Concordance of Emotional and Physiological Response Systems and the Role of Emotion Regulation During Parent-Adolescent Conflict

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Dissertation

Submitted to the Faculty of the

Graduate School of Vanderbilt University

in partial fulfillment of the requirements

for the degree of

DOCTOR OF PHILOSOPHY

in

Psychology

August 11, 2023

Nashville, Tennessee

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For my parents and family, who have modeled perseverance, compassion, curiosity, and collaboration. I thank you for your boundless support.

ACKNOWLEDGEMENTS

I am forever grateful for all the team members, lab mates, coaches, teachers, professors, and mentors who have guided me throughout my life. I am moved by generosity of those who have offered their time, support, and thoughts over the years. This is a tradition I will continue. My academic pursuits, as one example, would not have been possible without it.

A special thank you to Qimin Liu, as well as Dr. Kristopher Preacher and Lindsay Dickey, for answering my many statistical questions. I deeply appreciate the graduate program faculty and members of my dissertation committee who have supported and challenged me throughout my doctoral studies. I am especially grateful to my research advisor and mentor, Dr. Bruce Compas, for countless opportunities, many thoughtful discussions, and always believing in my abilities. Lastly, I thank my friends. You all are simply the best.

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BACKGROUND

Two core transdiagnostic features of psychopathology, and key targets for interventions, are emotional and physiological dysregulation. Evolutionary/functionalist theories have been central in emotion research and highlight that greater concordance across emotional response systems, including physiological systems, helps individuals effectively respond to challenges in their environment and promotes well-being (Ekman, 1992; Levenson, 2014; Mauss et al., 2005). Yet, research testing hypotheses based on theory postulating concordance between emotions and physiology (i.e., heightened physiological arousal in conjunction with heightened emotional state) has been surprisingly inconclusive, and researchers in the field have highlighted that factors affecting concordance require additional research (Brown et al., 2020; Hollenstein & Lanteigne, 2014; Lougheed et al., 2021). Research exploring the concordance between emotional and physiological systems has largely been conducted in adult samples and utilized standardized laboratory stimuli to elicit emotional responses. Further, emotion regulation hypothesized to affect concordance between emotions and physiology. Understanding the relations among emotion, physiology, and the ability to self-regulate are essential for determining when, and for whom, concordance between emotions and physiology is adaptive or maladaptive.

The present study builds on previous research by testing relations between autonomic nervous system physiology, emotion, and emotion regulation *within* youth and *within* their caregivers, assessed during a conflict discussion task. In this introduction, I first review the importance and relevance of the autonomic nervous system (ANS) for understanding stress responses and emotions. Second, I review the current literature on emotional and physiological concordance. Third, I review research on the influence of emotion regulation on physiological-emotional concordance. Lastly, I outline the goals of the current study.

1.1. Significance of the Autonomic Nervous System (ANS)

The ANS serves to regulate a wide range of the body's functions, including blood pressure, gastrointestinal function, bladder function, pupillary response, thermoregulation, and sexual function (Gibbons, 2019). The ANS controls resting functions (i.e., maintaining homeostasis) and responses required to respond to threat that operate largely through rapid automatic processes (Kemeny, 2003). The ANS is comprised of two branches: the sympathetic nervous system (SNS) and parasympathetic nervous system (PNS), which have a multitude of opposing, complementary, and coordinated functions. The SNS governs the body's "flight or fight" response and controls the body's mobilization of physiological resources to prepare for physical activity in response to environmental threats and challenges (McCorry, 2007). The PNS governs the "rest and digest" and "feed and breed" responses which return the body to a rest state and facilitate growth and restoration (McCorry, 2007).

1.1.1. PNS function. Vagal tone is one index of tonic PNS control over heart rate via the vagus nerve and has inhibitory influences that produces a heart rate that is lower than basal firing rate of the sinoatrial node in the heart (Porges, 1995, 2007). Cardiac vagal control is commonly measured noninvasively via assessing respiratory sinus arrhythmia (RSA). RSA reflects the physiological and rhythmic fluctuation of heart rate as a function of respiration and is quantified as the degree to which heart rate increases with inspiration and decreases with expiration, and is commonly more pronounced (i.e., greater in magnitude) in healthy individuals at rest (Berntson et al., 1997; Hinnant et al., 2017). Heart rate variability (HRV) reflects the fluctuation of instantaneous heart period (i.e., variation in beat-to-beat intervals or inter-beat interval) over time and is commonly used as an estimation of RSA (Berntson et al., 1997). While RSA emphasizes correspondence with respiration (e.g., inhalation vs. exhalation), HRV reflects the variation in the length between heart beats. Higher RSA at rest has been conceptualized as a marker of flexible and context-appropriate modulation of ANS activity. During challenge or threat, the "vagal brake" can be withdrawn, leading to decreased RSA, increased heart rate, and increased metabolic output to allow for engagement with environmental demands and threats (Beauchaine, 2001). Therefore, reductions in RSA during challenge should reflect flexible adaptation to environmental demands. RSA has been identified as playing a role in children's self-regulation, emotion regulation, and cognitive control, which are essential for children's adaptive functioning (Beauchaine & Thayer, 2015; Eisenberg et al., 2011).

