation strategies (i.e., no regulation instruction, suppression, mindfulness, acceptance, distraction, distancing, affect labeling, rumination.) and specifically largest compared to expressive suppression. Since studies have predominantly compared reappraisal to suppression and less so on other regulation strategies, I did not have a specific hypothesis about how the effect on physiology differs among the other strategies.

Types of emotion regulated. Other than specific types of regulation strategies that might create differential effects in behavioral and physiological change, theoretical factors of a study, such as different types of emotions being regulated could also create differences across systems. Surprise and anxiety was found to have a stronger cognitive component (e.g., Mauss et al., 2004) than other emotions like fear. Therefore, cognitive reappraisal could be more relevant for

emotions that require more cognitive processing, which could potentially create a bigger effect on those emotions than emotions that require less cognitive processing. In addition, cognitive reappraisal is mostly used in negative situations than in positive because it involves reframing of perspectives that are more applicable in negative situations. This stems from the idea that one would reappraise situation or stimulus when it was initially appraised as challenging, harmful, or threatening (Lazarus & Folkman, 1984). It is therefore seen as an integral component in treatment of clinical disorders, which are more likely to be associated with negative thoughts and emotions. The effect of cognitive reappraisal is therefore also predicted to be greater when reappraising negative emotions in general than in positive. Emotion regulation studies vary in the types of emotions induced and therefore the types of emotion for participants to regulate. Although most regulation studies induced negative emotions by presenting images from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008), film clips or having participants recall a negative experience (e.g., Germain & Kangas, 2015; Hofmann et al., 2009; Koval, Butler, Hollenstein, Lanteigne, & Kuppens, 2015; Meyer et al., 2014; Ortner, 2015; Wilhelm & Roth, 2001), studies have also induced positive emotions using similar techniques (e.g., Allard & Kensinger, 2018; Asnaani, Sawyer, Aderka, & Hofmann, 2013; Dillon & LaBar, 2005; Giuliani, McRae, & Gross, 2008; Lalot, Delplanque, & Sander, 2014). As mentioned earlier, there is some evidence for autonomic specificity in valence of emotion, such that negative emotions in general are associated with stronger physiological responses than positive emotions (see Cacioppo et al., 2000; Taylor, 1991 for reviews). Because experiencing negative or positive emotions is associated with different physiological responses, it is also predicted that reappraising negative or positive emotions would be associated with differential effects on physiology. Specifically, as negative emotions are associated with stronger physiological

responses, and individuals often try to decrease negative emotions, I hypothesized that cognitive reappraisal would have a larger effect on physiology for regulating negative than positive emotions.

Emotion Regulation Goal. Numerous emotion regulation studies employ more than one emotion regulation instruction such that participants would not only upregulate, but also downregulate their emotions. For instance, participants would be instructed to view, increase (upregulate), and/or decrease (downregulate) their emotions towards different emotional stimuli to compare the behavioral, emotional and physiological changes among instructions. Previous research has suggested divergent consequences of up- and down- regulation for emotional and physiological outcomes in both negative and positive emotions (Giuliani et al., 2008b; Jackson et al., 2000a; Kunzmann et al., 2005). For instance, downregulating negative emotions using suppression would be associated with a decrease in negative emotional experiences, smaller startle eyeblinks and decreased corrugator activity, whereas upregulating negative emotions would be associated with an increase in negative emotional experiences, larger startle eyeblinks and increased corrugator activity (Jackson et al., 2000a). Further, there has been neural evidence suggesting up- and down- regulation of negative emotion using cognitive reappraisal recruited different regions of the brain (Ochsner et al., 2004). Since upregulation and downregulation of emotions are two different emotional processes that would bring different emotional change (e.g., upregulating negative emotions would be associated with an increase in negative emotions, whereas downregulating negative emotions would be associated with a decrease in negative emotions), I predicted that upregulation and downregulation of emotions using cognitive reappraisal would also create differential effects on physiological change. Specifically, I predict that the changes would be in opposite directions such that overall physiological reactivity would

decrease when downregulating emotions, but overall physiological reactivity would increase when upregulating emotions. In addition, cognitive reappraisal is mostly utilized in downregulation of negative emotions and less so in upregulation, as reframing of the situation is less likely to be needed but other strategies could also be utilized when increasing negative (e.g., rumination) or positive emotions (e.g., benefit finding). I therefore predicted that the strength of the effect of cognitive reappraisal on physiological change would also be different depending on upregulation or downregulation of emotions. Specifically, I predicted to see a stronger effect of cognitive reappraisal on physiology when downregulating negative emotions. Under these theoretical assumptions and predictions that there would be differential physiological effects by using reappraisal based on up- or down-regulation of emotions, studies investigating upregulation of emotions should not be combined with those that investigated downregulation of emotions. Therefore, the effect sizes of results that involve up- or down-regulation of emotions were be averaged but examined separately.

Report and Participant characteristics.

Publication status. Publication bias, a tendency toward preparation, submission and publication of research findings based on the nature and direction of the research results, exists in all fields of research. Studies with statistically significant findings are more likely to be accepted for publication (Dickersin, 2005), and published research are more likely to be over-represented in meta-analysis. Studies with small or null effects tended to be ignored or go unpublished, resulting in only being aware of statistically significant effects in the scientific community (Rosenthal, 1987). To address this bias, researchers were contacted for any unpublished data that they might have. Master's and Doctoral theses and dissertations were categorized as unpublished. Since published and statistically significant findings receive more attention in the

scientific community, I hypothesized that published research reports will produce larger effect sizes than unpublished reports.

Age. Older age is associated with losses in numerous areas, such as cognitive and health decline (Carstensen et al., 1998). Despite these losses, older age is also related to increases in subjective well-being (Carstensen, 1995; Charles & Carstensen, 2014). Both cross-sectional and longitudinal studies have found age-related decreases in negative affect from early to midlife (e.g., Carstensen, Pasupathi, Mayr, & Nesselroade, 2000; Charles, Reynolds, & Gatz, 2001; Mroczek & Kolarz, 1998). Studies have also reported that positive affect is relatively stable in older adults (Charles et al., 2001), or slightly increases (Mroczek & Kolarz, 1998) and is at higher levels than younger adults (Stawski et al., 2008).

The socioemotional selectivity theory (SST) addresses how and why emotional well-being changes across the lifespan and posits that as we age, we monitor time and adjust the time horizons, which influence how we prioritize our goals (Carstensen, 1992, 2006). Older adults are more selective in deciding which activities to pursue and one of the goals they prioritize is the focus on deriving meaning and investing in emotional significance of the events. The Strength and Vulnerability Integration model endorses the SST, that aging is associated with motivational shifts such that people focus on positive rather than negative emotional experiences (Charles, 2010). This model also suggests older adults often engage in more emotion regulation strategies than younger adults to reduce negative affect and maintain or even enhance positive affect. Previous research also suggested that certain emotion regulation strategies might be more effective than some other for older age. For instance, older adults deployed more attention to positive than to negative information (Isaacowitz et al., 2008). They also showed larger decreases in negative emotion than younger adults when asked to focus their attention away from

an upsetting film to a positive autobiographical memory (Phillips et al., 2008). However, older adults were less successful in using cognitive reappraisal to decrease unpleasant emotion compared with younger adults (Opitz et al., 2014). These findings suggested attentional deployment might be more effective than reappraisal for older people in regulating emotions. Since there seem to be age differences in the use and effectiveness of cognitive reappraisal on emotional outcomes, age is expected to moderate the link between cognitive reappraisal and physiology. Specifically, I hypothesized that older participants would have a smaller effect from using cognitive reappraisal on their physiological outcomes.

***Gender*.** Gender differences may also moderate the relation between emotion regulation and physiological outcomes. Current literature indicated a difference in emotional experience such that men reported experiencing less frequent and less intense emotions on a daily basis (Grossman & Wood, 1993; Schimmack et al., 2002). In addition, men reported less emotional reaction to affective stimuli and affective memories (Bradley, Codispoti, Sabatinelli, et al., 2001; Chentsova-Dutton et al., 2007).There were also gender differences in selecting and using different strategies to regulate their emotions. For instance, men were more likely to use expressive suppression (Gross & John, 2003) but not rumination (Thomsen et al., 2005) compared to women. On the other hand, women were more likely to report using rumination and social support (Blanchard-Fields & Coats, 2008). These differences may be the result of adhering to gender roles or gender differences in socialization (Nelson et al., 2007). For example, parents tend to talk about emotions more with their daughters than their sons (Fivush et al., 2000), which could in turn affect their choice of regulation so that men were more likely to suppress than express.

Interestingly, previous emotion regulation studies indicated that men and women reported using cognitive reappraisal with comparable frequency in everyday life (Gross et al., 2007; Gross & John, 2003). However, these studies only employed self-report measures, which are prone to memory and desirability response biases. An fMRI experimental study of cognitive reappraisal found gender differences in neural responses, such that men showed lesser increases in prefrontal regions that are associated with reappraisal, suggesting men may expend less effort in using cognitive reappraisal (McRae et al., 2008). Yet, the effect of cognitive reappraisal on other physiological outcomes is still largely unknown.

The gender differences in the general bodily development and composition could also influence the effectiveness of emotion regulation on the physiological system. For instance, as men and women age, myocardial mass is better preserved in women (Olivetti et al., 1995) and women are associated with improved cardiac function and survival in heart failure studies (Adams et al., 1999; Ghali et al., 2003). Further, research suggested a predominance of sympathetic vascular regulation in men compared with a dominant parasympathetic vascular regulation in women, which is protective during periods of cardiac stress and incidents (Evans et al., 2001). Altogether, these studies suggest there are gender differences in a variety of individual processes, including emotional experiences, choice of emotion regulation strategies, and neural reactivity in cognitive reappraisal and physiology. However, how gender would moderate the relation of a combination of these processes, for instance, the relation between cognitive reappraisal and physiology is still unknown. This meta-analysis therefore examined this question. Consistent with previous research suggesting a decrease in neural response in cognitive regulation in men, I hypothesized that men would display a smaller effect of reappraisal on physiological outcomes.

Method

Strategy for Searching the Literature

The current meta-analysis followed reporting guidelines outlined by The PRISMA Group (Moher, Liberati, Tetzlaff, & Altman, 2009; see Appendix A and B for a flowchart and checklist respectively). Studies on cognitive reappraisal and physiological outcomes were retrieved by searching three electronic databases: *PsycINFO, ProQuest Dissertation and Theses A&I* and *PubMed* in May of 2018, and December of 2019. The following search terms were used to scan the abstract of documents in the three electronic databases: reapprais* AND physiolog* OR "heart rate" OR "blood pressure" OR "skin conductance" OR respiratory OR respiration OR face OR facial OR EMG OR finger OR cardiovascular OR cardiology OR cardiological OR ear OR pulse OR somatic OR thoracic OR pupil OR gaze. This search retrieved 689 documents across the three databases. A summary of these searches is presented in Table 1. A second search was conducted in December 2019 with additional variable names, including “temperature”, “startle”, “sympathetic activation”, “parasympathetic activation”, “sympathetic withdrawal”, “parasympathetic withdrawal”, “autonomic”, “autonomic imbalance”, “autonomic control”, “autonomic flexibility”, to better capture any other physiological outcomes that may have been missed in the first electronic database search. These searches collected 827 results.

Inclusion Criteria

Studies were included if they met the five initial screening criteria during the abstract screening process. Specifically, a document was retained if it (1) appeared not to be a systemic review or meta-analysis, (2) written in English, (3) was a sample of healthy (nonclinical) participants, (4) examined cognitive reappraisal, and (5) included at least one physiological measure of any kind. Next, the “Method” and “Results” sections of all the potentially relevant

articles were reviewed thoroughly again with the five criteria mentioned to determine if they have met the inclusion criteria as elaborated below.

First, a study should include empirical findings with a sample of healthy and nonclinical participants. Though recent research has suggested a bidirectional relationship between the brain and the gut, such that physiological expressions like alterations in gut microbiota could affect emotional behaviors (Tillisch et al., 2013), the current study specifically focuses on how manipulating strategies of emotion regulation would influence physiology. Therefore, experimental but not observational studies were included. Further, an experimental manipulation of cognitive reappraisal and at least one physiological measure should also be present, as they are the main variables of interest in this meta-analysis. Given that the primary focus of the meta-analysis is to compare the use of cognitive reappraisal with other emotion regulation strategies on physiological outcomes, we included contrasts comparing reappraisal with different strategies from the process model of regulation (Gross, 1998a), such as expressive suppression, distancing, and a control condition without explicit regulation. Studies examining neural correlates of emotion regulation or measures of the central nervous system (e.g., fMRI, EEG measures) were excluded, as these were not within the scope of the current meta-analysis. However, neuroimaging studies were included if they also included physiological measures in their studies (e.g., Meyer et al., 2014). Because of the specificity of the construct of cognitive reappraisal and physiological measures, this information was usually defined and explained in the "Method" section, which was thus examined first.

There were two types of comparisons that could provide relevant effects of cognitive reappraisal, including (1) a between-subject comparison in which participants were instructed to use cognitive reappraisal compared to those who were instructed to use another emotion

regulation strategy, or (2) a within-subject comparison between trials that participants were instructed to use cognitive reappraisal and trials that participants were instructed to use another emotion regulation strategy. We included all relevant comparisons if studies included more than one type of emotion regulation strategy.

Third, only research reported in English were included in this meta-analysis because of the practical difficulty of translation. Out of the 827 full texts retrieved in the literature search, 3 of them were non-English. It is important to note that this criterion might limit studies conducted in certain geographical locations, which in turn could influence the generalizability of findings to non-English speaking regions.

Exclusion criteria

Studies with participants who were clinically diagnosed or has had a clinical diagnosis in the past were excluded because individuals with psychological disorders were reported to have different patterns of emotion regulation and those studies have been reviewed before (see Watkins, 2008 for a review). Individuals with intellectual or physical disabilities were also excluded. Since the current analysis focused on the effectiveness of cognitive reappraisal on physiological outcomes, which signifies the importance of actual implementation of reappraisal and physiological changes, studies that only used a trait measure of cognitive reappraisal were excluded.

Screening procedure

Abstracts of all identified articles that met with the inclusion and the full articles were all reviewed independently by trained undergraduate assistants and me as a separate reviewer. These review processes eliminated duplicates and articles that did not meet the full inclusion criteria

listed below. Any disagreements between the two reviewers were resolved through discussion and consensus.

Coding Protocol

Five types of information necessary to collect for the current research question on the effectiveness of reappraisal on physiological outcomes and moderator analyses are as followed: (1) report characteristics, (2) setting characteristics, (3) sample characteristics, (4) information about the process of administering cognitive reappraisal, and (5) information about the measurement of the physiological variable(s). A complete list of information coded in research reports could be seen in Table 2.

Coding Procedure

Trained undergraduate research assistants and I independently coded each study. Any disagreement was resolved by discussion. When discrepancies could not be resolved, an independent expert in meta-analysis was consulted. An inter-rater reliability index will not be calculated, as we feel confident that having each study coded four times independently and resolving disagreements through discussion together as a team should provide highly reliable data (Rosenthal, 1987). Throughout the coding process, the first author and the trained research assistants ensured effect size is based on independent samples and coding was carried out for each independent sample. For instance, results for the two genders were coded separately; only results for nonclinical participants were included when an independent sample provided data for both clinical and nonclinical participants.

Categorical codes were coded into one or more predefined groups that best described that particular effect size of interest. There was always an option of "Other" along with an option to specify why the effect size was not best coded into any of the predefined categories. Having the

"Other" option enabled the coders to code more flexibly without limiting themselves to choose among categories that might not describe the information very well.

Effect Size Calculation

An effect size is a measure that quantifies the size of a relation between two variables or the difference between them (Coe, 2002). A *d*-index of effect size, a standardized difference between means from two independent groups, was chosen to represent the relation between cognitive reappraisal and physiological outcomes, as cognitive reappraisal was experimentally manipulated and used to compare against other emotion-regulation strategies. It is defined as:

$$d = \frac{\bar{X}_{CR} - \bar{X}_{C}}{SD_{pooled}}$$

in which $\bar{X}_{CR}$ and $\bar{X}_{C}$ represents the mean scores of physiological response from using cognitive reappraisal strategy and the comparison strategy respectively. The population standard deviations are not assumed to be the same, therefore using the pooled standard deviation. It is defined as:

$$SD_{pooled} = \sqrt{\frac{(n_{CR} - 1)SD_{CR}^2 + (n_C - 1)SD_C^2}{n_{CR} + n_C - 2}}$$

in which n_{CR} and n_c are the sample sizes from the two groups and S_{CR} and S_C are their standard deviations (Borenstein, Hedges, Hannah, & Higgins, 2009).

If emotion regulation adopted a within-subject design, such that participants were matched to themselves and not to an independent group to compare the effect of cognitive reappraisal with other strategies. The sample estimate of *d* was defined as:

$$d = \frac{\bar{X}_{pre} - \bar{X}_{post}}{SD_{pooled}} \ ,$$

in which $\bar{X}_{pre}$ and $\bar{X}_{post}$ represents the mean scores of physiological responses before and after using cognitive reappraisal strategy to regulate. The standard deviation within individual was computed from the standard deviation of the difference, using:

$$SD_{diff} = \sqrt{\frac{SD_{CR}^2 + SD_C^2 - 2 * r * SD_{pre} * SD_{post}}{n}},$$

in which *r* is the correlation between pre-regulation scores and post-regulation scores within the individual.

In this meta-analysis, the effect sizes quantified the magnitude and direction of the difference in different physiological outcomes between cognitive reappraisal and comparator conditions (e.g., other emotion regulation strategies). If a Cohen's d-index was not reported, they were calculated from the descriptive or inferential statistics the authors provided. If information necessary to calculate the effect sizes was missing, authors of the studies were contacted directly for the missing information. In addition to using Cohen's conventional benchmarking for assessing effect sizes, the current meta-analysis also interpreted the magnitude of effect sizes based on empirical benchmarks. Cohen's broad categories of small, medium, and large effect sizes have been suggested to be problematic since the normative distribution used for comparison might not be appropriate for certain outcomes (Lipsey et al., 2012). For instance, effect sizes of intervention studies that change the incidence of heart attacks were below .20 (McCartney & Rosenthal, 2000), which according to the Cohen's guidelines would be categorized as a "small" effect. However, these effects correspond to reducing the incidence of heart attacks by about half, which are of significant practical significance. Therefore, comparisons of effect sizes in the current meta-analysis would also use normative distributions

of effect sizes for comparable physiological outcome measures from comparable emotion regulation studies. Altogether, the current meta-analysis combined interpretations based on both conventional and empirical benchmarks to balance emerging best practices with established reporting expectations, such that effect sizes could be translated into more practically meaningful marker of impact (Lipsey et al., 2012).

A wide range of studies included more than one physiological measurement, for instance, electrodermal measures, electromyographical measures and cardiovascular measures, in which sometimes were combined as a composite measure to represent regulation outcome. Therefore, it could be difficult to determine whether each specific measure reflected success or failure at emotion regulation. However, the expected direction of effect for each measure was usually clearly hypothesized in the studies and this information was used to determine the direction of the coding of effect sizes. If hypotheses regarding physiological changes were not clearly stated, effect sizes were coded on the basis of previous evidence on the expected direction of effect for the induced emotion (see Kreibig, 2010 for a review). Since emotion regulation is a process, we used data from the start of the regulatory period (e.g., when stimulus and instruction to regulate were shown to participants) to the closest possible end time of the regulatory period (e.g., once the stimulus and instruction to regulate were not shown). When physiological outcomes were measured at multiple time points within the regulatory period, an average effect size was computed.

Since *d* has a slight bias that tends to overestimate the absolute value of the standardized mean difference of studies (Borenstein et al., 2009), a simple correction factor *J* will be applied to convert from *d* to Hedges' *g* for both between- and within-subjects studies (Hedges, 1981). The approximation is defined as:

$$J = 1 - \frac{3}{4df - 1},$$

in which the *df* is the degrees of freedom used to estimate the pooled standard deviation ($n_{CR} + n_C - 2$). This correction factor would then be multiplied by *d*, to achieve an unbiased estimate Hedges *g*.

Analysis Plan

Analyses were conducted using the *robumeta* package in R-Studio. A random-effects model instead of a fixed-effect model was chosen for the meta-analysis. A fixed-effects model assumes all studies in the meta-analysis are functionally identical and sampling error is the only source of error in a study. It assumes that there is only one "true" effect size in the population and also across studies in the meta-analysis (Borenstein et al., 2009). In contrast, a random-effects model assumes that not all studies are functionally identical, and error could come from not only sampling, but also from study methodologies or characteristics. Therefore, the true effect size may differ across studies and the model estimates the mean of a distribution of true effect sizes (Borenstein et al., 2009). Under this theoretical assumption, the observed differences in true effect sizes of cognitive reappraisal on physiological outcomes would differ across studies and in the population, based on sampling error as well as theoretical and/or methodological reasons. In existing emotion regulation research, the amount of between-study variation is high, since studies have used different design, manipulated different regulation strategies, instructions and emotional stimuli. Therefore, based on the theoretical assumption that more than one true effect would exist across studies as well as in the population, a random-effects model was adopted and conducted in the current meta-analysis.

Given than numerous experiments contained multiple physiological measures from participants, resulting in dependent effect sizes, the robust variance estimation method (RVE: Hedges et al., 2010), a random-effects meta-analytic technique was adopted to address the challenges of handling dependent effect sizes. Specifically, this method estimates the average effect sizes and meta-regression coefficients, such as conducting planned contrasts between different moderator categories by aggregating effect size estimates, or to collect information about the correlation between dependent effect size estimates. This method also provides valid meta-regression coefficients estimates for small samples with a small sample adjustment (Tipton & Pustejovsky, 2015).

Effect size weighting

Weights are determined by a number of factors, including the number of effect sizes per study, the sample size of each study, the average variances across effect sizes within a study, and the estimate of the between-study variability (τ^2). RVE comes with a general set of weighting options, including correlated effects, which are used when studies report multiple outcomes measured on the same individuals, or hierarchical effects that are used when outcomes are collected on different groups of individuals (Hedges et al., 2010). Since a majority of the studies reported multiple physiological outcomes measured on the same individuals, a correlated effects model was used in the current meta-analysis.

Testing for Moderators

For categorical moderators, moderators with two levels (e.g., gender) were dummy coded and entered into meta-regression models. For categorical moderators with more than two levels, Approximate Hotelling-Zhang (AHZ) test was conducted with small sample correction tests using the *clubSandwhich* R package (Pustejovsky, 2017). This test produces an *F*-value that

indicates whether there is a difference among all levels of the moderator. The AHZ test produces atypical degrees of freedom, and curious readers are encouraged to see Tanner-Smith et al. (2016) for a more detailed explanation. As mentioned above, τ^2 represents an estimate of the between-study variability, and the calculation of τ^2 relies on the value of correlation among the dependent effect sizes. When correlation is unknown, a default correlation of .80 is suggested but additional sensitivity analyses is recommended for this assumed value (Borenstein, 2009). Sensitivity analyses with correlations of 0 and 1 were thus also tested and any changes of results among these two correlations would be reported. For continuous moderators such as age, they were entered into the meta-regression model without transformation. A slope that significantly differs from zero indicates a significant relationship between a moderator and the sizing of the effect of cognitive reappraisal. For instance, if a significant positive coefficient was observed for the cardiovascular and respiratory outcome, it would represent a significant positive impact of cognitive reappraisal on the corresponding outcome. A list of moderator variables and the corresponding hypotheses can be found in Table 3.

Results

Retrieving Effect Sizes

As seen in Figure 1, 173 research reports that met the inclusion criteria were identified, including 13 unpublished dissertations. Out of these 173 selected articles, 53 reported the necessary information for the current meta-analysis after full-text screening, and the corresponding authors of the other 87[2] reports were emailed. 18 responses were received which included the necessary data to calculate effect sizes, resulting in a final sample of 71 articles. Since some of the articles included multiple experiments using independent samples, the total

[2] I was not able to get in touch with the authors for the remaining 33 reports.

number of independent experiments was 73. I calculated *ES* = 571 effect sizes from these 73 experiments, with the average independent sample contributing 8 effect sizes. Table 4 describes the different sample characteristics of every study included in the meta-analyses.

Summary Effect

Overall, there was not a statistically significant impact from cognitive reappraisal on all physiological outcomes, compared with using other regulation strategies combined, $g = 0.075$, 95% CI [-0.09, 0.24], $p = 0.37$. However, it is important to note that there was a large amount of heterogeneity between studies, $I^2 = 94.16$. Considering the difficulty in drawing meaningful conclusions and interpretations from results due to the varied nature of physiological outcomes, I therefore grouped physiological indices that belong to the same domain of physiological outcomes (e.g., heart rate and heart rate variability belongs to cardiovascular; skin conductance level and skin conductance response as electrodermal) and performed separate meta-analyses for each of these domains. Four outcome categories were formed, including outcome 1: cardiovascular and respiratory, outcome 2: electrodermal, outcome 3: facial expression, and 4: eye movement outcome. Separate summary effects and moderator analyses were then computed for each outcome[3]. Results found that cognitive reappraisal significantly impacted the eye movement outcome, $g = 0.52$, 95% CI [0.01. 1.03], $p = 0.045$ but not the cardiovascular and

[3] Cardiovascular and respiratory outcome includes heart rate, (low and high) heart rate variability (HRV), heart rate acceleration, interbeat interval, pre-ejection period, respiration depth, respiration rate, finger pulse, finger pulse transmission time, ear pulse, ear transmission time, respiratory sinus arrhythmia, heart rate inertia, cardiac output, total peripheral resistance, heart rate deceleration, respiratory amplitudes; Electrodermal outcome includes skin conductance level, skin conductance response, skin conductance response amplitude, electrodermal activity; finger temperature, finger temperature slope, skin conductance rise time to peak time; Facial outcome includes electromyography (corrugator, zygomaticus, levator, and orbicularis oculi muscle groups), facial action units (overall and mean levels of orbicularis oculi, zygomaticus major, and pain related muscle activities); Eye movement outcome includes startle eyeblink, reflexes, responses, reactivity or amplitude, pupil dilation or size, fixation count or duration.

respiratory, electrodermal, or facial expression outcomes (cardiovascular and respiratory: g = -0.11, 95% CI [-0.41. 0.19], p = 0.45; electrodermal: g = 0.087, 95% CI [-0.14. 0.32], p = 0.44; facial expression: g = -0.06, 95% CI [-0.38. 0.25], p = 0.67). However, the I^2 of all four outcomes ranges from 91.10 to 95.10 again suggesting a large amount of variation among studies due to heterogeneity rather than chance (Higgins & Thompson, 2002; Higgins et a., 2003). As suggested by Borenstein et al. (2009), the summary effect size should not be interpreted as meaningful, as information from each study or the extent to which effect sizes vary between studies is lost in the aggregated effect size. Instead, it is advised to use I^2 as a criterion to decide whether a subgroup analysis or moderator analysis should be performed. I therefore conducted a series of moderator analysis for each outcome separately to explore these moderators. All results from the moderator analyses could be seen in Table 5.

Moderators Analyses

Emotion regulation strategies

The type of emotion regulation strategy was a significant moderator of the effect size for only the eye movement outcome, $F(3.97) = 6.93$, $p < .001$, [cardiovascular and respiratory: $F(4.14) = 0.23$, $p = 0.93$; electrodermal, $F(0.64) = 0.54$, $p = 0.79$; facial, $F(2.18) = 0.19$, $p = 0.95$]. Follow up contrasts showed that the estimated average effect of cognitive reappraisal was significantly larger than that of acceptance for the eye movement outcome, b = -0.05, 95% CI [-0.05 -0.05], $t(1) = 0.00$, $p < .001$. Importantly to note, however, the number of independent studies contributing to each strategy was very low and each strategy was unbalanced, resulting in degrees of freedom below 4. In meta-regression, the estimates of the results with degrees of freedom below 4 are not reliable (Tipton, 2015). Due to low degrees of freedom, I created two new categories named “non-reappraisal” (i.e., suppression, acceptance, affect labeling,

rumination, attentional deployment) and "no-strategy" (i.e., no regulation or control condition) categories to test if they would moderate the effect of reappraisal on all physiological outcomes. This new classification of the strategy moderator also did not produce a significant result for any outcome, [cardiovascular and respiratory: $F(30.1) = 0.39$, $p = 0.68$; electrodermal, $F(23.5) = 0.38$, $p = 0.67$; facial, $F(17.8) = 0.84$, $p = 0.45$; eye movement: $F(8.75) = 2.21$ $p = 0.17$].

Types of Emotion Regulated

The type of emotion regulated was a significant moderator of effect size for the electrodermal outcome, $F(4.43) = 203$, $p < .001$, as well as the eye movement outcome, $F(4.75) = 8.81$, $p = 0.03$. Specifically, the effect of reappraisal on the electrodermal outcome was larger when regulating negative emotions compared with positive emotions, $b = 2.15$, 95% CI [-3.35, -0.64], $t(23.93) = -20.8$, $p = .002$, as well as when compared with regulating both positive and negative emotions, $b = -2.01$, 95%, CI [-2.15, -1.98], $t(2.43) = -0.99$, $p < .001$. The effect of reappraisal on the eye movement outcome was also larger when regulating negative compared with positive emotions, $b = 0.36$, 95%, CI [0.002, 1.19], $t(12) = 2.19$, $p = 0.005$, as well as when compared with regulating both negative and positive emotions, $b = 0.56$, 95%, CI [0.28, 1.65], $t(12) = 0.02$, $p < .001$. The type of regulated emotion was not a significant moderator for the cardiovascular and respiratory outcome, $F(4.67) = 0.74$, $p = 0.53$, or the facial outcome, $F(5.76) = 0.26$, $p = 0.86$.

Emotion Regulation Goal

Emotion regulation goal was a significant moderator of effect size for the cardiovascular and respiratory outcome, $F(21.5) = 1.68$, $p = .03$. Specifically, the effect of reappraisal was larger when the emotion regulation goal was unclear than when the goal was quantitative, $b = 0.63$, 95%, CI [0.03, 1.25], $t(26.6) = 2.16$, $p = 0.03$. For the electrodermal outcome, the effect of

reappraisal was marginally but nonsignificantly larger when the goal was unclear than when it was qualitative, $b = 0.32$, 95% CI [0.03, 0.90], $t(23.47) = 1.91$, $p = 0.06$. Emotion regulation goal was not a significant moderator for the facial outcome, $F(2.99) = 0.44$, $p = 0.74$, or eye movement outcome, $F(2.36) = 0.085$, $p = 0.92$.

Publication Status

Publication status was not a significant moderator for the cardiovascular and respiratory outcome, $F(17.8) = 0.95$, $p = 0.40$, electrodermal outcome, $F(12.8) = 1.03$, $p = 0.39$, eye movement outcome, $F(10.2) = 2.77$, $p = 0.11$, or the facial outcome, $F(1.77) = 1.91$, $p = 0.36$.

Age

Age was a significant moderator for only the cardiovascular and respiratory outcome, $F(2.7) = 53.5$, $p = 0.0075$, where effect sizes were larger in studies with a lower age in the sample. Specifically, for every one year increase in average age, the predicted effect size of cognitive reappraisal decreased by 0.08, $b = -0.08$, 95% CI [-0.12, -0.04], $t(2.7) = -7.31$, $p = 0.007$. Age was not a significant moderator for the electrodermal outcome, $F(1.73) = 0.25$, $p = 0.67$, facial outcome, $F(1.61) = 0.54$, $p = 0.55$, or eye movement outcome, $F(2.78) = 0.47$, $p = 0.55$.

Gender

Gender was not a significant moderator for the cardiovascular and respiratory outcome, $F(10.5) = 0.82$, $p = 0.39$, electrodermal outcome, $F(6.59) = 0.95$, $p = 0.36$, facial outcome, $F(5.72) = 0.01$, $p = 0.92$, or eye movement outcome, $F(4.62) = 0.00$, $p = 0.99$.

Other moderators:

Lastly, I investigated two exploratory moderators, including the types of induction task and motivations in regulation. The only significant moderator was motivation for the eye

movement outcome, $F(8.00) = 0.00$, $p < .001$. Specifically, the effect of cognitive reappraisal was significantly larger when the emotional stimuli activated both the appetitive or defensive motivation systems, compared to when only the approach motivation system was activated, $b = 0.62$, 95% CI [1.854, 1.85], $t(1) = 842$, $p < .001$.

Publication bias

Fail-safe N

Rosenthal (1987) suggested a 'Fail-safe N' method to assess the potential for publication bias to have influenced the results of a meta-analysis. This method calculates the number of additional missing studies averaging null results, or in which the intervention effect was zero, that would have to be added to the meta-analysis to reduce the significance level and make the effect size estimate non-significant (Borenstein et al., 2009; Rosenthal, 1987). Relatedly, the Orwin's 'Fail-safe N' method calculates the number of missing studies to bring the given set of effect sizes to a "trivial" point, that is the smallest effect deemed to be of substantive importance (Orwin, 1983).

For the current dataset of the cardiovascular and respiratory outcome, Rosenthal's fail-safe N was 13, suggesting there would need to be 13 studies with mean effect size of zero to be added to make the summary effect statistically non-significant. Orwin's fail-safe N was 39, suggesting 39 studies with mean effect size of zero would need to be added in order to cut the summary effect to $g = -0.07$ (half of the original effect size) for this meta-analysis. For the electrodermal outcome, Rosenthal's fail-safe N was 12 while Orwin's fail-safe N was 29, suggesting 12 studies with mean effect size of zero would be needed and added to make the summary effect statistically non-significant, as well as 29 studies to cut the summary effect in half to $g = 0.04$. For the facial outcome, Rosenthal's fail-safe N was 36 while Orwin's fail-safe N

was 24, suggesting 36 studies with mean effect size of zero would be needed to make the summary effect statistically non-significant, as well as 24 studies to cut the summary effect in half to g = -0.03. Lastly, for the eye movement outcome, Rosenthal's fail-safe N was 353, suggesting there would need to be 353 studies with mean effect size of zero to be added to make the summary effect statistically non-significant. Orwin's was 15 suggesting 15 studies with mean effect size of zero would need to be added in order to cut the summary effect to g = 0.27.

Funnel Plots

Another way to test publication bias visually and display the relationship between study size and effect size is the funnel plot. Effect sizes are plotted on the X axis and the standard errors are on the Y axis. Larger studies appear toward the top of the graph and generally cluster around the mean effect size, whereas smaller studies appear toward the bottom and tend to be spread across a wide range of values. Studies will be distributed symmetrically around the mean effect size, indicating random sampling error if there is no publication bias. On the other hand, if the plot appears asymmetrical that more studies are present on the bottom right than left, or studies appear to be systematically missing on one side, publication bias might be present (Borenstein et al., 2009). Figure 2 to 5 displays the funnel plots for all outcomes. All the plots do not seem visually symmetrical, yet the majority of studies seemed to stay in symmetry. I then conducted the Egger regression test to test for inferential significance for the funnel plots (Sterne et al., 2000). Although the test for symmetry was significant for the cardiovascular and respiratory outcome, z = -2.94, p = 0.003, the test statistic was negative, indicating that studies with increased standard error had smaller effect sizes. Test for symmetry was not significant for the other three outcomes, (Outcome 2: z =-0.0079, p = 0.99, Outcome 3: z = 1.27, p = 0.20, Outcome 4: z = 1.63, p = 0.10).

Trim-and-fill

The trim-and-fill method estimates potentially missing studies due to publication bias in the funnel plot and adjusts the overall effect estimate (Borenstein et al., 2009; Duval & Tweedie, 2000). This method trims the studies that cause asymmetry or suppresses the studies with the most extreme effect sizes either on the left or on the right side, then fills imputed missing studies on the opposite, less favorable direction in the funnel plot based on the bias-corrected overall estimate (Borenstein et al., 2009; Shi & Lin, 2019). For the current study, the effect sizes were imputed on the right side of the plot for the cardiovascular and respiratory, electrodermal, and eye movement outcomes, whereas on the left for the facial outcome. The trim-and-fill unbiased estimate of the effect sizes were all larger than the estimate using the original dataset except for outcome 2, (cardiovascular and respiratory: from g = -0.12 to -0.43, 11 effect sizes imputed; electrodermal: 0.09 unchanged, no effect size imputed; facial: -0.06 to -0.40, 8 effect sizes imputed; eye movement: 0.53 to 0.72, 3 effect sizes imputed). The $L0$ and $R0$ estimator were both recommended to calculate the theoretical p value of publication bias (Duval & Tweedie, 2000). Results found significance in the $L0$ estimator for the cardiovascular and respiratory outcome, p = .003 but not the $R0$ estimator, p = .08. No publication bias significance was found for the electrodermal, facial, and eye movement outcomes, all ps > .40.

All three methods of assessing publication bias provided complex insights, specifically, the trim-and-fill method but not the funnel plots indicated significant bias for the cardiovascular and respiratory outcome. It is important to note that the trim-and-fill method largely depended on the results of the funnel plot. The funnel plot's asymmetry may be attributable to some other factors besides publication bias (Higgins & Green, 2008; Sterne et al., 2000). For instance, between-study heterogeneity and small-study effects, including the tendency for smaller studies

to show greater effects than larger studies are also possible explanations. Further, application of this method in the presence of heterogeneity across small amounts of studies may lead to false-positive claims for publication bias (Ioannidis & Trikalinos, 2007). Considering all three assessments and the concern of large amount of heterogeneity across studies in this meta-analysis, there is little solid evidence of publication bias in the selected studies, yet conclusions should be interpreted with caution.

Discussion

The current meta-analysis integrated experimental studies that investigated cognitive reappraisal and physiological changes. This meta-analysis included 73 independent experiments with 571 total effect sizes that tested the effect of cognitive reappraisal on several physiological outcomes with different study design and manipulation between studies. Characteristics of every study can be found in Table 4. Results showed that cognitive reappraisal had a significant impact on the eye movement outcome. This effect was significantly larger when compared to using the acceptance strategy. The effect of reappraisal on the electrodermal and eye movement outcome was also significant when regulating negative compared to regulating positive emotions, or both positive and negative emotions together. The strength of effect of reappraisal was also stronger when there was not a clear regulatory goal compared with a goal to modulate the valence or arousal of emotions, as well as for younger than older adults. Potential reasons are discussed next for the numerous non-significant results in this study, followed by an interpretation of the pattern of results, as well as some limitations and future directions.

Immense methodological heterogeneity in physiology measurement

Results did not find a significant impact of cognitive reappraisal on the cardiovascular and respiratory outcome, electrodermal outcome, or the facial outcome. One possible reason to

observe these largely non-significant results is the large amount of variation in the indices included in each physiological outcome category. Other than the eye movement outcome, which comprised of three physiological indices that measured similar startle activities (startle reflex and visual gaze), the other three outcomes included from six to 25 physiological indices, of which some were representing more similar physiological activities with each other than the others. Take the cardiovascular and respiratory outcome as an example, this outcome consisted of cardiovascular indices such as heart rate variability (HRV) and interbeat interval (IBI), as well as respiratory indices such as respiration rate (RR). Although research has shown that there is a coupling relationship between the cardiovascular system and the respiratory system, there was also evidence suggesting the difference in functions of both systems, such that cardiovascular and respiratory indices might be independently associated with different cardiovascular or respiratory health outcomes (Fuertes et al., 2020; Henderson et al., 2011; Phung et al., 2016). Grouping indices that were associated with different functions and health outcomes could contribute to a large amount of heterogeneity that would be extremely difficult to be explained by just any one moderator between cognitive reappraisal and physiology.

Provided that there are differences in the functions and implications of each physiological index, perhaps it is not surprising that the measurements between each index is different. However, differences in measurement within an index, for instance, how one study measured HRV versus the other studies, is also common in the literature. In the current meta-analysis, HRV was measured in different ways across studies, including using RMSSD (root mean successive heartbeat interval difference; Denson et al., 2011), IBI (interbeat interval: e.g., Mauersberger et al., 2018; Shiota & Levenson, 2012), LF/HF of HRV (the ratio of low-frequency/high frequency of HRV; Svaldi et al., 2012), normalized LF and normalized HF of

HRV (Di Simplicio et al., 2012), and subtracting the minimum of heart rate from the maximum of heart rate (Hampton et al., 2015). These measurements are valid metrics of HRV, and they can be classified into time domain measures (e.g., RMSSD and IBI) and frequency domain measures (e.g., LF/HF, normalized LF and normalized HF). Previous research has suggested that time domain measures and frequency domain measures were associated with different autonomic activities. For instance, time domain measures of HRV have been associated with the parasympathetic activity in the heart (Bigger et al., 1988; Ewing et al., 1991; Penttilä et al., 2001), frequency domain measures such as a high frequency power of HRV was driven by the parasympathetic nervous system, and a low frequency power of HRV was attributed to the sympathetic nervous system (Spiers et al., 1993). Since even one physiological index could be measured differently with different implications, having six to 25 indices in the three outcomes shows a large amount of methodological heterogeneity is present in the current meta-analysis.

Although non-significant, cognitive reappraisal showed a bigger impact on most outcomes compared with other strategies

Though the effect of physiological outcomes was not significantly impacted by different emotion regulation strategies, findings reflect several general trends from the existing literature. For instance, results showed that suppression had smaller effects than cognitive reappraisal on the cardiovascular and respiratory outcome, which is in line with previous research that cognitive reappraisal is associated with larger decrease in overall physiology than suppression (Demaree, Robinson, et al., 2006; Gross & Levenson, 1993). At the same time, result also found that suppression had larger effects on the facial and eye movement outcome, which confirms the notion of suppression mainly focuses on the process of consciously inhibiting emotional expressions, therefore observing a bigger effect on facial expressions.

Some other interesting observations could also be seen from the effect of strategies on physiological outcomes. Regulation strategies including no regulation, attentional deployment, affect labeling, acceptance, and suppression had an averaged smaller effect for each physiological outcomes[4] than cognitive reappraisal, with the exception of several cases. For instance, compared to cognitive reappraisal, using affect labeling, rumination, attentional deployment, and no regulation had a greater effect on the electrodermal outcome. With four other strategies having a bigger impact on the electrodermal outcome, this finding suggested that electrodermal measures might not be as sensitive to cognitive reappraisal. Since reappraisal precedes emotional responses and focuses on modulating emotions through cognitive change, which is not always involved in other emotion regulation strategies (Gross, 1998b; Lazarus & Folkman, 1984), electrodermal activity might not be as responsive to cognitive processes. Future research could examine the relationship between electrodermal activity with specific characteristics in each strategy to inform whether electrodermal parameters are the best indicators for cognitive change. In addition, results also revealed that the estimated average effect of rumination on the electrodermal outcome is exceptionally huge (g = 1.40). This uncommonly seen large effect size compared with the other strategies in the current result, as well as in the general literature warrants further attention. Since there were only 2 independent studies that contributed to this result, more studies that examine the relationship between reappraisal, rumination, and electrodermal outcomes are encouraged.

Cognitive reappraisal showed a bigger effect on negative than positive stimuli

Results also found that the types of emotion regulated had differential influences on each physiological outcome. Specifically, effect sizes were larger when regulating negative emotions

[4] With the exception of the facial and eye movement outcomes mentioned previously, in which suppression had larger effects on

compared with regulating positive emotions for the eye movement outcome. Eye movement measures have been widely used in clinical research, which includes assessing attentional biases to threat in anxiety disorders (Waechter et al., 2014), diagnosing for depression (Alghowinem et al., 2013), and providing treatments for posttraumatic stress disorder (Gupta & Gupta, 2002; Levin et al., 1999; Shapiro et al., 1996). Apart from being an effective parameter to evaluate and monitor clinical conditions, current non-clinical studies from this meta-analysis also showed an effective impact on eye movement during the regulation of negative emotions. Importantly, compared to other physiological outcomes, there were fewest research studies to include eye movement outcome in existing regulation studies. Perhaps more research could investigate how eye movement outcomes, compared with the other outcomes, may be more beneficial in providing information on the success or failure in emotion regulation in the healthy population for potential early prevention of clinical disorders.

The current study also found that effect sizes were smaller when regulating positive emotions rather than negative emotions for the electrodermal outcome. One possible explanation is that skin conductance responses were smaller in reaction to positive auditory or visual stimuli than negative stimuli (Fowles et al., 2000). If electrodermal reactivity started out smaller for positive compared to negative stimuli, the corresponding effect when regulating positive emotions could also be less pronounced compared to when regulating negative emotions. This would be a reminder for future research, such that when selecting suitable physiological parameters, not only do we need to consider whether physiology might respond to changes during the regulation phase, but also to what extent would they react to the different types of emotions during the reaction phase, since both processes could affect the overall effect size of the outcome.

The effect of cognitive reappraisal was smaller for older than younger adults

As predicted, the effect of reappraisal on the cardiovascular and respiratory outcome is smaller for people in older age. Previous study has suggested that using other regulation strategy such as attentional deployment was more effective than reappraisal in overall regulation success for older people (e.g., Opitz et al., 2014). The current study also highlights that this effect in older adults is smaller especially for the cardiovascular and respiratory outcome. Since older adults are at higher risks for cardiovascular and respiratory diseases (Cigolle et al., 2009), and reappraisal might not be the most effective strategy to regulate physiological changes that are associated with those diseases, health practitioners could target non-reappraisal type of strategies for more effective regulation. Researchers could also further investigate longintudinally at around which age period in life that this effectiveness of reappraisal start to decline. For instance, if the effect were to be seen in middle-aged adults, health practitioners could act on preventative measures such as training to use other effective regulation strategies for middle-aged adults who are at high risks for cardiovascular and respiratory outcomes.

More research needed to examine how the effect of cognitive reappraisal on physiology depends on the goal of emotion regulation

Since emotion were suggested to be multidimensional with at least a valence and arousal dimension (Cacioppo, Gardner, et al., 1997; Russell, 1979, 1980; Watson et al., 1999), the current study explored whether regulating the valence or arousal dimension of emotions would have differential effects on physiological outcomes. To modulate the valence component, one might decrease initial experienced (negative) emotions and increase the oppositive (positive) emotions while maintaining the overal arousal experience of emotion. On the other hand, individuals could decrease the initial experienced (negative) emotions and the overall arousal

level to arrive at a non-negative and non-positive (neutral) experience. Whether indiviudals regulate the valence or arousal component depends on their goals of regulation. Since all eligible regulation studies in this meta-analysis did not explicitly manipulate regulatory goals, a set of standardized coding procedure was created to categorize whether the emotion regulation instructions followed a goal to modulate the valence or arousal dimension of emotions. 41% of all studies fell under a third category of "unclear", suggesting the instructions either contained languages to modulate both dimensions or did not provide sufficient information for coding. Analysis of emotion regulation goal found that it was a significant moderator between the effect of cognitive reappraisal on the cardiovascular and respiratory outcome. Specifically, the effect was significantly larger when emotion regulation goals were unclear. At the same time, the effect was trending significance for the electrodermal outcome when emotion regulatory goals were unclear as well. Since studies in this category had diverse regulation instructions, it is unknown if this effect represents an additive effect from modulating both valence and arousal dimensions on physiological changes, or some unique effect was present but not captured in those ambiguous regulation instructions. This finding suggests a future research direction on clearer manipulation of regulatory goals to further understand the effect of emotion regulation on physiological outcomes.

Limitations and future directions

The results and implications of the current meta-analysis should be interpreted in light of the following limitations. As discussed in the results section, there was an insufficient number of effect sizes for each physiological index, resulting in the groupings of similar yet different indices as a physiological outcome to avoid small degrees of freedom in moderator analyses. The large amount of heterogeneity in each outcome category could lead to unreliable results. One

way to ameliorate the problem of having huge methodological variation in the measurement of outcomes is to un-group physiological indices and conduct separate meta-analyses with each of them. For instance, a meta-analysis on the effect of reappraisal on the time domain measures of HRV and the effect on the frequency measures of HRV could be conducted in the future. The current meta-analysis did not adopt this approach because of the lack of effect sizes of each physiological index. However, a follow-up meta-analysis using the above suggestion could be done when more physiological studies with clear measurement are conducted. With such variation in the measurement and implication of each physiological index, the current study also suggests emotion regulation and physiology researchers to draw more specific conclusions and statements in their research results. For instance, instead of stating "cognitive reappraisal increases heart rate variability in response to an anger provocation", consider "cognitive reappraisal allows for greater sympathetic flexibility, indicated by an increase in RMSSD after an anger provocation". Though HRV is one metric to signify general health in the autonomic nervous system, focusing on a specific measurement of the HRV metric (i.e., RMSSD) and the benefits associated with it could uncover distinct pathways to different physiological health outcomes.

At the same time, there were also unbalanced number of effect sizes for subgroups of certain moderators. For instance, there was only one study that compared reappraisal and acceptance on the eye movement outcome, and there were only two studies that compared reappraisal to acceptance, and reappraisal to affect labeling on the electrodermal outcome. In the current meta-analysis, only 12 studies (11%) included positive stimuli in their experiments. It is perhaps not surprising, since negative emotions were suggested to linked to adverse mental and physical health (e.g., Consedine & Moskowitz, 2007; Hofmann et al., 2012; Mayne, 1999), and

effective regulation in negative emotions could be beneficial in ameliorating unwanted outcomes. However, it is important to note that disturbances in positive emotions also occurred in affective disorders and this topic has been under studied (see Carl et al., 2013 for a review). In addition, other than down-regulating negative emotions, up-regulating positive emotions could also be another technique to decrease the levels of negative emotions. Increasing positive emotions or even just maintaining positive experiences could promote resilience and could be important to overcome stressful events (Tugade & Fredrickson, 2004). More studies investigating the relationship between positive emotion regulation and physiological changes in both healthy individuals and patients with disorders are encouraged. These studies could shed light on not just the benefits of positive emotions have on different outcomes, but also the possible physiological pathways for resilience. Overall, more effect sizes in these categories would also allow for more reliable meta-analyses and specific conclusions to be drawn.

Another limitation is that the current meta-analysis only limits to research studies conducted in the United States, due to insufficient proficiency and resources to translate the three reports that were in another language. It is therefore unknown if results are generalizable to the other countries. In addition, there may have been missing unpublished research reports in this meta-analysis, which also affects the external validity of findings. With potential risk of having publication bias, the best way to account for this issue is to collect as many unpublished studies as possible. Though assessment of publication bias did not indicate consistent biases around the effect seen in this meta-analysis, a follow-up meta-analysis would be beneficial in providing more precise effect size estimates and implications.

The scope of the current meta-analysis also qualifies the interpretation of its results. Since emotion regulation in this current analysis was conceptualized within the process model of

emotion regulation (Gross, 1998a), cognitive reappraisal was defined accordingly based on the process model. As a result, the effect of emotion regulation on physiology could only be interpreted in the specific context of reappraising or interpreting the situation. Cognitive strategies from other frameworks were left out to be examined. For instance, downward social comparison and thinking of successes in other areas of life were suggested to be some other cognitive approach to regulate emotions (Larsen, 2000). Follow-up meta-analyses could expand their search and include other models and classification of emotion regulation (e.g., Koole, 2009; Larsen, 2000; Thayer et al., 1994) to measure the effect of cognitive-focused strategies and physiology.

Conclusion

Cognitive reappraisal has played a major role in the emotion literature and is considered the most popular and effective way to regulate emotions (Gross, 2002, 2013). This meta-analysis explored how cognitive reappraisal influences different types of physiological outcomes, followed by an examination of theoretical and methodological moderators of this relationship. Current findings indicate that different emotion regulation strategies impact different physiological outcomes with varying magnitude. This study also showed that the strength of the effect of cognitive reappraisal was stronger for certain physiological outcomes relative to other regulation strategies, for negative than positive emotions, and for younger than older adults. Understanding how the effects of cognitive reappraisal depended on different factors on specific physiological outcomes could provide insights on how this regulation strategy influences specific health outcomes, and its effects on potential pathways that lead to those outcomes. With this information, practitioners could tailor cognitive reappraisal in more effective context and to more specific population to modulate desirable health outcomes. Researchers could also make more

informed decisions when expanding on the regulation and health literature by selecting relevant physiological assessments and other study design characteristics to draw more specific conclusions.

Chapter 2: Introduction

Emotion regulation involves up- or down-regulating an emotional response (Gross et al., 2011), a process that is likely to be influenced by our goals. Different regulation goals, such as modifying the type versus the intensity of emotion, could lead to different experiential, behavioral and physiological outcomes. In order to better capture the different mechanisms between emotion regulation goals and outcomes, it may be important to specify more concrete regulatory goals for individuals to achieve in regulation studies. However, existing emotion regulation studies have mostly left the goal of regulation unspecified and focused on manipulating or measuring the processes of regulation, such as how people regulate by using different regulation strategies and responding to different emotional stimuli. Without giving participants a regulation goal, it is possible that some participants may consistently use quantitative emotion regulation to reinterpret all situations while others use qualitative emotion regulation, and others may attempt to use both. The failure to specify a regulation goal could result in inconsistent findings across different methodologies since emotion regulation might not be clearly operationalized; this, in turn, which would make it difficult to understand the true relationship between emotion regulation and the corresponding outcomes. The current study tested the link between regulation goals with specific emotional and physiological changes by analyzing data from an experimental study that included clear instructions of regulatory goals and real time assessment of physiology.

Emotion has been suggested to fall into at least two general dimensions, including valence (negative versus positive affect) and arousal (or the degree of activation) (Cacioppo, Gardner, et al., 1997; Russell, 1979, 1980; Watson et al., 1999). Prior research has suggested that an individual's experience of arousal level may be equivalent to the sum of positive and negative

valence (Kron et al., 2013). In other words, participants experiencing a low level of positive and negative (e.g., neutral) emotional experience are expected to give a low rating of overall arousal of emotion. At the same time, participants experiencing a high level of positive and/or negative affect would rate a high level of overall arousal of emotion. The above findings suggest that the valence and arousal component of emotion could be modulated differently, depending on an individual's emotional goal. For instance, we could *decrease* the overall arousal level of emotion by *decreasing* either positive or negative valence. In this case, one could potentially achieve a "neutral" state without experiencing any valence and arousal of emotion (see Figure 6). To my knowledge, there has not been any published research to coin a specific term for this type of regulation. For consistency and ease of interpretation, this type of regulation will be referred to as "Quantitative regulation" throughout this paper. That is, quantitative regulation represents a regulation goal of changing the degree of overall arousal level of emotional experience. Examples of instructions for a quantitative regulation goal include, "adopt a neutral attitude as you watch the video. To do this, we would like you to view the video with the detached interest of an impartial observer or a mediator of a debate" (Denson, Grisham, & Moulds, 2011) "try to think about what you are seeing in such a way that you feel less negative emotion" (Lee & Gino, 2015), or "think about your situation in such a way that you remain calm and dispassionate" (Butler et al., 2003).

In contrast, we could *maintain* the overall arousal level of emotion by decreasing negative valence *and* increasing positive valence. This type of regulation would involve changing the valence but not necessarily the overall arousal of emotion, as there will be a concurrent decrease in the intensity of the initial negative emotion and increase in the intensity of the alternative positive emotion (see Figure 7). This type of regulation will be referred to as

"Qualitative regulation" throughout this paper, which represents a goal of changing the type of emotion. Examples for a qualitative regulatory goal include, ""reappraise [positive pictures] in a way that would make their content more negative" (Karina S. Blair et al., 2012) or "to try to look on the bright side … and to try to find anything positive you can in the [negative stimuli]" (Butler et al., 2006).

To my knowledge, most existing emotion regulation studies instruct participants to engage in emotion regulation without clearly specifying the expected emotional state after emotion regulation. For instance, studies typically present general instructions such as: "reinterpret the content of the target pictures in order to alter their emotional responses" (Christou-Champi et al., 2015), "think about [the event] from a different perspective from the one you used earlier." (Ray et al., 2008), "instruction to increase served as a cue to actively try to feel more emotion…instruction to decrease signified the cue to actively try to feel less" (Urry, 2010). Further, some studies have presented conflicting instructions that appear to activate both goals. For instance, one study instructed participants to reinterpret the images in ways that decrease their negative emotional response, but then provided a concrete example in which they could reappraise a negative image to feel more positively (Bebko et al., 2011). The instruction to decrease the intensity of negative valence, which also means a decrease in overall emotional arousal would activate quantitative regulation. However, the example they provided would activate qualitative regulation, such that the overall emotional arousal would be maintained by not only decreasing the intensity of negative valence, but also increasing the intensity of positive valence. This lack of clarity in the desired regulation end state could mask the real effect of specific types of regulation on different outcomes.

Emotion regulation studies that include a quantitative or qualitative regulation goal indeed find divergent results in terms of both emotional and physiological responding. Studies using language that fits with a quantitative goal generally find a decrease (Denson et al., 2011) or no difference in negative emotion (Butler et al., 2003; Olatunji, Berg, & Zhao, 2017), no difference in positive emotion (Butler et al., 2003) and decreased (e.g., Ichikawa et al., 2011; Thiruchselvam et al., 2011) or unchanged (Adam et al., 2014) level of arousal for within-person comparisons.

Among experimental studies with language that fits with a qualitative regulation goal, in addition to finding a decrease in negative emotions, these studies have also found an increase in positive emotions when reappraising negative stimuli (Samson et al., 2014). The same directional change in emotional pattern was also found in studies using positive stimuli, such that in addition to a decrease in positive emotions, a decrease in negative emotion would also be observed for within-person comparisons (Karina S. Blair et al., 2012; Giuliani et al., 2008b). At the same time, quantitative and qualitative regulation goal inclusion seems to provide mixed findings with respect to physiological changes when reappraising negative stimuli. For instance, studies using language that fits with a quantitative goal have found an associated *decrease* in heart rate ; Hofmann et al., 2009), and an increase in heart rate variability, (Denson et al., 2011). On the other hand, studies using language that fits with a qualitative regulation goal suggested an increase in heart rate variability (Nasso et al., 2018), *increase* in heart rate, increase in respiration rate and respiratory sinus arrhythmia (Butler et al., 2006). Altogether, these studies provide preliminary evidence of mixed results on physiology outcomes that may stem from the use of differing descriptions of emotion regulation goals. An in-depth literature search for a related meta-analysis by the current author also found that, out of the 73 emotion regulation studies that

included physiological measures, about 43% included descriptions of a quantitative goal, 16% included descriptions of a quantitative goal, and 41% did not have a clear manipulation of either regulatory goal (or a mix of both). Admittedly it is hugely unknown whether these mixed results would also be explained by other methodological confounds, including the types of emotional stimuli used and differences in study samples. As such, the present study directly tests whether a clear specification of different emotion regulation goals (i.e., quantitative versus qualitative) produces divergent physiological changes by randomizing the regulation goal instructions while simultaneously collecting physiological indices. This type of design will address the unanswered question of whether having a clearer specification of the end goal of regulation influences physiological responses and, ideally, has the potential to resolve some of the inconsistent findings to date in the emotion regulation literature.