1.1.2. SNS function. Skin conductance is one common SNS measure that indexes electrodermal activity (EDA) generated by sweat glands. EDA includes both baseline tonic skin conductance level (SCL) and rapid phasic components that reflect skin conductance responses (SCR) resulting from sympathetic neuronal activity. In contrast to other sympathetic indices (e.g., cardiac pre-ejection period), SCL is arguably the most useful and "pure" SNS index because it is does not share any parasympathetic influence (Braithwaite et al., 2013; Critchley, 2002). EDA is responsive to nearly all discrete emotions (Cacioppo & Berntson, 1997; Kreibig, 2010; Quigley & Barrett, 2014) and has been linked to implicit emotional and attentional processing (e.g., threat responses, anticipation, salience, novelty) (Braithwaite et al., 2013).

1.1.3. Emotion. While debated, some theorize that emotions evolved as adaptations to fundamental recurring situations, with the primary goal being quick mobilization to address interpersonal encounters (Ekman, 1999; Keltner & Gross, 1999; add Russell & Feldman, 1999). Emotions have been defined as "episodic, relatively short-term, biologically based patterns of perception, experience, physiology, action, and communication that occur in response to specific physical and social challenges and opportunities" (Keltner & Gross, 1999). A large body of work has assessed the relationships of autonomic nervous system measures and discrete emotions (e.g., happiness, sadness, fear, anger, etc.) qualitatively and quantitatively (Cacioppo & Berntson, 1997; Kreibig, 2010; Lench et al., 2011; Quigley & Barrett, 2014). All demonstrated variable patterns of findings across different emotions and physiological measures. Quigley and Barrett (2014) conclude that there is minimal evidence supporting specificity of ANS responses to discrete emotions, though there is more support that emotion induction indeed consistently elicits an ANS response. The ANS also plays an important role in physical responses to environmental stressors, which are often highly emotional. As stated by Levenson (2014, p. 100), "When it comes to emotion, all roads lead to the autonomic nervous system," including emotion generation, expression, experience, recognition, and regulation. Yet Levenson's (2014) extensive review also highlights the significant challenges that need to be overcome for empirical studies to adequately test evolutionary/functionalist theories and resolve conflictual evidence. The relation between the ANS and experience of emotion is complicated, bidirectional, and intertwined over time. Despite decades of research, their correspondence is not fully understood.

1.2. Emotional and Physiological Concordance

Linkage between physiology and emotion measures has many names, and many terms have been used to describe their associations *within* individuals and *between* individuals. In the body of work assessing emotions or physiology between people (i.e., *inter*personal), the term *synchrony* has mainly been used, though a systematic review identified more than 12 different terms to define interdependence or association between people (Palumbo et al., 2017). *Synchrony* has been defined as the matching of behavior, affect, and/or biological states that together form a ‘relational unit’ (Feldman, 2007). Others utilize the term, *coregulation*, operationally defined as the bidirectional linkage of oscillating emotional channels between partners (Butler & Randall, 2013). Many researchers have drawn attention to the problematic nature of differing use of definitions and terminology for *inter*personal autonomic physiology (i.e., “methodology for studying temporal interactions in physiological processes between multiple people”), which has resulted in a fragmented literature, and made drawing conclusions across studies difficult (p. 100, Palumbo et al., 2017). Definitions in *intra*personal research assessing components of emotional systems (e.g., emotional experience, emotional expression, physiology) also varies (e.g., synchrony, response system coherence, organization of response tendencies, response components, response component syndromes) (Hollenstein & Lanteigne, 2014).

Hollenstein and Lanteigne (2014) advocate for use of the terms *concordance* and *discordance*, because they depict the two possible combinations of emotional responses, unlike other terms that incorrectly assume response components are “moving away” from each other (e.g., divergence), have a negative connotation (e.g., incoherence), imply haphazard coordination (e.g., disorganization), or terms that can describe both temporally positive and negative associations (e.g., synchrony). In the present study, the term *physiological-emotional concordance* is used to indicate the degree to which emotional and physiological responses are associated across emotional response components sampled over time during an emotional episode. *Concordance* will be used to reflect the *positive association* between autonomic function and emotional valence (i.e., higher autonomic activation corresponding to higher emotion ratings), while *discordance* will be used to reflect the *negative association* between autonomic function and emotional valence (i.e., higher autonomic activation corresponding to lower emotion ratings). In review of and comments on others' work, their reported terms (e.g., coherence) are used to most accurately depict their findings in conjunction with their definition.

For over a century, theorists and researchers have conceptualized emotion as the *synchronized* and *coordinated* combination of multiple physiological, cognitive, and behavioral components of the emotion system (Hollenstein & Lanteigne, 2014). Evolutionary/functionalist theories suggest that greater concordance across emotional response systems (e.g., experience, physiology) helps individuals effectively respond to challenges in their environment and promotes well-being (Brown et al., 2020; Ekman, 1992; Levenson, 2014; Mauss et al., 2005). In a simple example, perhaps a child sees that there is a poisonous snake close by on the ground; a concordant response involves experiencing fear and activating ANS physiological resources (heightened SNS arousal and PNS release) to effectively engage in fight or flight responses. In a more nuanced example, perhaps a child who has experienced physical abuse hears their parent arrive home at night. A concordant response may result in increased fear, vigilance for cues (e.g., that their parent is under the influence of alcohol), and ANS physiological activation to supply energy to mobilize the child to move out of the room if needed to avoid the potential negative consequences of an interaction.