The primary aim of the current study is to test how different emotion regulation goals (quantitative versus qualitative) influence emotional and physiological outcomes. This study builds on existing literature by broadening the current understanding of the link between emotion regulation and specific experiential and physiological responding. If differences in physiological indices are found when regulation goals are experimentally manipulated, then these findings would inform the design of future research by ensuring that regulation goals are controlled and/or manipulated and would support the inclusion of physiological indices in future studies.

Method

Participants

Data for this study came from the Tactics and Goals in Emotion Regulation study collected at a West coast university. 201 participants (108 women) from the University and the surrounding community were enrolled in a multi-session laboratory study. 31 participants

(15.4% of enrolled participants) were excused from further participation based on a manipulation check after the behavioral session, because they could not satisfactorily understand the regulation instructions and thus perform the experimental task. In the experimental session, 2 participants terminated the study early, 10 did not comply with instructions, and 2 were excluded due to technical problems. The final sample consists of 156 participants (84 women), 9.0% self-identified as African American, 21.8% as Asian-American, 50.0% as Caucasian, 10.3% as Hispanic, 2.6% as Native American, 5.1% as other, and 1.3% declined to state.

Participants received course credit or payment ($70) for their participation. Participants' eligibility was determined by a phone screening, in which potential participants were asked for demographic information and about their physical and mental health using an abbreviated version of the Structured Clinical Interview for DSM-IV, Axis I. All participants were aged between 18 and 30 years, native English speakers or of similar proficiency, and had at least eight years of schooling. Exclusion criteria included smoking, cardiovascular, pulmonary, neurological, or systemic disorders. Participants were also excluded based on self-reported current diagnosis or lifetime history of major depressive disorder, manic episodes, panic disorder, agoraphobia, social phobia, obsessive–compulsive disorder, post-traumatic stress disorder, or generalized anxiety disorder. Participants were also excluded if they had a substance use disorder currently or in the past. All participants were free of any kind of medication with effects on the cardiovascular, respiratory, autonomic, or central nervous system.

Procedure

Data collection took place individually in a multi-session laboratory study consisting of an online survey (1 hr), a behavioral assessment and instruction on the cognitive reappraisal task (behavioral session; 1.5 hrs), and the psychophysiological assessment of the cognitive reappraisal task (experimental session; 3 hrs). All participants were consented prior to participation. Before their first laboratory visit, participants completed an online survey of demographic and individual differences questionnaires. At the behavioral session, participants were extensively instructed on and practiced the cognitive reappraisal task. At the experimental session (1–3 days after the behavioral session), physiological sensors were attached while a reminder sheet of instructions of the cognitive reappraisal task was presented to the participants. After the placements of all physiological sensors, participants practiced the task with 5 example pictures (not repeated in the experiment) while saying their reappraisals out loud and receiving feedback from the experimenter. The experimenter then left the room, and participants started the cognitive reappraisal task. This task involved presentation of photo stimuli, which participants were instructed to cognitively reappraise after a short viewing period. In order to include more variety of affective stimuli to gather more information about the different reactions and regulations of the stimuli, photos with various content and validated normative ratings were used from three different standardized databases of emotion-inducing pictures. Specifically, stimuli are from the International Affective Picture System (IAPS; Lang et al., 2008), the Emotional Picture System (EmoPicS; Wessa et al., 2010), and the Nencki Affective Picture System (NAPS; Marchewka et al., 2014). A list of the stimuli used and the corresponding ratings of valence and arousal could be seen in Table 4.

Emotion regulation was manipulated through a within-subject emotion regulation paradigm, in which participants viewed in random order of the same images. Each trial consisted of a 8-second rest period, 1 to 3 second presentation of a fixation cross, 8-second picture presentation, 8-second picture presentation with regulation goal instructions appearing underneath, and three 4-second rating scales, asking for their positive emotions, negative emotions and arousal level (see Figure 8 for the flow of this experimental task). While the picture was presented, participants were instructed to "simply view the picture and understand its content". The regulation goal instruction, which subsequently appeared underneath the picture, directed participants to "continue viewing the picture" (VIEW; no regulation-goal condition); "tell [themselves] a story about what is going on in the picture so that the situation takes on a neutral meaning" (NEUTRALIZE; quantitative regulation-goal condition); or "tell [themselves] a story about what is going on in the picture so that [they] think about the situation as much as possible in the opposite direction from [their] initial response" (TRANSFORM; qualitative regulation-goal condition). Pictures of negative or positive valence were combined with either one of the three instructions (negative–no regulation, negative–quantitative regulation, negative–qualitative regulation, positive–no regulation, positive–quantitative regulation, positive–qualitative regulation), whereas pictures of neutral valence were always followed by no-regulation instructions (neutral–no regulation). There were 15 trials of each Picture Valence × Regulation Goal type for a total of 105 experimental trials. Pictures were presented in randomized order and randomly paired with instructions. To increase participants' motivation, they were told that $50 would be paid to the top 10% of participants who could best implement instructions.

After completing the cognitive reappraisal task, participants completed a post-task compliance check, in which they viewed all pictures again at their own pace in the same order as presented in the cognitive reappraisal task. For each picture, they were asked to rate their initial emotional response (i.e., during the viewing period, before the regulation instructions; see Ochsner, 2002 for reliability of such post-hoc ratings) and report their recollection of the reappraisal they had generated in response to the picture and instruction. These ratings allowed confirming that participants followed instructions appropriately. Subsequently, participants were unhooked from physiological recording equipment, debriefed, paid, and thanked for their participation.

Measures

Emotion experience. After each picture trial, participants rated their emotion experience on two items (scale definition is given in parentheses): negative emotion experience (unhappy, annoyed, unsatisfied, melancholic, despaired, bored, or any other negative feeling) and positive emotion experience (happy, pleased, satisfied, contented, hopeful, or any other positive feeling). Rating scales appeared in two possible orders, negative–positive (for odd participant numbers) or positive–negative (for even participant numbers). Participants were instructed to rate items according to "how [they] feel after applying the instructions" during the cognitive regulation task (regulated emotion experience score) and according to "how [they] initially felt in response to the picture" during the post-task compliance check (initial emotion experience score) on a 9-point Likert scale ranging from *not at all negative/positive* (1) to *very negative/positive* (9). Participants were instructed that they should accurately report their emotion experience whether or not their reappraisal had been successful in changing the way they felt.

Physiological responses. Disposable circular electrodes filled with silver or silver chloride were placed in an electrocardiography (ECG) and impedance cardiography (ICG) configuration. The ECG electrodes were placed at the right collarbone and the lowest-left rib with a ground electrode placed at the lowest-right rib. For ICG, two voltage electrodes were placed on the jugular notch just above where the collarbones meet, and just below the sternum (on xiphoid process). The two current electrodes were placed on the spine, at 1.5 inches above and below the voltage electrodes. Blood pressure (BP) was measured using a continuous inflatable finger cuff placed around the participants' forefinger. On the palmar surface of participants' nondominant hand, assessments of Finger pulse amplitude (FPA), skin conductance, and finger temperature (FT) were collected. FPA, the amplitude of blood volume in the finger that is associated with the beating of the heart, was recorded by clipping a UFI model Pulse Plethysmograph to the thumb of the nondominant hand. To measure skin conductance, a constant-voltage device was used to pass a small voltage between electrodes (using an electrolyte of sodium chloride in Unibase) attached to the middle phalanges of the middle and ring fingers. Finger temperature (FT) in degrees Fahrenheit was measured by a thermistor attached to the distal phalange of the fifth finger. Thoracic and abdominal respiration was recorded with two respiration belts from Mindware Technologies (Gahanna, OH). The abdominal belt was placed around the waist just below the rib cage, whereas thoracic belt was placed high on the chest just below the armpits. A calibration procedure was conducted once belts were correctly attached. All physiological data were collected continuously throughout the entire cognitive reappraisal task, except that all the sensors hooked up on the nondominant hand (i.e., BP, FPA, skin conductance, FT) was terminated during the post-task compliance check, since the sensors would interfere with the typing and reporting of their recollection of reappraisal.

Data Preprocessing

Physiological data were cleaned and analyzed using Mindware software (Gahanna, OH), which summarized data into time sampled windows prespecified by the author. Portions of the ECG and skin conductance signal thought to be contaminated by artifact were identified using Mindware's artifact detection algorithm and the flagged portions were then cleaned by hand. From the ECG measurement, interbeat interval (IBI), respiration rate (RR) and tidal volume (VI) could be calculated and analyzed with MindWare HRV Software (Version 3.0.25) (Gahanna, OH.) To calculate IBI values (i.e., the time between heartbeats), an algorithm that relied on the peak of the R wave as the reference point was used. From the IBI data, common time-domain parameters of the heart rate variability (HRV) features could then be captured. In particular, the standard deviation of successive interval differences (SDSD) and the root mean square of successive interval differences (RMSSD), which is an estimate of short-term components of HRV, were extracted. Other physiological indices such as pre-ejection (PEP) period was calculated from the Impedance Cardiography (ICG) Analysis whereas the skin conductance level (SCL), skin conductance response (SCR), and skin conductance amplitude (SRA) were calculated from the Skin Conductance (EDA) Analysis software provided by Mindware Technologies (Gahanna, OH).

Statistical Analyses

The current study tested both between and within person dynamic changes in each physiological index and involved repeated trials and assessments within person. Since the study design and resulting data structure violates the assumption that observations and residuals are independent, the statistical analysis strategy requires a method that can both account for the non-independence and model both between and within-person effects. Multi-level modeling (MLM)

was applied to meet these requirements as it is well accepted for use in psychophysiological research, offering the ability to model associations both between and within subjects, and accounting for the nesting of observations within persons (Page-Gould, 2017). A continuous autoregressive error structure was specified in the model estimation to account for nonstationary of repeated assessments (Schwartz & Stone, 1998). All hypotheses and the analytic plan for this study were pre-registered at the Open Science Framework in March 2019 (refer to Appendix C).

Categorization of physiological measurements

To streamline the analysis plan, the multiple physiological indicators recorded during the study session were mapped on to the specific parts of physiological system they are typically used to measures. This aggregation of measures resulted in 12 of the physiological indices being mapped on to four broader physiological domains (i.e., heart rate variability: IBI, RMSSD, SDSD, FT; blood pressure: PEP, SBP, DBP; electrodermal: SCL, SCR, SRA; and respiratory: RR, VI). The mapping of indicators to broader physiological domains/systems was based on both prior conceptual models and how researchers have utilized each of the indices in past research.

As seen in Table 6, measures within physiological domain showed stronger correlation with one another than they did with measures in other domains. For instance, IBI was most strongly correlated with other heart period measures including RMSSD, SDSD, and FT. Within each physiological category, the most robust measure, which was also the most commonly used measure in the literature, was highlighted in yellow in Table 6. The results of these main physiological measures, including IBI, SBP, SCR, and RR measures were reported in more detail in this paper. Results for the remaining eight physiological measures (i.e., heart rate variability: RMSSD, SDSD, FT; blood pressure: PEP, DBP; electrodermal: SCL, SRA; and respiratory: VI),

were included in the Appendix D as supplemental material for interested readers to review the patterns of results.

Though numerous emotion regulation studies have relied on Repeated Measures (M)ANOVAs (Gross, 1998a; Jackson et al., 2000b; Kunzmann et al., 2005; A. M. Lane et al., 2011; Zimmermann & Iwanski, 2014)), multivariate research question asks about the difference between groups based on the variate, or the linear combination of the dependent variables (Zientek & Thompson, 2009). MANOVA analyses were also run and yielded similar between subject results. However, due to the advantages offered by the MLM framework only, the MLM results are presented here. Repeated measures MANOVAs were also fitted to the data separately, and results were included in the Appendix E, but are not discussed in detail here.

The equation presented below is an example using one of the measures:

Level 1:

$$IBI_{ij} = \beta_{0j} + \beta_{1j}(PictureValence)_{ij} + \beta_{2j}(Goal)_{ij} + \beta_3(PictureValence)ij.(Goal)_{ij} + \beta_4(Time)ij + \beta_5(PictureValence)ij.(Time)_{ij} + \beta_6(Goal)ij.(Time)_{ij} + e_{ij}$$

Level 2:

$$\beta_{0j} = \gamma_{00} + \mu_{0j}$$

$$\beta_1 = \gamma_{10} + \gamma_{11}(PictureValence)_j + \mu_{1j}$$

$$\beta_2 = \gamma_{20} + \gamma_{21}(Goal)_j + \mu_{2j}$$

$$\beta_3 = \gamma_{30} + \gamma_{31}(PictureValence*Goal)_j + \mu_{3j}$$

$$\beta_4 = \gamma_{40} + \gamma_{41}(Time)_j + \mu_{4j}$$

$$\beta_5 = \gamma_{50} + \gamma_{51}(PictureValence*Time)_j + \mu_{5j}$$

$$\beta_6 = \gamma_{60} + \gamma_{61}(Goal*Time)_j + \mu_{6j}$$

Mixed model format: $IBIij = \gamma_{00} + \gamma_{11}(PictureValence)_j + \gamma_{21}(Goal)_{2j} + \gamma_{31}(PictureValence*Goal)_j + \gamma_{41}(Time)_j + \gamma_{51}(PictureValence*Time)_j + \gamma_{61}(Goal*Time)_j + \mu_{0j} + \mu_{1j}(PictureValence)_{1j} + \mu_{2j}(Goal)_{2j} + \mu_{3j}(PictureValence*Goal)_{3j} + \mu_{4j}(Time)_{4j} + \mu_{5j}(PictureValence*Time)_{5j} + \mu_{6j}(Goal*Time)_{6j} + e_{ij}$

The equation shows IBI as an example, in which IBI_{ij} is the level of IBI on time i for person j. It is a function of mean IBI for person j on a typical assessment window (β_{0j}) and the expected change in IBI for person j as a result of being randomly assigned to different picture valence ($\beta_1(PictureValence)_{ij}$, as well as to different emotion regulatory goal ($\beta_2(Goal)_{ij}$. The intercept and slope were allowed to vary (calculated by the RANDOM statement).

Results

The dataset consisted of 151 (participants) x 105 (trials) x 3 (trial type: rest, react, regulate) = 47565 observations. The interquartile rule was used to detect outliers before performing main analyses. Specifically, the interquartile range (IQR) was multiplied by 1.5 and the upper bound was created by adding 1.5x(IQR) to the third quartile, and the lower bound was created by subtracting 1.5x(IQR) from the first quartile. 7% of the data values that were above the upper bound and lower than the lower bound were removed. As seen in Figure 9, the percentage assessment of all variables for all participants reaches 100% except variable DBP, PEP, RR, SBP, and SRA, with the majority of participants completing at least half of the assessments. There was 8.71% missing data from all observations. Since real-world data are very unlikely to be missing at random, and listwise deletion is unbiased only when the restrictive missing at completely random assumption holds (Lall, 2016), none of participants were removed by listwise deletion, which is a default way to handle missing data in the current analytic

program, R Studio (2016). Instead, in order to retain other information that are still present in those incomplete observations, multiple imputation, which involves replacing each missing cell based on the distribution of other variables in the dataset, was specified. This method addresses the missingness issue by taking into account the variability and uncertainty due to sampling and imputation in the missing values. Physiological data, especially heart rate variability measures, are typically transformed (e.g., natural log transformation) to fit the assumption of normality (Ellis et al., 2008). All physiological data followed the recommended procedure and were log transformed to obtain approximately normal distribution.

Multi-level Modeling

To visually inspect the patterns of change over time in the four dependent variables, time course plots of the physiological measures can be seen from Figure 10 to Figure 13. Plots for the remaining eight physiological measures can be found in the Appendix D. The figures show that, for instance, the mean interbeat interval (IBI) during the regulation period when viewing negative stimuli of the 30 randomly selected participants from the whole sample. There seems to be some variations in change in the mean IBI over time across participants. For instance, there was an increase in IBI over time when regulating negative stimuli for participant ID 1, whereas a decrease for participant ID 2. To better understand how much variability there is between versus within individuals in a measure over time, intraclass correlation (ICC) for each physiological index was calculated. The total variances for each dependent variable were therefore partitioned into the proportion accounted for by individual differences (i.e., between-person differences in average levels) and fluctuations by second (i.e., the within-person variability around individual averages).

Does young people's physiology differ more from each other or from themselves over time?

For half of the physiological measures, young people differed more from their peers than from themselves over time. The ICCs for all the dependent variables are as followed, IBI: 0.69, RMSSD: 0.43, SDSD: 0.42, PEP: 0.50, SBP: 0.53, DBP: 0.58, FT: 0.91, SCL: 0.88, SRA: 0.06, SCR: 0.14, RR: 0.40, VI: 0.28. The two-level multilevel model (MLM) reflects the proportion of variance that is attributable to the differences among Level 2 units, that is the between-person variance. Specifically, take IBI as an example, 69% of the variance in IBI was between people whereas 31 % was within people over time. Current results showed that people differed more from each other than from themselves across assessments for five of the variables (IBI, SBP, DBP, SCL). Though SRA has a low ICC, the multi-level modeling literature often considered an ICC value above .05 as an indicator of non-trivial amount of non-independence. Since ICCs represent ratios of variances and provide no indication about how relationships between variables might vary across groups, even though ICC is low, there may still be meaningful (absolute) variance at the group level for a data set. According to the recommendation that multi-level analyses should be used whenever a researcher has a multi-level or nested data structure (Nezlek, 2012), this variable was still included in the supplemental analyses. Since emotion regulation goal was a nominal predictor with three levels (Emotion Regulatory Goal: view, quantitative, qualitative), I dummy coded the viewing condition as 0 the reference group, so as to compare both regulatory goals with the view condition. Planned contrasts were also performed to test for differences between the quantitative and qualitative goal. Table 7 provides an overview of the study findings. Within each physiological category, the most robust and commonly used measure in the literature was again highlighted in yellow. Note that this table represents a simplified

summary to display the overall pattern of results. Full details of each model and associated findings are discussed below.

***Between* subject IBI difference between regulation and view, but not between quantitative and qualitative goal.**

As seen in Table 8, results suggested that there were significant between subject differences depending on emotion regulation goal for the IBI measure, $F(2, 305.76) = 21.83$, $p < .001$. That is, IBI level was 0.1 unit higher when transforming compared to viewing emotional stimuli, $\gamma = 0.1$, $p < .001$. At the same time, IBI was 0.07 unit higher when neutralizing compared to viewing emotional stimuli, $\gamma = 0.07$, $p = .01$. No significant differences were observed between transforming and neutralizing emotional stimuli across participants, $\gamma = 0.03$, $p = .40$.

There was a significant gender and valence interaction on the effect of IBI levels $F(1, 15691) = 3.33$, $p = .03$. Specifically, compared to men, women displayed lower mean levels of IBI measures for emotional stimuli compared to neutral stimuli, (IBI: negative to neutral: $\gamma = -0.06$, $p = .01$; positive to neutral: $\gamma = -0.05$, $p = .03$).

***Within* subject IBI variations observed in regulation but did not differ by quantitative and qualitative goal.**

Results also showed that emotion regulation goal significantly predicted within-person variance in IBI. Figure 14 provides some additional information on this variance. The x-axis shows all the study members from subject 1 to 151 whereas the y-axis shows the averaged IBI coefficients across the multiple trials to view, neutralize, or transform emotional stimuli. Take subject 42 as an example, the average coefficient points of transforming, viewing, and neutralizing emotional stimuli were 1.49, 1.52, and 1.53 respectively. It shows a small amount of

variations within person by the different emotion regulation goals. More specifically, results suggested that a person's IBI level significantly differed from their own mean when they were provided with the goal to neutralize versus to view the stimuli; a significant within-person effect was also observed when study members were instructed to transform than to view emotional stimuli, (IBI: neutralize to view differed by ±0.077 units, $\gamma = 0.005$, $p = .01$, transform to view differed by ±0.08 units, $\gamma = 0.007$, $p = .002$). No significant within-person differences were observed when contrasting the goal to neutralize versus transform the stimuli, $\gamma = 0.03$, $p = .40$.

***Between* subject SBP levels differed by quantitative versus qualitative goal.**

As seen in Table 9, experimental manipulation of the emotion regulation goal significantly predicted mean SBP, $F(2, 15687) = 3.22$, $p = .04$ such that SBP were on average higher when transforming than neutralizing emotional stimuli, $\gamma = 0.07$, $p = .02$. No significant difference was found between neutralizing and viewing emotional stimuli, as well as between transforming and viewing emotional stimuli (*p*s > .10).

No *within* subject variations in SBP.

No significant within subject differences were observed in SBP based on emotion regulation goal conditions (p*s* > .31).

***Between* subject differences in SCR by gender, and by quantitative versus qualitative goals.**

Results showed significant between subject differences by gender, such that male had higher SCR responses than female on average, $F(1, 155.03) = 9.43$, $p = .002$ (see Table 10). There was also a significant goal by valence interaction, $F(4, 15583) = 5.88$, $p = .003$, such that individuals had lower SCR when neutralizing negative stimuli compared to viewing negative stimuli $t(15539) = -2.11$, $p = .004$, and compared to transforming negative stimuli, $t(15618) = -1.97$, $p = .008$.

***Within* subject SCR variations observed in moments using quantitative goal compared to moments using qualitative goal and passive viewing.**

Individuals displayed significant within-person variations SCR measures specifically when neutralizing than viewing emotional stimuli, ±0.17 units, $\gamma = 0.03$, $p = .002$, as well as when neutralizing than transforming emotional stimuli, ±0.17 unit, $\gamma = 0.03$, $p < .001$. No significant within-person variations were observed between transforming and viewing emotional stimuli, $\gamma = 0.0003$, $p = .89$.

No *between* subject differences in respiration rate (RR).

As seen in Table 11, no between subject differences on RR were observed by emotion regulation goals, picture valence, or gender (all *p*s > .15).

***Within* subject RR variations observed in regulation but did not differ by quantitative and qualitative goal.**

There were significant within-person RR fluctuations when study members were instructed to regulate than to view emotional stimuli, (neutralize to view: ±0.13 units, $\gamma = 0.01$, $p < .001$; transform to view: ±0.15 units, $\gamma = 0.02$, $p < .001$). There were no significant within-person fluctuations comparing a goal to neutralize and to transform $\gamma = 0.003$, $p = 0.22$.

Discussion and Implications

The current study is the first to systematically examine the influence of quantitative versus qualitative goals on specific physiological changes within an experimental paradigm. Overall, utilizing different emotion regulatory goals had differential effects on some, but not all physiological parameters. When study members were instructed to regulate their emotions using a qualitative (versus quantitative) goal, they showed higher mean levels of blood pressure and higher skin conductance levels. Conversely, when study members were instructed to regulate

their emotions using a quantitative (versus qualitative) goal, they exhibited lower levels of skin conductance response and skin conductance amplitude, as well as a higher tidal volume. Knowing that manipulating the goals of emotion regulation created different physiological response, these findings provided a more nuanced understanding of the relationship between emotion regulation and physiological outcomes.

The current study also informs our understanding of between versus within person variation in key physiological measures used in this field. Overall, results showed that individuals had significant fluctuations with themselves for the IBI, SCR, and RR measures. This finding suggested the importance of treating the change in regulation process and physiology over time as both a between and within person question. Future research should extend the use of within subject analytic methods to better characterize the relationship between emotion regulation and physiology over time, alongside the characterization of individuals' rates of change in these biomarkers.

Consistent findings in heart period measures and future directions

The current study found higher levels of IBI after being instructed to regulate versus view emotional stimuli. This result was consistent with previous studies in which emotion regulation instructions were not clearly specified, but the description of instructions followed either a quantitative or a qualitative goal (Denson et al., 2011a; Nasso et al., 2018). Interestingly, the other two supplemental heart period measures, SDSD and FT, did not follow this pattern of result. To my knowledge, there has not been much information on what the SDSD measure indicates. According to a meta-analytic study of 37 published studies on the relationship between HRV measures and psychological stress, SDSD has never been measured and thus did not appear in any of those published studies (Kim et al., 2018). One reason could be that the variance of heart

periods typically increases over time and SDSD is highly dependent on the measurement period. Instead of using SDSD, which refers to the standard deviation of the successive normal-normal (N-N) intervals, researchers have suggested SDANN, the standard deviation of the *average* N-N intervals over a fixed time epoch as a more well-defined statistic to measure the variance among heart periods (Berntson et al., 2016). A next step to follow up this analysis could be computing SDANN from the HRV measure to compare the results. Further, FT measure has mostly been found to be negatively associated with suppression and less is known with cognitive reappraisal (Egloff et al., 2006a; Gross, 1998a; Gross & Levenson, 1997; Lam et al., 2009). More research is needed to investigate whether FT is a reliable measure that correlates with emotion regulation, specifically cognitive reappraisal on physiology and health.

Other physiological measures reveal more nuanced relationship between emotion regulation and physiology.

Findings showed unique results of blood pressure between a quantitative and qualititave goal. Specifically, higher levels of both systolic and diastolic blood pressure were reported when using a qualitative goal compared with a quantitative goal. There has been preliminary mixed findings from previous studies, that participants either had lower diastolic blood pressure (Stemmler, 1997), or small increases in blood pressure (Jackson et al., 2000b; Ray et al., 2005; Richards & Gross, 2000) when regulating negative emotions compared to uninstructed view conditions. One speculation that explains this preliminary mixed findings could be the lack of clear manipulation of emotion regulation goals in those studies. Participants in studies that observed an increase in blood pressure might have used qualitative regulation goals whereas those in the study that observed a decrease in blood pressure mostly used quantitative regulation goals. Given that high blood pressure is mostly associated with unwanted health consequences

across the lifespan (Falkner et al., 2010; Obisesan et al., 2008), adopting a quantitative goal might be more favorable when regulating negative emotions. Future research could longitudinally investigate the benefits of quantitative regulation in people with or without high blood pressure to assess the preventative effects in reducing cardiovascular distress.

Current results also showed unique results of SCR between a quantitative and qualititave goal. Specifically, individuals had lower SCR when regulating with a quantitative goal compared to viewing the stimuli. This result was consistent with previous studies, in which regulation of negative emotion decreased SCR compared to no-regulation or neutral condition (Giuliani et al., 2008a; Raio et al., 2013). Current finding further suggests that having a quantitative but not a qualitative goal when regulating negative emotions could be the driving factor to explain the trend of results seen in previous studies. The possibility that quantitative regulation as the driving factor points to the importance of measuring an individual's specific goal in emotion regulation, as it might avoid adding confounding results in the current regulation literature. One reason the current study found significant impact on SCR with a quantitative, but not a qualitative goal could be qualitative regulation mainly involves changing the valence from positive to negative emotions and vice versa, and SCR generally does not differentiate reliably between positive and negative emotion (Dawson et al., 2007). Thus, the current finding also suggests that SCR might be a more reliable index to be selected for measuring arousal modulation in future regulation studies.

Significance and importance of adopting a within subject analytic method

Other than advocating for more research in including an emotion regulation goal in emotion regulation studies, current results also suggest measuring emotion and physiology on a within person level to better understand the corespondence between these two response systems.

This study provided some initial evidence of within-person fluctuations in physiology by different regulation goals over time. Overall, other than not finding within person variations in the blood pressure and one of the heart period measures (SDSD, see supplemental results in Appendix D), all the other physiological measures showed significant within subject fluctuations when using different emotion regulation goals. Specifically, individuals did not only show between level differences but also within-person fluctuations in IBI, RMSSD, and respiration measures when regulating versus viewing stimuli. Additionally, individuals showed unique within person fluctuations in all skin conductance measures (SCR, SCL, SRA) and respiratory changes when regulating with a quantitative versus qualitative goal. Although no significant between-person differences in skin conductance and respiratory responses was observed between quantitative or qualitative regulation, there were significant within-person changes in moments when study members adopted quantitative regulation versus moments when they adopted qualitative regulation. The current results advocate for more research questions on the within subject levels, with matching analytic strategy to better understand the relationship between emotional fluctuations and physiology that could be overlooked by between subject analyses.

Existing experiments investigating between subject differences in emotion regulation and physiology offered important insights, such as people instructed to use reappraisal exhibited more adaptive cardiovascular responses than to use other strategies (e.g., Gross, 1998a; Jamieson & Mendes, 2013). However, the association between emotional and physiological changes was often modest or even non-significant in magnitude. A previous meta-analysis found that in spite of observing large changes in negative emotions after encountering a stressor, the increased in negative emotions only accounted for 2-12% of changes in cardiovascular responses (Feldman et al., 1999). Researchers have spectulated that the effects of emotions on physiology may depend

on a variety of methodological variables. For instance the timing of emotion regulation, the type and order of presentation of stimuli (Ortner, 2015), as well as one's motivation and goal during regulation suggested by the current study. Additionally, the validity in using self-report measures of emotional experience could also determine the ability to detect the effect between emotional and physiological changes (Russell & Barrett, 1999). These issues are definitely important to consider and warranted for further investigations, but one other reason for the modest relationship between emotion and physiology could be due to using between person analyses to test within person questions.

A previous study examining the relationship between emotion and blood pressure also found unique results on a between and within person level (Zawadzki et al., 2017). Results showed that averaged levels of anger were unrelated to changes in blood pressure. In contrast, a fairly consistent effect of anger on blood pressure existed such that blood pressure was higher in moments when participants reported being angrier, than when they reported being less angry. There has also been growing studies using both between- and within-person analyeses to examine not just the stability of mood between persons, but also moment-to-moment emotional variations in different emotional disorders to provide better understanding in symptom fluctuations (e.g., Gloster et al., 2017; Holmes et al., 2016). Specifically, one study found that about 40-50% of the variance in interpersonal behavior and affect is actually due to daily fluctuations for people with personality disorders (Wright et al., 2015). Given that emotional and physiological changes are continual processes that are often measured repeatedly, within person analyses would go beyond than simply examining *whether* emotion influences or is related to physiology. Instead, within person analyses could enable us to identify *when* emotion influences or is related to the short-term changes in physiology within a person over time. These results

could provide further insights on how emotional and physiological processes can impact the etiology and progression of different physical and psychological disorders.

Limitations

Future studies should be conducted to solve the limitations and open questions of the current work. In particular, the current study only focused on administering one strategy, that is cognitive reappraisal to test how regulatory goals would affect physiology. As cognitive reappraisal is just one of many different strategies, attentional deployment and response modulation are two other commonly used families of strategies (Gross et al., 2006), studies should investigate if the effectiveness of other strategies would differ by using different regulatory goals. For instance, distraction has shown to reliably attenuate emotional responses through a variety of experimental tasks (e.g., Blair et al., 2007; Kanske et al., 2011; Lieberman et al., 2011; McRae et al., 2010). Future work could investigate whether using a quantitative or qualitative goal could also impose differential emotional and physiological changes in distraction to achieve more specifc outcomes.

In addition, the current study only included a narrow range of participants who were predominantly college students from 18 to 30 years old. Results would not be very generalizable for individuals outside of this age range. Importantly, the autonomic nervous system is affected by age. Studies have shown that aging is associated with a decrease in sympathetic and parasympathetic reactivity and responses, specifically in cardiac autonomic functions (e.g., Hotta & Uchida, 2010; Parashar et al., 2016; Vita et al., 1986). Further, the first study of this dissertation found that the effect of cognitive reappraisal on cardiovascular and respiratory outcome was smaller as age increased. These findings raised questions about how current results

might differ across age group and the corresponding implications to be drawn if it were a more diverse sample of study participants.

Another limitation is that this study only examined how emotion regulation goals influenced physiological change. Given that some theorists have argued that emotions are composed of specific patterns of correlated responses between behaviors, self-reported experience, and physiology (e.g., Dan-Glauser & Gross, 2013; Ekman et al., 1990; Mauss et al., 2005), future studies are suggested to also measure experiential, behavioral, and neural changes to inform how goals might affect the coherence of emotional processes across multiple response systems.

Conclusion

The results of the present investigation suggest the importance of measuring one's goal in emotion regulation to draw more specific conclusions about the relationship between emotion and physiology. Perhaps it is not just adopting cognitive reappraisal, but also how to reappraise that could be important in achieving desired outcomes. By instructing participants to adopt different goals, we are not only measuring how moving away from initial emotions, but also how arriving at another dimension of emotion could affect physiology. For instance, when asked to simply regulate a negative stimulus without clear instructions, participants could experience neutral or positive emotions, thus either decreasing or maintaining their arousal level and show different physiological changes in their end outcome. With clear instructions, we would be able to better capture the end physiological state of their regulation, and better predict how it is related to psychological and physical health.

Since this is just the beginning of testing how regulatory goals could influence physiology, it leaves room for follow-up studies to examine this relationship. For instance, as the

current study instructed participants to follow the specified goals, future research could measure one's self-reported goals to see what goals individuals prefer, and whether the strategies they use to regulate would depend on their goals. The study also excluded a certain number of participants because they failed to pass the manipulation checks and understand the differences in regulatory goals. Thus, future research is needed to understand how beliefs about the feasibility of adopting different goals and other desirability considerations could influence the selection of goals and the corresponding effect on physiology.

Further, results also suggest the importance of examining within person variations to uncover significant moment-to-moment changes that might also be indicative to one's health conditions. Given that individuals have different emotional and physiological baseline and reactivity, and the nature of these processes are dynamic, study design that includes multiple assessments over time are encouraged to help advance the understanding of emotional and physiological flexibility on well-being.

General Discussion

Though emotion regulation has been a growing field of research, much could still be understood, and the current dissertation provided new insights and addressed some significant gaps in the literature. Chapter 1 first integrated and synthesized current findings of the impact of cognitive reappraisal on different physiological outcomes. Results established that cognitive reappraisal was an effective way to influence the eye movement outcomes. Given that there were comparatively fewer studies using startle eye blinks and responses than other physiological indices in emotion regulation research, the current meta-analysis calls for more examination using these measures to better understand the relationship between cognitive reappraisal, eye movement, and health. Results also found that the effect of cognitive reappraisal on the electrodermal and eye movement outcome was significant when regulating negative than positive emotions. This further suggested the eye movement indices were reliable in not only indicating the effectiveness of regulation success, but also responding to different emotional changes.

Although results were non-significant, the current meta-analysis reflects the following trends from the existing literature. Cognitive reappraisal had a large impact than suppression on the cardiovascular and respiratory outcome, which is in line with previous research that cognitive reappraisal was associated with larger decrease in overall physiology than suppression (Demaree et al., 2006; Gross & Levenson, 1993). At the same time, suppression had larger effects on the facial and eye movement outcomes, which supports that suppression mainly focuses on the process of consciously inhibiting emotional expressions. An important observation that could speak to the non-significant patterns of results in the current review is that there were immense methodological variances between studies. Specifically, there were a wide range of physiological

indices included in a research study, and how they were measured differed hugely. This unfortunately resulted in a very small number of studies that used identical measurement of physiological index. Similar indices were therefore grouped, which inevitably added more heterogeneity in the variables of interest. Existing studies drawing conclusions regarding the effect of regulation on different physiology (e.g., heart rate variability) have included different indices (e.g., time domain measures such as RMSSD or frequency domain measures such as the ratio of low-frequency/high frequency of HRV), and different domain measures have been suggested to be associated with different nervous systems (e.g., Bigger et al., 1988; Ewing et al., 1991; Penttilä et al., 2001; Spiers et al., 1993). The current review thus recommends future research to be more discreet in describing study questions and implications on specific physiological outcomes, and include relevant physiological measures to the corresponding research questions. Only if we specified clear hypotheses with the appropriate measures to evaluate the questions, then we could better understand the relationship between emotion regulation and physiological response systems.

While synthesizing the literature in Chapter 1, another important observation was that the instructions of emotion regulation varied hugely, such that participants were not clearly directed to regulate to a specific desired end emotional state. Though we assume people typically want to feel good and avoid bad feelings (e.g., English et al., 2017; Riediger et al., 2009), research has shown that emotion goals differed by context and person characteristics (e.g., Tamir et al., 2020; Wood et al., 2003). People could pursue more or less happiness and could be motivated to decrease and increase pleasant and unpleasant emotions (see Tamir, 2016 for a review). Interestingly, Chapter 1 found that the strength of effect of reappraisal was stronger when there was not a clear regulatory goal compared with a goal to modulate the valence or arousal of

emotions. It is unknown whether this result stems from the potential additive effect of modulating both the valence and arousal dimensions of emotion on physiology, or some unique effect from the unclear regulation instructions in those studies.

Chapter 2 therefore explored this question about how the effect of cognitive reappraisal on physiology would depend on the goal of emotion regulation. Results revealed that having distinct emotion regulation goals indeed created differential impacts on physiology. Specifically, blood pressure and skin conductance measures were found to be lower when using a quantitative compared with a qualitative goal. Since there were some preliminary mixed findings of the effect of reapraisal and blood pressure in previous studies, in which blood pressure might increase or decrease when regulating negative emotions compared to uninstructed view conditions (decrease: Jackson et al., 2000; Ray et al., 2005; Richards & Gross, 2000.; increase Stemmler, 1997), current results offered a potential explanation for those mixed findings, which is the lack of clear manipulation of emotion regulatory goals in those studies.

Current results found lowered skin conductance responses when using quantitative regulation versus qualitative regulation. This result could add more information on the finding from Chapter 1, that the stronger effect on electrodermal outcomes by reappraisal when regulating negative versus positive emotions is driven by quantitative, but not qualitative regulation. In other words, participants might show bigger reduction in skin conductance responses specifically when regulating negative emotions quantitatively (e.g., decrease negative emotion to a neutral point) compared with when regulating qualitatively (e.g., decrease negative emotions and increase positive emotions). This is in line with previous evidence that skin conductance was an index for autonomic arousal (Jacobs et al., 1994) and skin conductance responses were not as distinguishable between positive and negative valence (Dawson et al.,

2007). As mentioned above that including relevant physiological indices are important in presenting a clear relationship between regulation and physiology, this result suggested skin conductance was a more reliable and relevant index to measure emotion regulation with a goal of regulating the arousal aspect of emotions. Results have significant contribution to research and clinical practice. Since physiological changes are mostly tied to one's autonomic nervous system, which is more responsive to quantitative regulation, current findings suggest that measuring the goals in emotion regulation could provide insights on the physiological mechanisms of emotion regulation. Results also suggested that more specific regulation instructions could be trained and tailored to patients with different needs in health outcomes. For instance, quantitation regulation could be a long-term prevention or treatment for people with high blood pressure, or abnormally high levels of skin conductance responses.

Apart from investigating the between subject effects of regulation goal on physiology, Chapter 2 also examined the within subject effect. Results showed significant within-person variations in physiology by different regulatory goals over time. For instance, individuals showed unique within person fluctuations in all skin conductance measures and tidal volume changes when regulating with a quantitative goal compared with a qualitative goal. Although quantitative regulation did not have a between-person impact on the averaged skin conductance and tidal volume responses, there were significant moment-to-moment fluctuations when a person adopted quantitative versus qualitative regulation. This finding suggested that since between and within person analyses test different questions, results may not converge on a similar answer (e.g., Hoffman & Stawski, 2009). It is therefore important to handle and interpret data appropriately to avoid ecological fallacy (see Kramer, 1983 for reviews; Robinson, 2009),

so that results highlighting the nature of relationships between variables at one level (e.g., between person) would not be assumed to exist at another (within person).

If multilevel modeling was not adopted, we would only assume emotion regulation goals had no significant effect on averaged skin conductance and respiratory changes. The insights discovered by the within subject analyses would not be realized. This is not to suggest multilevel modeling should always be used for all types of research questions, but only when data warrants for more complex modeling, especially when it comes to physiological data with repeated observations nested within persons (Page-Gould, 2017). Since emotion research has suggested that excessive within person variability in negative and positive emotions can signal psychological instability associated with distress and lower well-being and life satisfaction (Gruber et al., 2012; Kashdan et al., 2006), investigating within person level of emotion regulation based on one's need could be beneficial for maximizing one's health. Indeed, one recent study investigated the individual differences and intraindividual variability in self-reported emotion regulation found different between and within person structure of regulation strategy use (McMahon & Naragon-Gainey, 2019). Given that Chapter 2 provided some initial evidence that different regulatory goals could influence physiology on both between and within person levels with experimental data, more work is needed to examine the momentary variances of emotion regulation and subsequent health outcomes.

Altogether, findings from the two studies provide a more nuanced understanding between the relationship of cognitive reappraisal and physiological outcomes. This dissertation highlights the importance of regulatory goals in emotion regulation. Findings from this dissertation could enhance interventions that focus on using quantitative regulation to modulate high levels of arousal in patients with high blood pressure and skin conductance responses that are linked to

adverse health outcomes. It also lays a theoretical foundation for future regulation studies to investigate the effects of different emotion regulation goals in the context of other emotion regulation strategies other than cognitive reappraisal. The dissertation also recommends two methodological improvements from the synthesis of the current studies, including more discreet in selecting and reporting relevant physiological measures and analytic strategies to minimize heterogeneity in the literature. Finally, continuing study of the dynamic process of regulatory goals on both between and within subject levels, and how these processes influence our physiology, is important for the enhancement of health and well-being.

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Table 1. Overview of Literature Search

Literature Search Variable Name (May 2018):	Search Terms: "reappraisal" and "physiology" or "heart rate" or "blood pressure" or "skin conductance" or "respiration" or "facial expression" or "EMG" or "pulse" or "cardiovascular" or "thoracic" or "pupil"	Search Parameters: The full text of documents was searched using the PsycINFO ProQuest search engines	Electronic Databases: *PsycINFO*, *ProQuest Dissertation and Theses A&I*, *PubMed*	Documents Retrieved: 689
(December, 2019)	Additional Search Terms Added: "temperature", "startle", "sympathetic activation", "parasympathetic activation", "sympathetic withdrawal", "parasympathetic withdrawal", "autonomic", "autonomic imbalance", "autonomic control", "autonomic flexibility"			Total Documents Retrieved: 827

Table 2. Complete list of information coded in research reports

Report Characteristics
1. Author names 2. Year 3. Report type (e.g., Book Chapter, Conference paper/Poster/Abstract, Dissertation, Government report, Journal article, Master's Thesis, Manuscript submitted for publication, Private report)
Setting characteristics
1. Country 2. Organization type 3. Funding Source
Sample characteristics
1. Sample identification number 2. Defining characteristics of overall sample (e.g., all females) 3. Sample size 4. Defining characteristics of sample subgroups (e.g., SES status) 5. Subgroup label (e.g., high SES, low SES) 6. Subgroup size 7. Average age 8. Age range of participants 9. Ratio of males to females 10. Race/Ethnicity breakdown
Cognitive reappraisal variable
1. CR measure citation 2. CR manipulation 3. Was the manipulation created or adapted? 4. If so, how was it created or adapted? 5. Was CR designed for self- or other- regulation? 6. Was there an emotion induction? 7. If so, what type of stimuli did they use? (e.g., Pictures, Film, Pain or shock, Past experience or personally relevant thought, Stressor task, Verbal or written instructions, verbal or written feedback from another task 8. Valence of emotion induced? (e.g., positive, negative, neutral) 8a. Type of emotion induced? (e.g., Happiness, sadness, anger) 8b. Was this emotion connected to an approach or avoidance motivation? 9. Was there an emotion regulation instruction 10. If yes, time given (before, after or same as the induction) 10a. Copy the reappraisal instruction provided to the participants 11. Levels of instructions (e.g., look, increase, decrease) 12. Number of trials for each valence of emotions

Table 2 Continues

13. Experimental blocks
14. Duration of baseline
15. Duration of emotion induction period
16. Fixation time
17. Duration of instruction period
18. Duration of regulation period
19. Duration of post-regulation period
20. Duration of each trial
21. Within, between or mixed-groups design
22. Hedonic or Contra-hedonic goal of regulation
23. Qualitative or Quantitative goal of regulation

Physiological outcomes variable
1. Outcome ID
2. Type of physiological outcome measured (e.g., heart rate, heart rate variability, blood pressure, interbeat interval, pre-ejection period, skin conductance, respiration, electromyography, finger temperature, finger pulse, finger transmission time, ear pulse, ear transmission time, pupil dilation)
3. Time point of measurement (continuous or single or multiple time points)
4. Specification for time points

Effect Size information

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1. Effect Size ID
2. Effect Size Index
3. Effect Size Page
4. Effect size coefficient
5. Effect size coefficient page
6. ES for self- or other-regulation
7. Comparison group or level
8. Ordering of emotion induction valence
9. Moderator
10. Specify moderator and levels
11. Sample size for specific analysis
12. Sample size for CR and comparison groups
13. Sample size for PO
14. PO time point and specifications
15. PO mean
16. PO standard deviation
17. Relevant inferential statistics
18. Calculated Effect Size
19. Method of calculating the effect size

Table 3. Summary of moderators and hypotheses

Moderators	Hypotheses
Cardiovascular and respiratory Outcomes	Respiratory Sinus Arrhythmia, Respiration Rate, and Respiration Depth are expected to produce the smallest effects compared to all the other cardiovascular measures (i.e., HR, HRV, IBI, SBP, DBP, FPT, FPA)
	Finger pulse transmission time and finger pulse amplitude would produce a smaller effect relative to these cardiovascular measures that involves a direct measurement of the heart: HR, HRV, IBI, BP
Electrodermal Outcomes	No specific hypothesis about how the effect of cognitive reappraisal on SCL and SCR will differ.
	No specific prediction on how the effect of cognitive reappraisal on cardiovascular and electrodermal outcomes would differ.
Facial Outcomes	I predict that the effect of cognitive reappraisal would be larger for facial EMG than facial expressions coded by the FACS
	No specific predictions on how the effect of cognitive reappraisal on cardiovascular, electrodermal and facial behavioral outcomes would differ from each other.
Eye Movement Outcomes	No specific hypothesis about how the effect of cognitive reappraisal on startle responses and startle response amplitudes will differ.
	No specific prediction on how the effect of cognitive reappraisal on cardiovascular and electrodermal outcomes would differ.
Types of Emotion Regulation Strategies	I predict that the effect of cognitive reappraisal would be larger comparing to all the other types of regulation strategies (i.e., no regulation, expressive suppression, mindfulness, acceptance, distraction, distancing, affect labeling, rumination) [5]
Age	Larger effects will be seen in younger participants than older participants.
Gender	I predict that women will have larger CR effects than men.
Publication status	I predict that published research reports will have larger CR effects than unpublished reports.

[5] A count of strategies in existing screened articles: no regulation instruction/passive viewing: 64; cognitive reappraisal: 85; expressive suppression: 31, mindfulness: 2, acceptance: 7, distraction: 11, distancing: 6, affect labeling: 2, rumination: 4)

Table 4. List of all reports included in the Meta-Analysis

Report	Publication Type	Study	Outcome Type	Age	White	Female
Asnaani, Sawyer, Aderka, & Hofmann (2013)	Journal article	Study 1	Eye movement	18.9	41.5%	70.1%
Bebko, Franconeri, Ochsner, & Chiao (2011)	Journal article	Study 1	Eye movement	19.67		47.6%
Birk & Bonanno (2016)	Journal article	Study 1	Cardiovascular and Respiratory	31.6	23.33%	55.56%
Bowlin (2014)	Dissertation/Thesis	Study 1	Cardiovascular and Respiratory		78.5%	53.6%
Butler, Gross & Barnard (2014)	Journal article	Study 1	Cardiovascular and Respiratory, electrodermal, facial	20.1	44%	100%
Butler, Wilhelm & Gross (2006)	Journal article	Study 1	Cardiovascular and Respiratory	20	43.2%	100%
Denny (2012)	Dissertation/Thesis	Study 1	Cardiovascular and Respiratory	23.23		70.6%
Denson, Crewswell, Terides, & Blundell (2014)	Journal article	Study 1	Cardiovascular and Respiratory	20.54		52%
Denson, Crewswell, Terides, & Blundell (2014)	Journal article	Study 2	Cardiovascular and Respiratory	21.57		58%
Denson, Grisham & Moulds (2011)	Journal article	Study 1	Cardiovascular and Respiratory	20.23		100%
Deveney & Pizzagalli (2008)	Journal article	Study 1	Electrodermal	23.97	81.3%	78.14%
Di Simplicio, Costoloni, Western, Hanson, Taggart, & Harmer (2012)	Journal article	Study 1	Cardiovascular and Respiratory	28.59		53.33%
Dillion & LaBar (2005)	Journal article	Study 1	Electrodermal	22		22.92%
Efinger, Thuillard, & Dan-Glauser (2019)	Journal article	Study 1	Cardiovascular and Respiratory, electrodermal, facial	20.7		100%
Eippert, Veit, Weiskopf, Erb, Birbaumer, & Anders (2007)	Journal article	Study 1	Facial and eye movement	23.3		100%

Fuentes-Sanchez, Jaen, Escrig, Lucas, & Pastor (2019)	Journal article	Study 1	Cardiovascular and Respiratory, electrodermal, eye movement	25.1		59.02%
Germain and Kangas (2015)	Journal article	Study 1	Cardiovascular and Respiratory	30.26		
Gessner (2015)	Dissertation/Thesis	Study 1	Electrodermal, facial	24	53.75%	75%
Graham, Ash, & Den (2017)	Journal article	Study 1	Electrodermal		29.54%	100%
Gross (1998)	Journal article	Study 1	Cardiovascular and Respiratory, electrodermal	21	33%	50%
Hamptom, Hadjistavropoulos, Gagnon, Williams, Clark (2015)	Journal article	Study 1	Electrodermal, facial	20.78		68%
Hangen, Elliot, & Jamieson (2019)	Journal article	Study 1	Cardiovascular and Respiratory	19.9	67.0%	75.8%
He, Lin, Xia, Liu, Zhang, & Elliott (2018)	Journal article	Study 1	Facial	21		54.55%
He, Lin, Xia, Liu, Zhang, & Elliott (2018)	Journal article	Study 2	Facial	21		55%
Hendricks & Buchanan (2016)	Dissertation/Thesis	Study 1	Cardiovascular and Respiratory, electrodermal, facial, eye movement	19.31		57%
Hofmann, Heering, Sawyer, Asnaani (2009)	Journal article	Study 1	Cardiovascular and Respiratory	19.6	53.5%	58.9%
Jamieson, Nock, & Mendes (2012)	Journal article	Study 1	Cardiovascular and Respiratory	21.88		50%
Kesek (2010)	Dissertation/Thesis	Study 1	Electrodermal		86.4%	47.1%
Kim & Hamann (2012)	Journal article	Study 1	Electrodermal, facial	20.19	63.9%	50%
Kinner, Kuchinke, Dierolf, Merz, Otto, & Wolf (2017)	Journal article	Study 1	Electrodermal, facial, eye movement	24.4		100%
Kircanski, Lieberman, & Craske (2012)	Journal article	Study 1	Electrodermal	20.5	24%	82%

Koval, Butler, Hollenstein, Lanteigne, & Kuppens (2015)	Journal article	Study 1	Cardiovascular and Respiratory	20.05	43.2%	100%
Lalot, Delplanque, & Sander (2014)	Journal article	Study 1	Facial	27.3		66.67%
Le, Moulds, & Nickerson (2018)	Journal article	Study 1	Electrodermal	22.18		51.6%
Leiberg, Eippert, Veit, & Anders (2012	Journal article	Study 1	Electrodermal, eye movement	24.1		100%
Levy (2016)	Dissertation/Thesis	Study 1	Cardiovascular and Respiratory	22.43		67.7%
Li, Yin, Feng, Hu, Ding, & Chen (2018)	Journal article	Study 1	Facial	20		58.82%
Lohani & Isaacowitz (2014)	Journal article	Study 1	Electrodermal, facial, eye movement	Younger adults: 18.5 Older adults: 71.42	78%	Younger adults: 73.8% Older adults: 79.2%
Major (2013)	Dissertation/Thesis	Study 1		18.99	82%	53%
Martins, Florjanczyk, Jackson, Gatz, & Mather (2018)	Journal article	Study 1	Eye movement			
Mauersberger, Hoppe, Brockmann, & Hess (2018)	Journal article	Study 1	Cardiovascular and Respiratory	32.2		66.2%
Menchola (2017)	Dissertation/Thesis	Study 1	Electrodermal, facial, eye movement	20.11		55%
Myruski (2018)	Dissertation/Thesis	Study 1	Cardiovascular and Respiratory	6.94	44.2%	51.2%
Ortner (2015)	Journal article	Study 1	Electrodermal			75.8%
Ossenfort, Harris, Platzek, & Isaacowitz (2019)	Journal article	Study 1	Eye movement	70.57	100%	69%
Pedder, Terrett, Bailey, Henry, Ruffman, & Rendell (2016)	Journal article	Study 1	Facial	23.3		68.6%
Pizzie & Kraemer (2018)	Dissertation/Thesis	Study 1	Electrodermal	19.56		63.5%
Popham (2014)	Dissertation/Thesis	Study 1	Cardiovascular and Respiratory	49.5		51.5%

Ray, McRae, Ochsner, & Gross (2010)	Journal article	Study 1	Facial	18.9		100%
Ray, Wilhelm & Gross (2008)	Journal article	Study 1	Cardiovascular and Respiratory	20	47.9%	100%
Rohramann, Hopp, Schienle, & Hodapp (2009)	Journal article	Study 1	Cardiovascular and Respiratory, electrodermal	25.47		0%
Sammy (2018)	Dissertation/Thesis	Study 1	Cardiovascular and Respiratory	21.72		38.9%
Shiota and Levenson (2012)	Journal article	Study 1	Cardiovascular and Respiratory	36.5	52%	50%
Stiller, Kattner, Gunzenhauser, & Schmitz (2019)	Journal article	Study 1	Cardiovascular and Respiratory, electrodermal	24.3		73.8%
Svaldi, Tuschen-Caffier, Lackner, Zimmermann, & Naumann (2012)	Journal article	Study 1	Cardiovascular and Respiratory	22.83		100%
Timmer-Murillo (2017)	Dissertation/Thesis	Study 1	Cardiovascular and Respiratory	19.14	66.3%	
Troy, Shallcross, Brunner, Friedman, & Jones (2018)	Journal article	Study 1	Electrodermal	18.3	57%	72%
Urry (2001)	Dissertation/Thesis	Study 1	Cardiovascular and Respiratory, electrodermal, facial		81.7%	
Urry (2009)	Journal article	Study 1	Cardiovascular and Respiratory, electrodermal, facial		68.4%	63.4%
Urry (2010)	Journal article	Study 1	Cardiovascular and Respiratory, electrodermal, facial	18.8	76%	52%
Urry, van Reekum, Johnston, & Davidson (2009)	Journal article	Study 1	Cardiovascular and Respiratory, electrodermal, eye movement	64.8		57.7%
van Reekum et al., (2007)	Journal article	Study 1	Eye movement			62.1%

Westermann, Rief, & Lincoln (2014)	Journal article	Study 1	Cardiovascular and Respiratory, electrodermal,	21.2		97%
Witvliet, Mohn, Hinman, & Knoll (2015)	Journal article	Study 1	Cardiovascular and Respiratory, facial	19.24	90%	50%
Wolgast, Lundh, & Viborg (2011)	Journal article	Study 1	Electrodermal, facial	27.4		58.9%
Wu, Winkler, Wieser, Andreatta, Li, & Pauli (2015)	Journal article	Study 1	Facial	24.31		49.33%
Yeh, Barber, Suri, & Opitz (2019)	Journal article	Study 1	Facial	23.8	33%	85.11%
Yuan, Ding, Liu, & Yang (2015)	Journal article	Study 1	Cardiovascular and Respiratory	21.6		41.7%
Zhan et al., (2017)	Journal article	Study 1	Electrodermal	20.76		66%
Zhou and Bishop (2012)	Journal article	Study 1	Cardiovascular and Respiratory	20.91	50%	100%
Zinner (2008)	Dissertation/Thesis	Study 1	Electrodermal, facial			0%

Table 5. Results of Moderator Analyses

Moderator	*F*	*df*	*g*	*df*	95% CI	*ES*	*k*	I^2	T^2
Emotion Regulation Strategies								95.04	1.10
Cardiovascular and respiratory outcome	0.23	4.14							
Suppression			-0.04	15.85	[-0.18, 0.10]	49	19		
No regulation			-0.14	29.25	[-0.60 0.33]	121	33		
Acceptance			-0.06	2.86	[-0.23, 0.10]	13	4		
Rumination			-0.10	3.47	[-1.21, 1.01]	10	5		
Attentional Deployment			-0.28	1.00	[-12.80, 12.23]	4	2		
Electrodermal Outcome	0.54	0.64						91.30	0.58
Suppression			-0.19	10.2	[-0.63, 0.25]	35	12		
No regulation			0.11	14.09	[-0.15, 0.39]	102	28		
Acceptance			-0.28	1.58	[-1.13, 0.57]	5	2		
Affect Labeling			0.11	1.31	[-3.32, 3.54]	2	2		
Rumination			1.40	1.32	[-19.62, 22.41]	2	4		
Attentional Deployment			0.27	6.54	[-0.23, 0.76]	8	5		
Facial outcome	0.19	2.18						95.14	1.05
Suppression			0.35	8.59	[-0.35, 1.05]	28	11		
No regulation			-0.52	13.11	[-0.51, 0.17]	93	22		
Acceptance			-0.41	1.17	[-2.26, 2.14]	4	2		
Rumination			-0.46	1.92	[-1.98, 1.75]	6	3		
Attentional Deployment			-0.68	4.96	[-2.14, 1.47]	9	4		
Eye movement outcome								94.54	1.28
Suppression	1.47	3.86	0.97	3.40	[-0.67, 2.61]	12	5		
No regulation			0.47	5.36	[-0.22, 1.17]	59	13		
Acceptance			-0.05	3.40	[-0.05, -0.05]	2	1		
Attentional Deployment			0.20	3.51	[-1.68, 2.08]	5	3		

Types of Emotion Regulated	0.74	4.67						95.14	1.15
Cardiovascular and respiratory outcome									
Negative			-0.09	34.9	[-0.41, 0.23]	176	34		
Both			-0.38	2	[-1.72, 0.97]	21	3		
Electrodermal Outcome	203	4.43***						91.08	0.55
Negative			0.17*	23.93	[-0.05, 0.39]	124	25		
Positive			-2.03***	23.93	[-3.35, -0.64]	2	1		
Both			-0.09	2.43	[-1.15, 0.97]	30	3		
Facial outcome	0.26	5.76						95.39	1.12
Negative			0.03	13.99	[-0.34, 0.41]	91	15		
Positive			-0.12	1.99	[-0.79, 0.56]	20	3		
Both			-0.28	4.99	[-1.37, 0.80]	29	6		
Eye movement outcome	8.81	4.75*						94.52	1.31
Negative			0.60**	12	[0.003, 1.19]	72	13		
Positive			0.29	10.99	[-0.90, 0.28]	1	1		
Both			0.001	1	[-0.89, 0.89]	5	2		
Emotion Regulation Goal								95.23	1.17
Cardiovascular and respiratory outcome	1.68	21.5*							
Quantitative			-0.38	13.63	[-0.92, 0.16]	78	15		
Qualitative			-0.25	9.64	[-1.08, 0.57]	67	11		
Unclear			0.26**	12.99	[0.08, 0.60]	52	14		
Electrodermal Outcome	2.19	5.63						91.00	0.56
Quantitative			-0.07	12.88	[-0.39, 0.24]	91	14		
Qualitative			-0.23	2.98	[-1.34, 0.88]	10	3		
Unclear			0.44*	23.47	[-0.03, 0.90]	55	12		
Facial outcome	0.44	2.99						95.15	1.07
Quantitative			-0.25	1	[-0.68, 0.17]	60	12		
Qualitative			0.57	1.36	[-10.08, 11.21]	3	2		
Unclear			0.04	1.44	[-0.49, 0.56]	77	10		
Eye movement outcome	1.35	2.31						94.41	1.20
Quantitative			0.57	3.99	[-1.16, 2.31]	12	5		
Qualitative			0.87	1.00	[-12.80, 14.54]	9	2		