Despite the longstanding theory that emotional and physiological responses are linked and demonstrate *concordance* within an individual (Darwin, 1872; James, 1884; Kreibig, 2010; Levenson, 2003), a large body of research has shown that these relations are not always found empirically or are weak in magnitude (Ekman, 1992; Mauss et al., 2005; Sze et al., 2010). The topic continues to be debated and lacks consensus. It is argued that theories may need to be updated to adequately align with the current state of research in the field, and the gap between theory and empirical findings may be due to methodological challenges, as well as a very complex relationship between emotion and physiology, which is moderated by a multitude of factors including emotion regulation, context, and individual differences (Hollenstein & Lanteigne, 2014; Levenson, 2014; Quigley & Barrett, 2014). An essential question posited by Friedman et al. (2014) is that it is not whether emotional components are concordant or to what degree emotional components are concordant, but rather what are the contextual factors and individual differences that mediate or moderate concordance among emotional components and in what manner do they operate? Others pose the question, if discordance is the norm, when does concordance occur (Lougheed et al., 2021)? It is indeed plausible to expect discordant responses across emotional response systems within an individual. In another example, perhaps a child has been chronically exposed to physical abuse and their physiological system has experienced wear and tear, resulting in an inadequate or blunted response to threat (McEwen, 1998). Therefore, when the child's parent who appears under the influence of alcohol arrives home, perhaps they experience increased fear, but do not mobilize physiological resources to respond.

Concordance between emotional and physiological components within individuals has important clinical applications, particularly when assessed in interpersonal settings. Butler et al. (2014) contend that concordance likely varies across emotions and situations. Researchers often transform bipolar (i.e., reflecting positive and negative emotion) rating scales by using the absolute value of responses to assess emotion intensity regardless of valence (Butler et al., 2014; Dan-Glauser & Gross, 2013), however, a recent review highlights the importance of assessing both positive and negative valence (Lougheed et al., 2021). For example, experiencing and displaying positive affect (e.g., happiness) may be adaptive, while experiencing and displaying negative affect (e.g., anger) may be maladaptive. Social and situational factors are also essential to consider when determining if emotional concordance is adaptive. For example, remaining stoic while experiencing intense emotion during a family discussion of politics may prevent escalation into a heated argument, or a parent remaining calm while experiencing distress or anger may prevent them from eliciting fear in their child. Therefore, concordance research should incorporate valence and context, as shifts may be expected in some instances.

Processes involving the *intra*individual concordance of emotional and physiological components have yet to be explored in the context of parent-child dyadic interactions and could have important implications for understanding family relationships. A body of work has assessed concordance of various components of emotional responding (e.g., physiology, behavior) *between* parents and children; similar to intraindividual concordance, these findings in the literature on interpersonal dyadic concordance is riddled with mixed results and complex relations (Creaven et al., 2014; Cui et al., 2015; Davis et al., 2017; Feldman, 2012; Henry et al., 2021; Lunkenheimer et al., 2018; Palumbo et al., 2017; Suveg et al., 2016, 2019; Vreeland, 2020; Woltering et al., 2015). Both intrapersonal dynamics and dyadic relationships are important targets for intervention for families. A deeper understanding of how these processes unfold *within* children and caregivers individually can provide important foundational insight for work on dyadic concordance, co-regulation, or synchrony *between* caregivers and children.

1.3. Emotion Regulation and Coping

The experience of emotion involves feedback and control processes to adjust emotional responses to changing environments and internal states (Keltner & Gross, 1999). While there are multiple definitions of emotion regulation and the related concept of coping with stress, *coping* is most commonly defined as a conscious, controlled, and effortful process of responding to stress, and *emotion regulation* is most commonly defined as the monitoring, evaluation, and modification of emotional reactions that can occur at both an automatic and purposeful level

(Compas et al., 2017). Individuals often try to modulate automatic emotional tendencies to improve their own welfare and that of others.

It is posited that emotion regulation may disrupt or enhance concordance to facilitate socially adaptive functioning (Friedman et al., 2014; Hollenstein & Lanteigne, 2014; Lougheed et al., 2021). In addition, just as different emotions (e.g., anger, fear, happiness, amusement) may demonstrate different physiological responses (Kreibig, 2010), different emotion regulation strategies also demonstrate different patterns of ANS activity (Levenson, 2003). Therefore, it may be expected and adaptive to have a concordant emotional response (e.g., increased emotional experience, increased physiological response) for a period of time, and then adjust based on the environment (e.g., in your home where the full emotional process can unfold vs. in public talking with someone and tempering one's emotional expression), and type/valence of emotion (e.g., positive or negative). Another factor, and one less well studied, is the temporal course of emotions. Emotions develop over varying periods of time, and the process model of emotion regulation emphasizes the importance of varying time scales in the generation and regulation of emotion (Gross, 1998, 2015). Therefore, it is important to look at patterns of concordance over time within individuals, as measures of overall concordance may not reflect the complex unfolding of all emotional responses and regulation processes. Over the course of several minutes, there are likely multiple phases of synchronization and desynchronization of emotional systems (Dan-Glauser & Gross, 2013). This highlights the importance of considering ecologically relevant situations and environments, emotional valence, and time course when assessing emotional-physiological concordance and the role of emotion regulation.