Unclear			0.41*	6.99	[0.01, 0.80]	57	8		
Publication status									
Cardiovascular and respiratory outcome	0.95	17.8						94.97	1.08
Published			-0.47	8.00	[-1.23, 0.30]	158	30		
Unpublished			-0.005	28.9	[-0.33, 0.33]	39	9		
Electrodermal Outcome	1.03	12.8						91.37	0.58
Published			-0.17	5.90	[-0.79, 0.45]	125	24		
Unpublished			0.17	20.9	[-0.09, 0.42]	31	9		
Facial outcome	2.77	10.2						94.91	1.00
Published			-0.55	4.77	[-1.13, 0.04]	119	21		
Unpublished			0.08	7.72	[-0.29, 0.44]	21	7		
Eye movement outcome	1.91	1.77						94.07	1.11
Published			-0.14	1	[-3.20, 2.92]	125	24		
Unpublished			0.63*	12	[0.05, 1.20]	31	9		
Age[6]									
Cardiovascular and respiratory outcome			-0.08**	2.7	[-0.12, -0.04]	163	37	94.24	0.92
Electrodermal Outcome			-0.002	1.73	[-0.02, 0.02]	114	25	91.93	0.57
Facial outcome			0.01	1.61	[-0.04, 0.05]	116	22	95.35	1.04
Eye movement outcome			0.47	2.78	[-0.06, 0.10]	64	13	94.80	1.21
Gender (Percentage male)									
Cardiovascular and respiratory outcome			-0.005	10.53	[-0.02, 0.01]	180	36	95.58	1.23
Electrodermal Outcome			-0.01	6.59	[-0.02, 0.01]	132	28	91.68	0.58
Facial outcome			-0.001	5.72	[-0.02, 0.02]	132	23	95.47	1.10

[6] meta-regression coefficients *b*s, and not the estimated average effect size coefficients (*g* indices) are reported for the age moderator, to indicate the changes in effect sizes with cognitive reappraisal by age

Eye movement outcome			-0.0001	4.62	[-0.03, 0.03]	76	14	94.58	1.2
Study Design									
Cardiovascular and respiratory outcome	0.43	21.1						95.64	1.53
Between Subjects			-0.16	23.4	[-0.50, 0.19]	114	27		
Within Subjects			-0.04	12.6	[-1.19, 1.11]	62	16		
Electrodermal Outcome	1.3	10.8						90.22	0.64
Between Subjects			-0.12	11.29	[-0.59, 0.35]	68	13		
Within Subjects			0.16	6.94	[-0.13, 0.45]	32	10		
Facial outcome	0.34	7.7						92.56	0.72
Between Subjects			-0.05	5.57	[-0.85, 0.74]	35	7		
Within Subjects			0.13	6.54	[-0.23, 0.49]	49	8		
Eye movement outcome	0.36	0.5						97.83	4.45
Between Subjects			1.02	1	[-10.8, 12.8]	8	2		
Within Subjects			1.58	1	[-18.7, 21.9]	6	2		
Induction type (Exploratory)									
Cardiovascular and respiratory outcome	0.25	6.14						95.58	1.30
Picture			-0.41	10.98	[-1.06, 0.23]	63	12		
Film			-0.01	6.97	[-0.74, 0.71]	58	8		
Recall Task			-0.03	5	[-0.67, 0.62]	28	6		
Stressor Task			0.02	4	[-2.06, 2.09]	13	5		
Pain Task			0.34	1	[-4.95, 5.62]	7	2		
Other			0.005	5	[-0.51, 0.51]	28	6		
Electrodermal Outcome	1.51	6.47						91.39	0.59
Picture			0.19	15.49	[-0.06, 0.43]	90	17		
Film			-0.26	7.94	[-0.77, 0.26]	44	9		
Pain Task			-0.03	1.00	[-0.03, -0.03]	4	1		
Other			0.69	1.95	[-1.73, 3.11]	18	3		
Facial outcome	1.04	6.35						95.58	1.18
Picture			-0.12	14.99	[-0.55, 0.31]	82	16		
Film			0.18	3.99	[-0.63, 1.23]	34	5		
Recall Task			-0.28	1	[-0.59, 0.27]	2	1		
Pain Task			-0.10	1	[-0.41, 0.46]	16	1		

Other			-0.12	1	[-0.43, 0.43]	6	1		
Eye movement outcome	3.22	37.9						94.13	1.07
Picture			0.50	13	[-0.05, 1.05]	72	14		
Film			0.82***	1	[0.816, 0.817]	6	1		
Motivation (Exploratory)								96.34	1.50
Cardiovascular and respiratory outcome	1.33	10.4							
Approach			0.07	5	[-0.31, 0.46]	33	6		
Avoid			-0.13	16	[-0.68, 0.46]	83	17		
Both			-0.18	1	[-0.18, 0.13]	12	1		
Electrodermal Outcome								90.42	0.53
Approach	0.13	1.81	0.11	2.95	[-2.01, 2.23]	14	4		
Avoid			0.05	13.97	[-0.25, 0.34]	71	15		
Both			0.17	1	[-1.47, 1.81]	25	2		
Facial outcome	0.55	4.62						91.80	0.77
Approach			-0.08	4.98	[-0.62, 0.47]	37	6		
Avoid			0.30	3	[-0.98, 1.52]	32	4		
Both			-0.14	1	[-0.14, 0.12]	6	1		
Eye movement outcome	8.33	3*							
Approach			0.09	1	[-0.62, 0.47]	2	1	96.74	2.33
Avoid			0.51	3	[-0.19, 1.39]	12	4		
Both			1.85***	1	[1.948, 1.95]	6	1		

Notes. F = Wald-type test statistic using the AHZ test (Tipton & Pustejovsky, 2015); df = degrees of freedom; g = estimated average effect size coefficient; ES = number of effect sizes; k = number of independent samples.
***$p < .001$ **$p < .01$ *$p < .05$

Table 6. Correlations among physiological indices

	Heart Rate Measures				Blood Pressure Measures			Electrodermal Measures			Respiratory Measures	
	IBI	RMSSD	SDSD	FT	PEP	SBP	DBP	SCR	SRA	SCL	RR	VI
IBI	1											
RMSSD	.378**	1										
SDSD	.295**	.591**	1									
FT	-.137**	-.053**	-.063**	1								
PEP	.035*	.087**	.057**	-.077**	1							
SBP	-.010	.069**	.006	-.013	. 218*	1						
DBP	-.116**	.027**	-.083**	-.065**	.064**	.74**	1					
SCR	-122**	-.082**	-.033**	.119**	-.034**	.030**	.045**	1				
SRA	-.096**	.023**	.009	.110**	-.002	.041**	.021**	.221**	1			
SCL	-.150**	.013	.007	.102**	.041**	.050**	.073**	.264**	.013	1		
RR	-.059**	.016*	.007	-.065**	-.015	.033**	.022**	-.038**	-.049**	-.063**	1	
VI	-.118**	.044**	.028**	-.146**	-.019*	-.049**	-.057**	.025**	.084**	.102**	-.205**	1

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

Table 7. Overview of study 2 findings

Heart period measures	Between subject Differences	Within subject variations
IBI	✓	✓
RMSSD	✓	✓
SDSD		
FT		
Blood pressure measures		
SBP	✓	
DBP	✓	
PEP	✓	
Electrodermal measures		
SCR	✓	✓
SCL		✓
SRA		✓
Respiratory measures		
RR		✓
VI	✓	✓

Table 8. Multi-level Model of Emotion Regulatory Goal, Picture Valence on Standardized IBI measure with time

					CI_{95}	
Fixed effects (intercepts, slopes)	Estimate	*SE*	t-value	p-value	Lower	Upper
Intercept	-0.20	0.10	-2.04	0.04*	-0.28	1.13
Time	0.002	0.0002	13.74	0.00***	0.0019	0.0026
Gender (female)	-0.12	0.14	0.87	0.38	-0.40	0.16
Goal						
Transform	0.10	0.03	3.25	0.0012	0.0005	0.12
Neutralize	0.07	0.03	2.33	0.01	0.03	0.08
Picture Valence						
Positive	-0.006	1.07	-0.94	0.34	-0.10	0.01
Negative	0.015	0.02	0.68	0.49	-0.09	0.04
Transform X Negative	-0.014	0.02	-0.47	0.63	-0.09	0.02
Neutralize X Negative	0.05	0.03	1.58	0.11	-0.03	0.08
Transform X Positive	-0.04	0.03	-1.19	0.23	-007	0.04
Neutralize X Positive	-0.04	0.03	0.77	0.44	-0.01	0.11
Transform X Female	0.02	0.02	-1.51	0.13	-0.008	0.09
Neutralize X Female	-0.03	0.02	-1.66	0.10	-0.004	0.09
Negative X Female	-0.06	0.02	-2.56	0.01*	0.01	0.11
Positive X Female	-0.05	0.02	-2.15	0.03*	0.005	0.10
					CI_{95}	
Random effects (variances)	Estimate	SE	z value	p-value	Lower	Upper
Intercept variance	0.28	0.85	84.04	0.00	0.27	0.28
Goal Intercept Variance	0.73	0.09	8.46	0.00	0.18	0.22
Neutralize	0.005	0.002	2.39	0.01	0.002	0.01
Transform	0.007	0.002	3.17	0.002	0.004	0.01

***$p < .001$ **$p < .01$ *$p < .05$

Table 9. Multi-level Model of Emotion Regulatory Goal, Picture Valence on SBP measure with time

					CI_{95}	
Fixed effects (intercepts, slopes)	Estimate	*SE*	t-value	p-value	Lower	Upper
Intercept	0.03	0.09	0.39	0.69	-0.15	0.22
Time	0.0015	0.0002	6.58	0.00***	0.0010	0.0019
Gender (female)	-0.10	0.12	-0.81	0.41	-0.35	0.14
Goal						
View	-0.02	0.02	0.77	0.43	-0.03	0.07
Transform	0.07	0.03	-2.08	0.03*	-0.14	-0.004
Picture Valence						
Negative	0.02	0.02	0.98	0.32	-0.02	0.08
Positive	0.02	0.02	0.77	0.43	-0.04	0.07
Neutralize X Negative	-0.005	0.03	-0.14	0.88	-0.07	0.06
Transform X Negative	-0.06	0.03	-1.88	0.06	-0.14	0.002
Neutralize X Positive	0.02	0.03	0.64	0.51	-0.04	0.09
Transform X Positive	-0.05	0.03	-1.55	0.12	-0.13	0.01
Neutralize X Female	-0.01	0.02	-0.55	0.58	-0.07	0.03
Transform X Female	-0.01	0.02	-0.55	0.58	-0.07	0.03
Negative X Female	-0.02	0.03	-0.78	0.43	-0.08	0.03
Positive X Female	-0.04	0.03	-1.44	0.14	-0.10	0.01
					CI_{95}	
Random effects (variances)	Estimate	SE	z value	p-value	Lower	Upper
Intercept variance	0.46	0.005	81.83	0.00***	0.45	0.47
Goal Intercept Variance	0.50	0.07	6.86	0.00***	0.38	0.67
Neutralize	0.00006	0.0007	0.095	0.92	0.00	606.56
Transform	0.003	0.003	1.002	0.31	0.0004	0.02

***neutralize goal as reference group**

***$p < .001$ **$p < .01$ *$p < .05$

Table 10. Multi-level Model of Emotion Regulatory Goal, Picture Valence on SCR measure with time

					CI_{95}	
Fixed effects (intercepts, slopes)	Estimate	*SE*	t-value	p-value	Lower	Upper
Intercept	0.12	0.06	2.04	0.04	0.004	0.24
Time	-0.0004	0.0002	-1.92	0.05	-0.0009	0.000007
Gender (female)	-0.19	0.07	-2.44	0.002*	-0.34	-0.03
Goal						
Neutralize	-0.023	0.05	-0.43	0.66	-0.13	0.08
Transform	-0.01	0.05	-0.18	0.85	-0.12	0.10
Picture Valence						
Negative	0.03	0.04	0.87	0.37	-0.04	0.11
Positive	0.05	0.04	1.30	0.19	-0.02	0.13
Neutralize X Negative	-0.05	0.05	-1.00	0.31	-0.16	0.05
Transform X Negative	0.01	0.05	0.37	0.71	-0.08	0.12
Neutralize X Negative	-0.11	0.05	-2.11	0.03*	-0.22	-0.008
Transform X Positive	0.003	0.05	0.07	0.94	-0.10	0.10
Neutralize X Female	0.01	0.04	0.33	0.73	-0.07	0.10
Transform X Female	-0.003	0.05	-0.07	0.94	-0.11	0.10
Negative X Female	-0.02	0.04	-0.50	0.61	-0.10	0.06
Positive X Female	-0.02	0.04	-0.52	0.60	-0.10	0.06
					CI_{95}	
Random effects (variances)	Estimate	SE	z value	p-value	Lower	Upper
Intercept variance	0.81	0.009	87.74	0.00***	0.80	0.83
Goal Intercept Variance	0.03	0.008	3.74	0.00***	0.01	0.04
Neutralize	0.030	0.009	3.11	0.002**	0.01	0.05
Transform#	0.031	0.008	3.52	0.00***	0.01	0.05

#recoded neutralize as reference group to compare neutralize to transform
***$p < .001$ **$p < .01$ *$p < .05$

Table 11. Multi-level Model of Emotion Regulatory Goal, Picture Valence on RR

Fixed effects (intercepts, slopes)	Estimate	*SE*	t-value	p-value	CI_{95} Lower	CI_{95} Upper
Intercept	-0.06	0.08	-0.74	0.45	-0.22	0.10
Time	-0.001	0.0002	-4.61	0.00***	-0.001	-0.0005
Gender (female)	0.17	0.11	1.55	0.12	-0.04	0.39
Goal						
Neutralize	0.06	0.04	1.36	0.17	-0.02	0.14
Transform	0.08	0.04	1.81	0.06	-0.006	0.17
Picture Valence						
Negative	-0.009	0.03	-0.28	0.77	-0.07	0.05
Positive	0.04	0.03	1.27	0.20	-0.02	0.10
Neutralize X Negative	-0.02	0.04	-0.56	0.57	-0.11	0.06
Transform X Negative	0.002	0.04	0.05	0.95	-0.08	0.08
Neutralize X Positive	-0.05	0.04	-1.30	0.19	-0.14	0.02
Transform X Positive	-0.06	0.04	-1.50	0.13	-0.15	0.01
Neutralize X Female	-0.02	0.03	-0.74	0.45	-0.09	0.04
Transform X Female	-0.03	0.03	-0.91	0.36	-0.11	0.04
Negative X Female	-0.006	0.03	-0.18	0.85	-0.07	0.06
Positive X Female	-0.001	0.03	-0.05	0.95	-0.07	0.06

Random effects (variances)	Estimate	SE	z value	p-value	CI_{95} Lower	CI_{95} Upper
Intercept variance	0.57	0.006	86.40	0.00***	0.56	0.58
Goal Intercept Variance	0.41	0.04	8.42	0.00***	0.33	0.52
Neutralize	0.02	0.005	4.50	0.00***	0.01	0.03
Transform	0.01	0.004	3.79	0.00***	0.01	0.03

***$p < .001$ **$p < .01$ *$p < .05$

Figure 1. Flow Chart of Abstract and Full-Text Screening Process

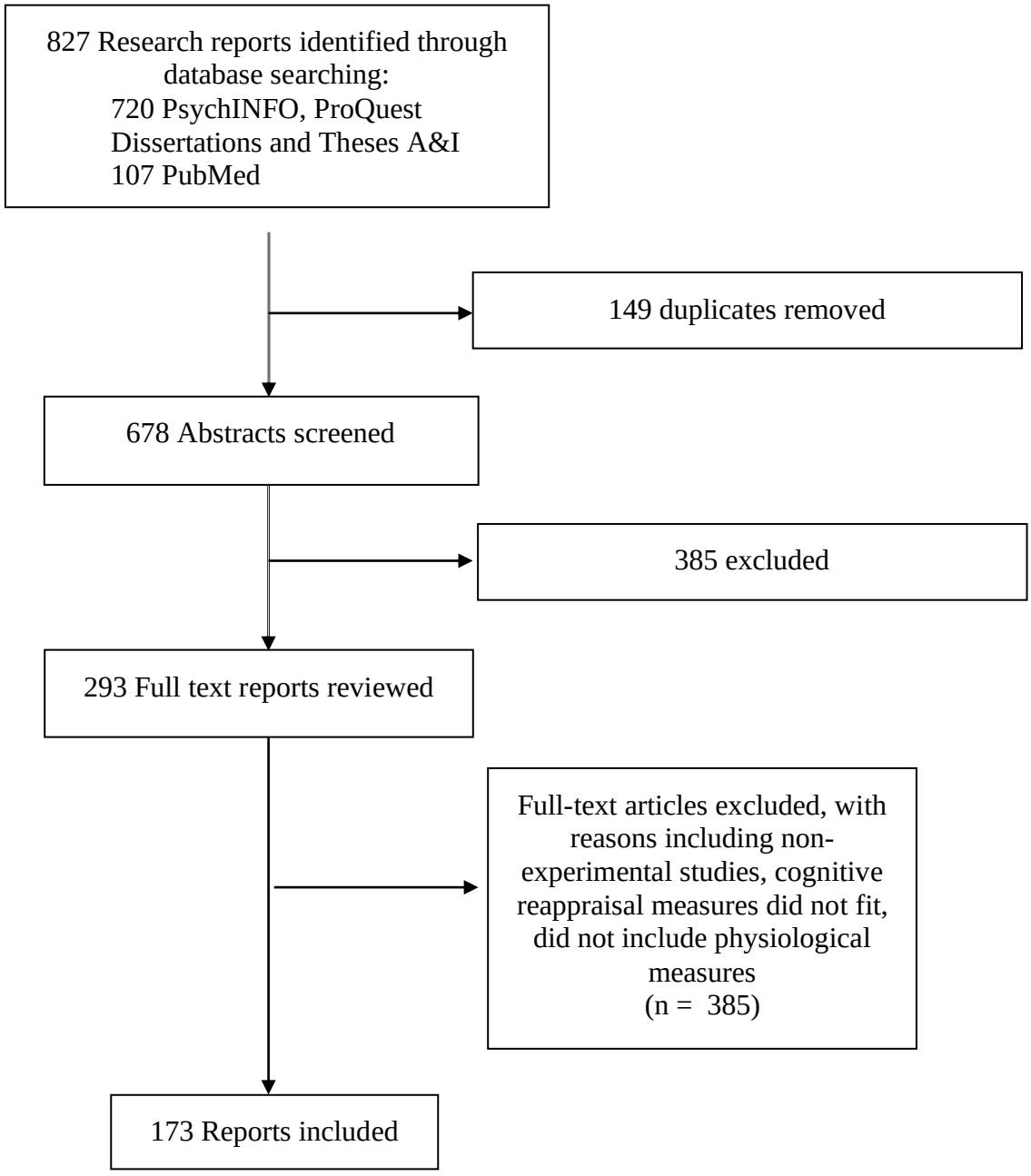


Figure 2. Funnel plot of effect sizes for the cardiovascular and respiratory outcome

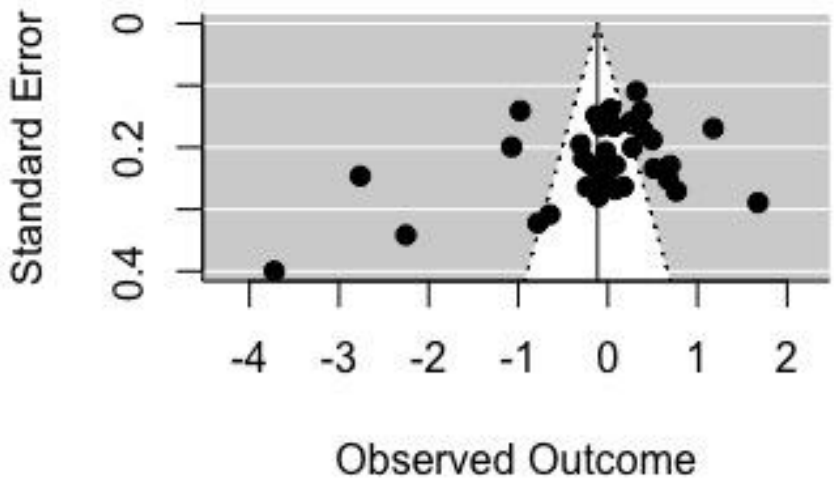


Figure 3. Funnel plot of effect sizes for the electrodermal outcome

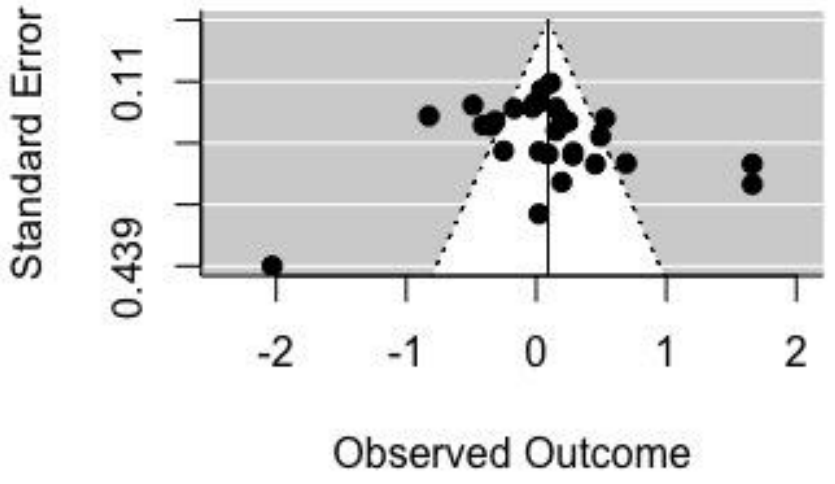


Figure 4. Funnel plot of effect sizes for the facial outcome

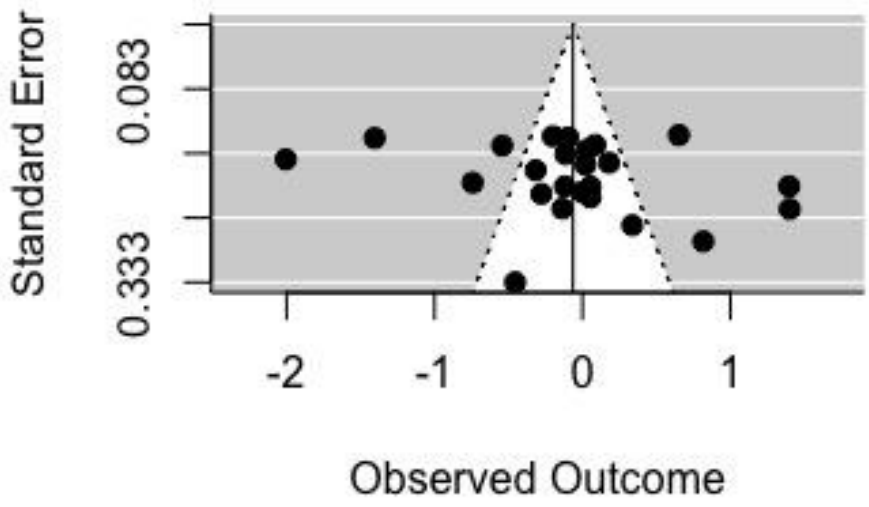


Figure 5. Funnel plot of effect sizes for the eye movement outcome

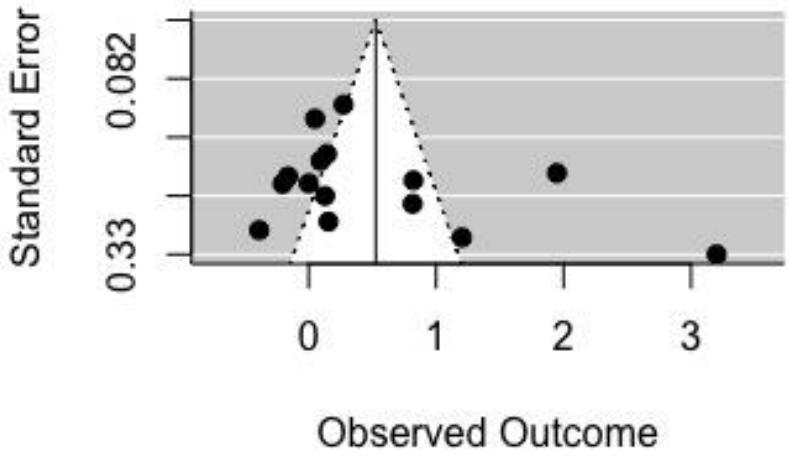


Figure 6. An example of having a Quantitative emotion regulation goal: decrease both positive and negative valence, as well as decrease the overall arousal level of emotions

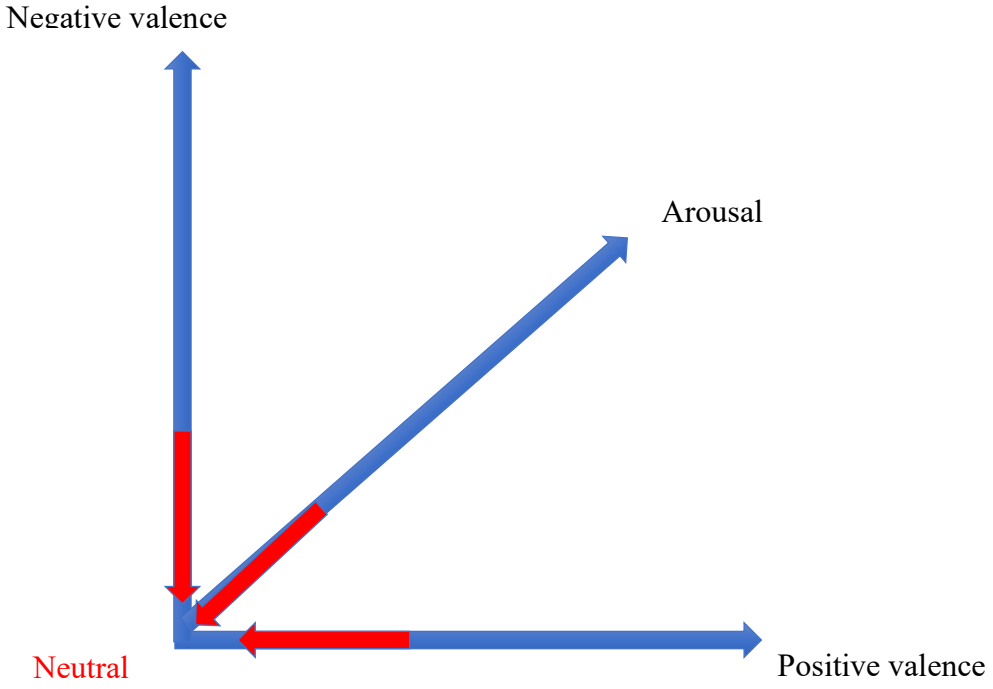


Figure 7. An example of Qualitative emotion regulation goal: decrease negative valence and increase positive valence, therefore maintaining the overall arousal level of emotions