1.3.1. Emotion regulation and concordance. Gross (1998) found that expressive suppression (i.e., a form of emotion regulation involving suppression of outwardly expressing an emotion) corresponded to large reductions in facial expressions, no change in subjective emotional experience, and a large increase in physiological activation. In contrast, cognitive reappraisal (i.e., changing the way one thinks about an emotional or stressful event) corresponded to some reduction in facial expressions, some reduction in subjective experience, and did not change physiology (Gross, 1998). In a study of adults watching emotional films, participants with higher utilization of expressive suppression had lower concordance between physiology and emotion ratings, while no effects were found for cognitive reappraisal (Brown et al., 2020). Another study found that adults instructed to reappraise displayed reduced concordance for negative emotions and enhanced concordance for positive emotions (Butler et al., 2014). Further, research has shown that when participants were instructed to suppress emotional expressions and physiological responses to both negative and positive stimuli, coherence between multiple emotion response measures decreased, yet, when instructed to use acceptance regulation strategies, emotion concordance was stronger (as compared to suppression) (Dan-Glauser & Gross, 2013). In a study of female college student dyads instructed to watch and discuss a negative film, one partner was instructed to either emotionally suppress or reappraise during the conversation (Butler et al., 2014). Results showed that "suppressors" demonstrated a pattern of disrupted concordance (i.e., associations between subjective experience, expressive behavior, and inter-beat interval, SCL, and blood pressure) for both positive and negative emotion, while "reappraisers" showed less concordance than controls for negative emotions but displayed more concordance for positive emotions. While these effects were small, it is noteworthy that empirical evidence demonstrates that emotion regulation strategies can affect emotion concordance in college student and general adult samples.

Taken together, there is evidence that emotion regulation affects concordance between physiology and emotion in adults in both positive and negative emotional contexts. Expressive suppression has been generally shown to reduce physiology-emotion concordance, and effects of cognitive reappraisal on concordance are mixed. In addition, existing research has focused on standardized images or films.

Research on the effects of emotion regulation on concordance has relied on brief questionnaire measures (e.g., Emotion Regulation Questionnaire [ERQ]; Gross & John, 2003) or experimental manipulation of single indices of emotion regulation (e.g., instructions to suppress emotional expression or use cognitive reappraisal). Often, research literatures on emotion regulation and coping have been siloed, though both terms reflect adaptive processes to regulate emotions, thoughts, physiology, and behavior, and emphasize that strategy effectiveness likely depends on the context in which they are employed (Compas et al., 2017). A next step for assessing the moderating role self-regulation on concordance is to integrate measures of both emotion regulation and coping, particularly the well-validated and researched ERQ and Responses to Stress Questionnaire (RSQ; Connor-Smith et al., 2000). The ERQ is a brief (10 item) measure assessing use of two specific strategies in response to emotions: cognitive reappraisal (i.e., changing the way one thinks about a potentially emotion-eliciting event) and expressive suppression (i.e., changing the way one responds behaviorally to an emotion-eliciting event) (Gross & John, 2003; John & Gross, 2004). In contrast, the RSQ is a more comprehensive (57 item) measure assessing the use of three coping strategies and two involuntary responses to stress, confirmed in factor analytic studies, in response to specific stressors (e.g., Benson et al., 2011; Compas et al., 2006; Connor-Smith et al., 2000; Wadsworth et al., 2004). Coping strategies include primary control coping (i.e., emotional modulation, problem solving, emotional expression), secondary control coping (i.e., acceptance, distraction, positive thinking, cognitive reappraisal), and disengagement coping (i.e., avoidance, denial, wishful thinking), and responses to stress include involuntary engagement (i.e., rumination, intrusive thoughts, emotional and physiological arousal, impulsive action) and involuntary disengagement (i.e., escape, inaction, emotional numbing, cognitive interference). The disengagement coping and involuntary engagement factors have been shown to correlate with physiological measures (e.g., heart rate) in previous research (Connor-Smith et al., 2000; Connor-Smith & Compas, 2004).

1.3.2. Emotion regulation and development. Changes occur in cognitive and emotional development that may affect emotional responses and emotion regulation ability (Skinner & Zimmer-Gembeck, 2007; Zimmer-Gembeck & Skinner, 2011). Research has demonstrated age differences in emotion regulation and coping strategies (Eschenbeck et al., 2018; Zimmer-Gembeck & Skinner, 2011). In addition, age has been shown to moderate the association between coping and symptoms of psychopathology, where the associations between the use of different types of coping strategies and psychological symptoms were stronger for adolescents than for younger children (Compas et al., 2017). Therefore, emotion regulation and coping ability in youth may differ from adults, and the influence of regulatory abilities on concordance may also differ. Research on physiological-emotional concordance has been primarily focused on adult samples to date. Assessing concordance in youth can expand the understanding of this complex interplay, particularly as emotion regulation abilities are developing, and could provide a helpful biomarker of risk or resilience in children and adolescents.

1.3.3. Context. Research that has utilized standardized stimuli to elicit emotions has been essential for establishing foundational work on emotion and emotion regulation. However, an important and dynamic context for emotional exchanges is within parent-child interactions.

While youth increasingly interact with peers across adolescence, interpersonal functioning within the family remains a particularly salient environment (Laursen & Collins, 1998). For example, one of the primary contexts in which youth see emotional expression and regulation modeled is in the home. Parents' frequency, intensity, and valence of emotional expressions in the family context is related to child functioning, yet most empirical work on parent and child emotion regulation has been assessed in early childhood, not school-aged children and adolescents (Bariola et al., 2011). In dyadic parent-child tasks, discussions of pleasant and stressful topics differentially effectively elicit positive mood, and hostility and sadness, respectively (e.g., Gruhn et al., 2019). Further, Gruhn et al. (2019) found that youth coping was differentially related to observed emotions during pleasant and stressful discussions, where secondary control coping strategies corresponded to more observed positive mood and less observed hostility during a stressful parent-child conflict task. This demonstrates that parent-child tasks are effective in eliciting distinct emotions and emotion regulation. In addition, dysfunctional parenting is a non-specific risk for both internalizing and externalizing problems in youth (Berg-Nielsen et al., 2002). Assessing these processes within the context of a parent-child interaction is not only ecologically relevant, but an important setting for translating research to family outcomes.

1.4. Summary and Integration

As reviewed above, concordance between emotions and physiology is often assumed, while empirical evidence is mixed, with varied findings based on varied methodologies. The question remains: when and for whom is concordance adaptive? Recent calls have been made for researchers to assess within-individual levels of emotional concordance with attention to (1) biological mechanisms underlying concordance, (2) influences of emotion regulation on concordance, (3) individual differences in concordance, and (4) meaningful functional correlates of concordance (Lougheed et al., 2021). Assessing multiple indices of ANS function within the same sample is also essential to help elucidate complex patterns of emotional responses (Lougheed et al., 2021). Further, within individual approaches are necessary, as between-individual approaches do not capture true physiological-emotional concordance, which reflects coupling across response systems within an individual over time (Brown et al., 2020). Lastly, work on intraindividual physiological-emotional concordance has yet to be studied in youth, which may be particularly relevant as regulatory functions are developing.

1.5. The Current Study

The current study assessed the complex and multifaceted relations between moment-to-moment emotion ratings and continuous SNS and PNS responses during a an ecologically relevant dyadic (i.e., parent and adolescent) conflict discussion task, using video-mediated recall procedures to collect self-rated emotion, and employing a within individual methodological approach. While the PNS and SNS work in concert, they also enact different processes and may have distinct influences on outcomes (Levenson, 2014; Porges, 2007; Siciliano et al., 2022). Therefore, SNS and PNS measures were assessed separately. Lastly, the present study assessed how concordance between emotions and physiology varied as a function of emotion regulation, coping and involuntary responses to stress. This study sought to extend current literature assessing emotion regulation using a well-studied, yet brief, 10-item questionnaire measure (i.e., ERQ), as well as assess the role of conscious controlled coping and involuntary responses to stress utilizing another more comprehensive measure (i.e., RSQ).

1.5.1. Aim 1. Assess the *intra*personal concordance of PNS and SNS measures of ANS physiology, and emotion ratings during a dyadic conflict task in both youth and in their caregivers. Key study variables will be examined initially with correlations. In multilevel analyses, it is hypothesized that there will be a significant within individual association between emotion ratings and physiology, such that SCL and RSA will each be significantly related to emotions for youth and caregivers. As outlined by Hollenstein and Lanteigne (2014), the terms *concordance* (i.e., positive association) and *discordance* (i.e., negative association) will be used to describe associations. Specifically, the SCL-emotion slope will be negative, where higher SNS-mediated SCL will be associated with more negative emotion ratings (i.e., discordance) (**Hypothesis 1a**), and higher PNS-mediated RSA (i.e., more parasympathetic regulatory control) will correspond to more positive emotion ratings (i.e., concordance) (**Hypothesis 1b**). Analyses of possible differences that emerge between youth and caregivers will be exploratory. While no research has assessed these associations in youth, it is hypothesized that relations between emotions and physiology may be stronger for adults than for youth. Further, variability in physiological-emotional associations will be explored (via random slopes), as it is hypothesized that physiological-emotional concordance will demonstrate significant individual differences and moderators of this association exist (Lougheed et al., 2021).

1.5.2. *Aim 2*. Assess if emotion regulation moderates the association between emotion ratings and physiological activity in youth and caregivers. While this aim has been identified as an area of high importance (Lougheed et al., 2021), it has only been examined in a few studies of adults, often using non-specific composites of physiological measures (Brown et al., 2020; Butler et al., 2014; Dan-Glauser & Gross, 2013). Therefore, this aim will be tested using specific measures of PNS and SNS function, and two well-validated measures of emotion regulation: the ERQ comprised of the cognitive reappraisal and emotional suppression scales, and the RSQ comprised of primary control coping, secondary control coping, disengagement coping, involuntary engagement, and involuntary disengagement factors. While empirical evidence for cognitive reappraisal's relation to concordance is mixed, increased cognitive reappraisal may correspond to more adaptive emotional responses (i.e., concordance) because the preponderance of evidence shows that efforts to adapt to the source of stress or one's emotional response or to temporarily direct attention to positive aspects of the situation or non-stressful alternative thoughts (e.g., cognitive reappraisal and acceptance) are associated with lower internalizing and externalizing symptoms of psychopathology (Compas et al., 2017). Therefore, it is hypothesized (**Hypothesis 2a)** that cognitive reappraisal (ERQ scale), will moderate the physiological-emotional association and higher cognitive reappraisal will correspond to stronger physiological-emotional concordance in youth and caregivers. Based on previous research, it is hypothesized (**Hypothesis 2b**) that expressive suppression (ERQ scale), which is often associated with maladaptive outcomes, will moderate the physiological-emotional association, such that at higher levels of expressive suppression, the relation between emotions and ANS measures will be weaker for youth and caregivers. For analyses of the RSQ's controlled coping strategies, it is hypothesized that higher reported use of primary control coping (**Hypothesis 2c**) and secondary control coping (**Hypothesis 2d**) will predict stronger physiological-emotional associations, while higher use of disengagement coping (**Hypothesis 2e**) will predict a weaker physiological-emotional association. For the RSQ's indices of automatic responses to stress, it is hypothesized that higher levels of involuntary engagement (**Hypothesis 2f**) will predict a stronger physiological-emotional association, while higher levels of involuntary disengagement (**Hypothesis 2g**) will predict a weaker physiological-emotional association. The degree to which this association holds for distinct PNS and SNS measures will be explored.