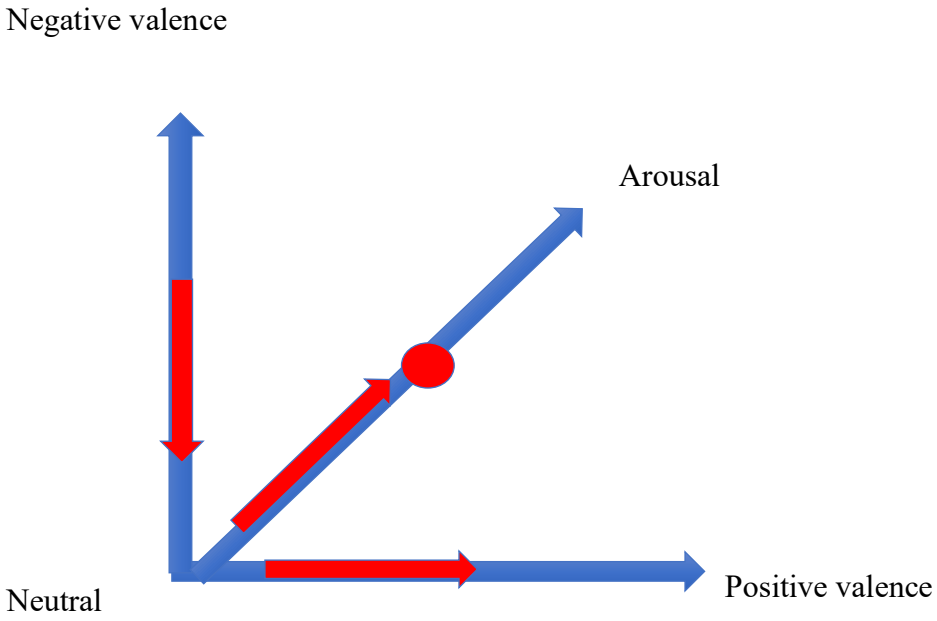
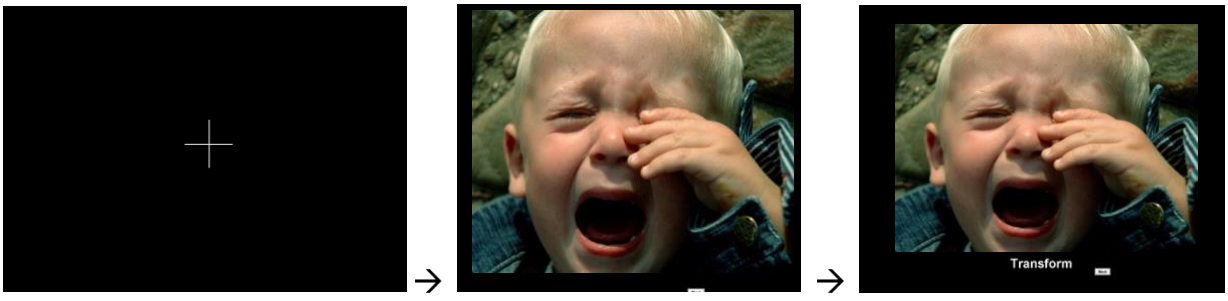
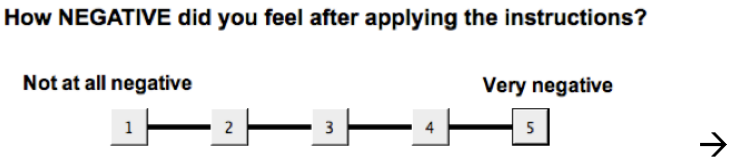


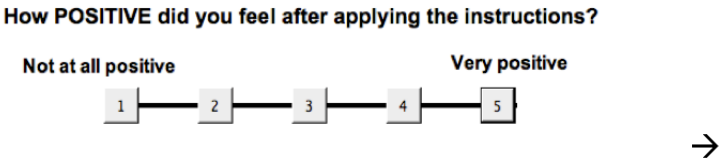
Figure 8. Flow of the emotion regulation task



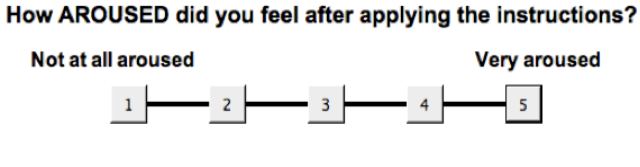
(Crosshair: 1-3s) (Image: 8s) (Instruction: View/Transform/Neutralize: 8s)



(Ratings: 4s)



(Ratings: 4s)



(Ratings 4s) (Rest: 8s)

Figure 9. Percentage assessment of all variables

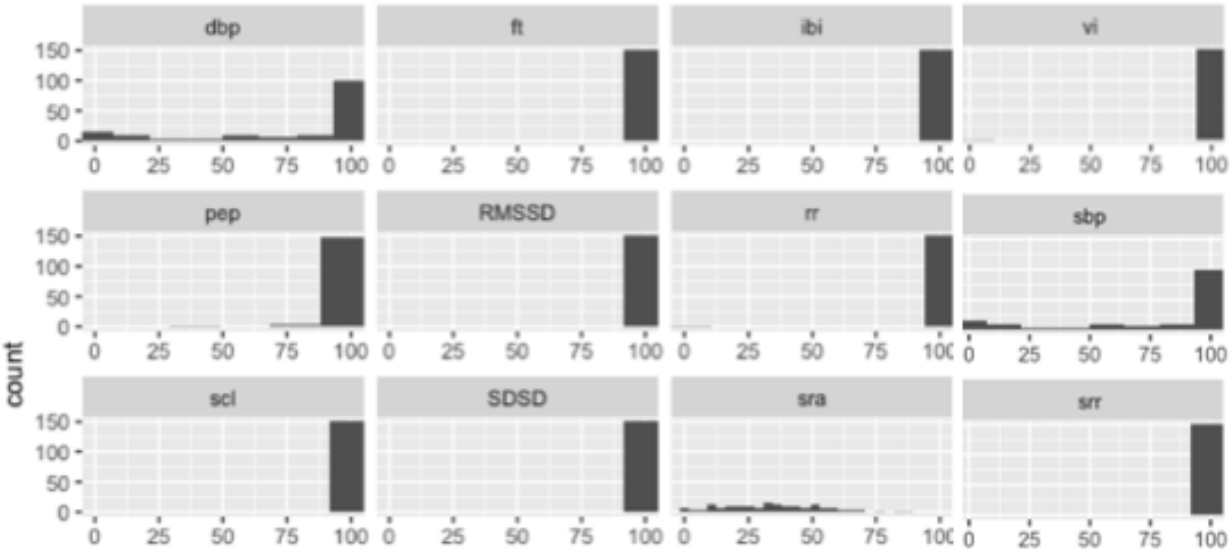
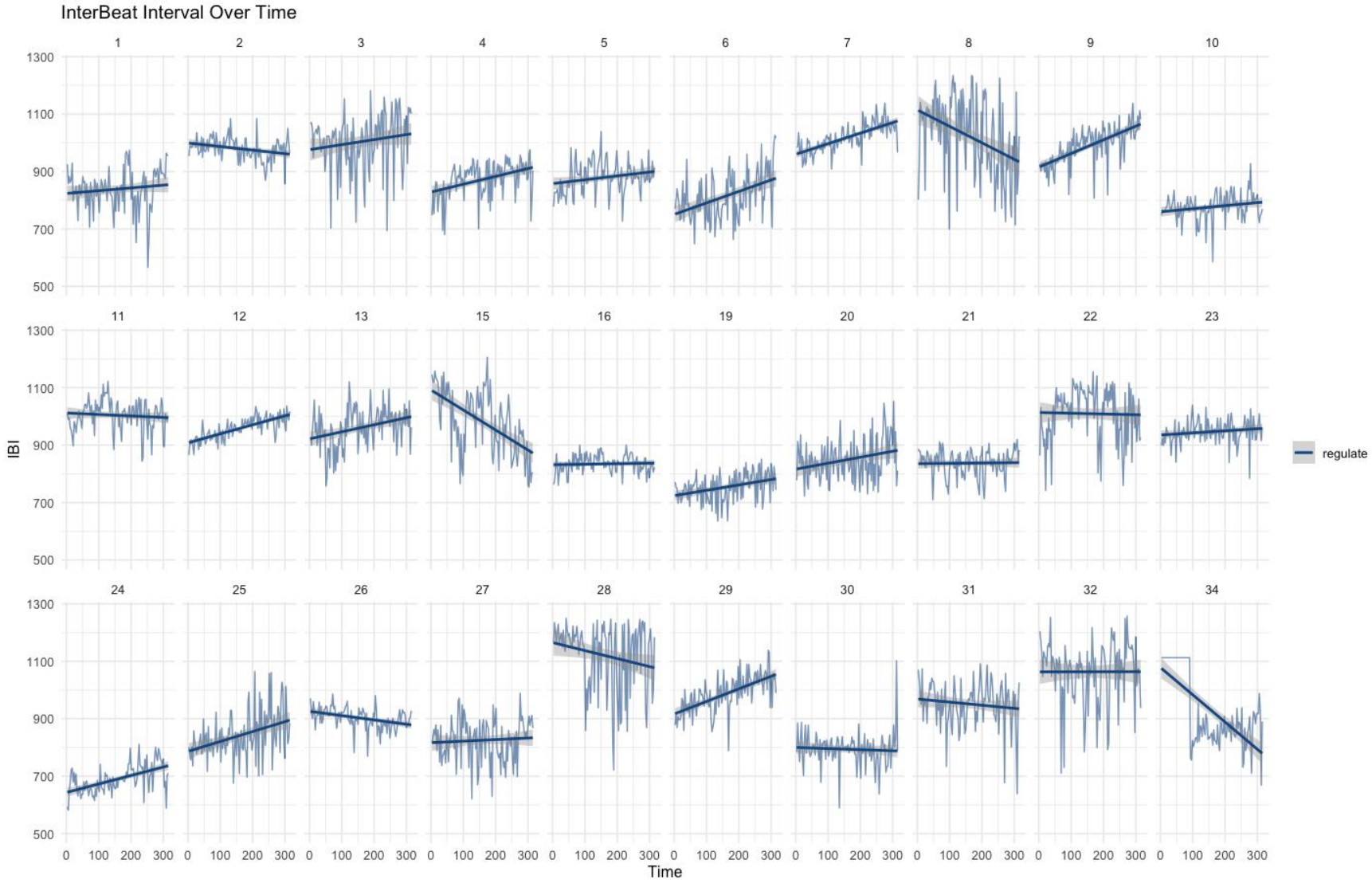


Figure 10


InterBeat Interval Over Time
1
2
3
4
5
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7
8
9
10
11
12
13
15
16
19
20
21
22
23
24
25
26
27
28
29
30
31
32
34
IBI
1300
1100
900
700
500
0
100
200
300
Time
regulate

Figure 11

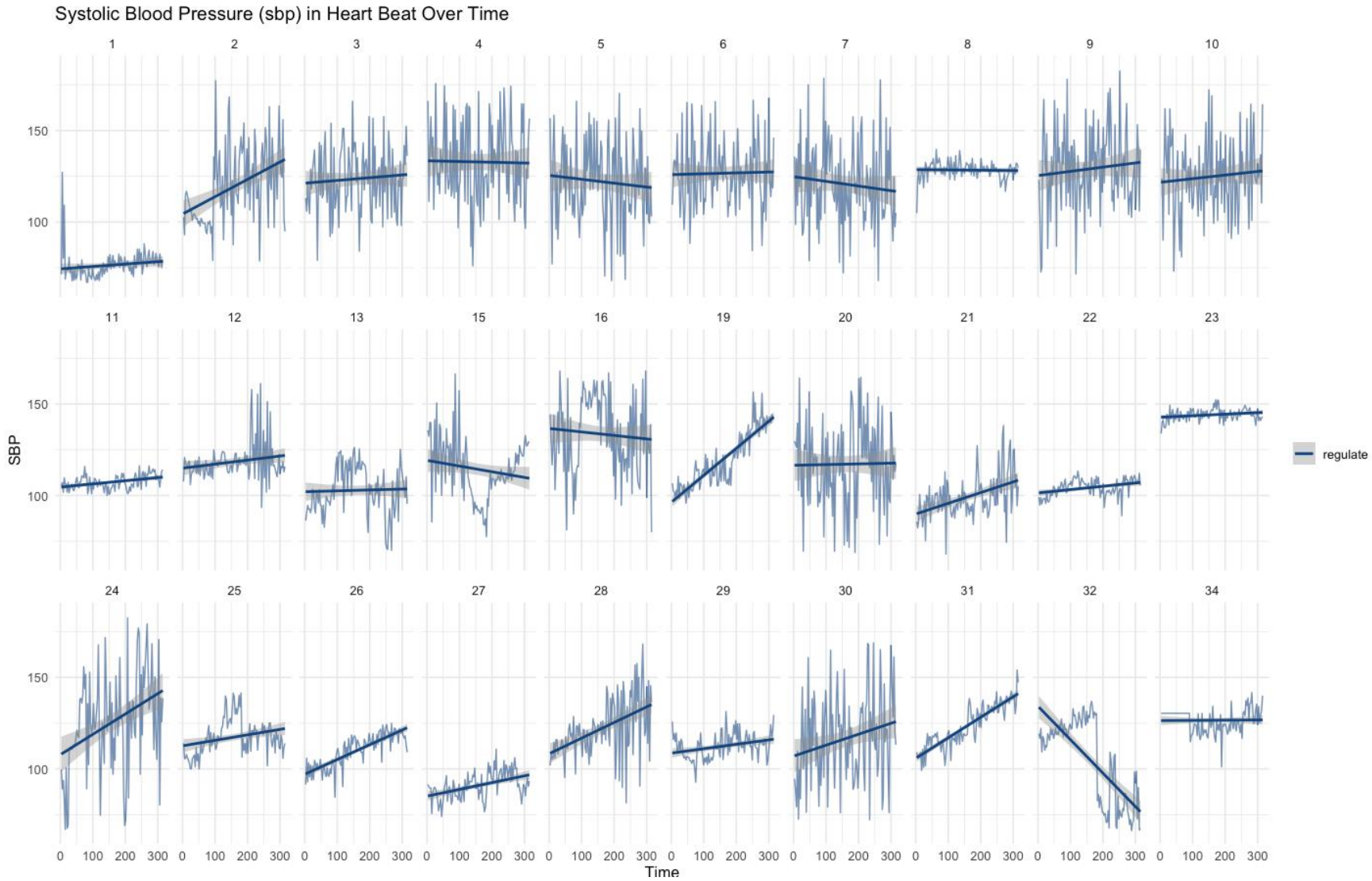

Systolic Blood Pressure (sbp) in Heart Beat Over Time
SBP
Time
regulate

Figure 12

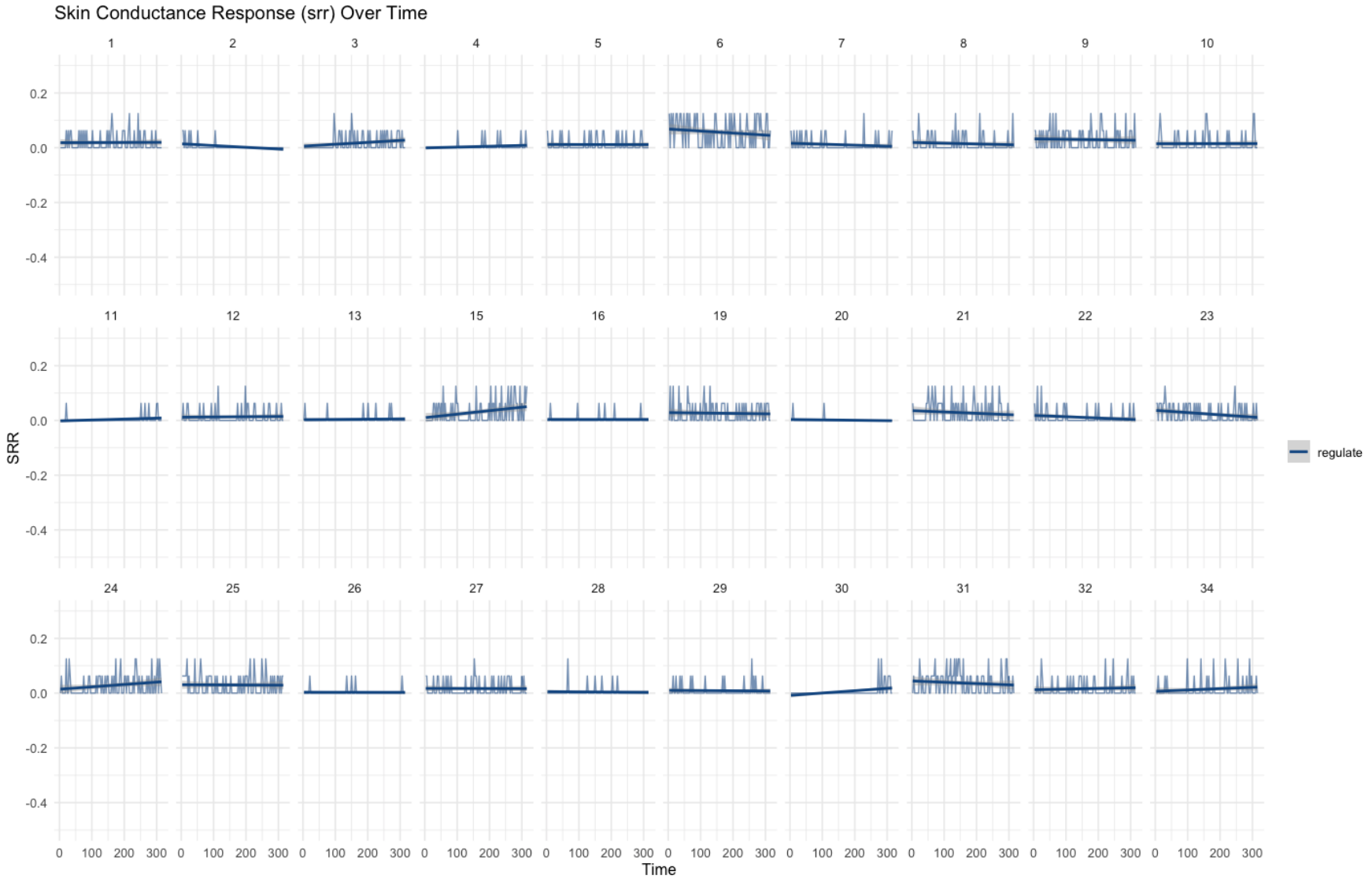

Skin Conductance Response (srr) Over Time
1
2
3
4
5
6
7
8
9
10
11
12
13
15
16
19
20
21
22
23
24
25
26
27
28
29
30
31
32
34
0.2
0.0
-0.2
-0.4
SRR
0
100
200
300
Time
regulate

Figure 13

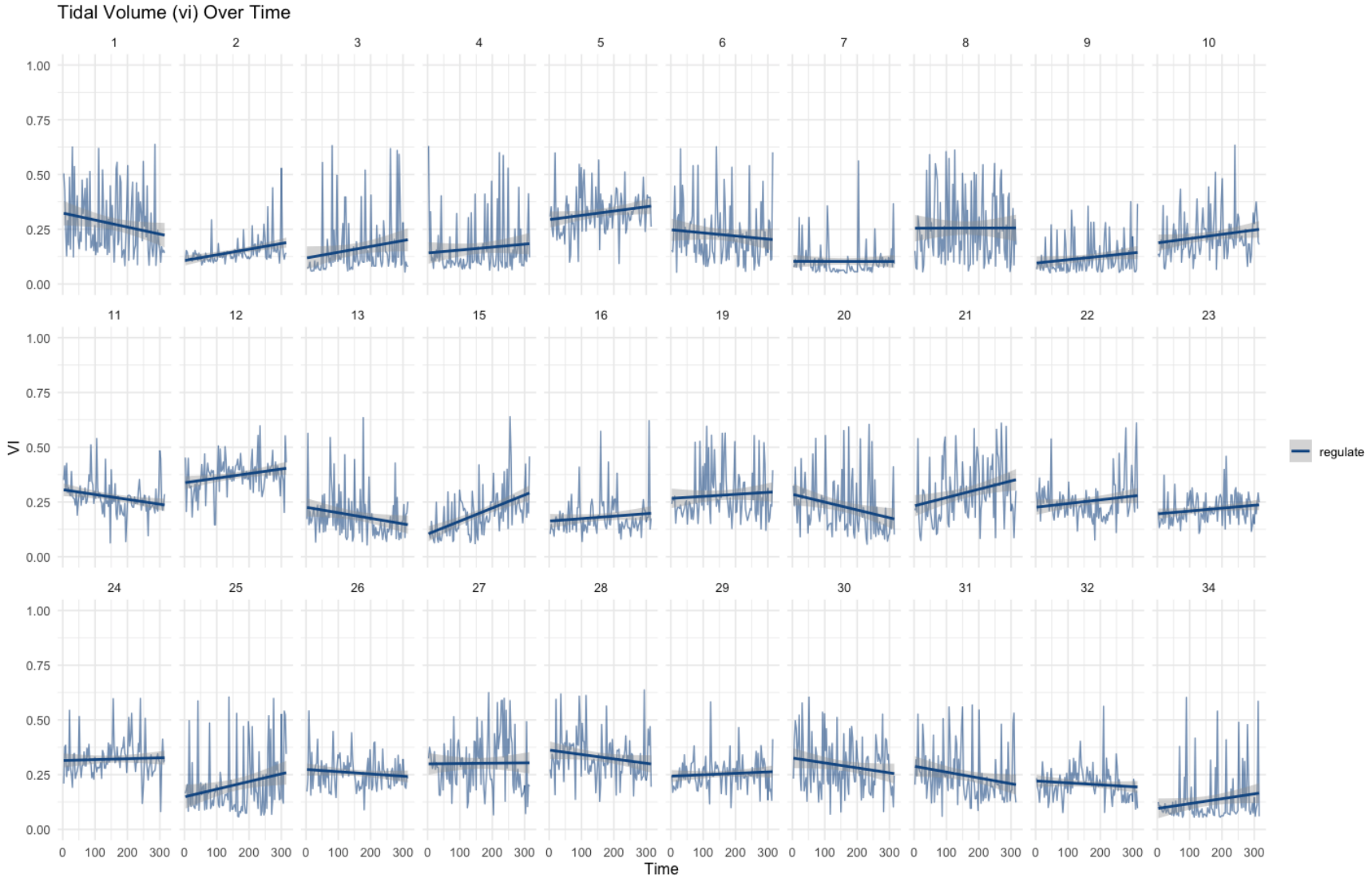
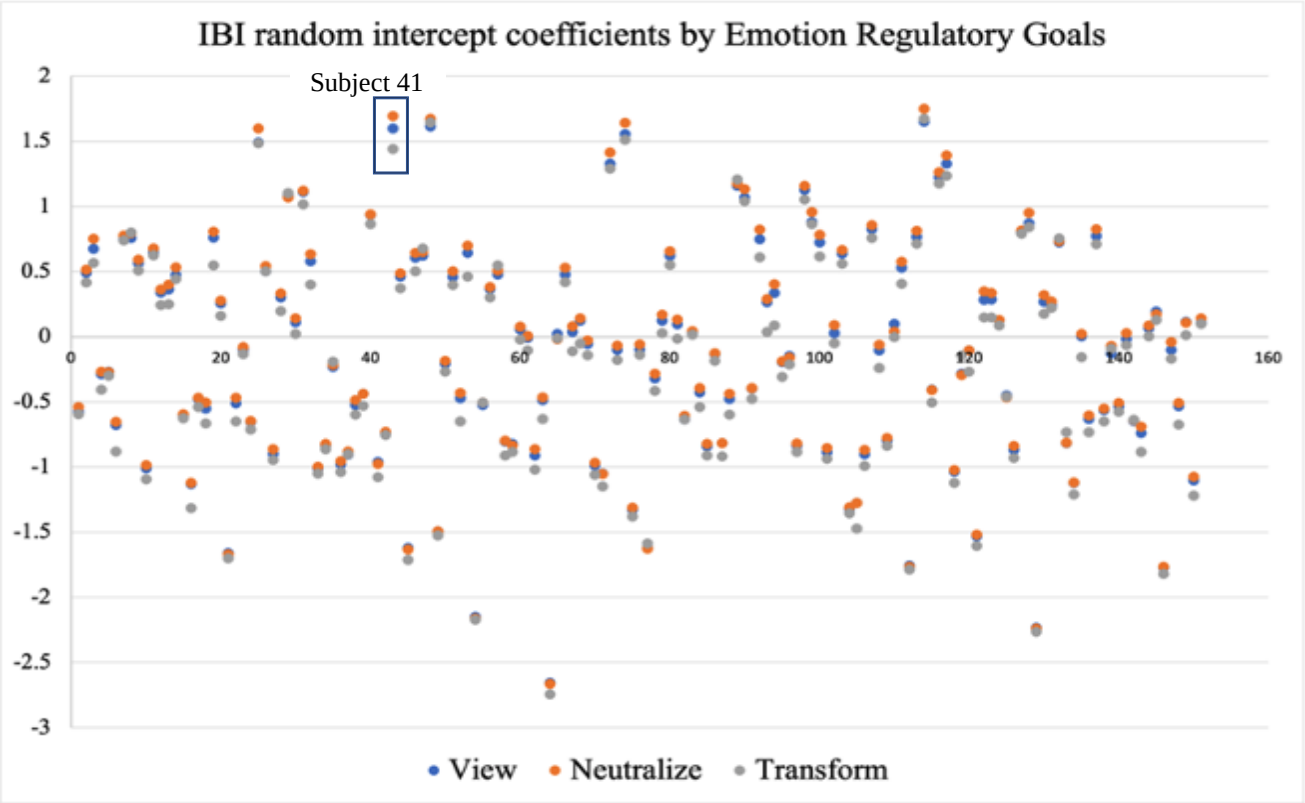
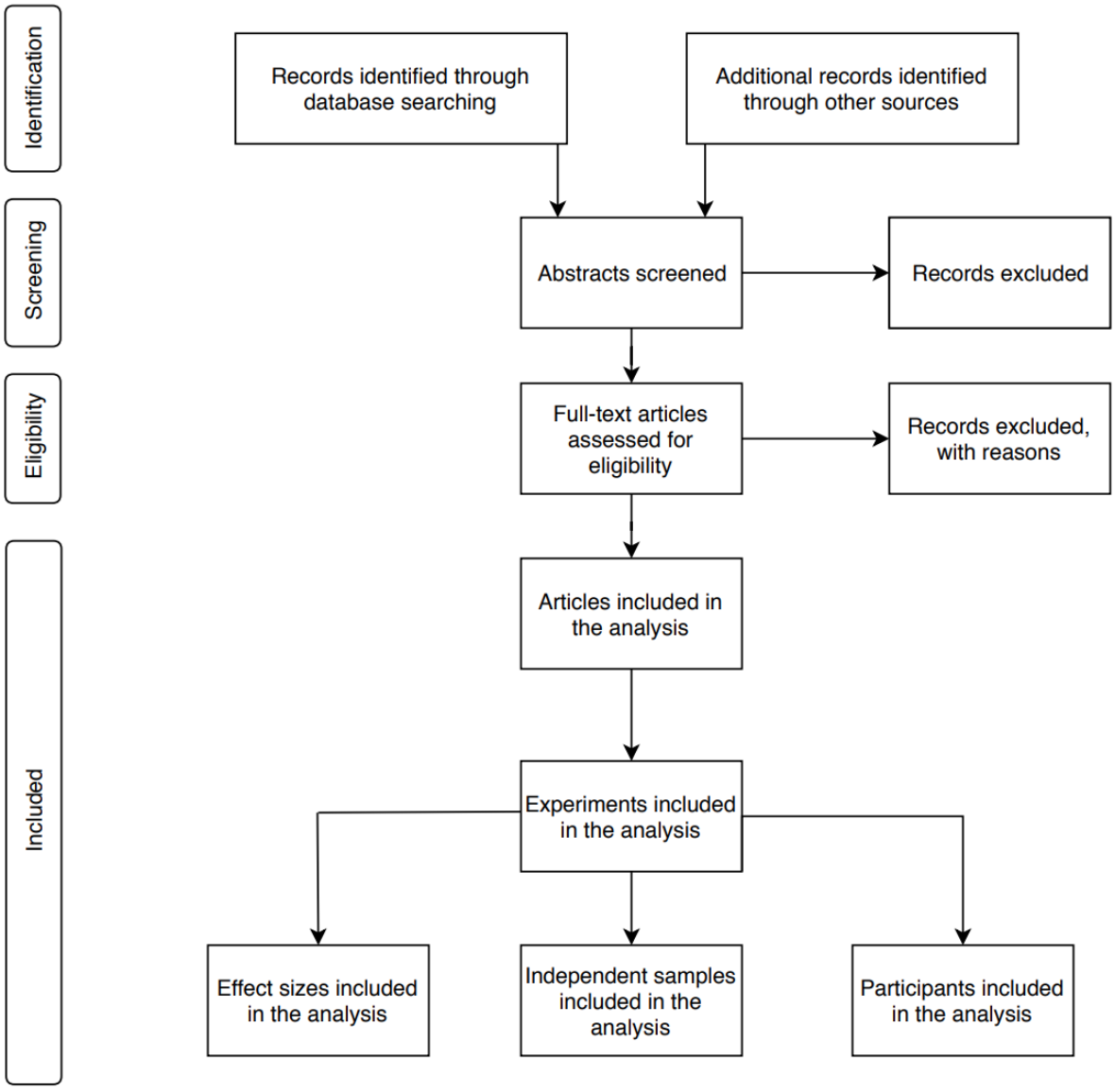

Tidal Volume (vi) Over Time
1
2
3
4
5
6
7
8
9
10
11
12
13
15
16
19
20
21
22
23
24
25
26
27
28
29
30
31
32
34
1.00
0.75
0.50
0.25
0.00
VI
0
100
200
300
Time
regulate

Figure 14


IBI random intercept coefficients by Emotion Regulatory Goals
Subject 41
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0
20
40
60
80
100
120
140
160
View
Neutralize
Transform

APPENDIX A – PRISMA flowchart



APPENDIX B — PRISMA CHECKLIST

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	

Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	
Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

APPENDIX C – Study 2 Preregistered List of Hypotheses

Hypotheses:

For Passive Viewing conditions:

1a. When passively viewing *negative* stimuli compared to neutral stimuli, we predict that there will be an *increase* in average levels of these physiological measures: Heart rate (HR), Systolic blood pressure (SBP), Diastolic blood pressure (DBP), Skin conductance level (SCL), Skin conductance response (SCR), Skin conductance amplitude (SCRA) as well as a *decrease* in average levels of these physiological measures: Pre-ejection Period (PEP), Respiratory Sinus Arrhythmia (RSA), Finger pulse (FP), Finger temperature (FT), and and Respiration rate (RR), respiration depth (RD).