CHAPTER 2

METHOD

2.1. Participants

Youth between the ages of 10 and 15 years and their caregivers were recruited to participate in a study on stress and emotions in the lives of families (R21HD098454; PI: Compas). The final sample was comprised of 97 parent-adolescent dyads (194 total participants), who were enrolled and completed laboratory study visit procedures. Youth were 12.22 years of age on average (*SD* = 1.68); 46.4% (*n* = 45) identified as female, 52.6 (*n* = 51) identified as male, and 1% (*n* = 1) identified as non-binary. Parents were 42.04 years of age on average (*SD* = 6.98); 89.7% (*n* = 87) of caregivers were female, and 10.3% were male (*n* = 10). Most caregivers were biological parents of youth (90, 92.8%). The remainder of caregivers included adoptive parents (4, 4%), stepparents (2, 2%) and other family members (e.g., uncle; 1, 1%). The sample was predominantly non-Hispanic or Latino (96% of parents, 93% of youth), and 75% of parents and 72% youth identified as White, 16% of youth and 16% parents identified as Black or African American, 5% of youth and 4% parents were Asian, and 7% of youth and 5% parents reported mixed racial/ethnic background or "other." The majority of parents (71%) reported being married, partnered, or cohabitating with someone, and 29% reported being single, divorced, separated, or widowed. Overall, most parents were college graduates: 3.1% completed high school or equivalency exam, 20.6% attended some college, 27.8% were college graduates, and 8.2% reported some graduate education, and 39.2% reported graduate level education. Families reported a range of gross household incomes; 3.1% reported earning under $15,000, 6.2% earned $15,000 to $29,999, 14.4% earned $30,000 to $44,999, 12.4% earned $45,000 to $59,999, 15.5%

earned \$60,000 to 74,999, 5.2% earned \$75,000 to 89,999, 7.2% earned \$90,000 to 104,999, 6.2% earned \$105,000 to 119,999, 5.2% earned \$120,000 to 134,999, 6.2% earned \$135,000 to 149,999, 17.5% reported earning more than \$150,000, and 1% did not know or did not report total household yearly income. See Table 1 for participant characteristics.

The 97 dyads were recruited from various sites in the greater Nashville metropolitan area, including Vanderbilt University listservs (*n* = 63), Vanderbilt Child and Adolescent Psychiatry Outpatient Clinic (*n* = 7), Vanderbilt Center of Excellence for Children in State Custody (*n* = 3), Mental Health Co-operative of Middle Tennessee (*n* = 5), Adoption Support and Preservation Program (*n* = 3), and other avenues (e.g., word of mouth; *n* = 16). The recruitment sites were chosen to obtain a sample of youth and caregivers with varied histories of exposure to adverse childhood experiences and family functioning. Research participants were recruited from October 2018 through November 2021. During this period, recruitment was interrupted due to the closure of the research laboratory with COVID-19 pandemic university regulations from March 2020 until February 2021. Recruitment resumed in February 2021 and continued through November 2021.

Participants were excluded if caregivers reported (1) a diagnosis of schizophrenia (history or current) in themselves or their child; (2) a diagnosis of autism spectrum disorder in their child; or (3) the caregiver and child had not lived together for at least 50% of the time in the past six months. For families with multiple children meeting inclusion criteria, parents were asked to select one eligible child to participate in the study or the oldest child was invited to participate. Additional considerations for participant enrollment were adjusted due to the COVID-19 pandemic. In order to participate, families had to agree to wear a face covering for the duration of the in-person laboratory visit and were screened to be free of COVID-19 symptoms and/or exposures in the two weeks preceding their laboratory visit. This stipulation began in March 2020 and continued for the remainder of laboratory visits in alignment with Vanderbilt policy.

2.2. Procedure

Prior to the in-person laboratory visit, caregivers and youth completed an online battery of questionnaires administered via REDCap survey software (Harris et al., 2009). Due to university regulations research to address the COVID-19 pandemic, research assistants completed a COVID-19 symptom check 24 hours prior to the study, as well as the day of the visit upon the family's arrival to the laboratory. Research assistants similarly completed COVID-19 symptom checks on themselves 24 hours prior to the study and the day of the laboratory visit. Research assistants took participants and their own temperatures the day of the study visit. If research assistants or the participating caregiver or child endorsed COVID-19 symptoms or exposure within the previous two weeks of the study visit, the study visit was postponed.

Caregivers and youth then completed a laboratory visit lasting approximately four hours, including a series of questionnaires, interviews, and laboratory tasks. First, caregivers and youth were asked to independently complete an adapted version of the Issues Checklist (Robin & Foster, 1989) to determine a recent source of conflict. Research assistants selected one topic rated highly by both the parent and adolescent. Dyads then participated in the physiological data protocol. Trained research assistants assisted both the caregiver and youth in placing seven sensors at various locations on the torso and hand. Participants completed an adaptation phase (3 min) to acclimate to the sensors, a resting baseline phase (3 min), star-tracing task nonsocial stress task (3 min), stress recovery phase (3 min), speaking baseline (3 min), conflict discussion task (10 min), stress recovery phase (3 min), and final baseline (3 min). The conflict discussion task data were the focus of the present study. During the videotaped conflict discussion task, participants were instructed to discuss the selected conflict topic for 10 minutes. Research assistants prompted participants to (a) describe the issue, (b) explain each of their positions on the issue, (c) discuss why it has become a source of conflict, and (d) attempt to resolve the issue. The interaction was videotaped for the entirety of the conflict discussion task. After completion of the physiological data protocol, sensors and wire leads were removed. Caregivers and youth then independently watched the videotape of their conflict discussion in separate rooms and provided moment-to-moment ratings of their own in-task emotion (Girard, 2014). Finally, participants completed additional laboratory questionnaires and tasks not reported as a part of this study. Parents received $100 and adolescents received $50 for completing study procedures. All procedures were approved by the Vanderbilt University Institutional Review Board.

2.3. Measures

2.3.1. Dyadic conflict task topic selection. Caregivers and youth both independently completed the Issues Checklist (Robin & Foster, 1989), in which respondents indicated which of 44 topics they discussed with each other in the last four weeks (e.g., coming home on time, helping around the house, fighting with siblings), and how they felt during those discussions (1 = calm, 5 = angry). Research assistants compared caregiver and youth responses on the Issues Checklist to determine which topics were highly rated for both members of the dyad. If responses were inconsistent, the topic that the child rated highest was selected.

2.3.2. ANS activity. Physiological measures of ANS function were measured in both caregivers and youth throughout multiple tasks (i.e., conflict discussion task, resting baseline). Specifically, RSA, a primarily parasympathetic nervous system measure, and SCL, a primarily sympathetic nervous system measure, were collected. Standard methods for acquiring SCL and RSA were followed (Berntson et al., 1991; Scerbo et al., 1992). Electrodes were placed over the central clavicle, right clavicle, xiphoid process, on the right and left sides below the rib cage to obtain RSA readings. Two disposable silver/silver-chloride (Ag-AgCl) electrodes (1” x 1” foam, 0% chloride gel) were placed on the thenar and hypothenar eminences of participants’ non-dominant hand to obtain SCL readings. Physiological data was recorded via the MW1000A acquisition system, BioNex 8-slot chassis (MW50371108), BioNex Impedance Cardiograph, and GSC (M371100-00), and disposable pediatric snap electrocardiogram (ECG) electrodes from MindWare, Technologies Ltd (Gahanna, OH, USA). Physiological data was collected throughout the entire physiological data protocol.

2.3.3. *Emotion ratings*. Caregivers and youth rated their moment-to-moment emotion using a video mediated recall (VMR) procedure. VMR involved obtaining reports from parents and youth about their experience while they viewed video recordings of their face-to-face interaction (Welsh & Dickson, 2005). Compared to retrospective reports, VMR minimizes recall errors, and allows for the measurement of covert, internal emotional processes versus emotion measures that are limited to observed or overt behavioral observations. Continuous Affect Rating and Media Annotation (CARMA) software (Girard, 2014) is a media annotation program that displays audio and video files while collecting continuous ratings on a selected dimension. CARMA was used to display participant conflict discussion videos and record continuous emotion ratings. Caregivers and youth separately watched their 10-min video recorded discussion task on a computer while continuously rating their own in-task emotion valence and intensity using a bi-polar rating joystick to indicate their experience. The joystick displayed ranges from very negative (-100) to very positive (+100), with neutral in the middle (0), similar to previous studies (Brown et al., 2020; Butler et al., 2014; Dan-Glauser & Gross, 2013; Henry et al., 2022). Participants were instructed to move the joystick continuously to indicate how they felt during the conversation specifically, not how they felt at the time of the rating. CARMA software sampled the position of the joystick 10 times per second and computed second-by-second emotion rating means. Acceptable construct, concurrent, and discriminant validity have been established for VMR procedures (Lorber, 2007; Mauss et al., 2005).

2.3.4. Emotion regulation and coping. Both caregivers and youth completed the Emotion Regulation Questionnaire (ERQ; Gross & John, 2003). The ERQ is a self-report measure including 10 items assessing cognitive reappraisal (6 items, e.g., “When I want to feel more positive emotion, such as joy or amusement, I change what I'm thinking about”) and expressive suppression (4 items, e.g., “I control my emotions by not expressing them”) strategies. Participants rated their responses on a 7-point Likert scale (i.e., “strongly agree” to “strongly disagree”). Higher scores indicate greater use of each emotion regulation strategy. The ERQ has been reported to have high internal consistency (cognitive reappraisal α= .79, expressive suppression α=.73) and 3-month test–retest reliability (r = .69 for both scales), as well as good convergent and discriminant validity with both younger and older adults (Gross & John, 2003; John & Gross, 2004). In the present study, these scales demonstrated acceptable internal consistency for the parent self-report (cognitive reappraisal, α= .84; expressive suppression, α= .75), and child self-report (cognitive reappraisal, α= .80; expressive suppression, α= .67).