1b: When passively viewing *positive* stimuli compared to neutral stimuli, we predict that there will be an *increase* in average levels of these physiological measures: PEP, SCL, SCR, SCRA, FP, FT and RSA, RR, RD. We also predict a *decrease* in average levels of these physiological measures: HR, SBP, DBP

2a. When passively viewing negative stimuli compared to neutral stimuli, we predict that there will be significant associations between the degree of self-reported negative emotional feelings and the following physiological measures: HR, PEP, RSA, SBP, DBP, FP, FT, SCL, SCR, SCRA, RR, and Vt.

2b. When passively viewing positive stimuli compared to neutral stimuli, we predict that there will be significant associations between the degree of self-reported positive emotional feelings and the following physiological measures: HR, PEP, RSA, SBP, DBP, FP, FT, SCL, SCR, SCRA, RR, and Vt.

2c. When passively viewing either positive or negative stimuli compared to neutral stimuli, we predict that there will be significant associations between the levels of self-reported emotional arousal and the following physiological measures: HR, PEP, RSA, SBP, DBP, FP, FT, SCL, SCR, SCRA, RR, and Vt.

For Regulated Viewing conditions:

3: Relative to passively viewing negative or positive stimuli, we predict that there will be significant changes in the average levels of the following physiological responses when reappraising negative or positive emotion with a quantitative regulation goal: ,HR, PEP, RSA, SBP, DBP, FP, FT, SCL, SCR, SCRA,RR,and Vt. Specficially, we predict that the physiological responses will be less activated and more alike neutral.

4a. Relative to passively viewing negative stimuli, we predict that there will be significant changes in the average levels of the following physiological responses when reapprasing negative emotion with a qualitative regulation goal: HR, PEP, RSA, SBP, DBP, FP, FT,

SCL, SCR, SCRA, RR, and Vt. We also predict that these changes should resemble those when passively viewing positive stimuli.

4b. Relative to passively viewing positive stimuli, we predict that there will be significant changes in the average levels of the following physiological responses when reapprasing positive emotion with a qualitative regulation goal: HR, PEP, RSA, SBP, DBP, FP, FT, SCL, SCR, SCRA, RR, and Vt . We also predict that these changes should resemble those when passively viewing negative stimuli.

5a. When reapprasing negative or positive emotion with a quantitative regulation goal, we predict that there will be significant associations between the degree of self-reported negative emotional feelings and the following physiological measures: HR, PEP, RSA, SBP, DBP, FP, FT, SCL, SCR, SCRA, RR, and Vt.

5b. When reapprasing negative emotion with a qualitative regulation goal, we predict that there will be significant associations between the degree of self-reported negative and positive emotional feelings and the following physiological measures: HR, PEP, RSA, SBP, DBP, FP, FT, SCL, SCR, SCRA, RR, and Vt. We also predict that the associations should resemble those when passively viewing positive stimuli.

5c. When reapprasing positive emotion with a qualitative regulation goal, we predict that there will be significant associations between the degree of self-reported negative and positive emotional feelings and the following physiological measures: HR, PEP, RSA, SBP, DBP, FP, FT, SCL, SCR, SCRA, RR, and Vt. We also predict that the associations should resemble those when passively viewing negative stimuli.

6a.When reappraising negative or positive emotion with a quantitative regulation goal, we predict that there will be significant associations between the degree of self-reported emotional arousal and the following physiological measures: HR, PEP, RSA, SBP, DBP, FP, FT, SCL, SCR, SCRA, RR, and Vt. We also predict that the associations should resemble those when passively viewing neutral stimuli.

6b.When reapprasing negative emotion with a qualitative regulation goal, we predict that there will be significant associations between the degree of self-reported emotional arousal and the following physiological measures: HR, PEP, RSA, SBP, DBP, FP, FT, SCL, SCR, SCRA, RR, and Vt. We also predict that the associations should resemble those when viewing neutral stimuli.

6c.When reapprasing positive emotion with a qualitative regulation goal, we predict that there will be significant associations between the degree of self-reported emotional arousal and the following physiological measures: HR, PEP, RSA, SBP, DBP, FP, FT, SCL, SCR, SCRA, RR, and Vt. We also predict that the associations should resemble those when viewing neutral stimuli.

Manipulation checks:

7a: We predict that only self-reported negative emotion will decrease when reappraising negative stimuli with a quantitative regulation goal, whereas self-reported negative emotion will decrease but self-reported positive emotion will increase with a qualitative regulation goal.

7b. We predict that only self-reported positive emotion will decrease when reappraising positive stimuli with a quantitative regulation goal, whereas self-reported positive emotion will decrease but self-reported negative emotion will increase with a qualitative regulation goal.

7c. We predict that self-reported emotional arousal will decrease when reapprasing either negative or positive stimuli with a quantitative regulation goal. Specifically, we predict that the changes would resemble to viewing neutral stimuli.

7d. We predict that self-reported emotional arousal will not change significantly when reapprasing either negative or positive stimuli with a qualitative regulation goal. Specifically, we predict that the changes would resemble to viewing positive or negative stimuli respectively.

8. I also predict that there would be between-subject differences in the average levels, as well as within-subject differences across time in the modulation of the following physiological measures: HR, PEP, RSA, SBP, DBP, FP, FT, SCL, SCR, SCRA, RR, and RD by picture valence and regulation goal

APPENDIX D – Supplemental MLM figures

Figure 15

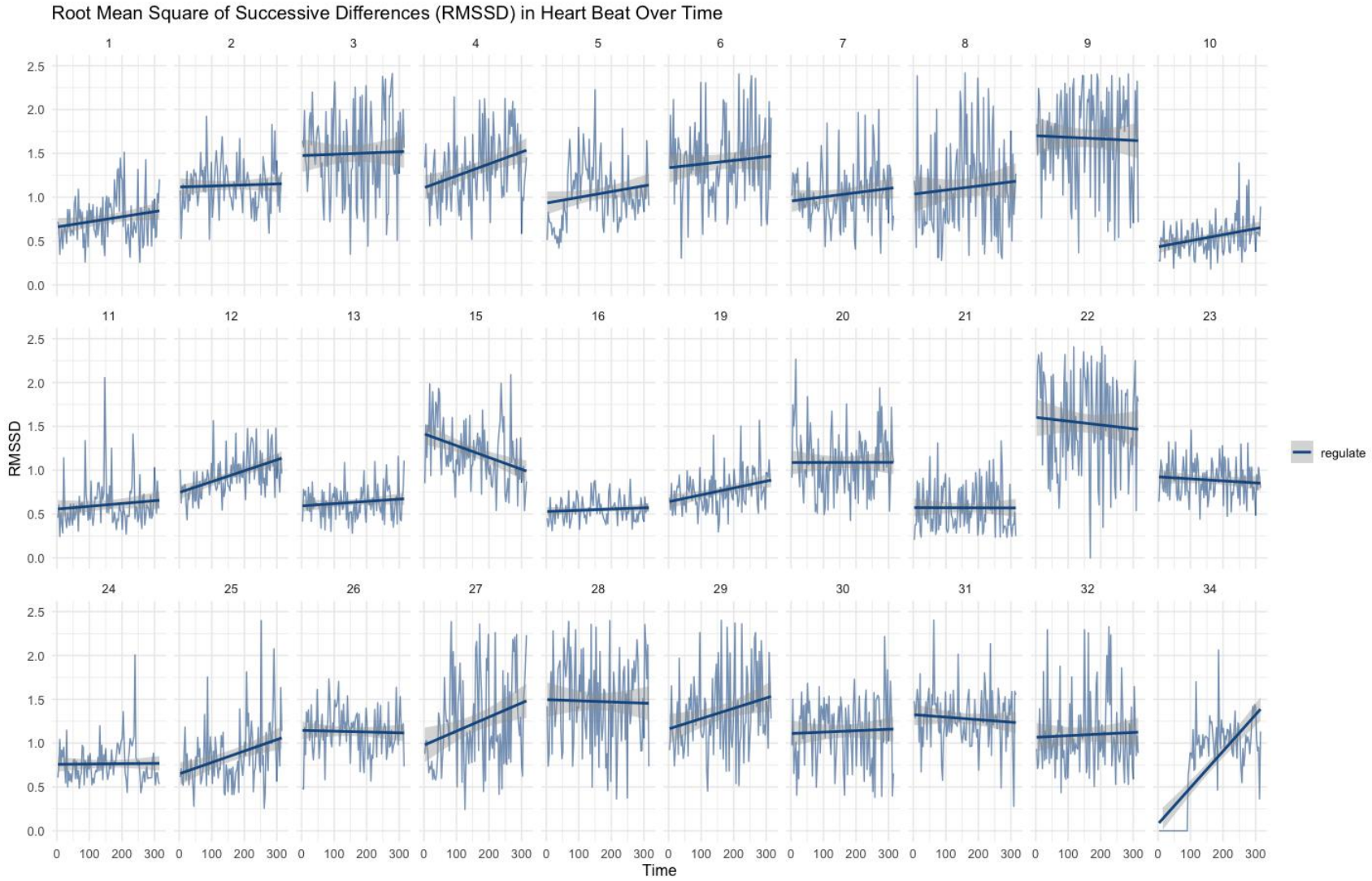


Figure 16

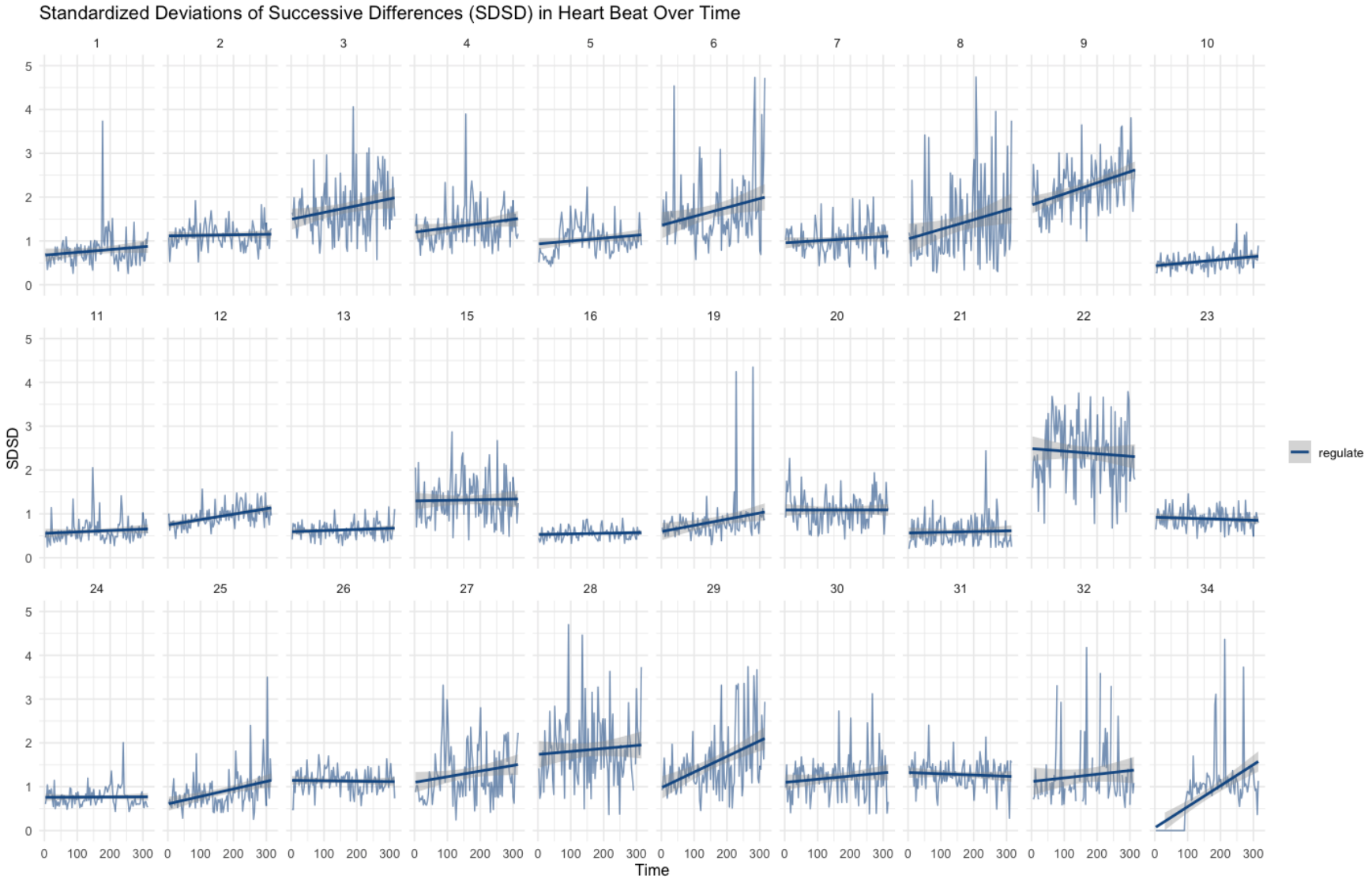

Standardized Deviations of Successive Differences (SDSD) in Heart Beat Over Time
SDSD
Time
regulate

Figure 17

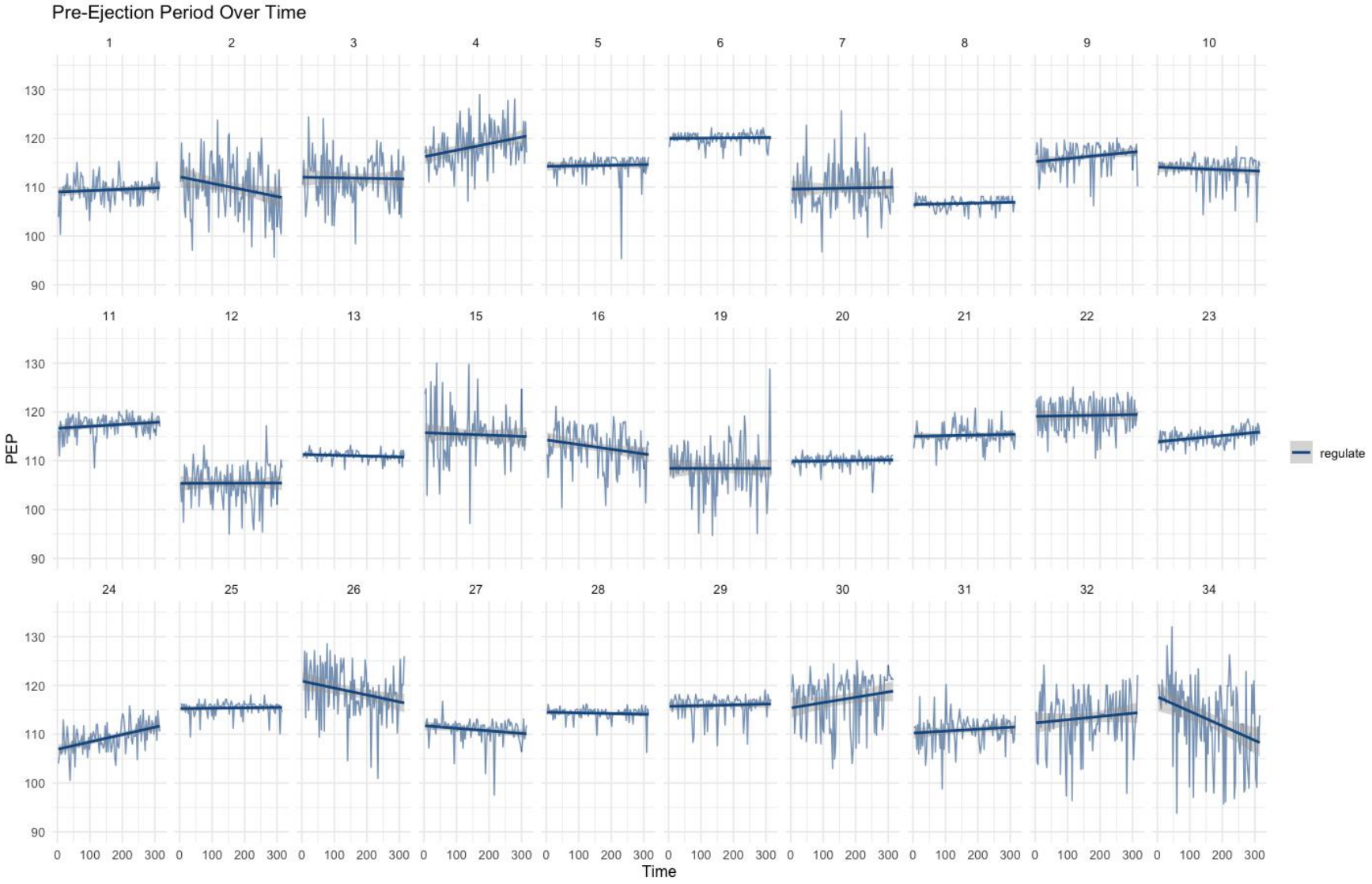


Figure 18

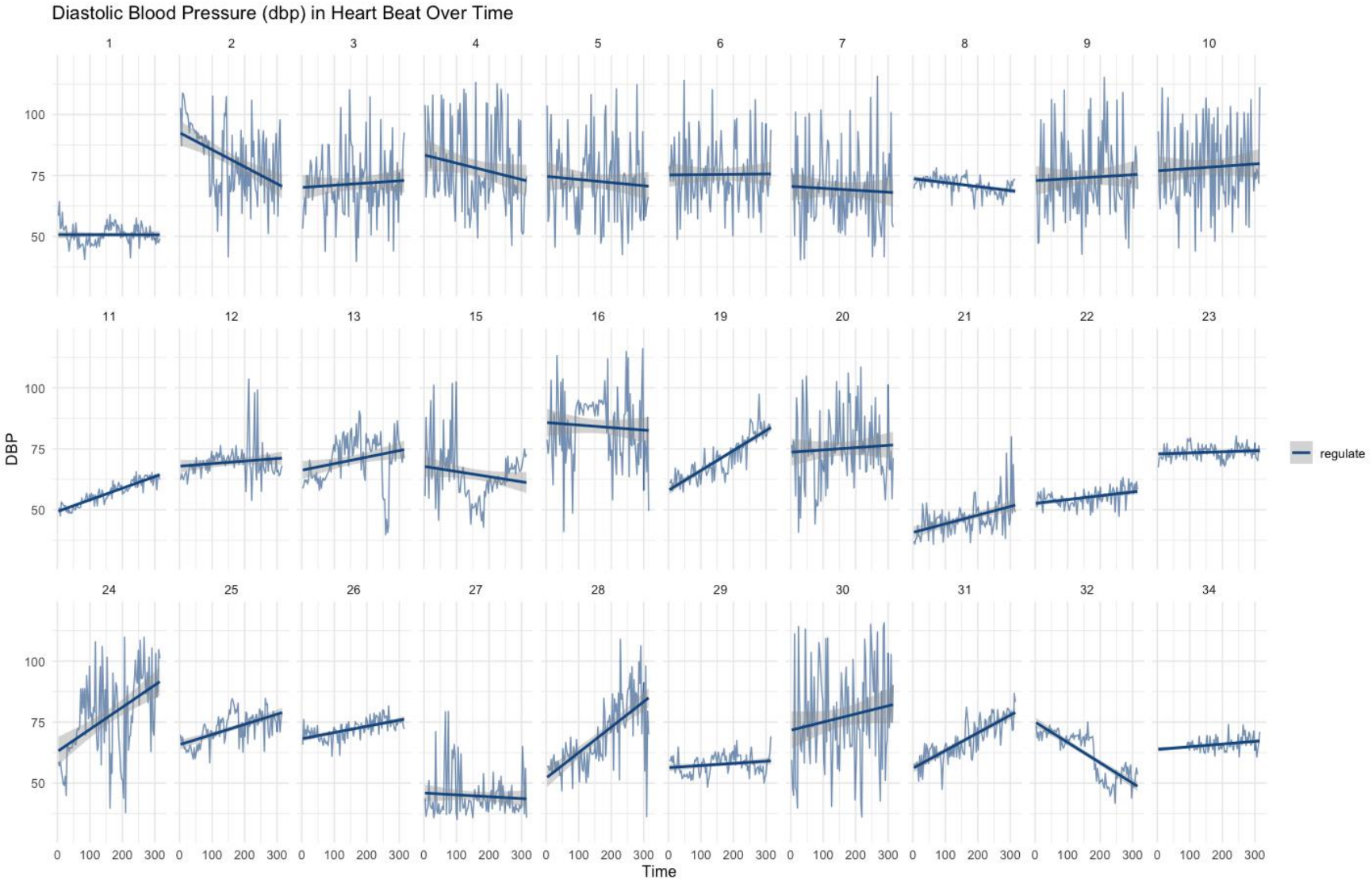
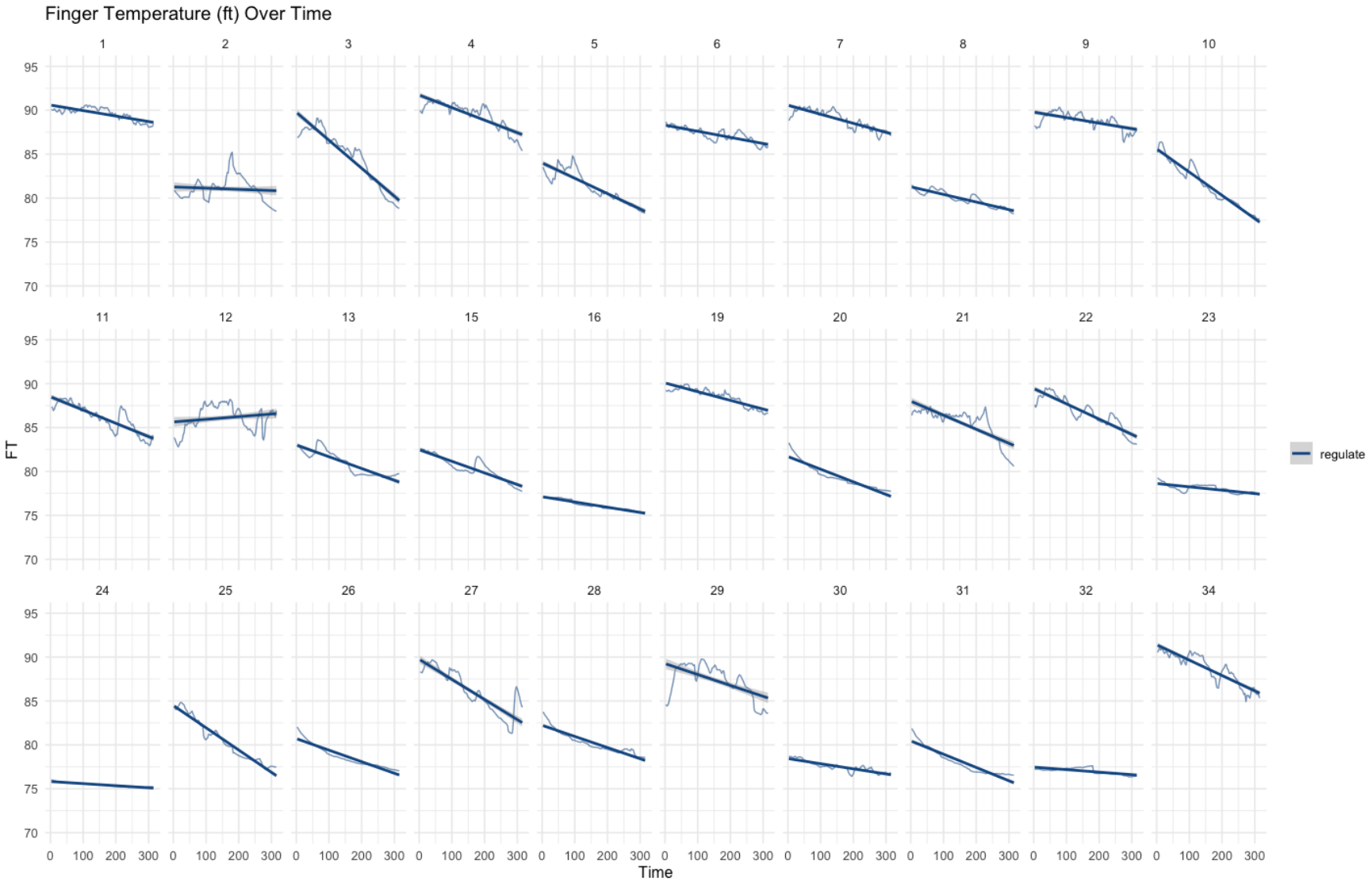

Diastolic Blood Pressure (dbp) in Heart Beat Over Time
DBP
Time
regulate

Figure 19


Finger Temperature (ft) Over Time
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21
22
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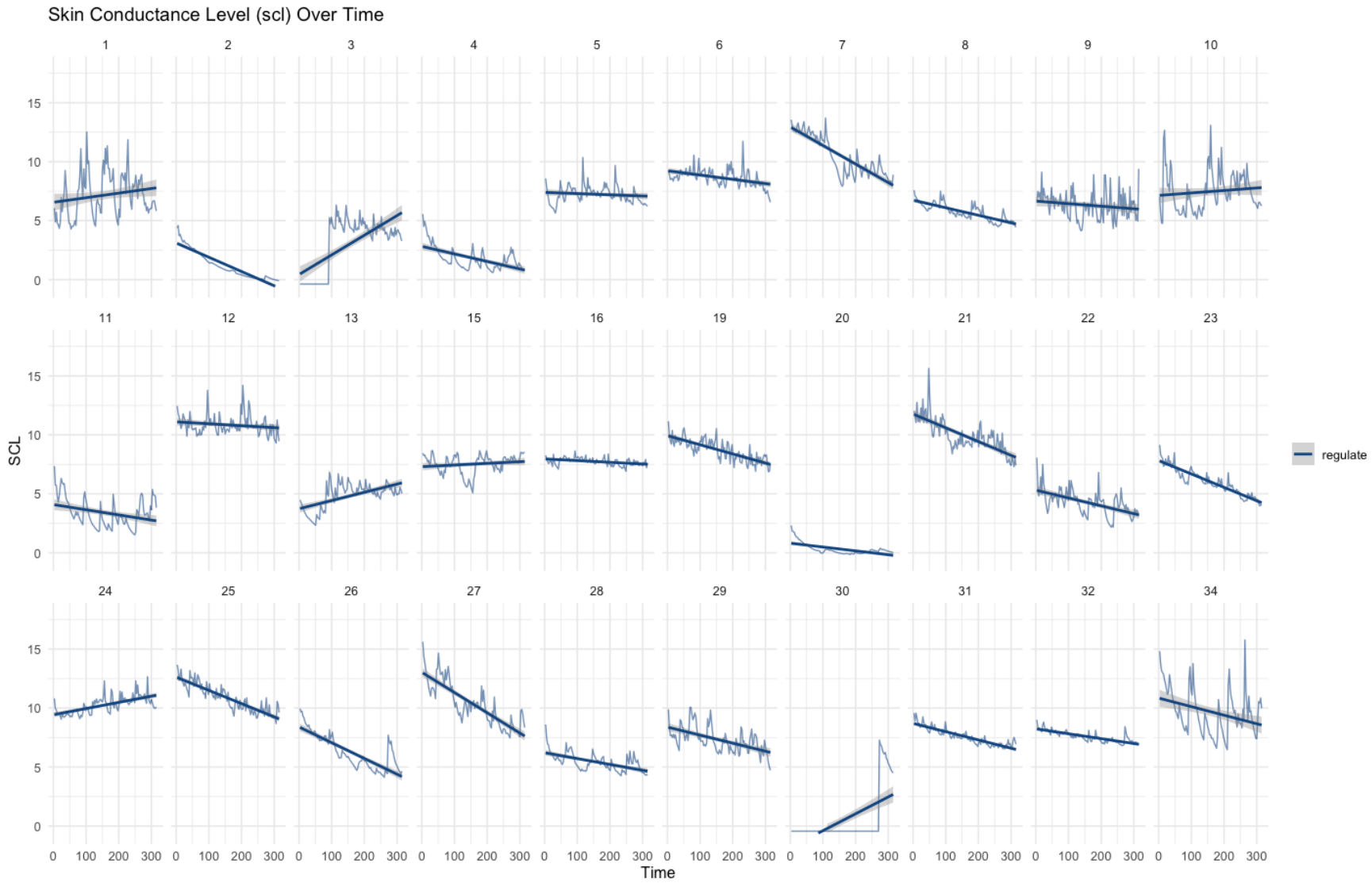
24
25
26
27
28
29
30
31
32
34
FT
95
90
85
80
75
70
0
100
200
300
Time
regulate

Figure 20


Skin Conductance Level (scl) Over Time
1
2
3
4
5
6
7
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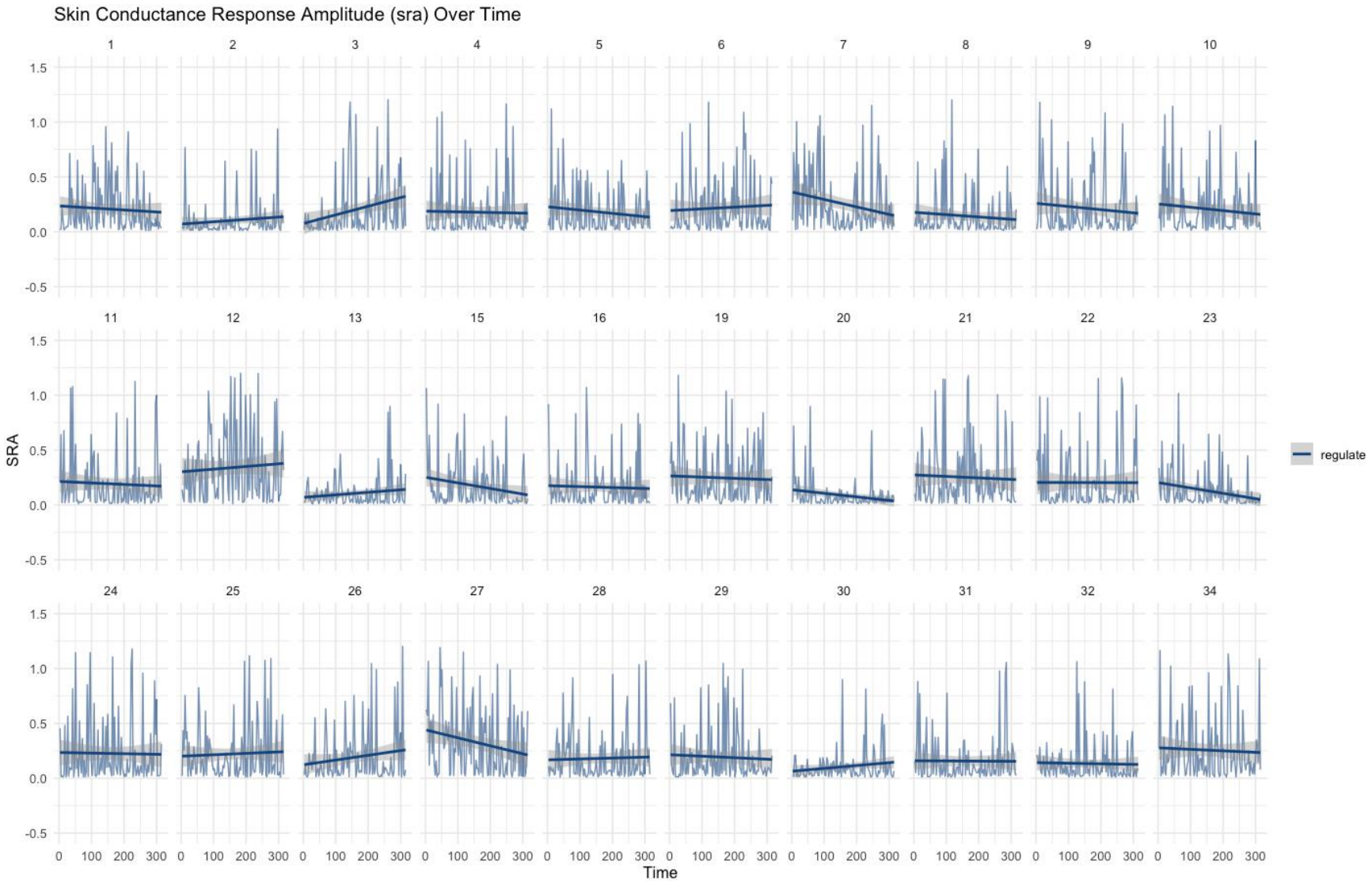
9
10
11
12
13
15
16
19
20
21
22
23
24
25
26
27
28
29
30
31
32
34
SCL
Time
regulate

Figure 21


Skin Conductance Response Amplitude (sra) Over Time
1
2
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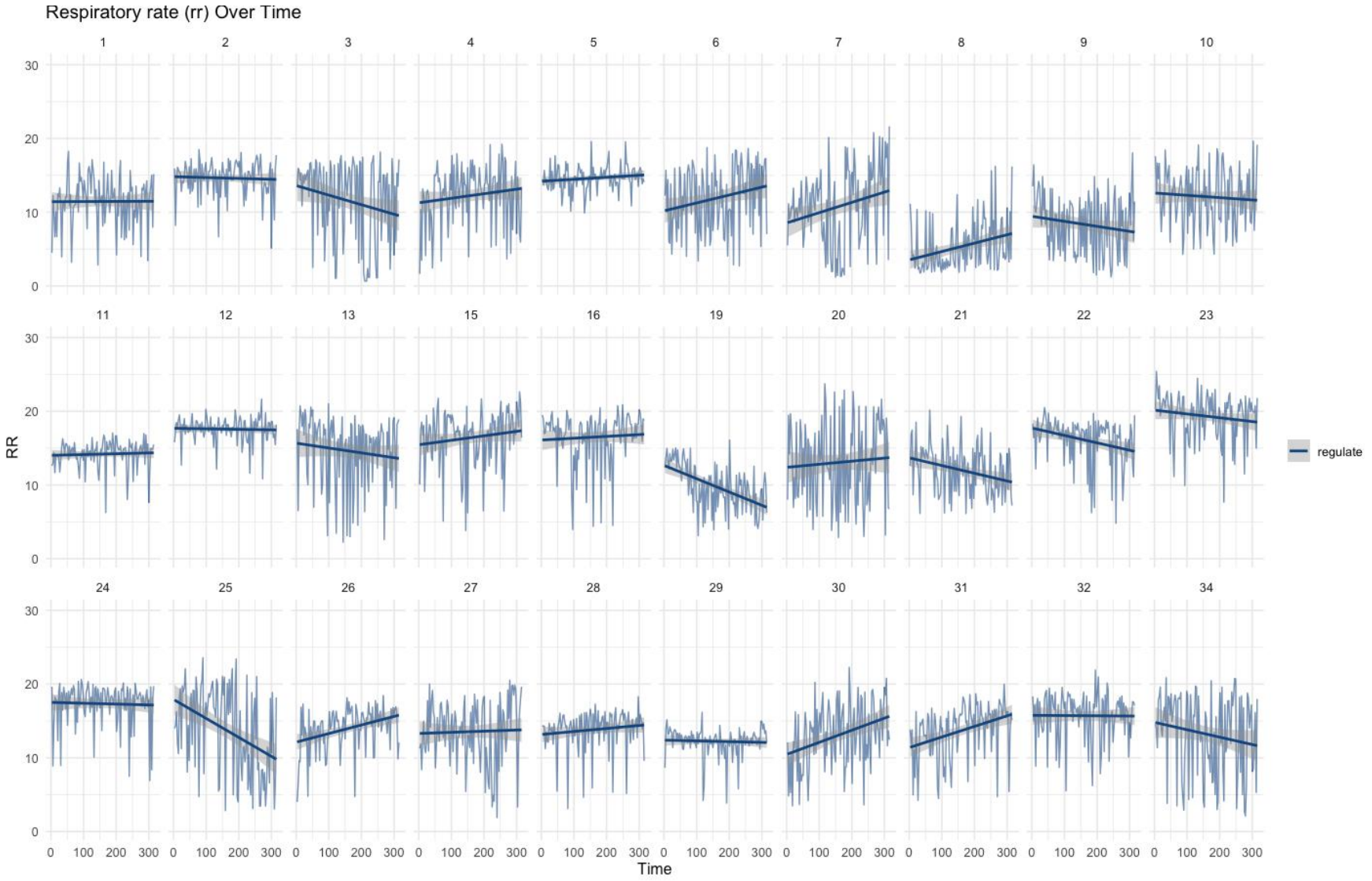
12
13
15
16
19
20
21
22
23
24
25
26
27
28
29
30
31
32
34
SRA
Time
regulate

Figure 22


Respiratory rate (rr) Over Time
1
2
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6
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8
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10
11
12
13
15
16
19
20
21
22
23
24
25
26
27
28
29
30
31
32
34
RR
Time
regulate

SUPPLEMENTAL MLM results

Results of RMSSD followed the patterns of IBI.

Separate models were also conducted with RMSSD, SDSD (standard deviation of the successive differences of the RR intervals) measure, and FT (see Table 12 to Table 13). Overall, RMSSD showed consistent findings including a significant goal and valence interaction, $F(2, 14973) = 4.38$, $p = .01$, so that women displayed lower mean levels of RMSSD measures for emotional stimuli compared to neutral stimuli (negative to neutral: $\gamma = -0.10$, $p = .006$; positive to neutral: $\gamma = -0.08$, $p = .02$). Emotion regulation goal also significantly predicted within-person variance in RMSSD with a goal to neutralize than to view, as well as to transform than to view emotional stimuli, (neutralize to view differed by ±0.077 units, transform to view differed by ±0.12 units, $\gamma = 0.02$, $p = .001$). No significant within-person differences were found when contrasting the goal to neutralize versus transform the stimuli, $\gamma = 0.00005$, $p = .97$. On the other hand, results from SDSD and FT did not follow the above pattern, with respect to between or within-person effects when comparing the goal to neutralize, transform, or view emotional stimuli (all *p*s > .06).

Results of DBP and PEP followed a similar pattern of SBP results.

The trend was consistent for the other two blood pressure measures, for instance, there was also a significant main effect of emotion regulatory goal on DBP, $F(2, 15671) = 2.66$, $p = .03$, so that DBP were on average higher when transforming than neutralizing emotional stimuli, DBP: $\gamma = 0.06$, $p = .03$. There were non-significant within subject differences by emotion regulatory goal or picture valence for both DBP and PEP (all *p*s > .30, see Table 13-14). A unique finding was that a between subject gender effect was found for PEP, so that male displayed higher average level of PEP than female $F(1,150.248) = 5.96$, $p = .01$.

***Within* subject SCL variations observed in regulation but did not differ by quantitative and qualitative goal.**

Individuals displayed significant variations with themselves for the SCL measures specifically when regulating than viewing emotional stimuli, (neutralize to view: ±0.04 units, γ = 0.002, $p < .001$; transform to viewing: ±0.05 units, $\gamma = 0.003$, $p < .001$).

Unique findings from SCL and SRA showed *within* subject variations influenced by quantitative and qualitative goal.

SRA measure showed consistent results with SCR such that no significant between subject differences were found by emotion regulatory goals, picture valence, or gender (all *p*s > .51, see Table 16). On the other hand, results showed no significant between subject differences in SCL predicted by emotion regulatory goals, picture valence, or gender (all *p*s > .51) on SCL (Table 15).

For within-subject effects, SCL and SRA showed consistent results with SCR such that individuals displayed significant variations with themselves, specifically when neutralizing versus viewing emotional stimuli, (SCL: ±0.04 units, $\gamma = 0.002$, $p < .001$; SRA: ±0.12 units, γ = 0.016, $p = .001$). Unique results were also seen from these two measures. For instance, there was a significant within-person variations for the SRA when neutralizing than transforming emotional stimuli, $\gamma = 0.016$, $p = .001$. Additionally, there was a significant within-person variations for the SCL measure when transforming versus viewing emotional stimuli, ±0.05 units, $\gamma = 0.003$, $p < .001$).

Unique findings from VI showed *within* subject variations influenced by quantitative and qualitative goal.

VI showed consistent findings on within-person fluctuations with RR, such that there were significant within-person fluctuations when transforming than viewing emotional stimuli, (±0.22 units, $\gamma = 0.05$, $p < .001$, see Table 19). There was also a significant within-subject effect for neutralizing than transforming emotional stimuli, (±0.24 units, $\gamma = 0.06$, $p < .001$)

Some unique findings from VI include a significant gender effect, $F(1, 150.8) = 15.50$, $p < .001$, such that male showed higher VI than female on average. There was also a significant goal by gender interaction, $F(2, 284) = 2.82$, $p = .02$, such that male had higher VI level than female when neutralizing than viewing emotional stimuli, $\gamma = 0.007$, $p = .04$, as well as when transforming than viewing emotional stimuli, $\gamma = 0.008$, $p = .04$. At the same time, there was a significant goal by valence interaction, $F(4, 15610.8) = 3.15$, $p = .02$, such that VI level was significantly higher when transforming positive than viewing positive emotional stimuli, $\gamma = 0.10$, $p = .02$.

Supplemental tables for MLM results

Table 12. Multi-level Model of Emotion Regulatory Goal, Picture Valence on Standardized RMSSD measure with time

					CI_{95}	
Fixed effects (intercepts, slopes)	Estimate	*SE*	t-value	p-value	Lower	Upper
Intercept	-0.20	0.08	-2.40	0.017*	-0.36	-0.04
Time	0.003	0.0002	12.33	0.00*	0.002	0.003
Gender (female)	-0.11	0.11	-0.99	0.33	-0.109	0.33
Goal						
Neutralize	0.02	0.04	0.41	0.68	-0.06	0.10
Transform	0.03	0.04	0.71	0.48	-0.05	0.11
Picture Valence						
Negative	0.003	0.003	1.07	0.29	-0.13	0.009
Positive	0.004	0.003	0.13	0.90	-0.14	0.02
Neutralize X Negative	0.001	0.04	0.03	0.97	-0.08	0.08
Transform X Negative	-0.05	0.04	-1.23	0.21	-0.15	0.03
Neutralize X Positive	0.002	0.04	0.04	0.96	-0.08	0.08
Transform X Positive	0.05	0.04	1.40	0.15	-0.02	0.14
Neutralize X Female	0.01	0.03	0.54	0.58	-0.04	0.07
Transform X Female	0.005	0.03	0.15	0.86	-0.06	0.07
Negative X Female	-0.10	0.02	-2.26	0.02*	-0.15	-0.01
Positive X Female	-0.08	0.03	-2.77	0.006**	-0.16	-0.03
					CI_{95}	
Random effects (variances)	Estimate	SE	z value	p-value	Lower	Upper
Intercept variance	0.53	0.006	86.49	0.00***	0.52	0.54
Goal Intercept Variance	0.41	0.05	8.35	0.00	0.33	0.52
Neutralize	0.006	0.003	2.25	0.02*	0.003	0.01
Transform	0.02	0.005	3.23	0.001**	0.008	0.03

****p<.001*. ***p* < .01. **p* < .05.

Table 13. Multi-level Model of Emotion Regulatory Goal, Picture Valence on SDSD measure with time

					CI_{95}	
Fixed effects (intercepts, slopes)	Estimate	*SE*	t-value	p-value	Lower	Upper
Intercept	-0.17	0.08	-2.02	0.04*	-0.35	-0.005
Time	0.002	0.0002	8.98	0.00***	0.0015	0.002
Gender (female)	0.17	0.11	1.50	0.13	-0.05	0.40
Goal						
Neutralize	-0.0009	0.04	-0.02	0.98	-0.08	0.08
Transform	0.04	0.04	0.95	0.34	-0.04	0.13
Picture Valence						
Negative	-0.04	0.03	-1.08	0.27	-0.11	0.03
Positive	-0.03	0.03	-0.96	0.33	-0.11	0.03
Neutralize X Negative	-0.009	0.04	-0.22	0.83	-0.09	0.07
Transform X Negative	0.03	0.04	0.62	0.53	-0.06	0.11
Neutralize X Positive	-0.04	0.03	0.77	0.44	-0.08	0.24
Transform X Positive	0.06	0.04	1.41	0.16	-0.02	0.14
Neutralize X Female	0.02	0.03	0.54	0.59	-0.04	0.08
Transform X Female	0.006	0.03	0.17	0.87	-0.06	0.07
Negative X Female	-0.10	0.02	-2.26	0.02*	-0.15	-0.01
Positive X Female	-0.08	0.03	-2.77	0.006***	-0.16	-0.03
					CI_{95}	
Random effects (variances)	Estimate	SE	z value	p-value	Lower	Upper
Intercept variance	0.55	0.006	85.79	0.00***	0.54	0.56
Goal Intercept Variance	0.43	0.05	7.87	0.00***	0.33	0.55
Neutralize	0.00005	0.0008	0.05	0.95	0.00	0.00
Transform	0.0005	0.002	0.17	0.85	0.00	30.24

***$p < .001$ **$p < .01$ *$p < .05$

Table 14. Multi-level Model of Emotion Regulatory Goal, Picture Valence on FT measure with time

					CI_{95}	
Fixed effects (intercepts, slopes)	Estimate	*SE*	t-value	p-value	Lower	Upper
Intercept	0.56	0.10	5.49	0.00***	-0.36	0.77
Time	-0.004	0.0003	-15.07	0.00***	-0.005	-0.003
Gender (female)	-0.73	0.13	-5.26	0.00***	-1.01	-0.45
Goal						
Neutralize	-0.0006	0.001	-0.35	0.72	-0.003	0.002
Transform	-0.002	0.001	-1.23	0.21	-0.006	0.001
Picture Valence						
Negative	0.0006	0.001	0.40	0.68	-0.002	0.003
Positive	0.0006	0.001	0.44	0.66	-0.002	0.003
Neutralize X Negative	-0.001	0.002	-0.52	0.59	-0.005	0.003
Transform X Negative	0.001	0.002	0.61	0.53	-0.002	0.005
Neutralize X Positive	-0.007	0.002	-0.37	0.71	-0.004	0.003
Transform X Positive	0.003	0.002	1.57	0.11	-0.0008	0.007
Neutralize X Female	0.001	0.001	1.08	0.28	-0.001	0.004
Transform X Female	0.0009	0.001	0.72	0.47	-0.001	0.003
Negative X Female	-0.006	0.001	-0.35	0.72	-0.003	0.002
Positive X Female	-0.0002	0.001	-0.15	0.87	-0.003	0.003
					CI_{95}	
Random effects (variances)	Estimate	SE	z value	p-value	Lower	Upper
Intercept variance	0.10	0.008	12.36	0.00***	0.08	0.12
Goal Intercept Variance	0.67	0.08	8.22	0.00***	0.53	0.85
Neutralize	0.00	0.007	0.05	0.97	-0.14	0.14
Transform	0.00	0.007	0.02	0.93	-0.14	0.14

***$p < .001$ **$p < .01$ *$p < .05$

Table 15. Multi-level Model of Emotion Regulatory Goal, Picture Valence on DBP measure with time

					CI_{95}	
Fixed effects (intercepts, slopes)	Estimate	*SE*	t-value	p-value	Lower	Upper
Intercept	0.03	0.09	0.39	0.69	-0.15	0.22
Time	0.0015	0.0002	6.58	0.00***	0.0010	0.0019
Gender (female)	-0.17	0.12	-1.33	0.18	-0.42	0.08
Goal						
View	-0.05	0.03	01.62	0.10	-0.12	0.01
Transform	0.06	0.03	1.69	0.03*	0.01	0.14
Picture Valence						
Negative	-0.04	0.03	-1.47	0.14	-0.10	0.01
Positive	-0.05	0.03	-1.69	0.09	-0.11	0.008
Neutralize X Negative	0.03	0.04	0.81	0.41	-0.04	0.11
Transform X Negative	0.05	0.03	1.65	0.09	-0.01	0.12
Neutralize X Positive	0.05	0.04	1.48	0.13	-0.01	0.13
Transform X Positive	0.05	0.03	1.60	0.10	-0.01	0.12
Neutralize X Female	0.0008	0.02	0.03	0.97	-0.05	0.05
Transform X Female	0.008	0.02	0.35	0.72	-0.04	0.05
Negative X Female	-0.006	0.02	-0.20	0.83	-0.06	0.05
Positive X Female	-0.008	0.03	-0.29	0.76	-0.06	0.04
					CI_{95}	
Random effects (variances)	Estimate	SE	z value	p-value	Lower	Upper
Intercept variance	0.41	0.004	82.88	0.00***	0.40	0.42
Goal Intercept Variance	0.56	0.06	8.40	0.00***	0.45	0.71
Neutralize	0.001	0.001	0.77	0.43	0.0000008	0.01
Transform	0.004	0.002	1.74	0.08	0.001	0.015

***neutralize goal as reference group**

***$p < .001$ **$p < .01$ *$p < .05$

Table 16. Multi-level Model of Emotion Regulatory Goal, Picture Valence on PEP measure with time

					CI_{95}	
Fixed effects (intercepts, slopes)	Estimate	*SE*	t-value	p-value	Lower	Upper
Intercept	0.11	0.08	1.37	0.17	-0.05	0.29
Time	0.0005	0.0001	2.93	0.003**	0.0001	0.0009
Gender (female)	-0.28	0.11	-2.51	0.01*	-0.51	-0.06
Goal						
Neutralize	-0.05	0.04	-1.36	0.17	-0.14	0.02
Transform	0.01	0.03	0.51	0.61	-0.05	0.09
Picture Valence						
Negative	-0.002	0.03	-0.07	0.93	-0.07	0.06
Positive	0.02	0.03	0.64	0.52	-0.04	0.09
Neutralize X Negative	0.06	0.04	1.31	0.19	-0.02	0.14
Transform X Negative	-0.01	0.04	-0.45	0.65	-0.09	0.06
Neutralize X Positive	0.04	0.04	0.92	0.35	-0.04	0.13
Transform X Positive	-0.04	0.04	-1.18	0.23	-0.12	0.03
Neutralize X Female	0.009	0.03	0.31	0.75	-0.05	0.07
Transform X Female	-0.002	0.02	-0.09	0.92	-0.05	0.05
Negative X Female	0.0001	0.03	0.004	0.99	-0.06	0.06
Positive X Female	0.008	0.03	0.25	0.80	-0.05	0.07
					CI_{95}	
Random effects (variances)	Estimate	SE	z value	p-value	Lower	Upper
Intercept variance	0.48	0.005	88.87	0.00***	0.47	0.49
Goal Intercept Variance	0.03	0.007	4.28	0.00***	0.01	0.04
Neutralize	0.00002	0.0005	0.04	0.96	0.00	0.00
Transform	0.0003	0.001	0.25	0.79	0.00	0.67

***$p < .001$ **$p < .01$ *$p < .05$

Table 17. Multi-level Model of Emotion Regulatory Goal, Picture Valence on SCL measure with time

					CI_{95}	
Fixed effects (intercepts, slopes)	Estimate	*SE*	t-value	p-value	Lower	Upper
Intercept	0.23	0.11	2.10	0.03*	0.01	0.46
Time	-0.003	0.0001	-20.92	0.00***	-0.0037	-0.0031
Gender (female)	-0.10	0.15	-0.65	0.51	-0.40	0.20
Goal						
Neutralize	0.007	0.01	0.54	0.58	-0.01	0.03
Transform	-0.001	0.01	-0.11	0.90	-0.02	0.02
Picture Valence						
Negative	0.0004	0.009	0.04	0.96	-0.01	0.01
Positive	0.002	0.009	0.20	0.83	-0.01	0.02
Neutralize X Negative	-0.006	0.01	-0.49	0.61	-0.03	0.01
Transform X Negative	0.005	0.01	0.44	0.65	-0.01	0.03
Neutralize X Positive	0.04	0.04	0.92	0.35	-0.04	0.13
Transform X Positive	-0.04	0.04	-1.18	0.23	-0.12	0.03
Neutralize X Female	-0.009	0.009	-0.90	0.36	-0.02	0.01
Transform X Female	-0.008	0.009	-0.89	0.37	-0.02	0.009
Negative X Female	0.008	0.01	0.75	0.45	-0.01	0.02
Positive X Female	0.007	0.01	0.72	0.46	-0.01	0.02
					CI_{95}	
Random effects (variances)	Estimate	SE	z value	p-value	Lower	Upper
Intercept variance	0.10	0.001	58.44	0.00***	0.10	0.11
Goal Intercept Variance	0.79	0.09	8.08	0.00***	0.62	1.01
Neutralize	0.002	0.0007	3.95	0.00***	0.001	0.004
Transform	0.003	0.0007	5.36	0.00***	0.002	0.005

***$p < .001$ **$p < .01$ *$p < .05$

Table 18. Multi-level Model of Emotion Regulatory Goal, Picture Valence on SRA

Fixed effects (intercepts, slopes)	Estimate	*SE*	t-value	p-value	CI_{95} Lower	CI_{95} Upper
Intercept	0.03	0.04	0.69	0.48	-0.06	0.13
Time	-0.0008	0.0002	-3.40	0.001**	-0.001	-0.0003
Gender (female)	-0.006	0.05	-0.10	0.91	-0.12	0.11
Goal						
Neutralize	0.03	0.05	0.64	0.52	-0.07	0.14
Transform	0.05	0.05	1.00	0.31	-0.05	0.15
Picture Valence						
Negative	0.04	0.04	0.93	0.35	-0.04	0.12
Positive	0.03	0.04	0.74	0.45	-0.05	0.11
Neutralize X Negative	-0.05	0.05	-1.03	0.30	-0.17	0.05
Transform X Negative	-0.06	0.05	-1.21	0.22	-0.17	0.04
Neutralize X Positive	-0.06	0.05	-1.10	0.27	-0.17	0.04
Transform X Positive	-0.04	0.05	-0.78	0.43	-0.15	0.06
Neutralize X Female	0.007	0.03	0.20	0.84	-0.06	0.08
Transform X Female	-0.03	0.03	-0.79	0.42	-0.10	0.04
Negative X Female	-0.009	0.04	-0.19	0.84	-0.10	0.08
Positive X Female	-0.02	0.04	-0.54	0.58	-0.11	0.06

Random effects (variances)	Estimate	SE	z value	p-value	CI_{95} Lower	CI_{95} Upper
Intercept variance	0.94	0.01	88.54	0.00***	0.92	0.96
Goal Intercept Variance	0.01	0.004	3.40	0.001**	0.009	0.02
Neutralize	0.01	0.005	3.19	0.001**	0.009	0.03
Transform	0.005	0.002	1.80	0.07	0.001	0.01

***$p < .001$ **$p < .01$ *$p < .05$

Table 19. Multi-level Model of Emotion Regulatory Goal, Picture Valence on VI

					CI_{95}	
Fixed effects (intercepts, slopes)	Estimate	*SE*	t-value	p-value	Lower	Upper
Intercept	-0.25	0.07	-3.58	0.00***	-0.40	-0.11
Time	0.001	0.0002	4.59	0.00***	0.0005	0.001
Gender (female)	-0.33	0.09	-3.53	0.001**	-0.52	-0.14
Goal						
Neutralize	-0.04	0.04	-0.98	0.32	-0.13	0.04
Transform	-0.08	0.04	-1.68	0.09	-0.17	0.01
Picture Valence						
Negative	0.06	0.03	1.71	0.08	-0.008	0.13
Positive	0.04	0.03	1.18	0.23	-0.02	0.11
Neutralize X Negative	-0.02	0.04	-0.58	0.56	-0.12	0.06
Transform X Negative	0.03	0.04	0.81	0.41	-0.05	0.13
Neutralize X Positive	-0.04	0.04	-0.88	0.37	-0.13	0.05
Transform X Positive	0.10	0.04	2.21	0.02*	0.01	0.19
Neutralize X Female	-0.07	0.03	-1.97	0.04*	-0.14	-0.0002
Transform X Female	-0.08	0.03	-2.07	0.04*	-0.16	-0.003
Negative X Female	-0.03	0.03	-0.98	0.32	-0.11	0.03
Positive X Female	-0.02	0.03	-0.68	0.49	-0.10	0.05
					CI_{95}	
Random effects (variances)	Estimate	SE	z value	p-value	Lower	Upper
Intercept variance	0.66	0.007	87.69	0.00***	0.64	0.67
Goal Intercept Variance	0.32	0.04	7.27	0.00***	0.24	0.42
Neutralize	0.02	0.005	4.50	0.00***	0.01	0.03
Transform	0.01	0.004	3.79	0.00***	0.01	0.03

***$p < .001$ **$p < .01$ *$p < .05$

APPENDIX E – Supplemental MANOVA results

Prior to testing the effect of the emotion regulatory goal manipulations, a MANCOVA test of manipulation check was performed to see whether there were differences in physiology during the mean reaction period by picture valence and gender, controlling for participants' rest period reactions. Interestingly, there was not a significant difference in physiology during the mean reaction period across emotional stimuli, $F(2) = 1.09$, $p = 0.34$, $\eta_p^2 = .001$. There was a significant effect of gender on overall physiological indices, $F(2) = 58{,}75$ $p < .001$ $\eta_p^2 = .03$. Specifically, females displayed significantly higher values than males on the following physicological indices including IBI, RMSSD, SDSD, SCR, RR, and VI. [IBI: $t(14748) = 4.45$, $p < .001$, RMSSD: $t115622) = 18.68$ $p < .001$, SDSD: $t(15621) = 18.67$, $p < .001$, RR: $t(15748) = 11.90$, $p < .001$, VI: $t(15748) = 19.68$, $p < .001$]. On the other hand, male displayed higher levels of physiology than females on the other indices including PEP, SBP, DBP, FT, and SCL [PEP: $t(15748) = -12.96$, $p < .001$, SBP: $t(15748) = -6.26$, $p < .001$, DBP: $t(15748) = -12.88$, $p < .001$, FT: $t(15748) = -50.87$, $p < .001$, SCL: $t(15748) = -6.73$, $p < .001$].

To test for whether physiological indices differed within different emotion regulatory goals and picture valence, a second MANCOVA was carried out with physiological indices during the regulation period as dependent variables, the emotion regulatory goal and picture valence as independent variables, and with gender and physiological indices during the reaction period as covariates. Results show that there was not a significant interaction between emotion regulatory goals and picture valence on physiological indices after controlling for the covariates, $F(9, 8572) = 0.72$, $p = 0.68$, Wilk's $\Lambda = 0.99$, $\eta_p^2 = .001$, suggesting the effect of goals was consistent across different valence of emotional stimuli. In addition, there was not a significant effect on both emotion regulatory goal, $F(9, 8572) = 0.47$, $p = 0.89$, Wilk's $\Lambda = 0.99$, $\eta_p^2 = .001$,

and picture valence, $F(9, 8572) = 0.41$, $p = 0.92$, Wilk's $\Lambda = 0.99$, $\eta_p^2 = .001$, after controlling for the covariates. No follow-up post-hoc tests were conducted given there were no significant interactions or main effects in the main model.