Caregivers and youth also completed the Responses to Stress Questionnaire—Family Stress version (RSQ; Connor-Smith et al., 2000) to assess how they cope with and regulate their emotions in response to family stress. The RSQ is a self-report questionnaire that includes 12 items measuring level of family stress (e.g., arguing with your mother), and 57 items measuring three volitional coping scales (i.e., primary control coping, secondary control coping, disengagement coping), and two involuntary responses to stress scales (i.e., involuntary engagement, involuntary disengagement). The primary control coping scale includes items assessing problem solving, and emotional modulation and expression. The secondary control coping scale includes items assessing acceptance, cognitive reappraisal, positive thinking, and distraction. The disengagement coping scale includes items assessing avoidance, denial, and wishful thinking. The involuntary engagement scale includes items regarding rumination, intrusive thoughts, emotional arousal, physiological arousal, and impulsive action. The involuntary disengagement scale includes items regarding escape, inaction, emotional numbing, and cognitive interference. The RSQ utilizes proportion scores with the total score for each scale divided by the total score on the RSQ, therefore controlling for the total number of responses for each individual and reflecting relative value for each coping or stress response (Conner-Smith et al., 2000). The RSQ has demonstrated excellent reliability and validity (Conner-Smith et al., 2000). In the present study, these scales demonstrated acceptable internal consistency for parent self-report (primary control coping, α= .76; secondary control coping, α= .83; disengagement coping, α= .74; involuntary engagement, α= .91; involuntary disengagement, α= .86), and child self-report (primary control coping, α= .78; secondary control coping, α= .75; disengagement coping, α= .83; involuntary engagement, α= .92; involuntary disengagement, α= .88).

2.4. Data Analytic Strategy

2.4.1. Data preparation overview. All physiological data were processed and scored using MindWare analysis software. Trained research assistants visually inspected all continuous data for each participant. The MindWare program identified potential artifacts, and additionally, research assistants visually scanned all participant data to identify additional artifacts and missing and/or misidentified physiological responses. Identified artifacts and program issues were manually edited. Data were scored in 60-second intervals using MindWare analysis software (HRV version 3.2.4, EDA version 3.2.4.). While greater temporal resolution may be preferred, 60-seconds is considered the minimum length for spectral analysis of HRV (Berntson et al., 1997). As there is no consensus in the field for the use of time lags or a standard for an appropriate time lag specification, in this initial assessment of the correspondence between emotion ratings and physiology, the concurrent (i.e., no time lag) relations between variables were calculated. Of the total 194 participants (97 youth and 97 caregivers), five did not complete physiological data collection procedures. Of these five participants, two participants (1 parent-adolescent dyad) did not finish procedures due to time constraints; two participants (1 parent-adolescent dyad) did not finish procedures due to technical issues; one caregiver was unable to complete physiological data collection due to an adhesive material allergy.

2.4.2. SCL pre-processing. MindWare's EDA analysis software was used to calculate SCL values. Data was scored in 60-second epochs. Epochs that required greater than 50% of data estimation and editing were excluded from analysis as recommended in the MindWare manual (https://support.mindwaretech.com/manuals/software/eda/3-2/). Resting levels of skin conductance were obtained by averaging each 60 second mean SCL response during baseline conditions. Skin conductance levels during stress tasks were obtained by averaging responses during 60-second epochs of the conflict discussion task. Of available SCL data epochs, 2.68% was missing. Three participants (1 youth, 2 parents) had unusable SCL data for the entirety of the task, two participants (2 youth) had unusable epochs from the conflict discussion task (ranging from 3 to 9 unusable epochs of the 10 total epochs), one youth was missing data due to data output loss.

2.4.3. RSA data pre-processing. Cardiovascular data were collected using the MindWare MW100A Acquisition System (MindWare Technologies, Gahanna, OH, USA) connected to an

ECG activity amplifier module and disposable pediatric snap ECG electrodes. Respiration was derived from spectral analysis of thoracic impedance (Ernst et al., 1999). RSA was assessed via rhythmic fluctuations in heart rate that are accompanied by phases of the respiratory cycle (Grossman et al., 1991) using the peak-to-valley method (Mindware Technologies, Ltd., Gahanna, OH, USA), which has been validated for RSA quantification (Berntson et al., 1997). RSA data was visually inspected and processed using well-validated procedures (Hinnant et al., 2015). Data was scored in 60-second intervals using MindWare analysis software (HRV version 3.2.7). Epochs that required greater than 10% of data estimation/editing or epochs with less than 30-seconds of continuous usable data for the epoch were dropped from analysis as recommended in the MindWare manual (https://support.mindwaretech.com/manuals/software/hrv/3-2/). RSA was derived from the natural log of the high frequency power (0.12-0.40 Hz), a validated method used to isolate parasympathetic influence on cardiac activity (Berntson et al., 1997). Of all available RSA data epochs, 5.93% was missing. Seven participants (4 youth, 3 parents) had unusable RSA data for the entirety of the task, and 22 participants (16 youth, 6 parents) were missing some epochs from the conflict discussion task (ranging from 1 to 8 unusable epochs of the 10 total epochs).

2.4.4. Mean level physiology. To calculate overall physiological activity, caregiver and youth physiological predictors were averaged across all task epochs (i.e., $\text{SCL}_{.p}$ and $\text{RSA}_{.p}$) to create separate mean values for SCL and RSA across the entirety of the conflict discussion task. To create a time-varying component, physiological activity from each time segment (SCL_{tp} and RSA_{tp}) reflected the deviation from participants' mean physiology during the task (e.g., $\text{SCL}_{tp} - \text{SCL}_{.p}$). Therefore, physiological predictors were person mean centered and modeled in relation to the individual's average (i.e., serving as a reference point), versus an overall increase or decrease (Bolger & Laurenceau, 2013). This allows for interpretation of what the change is for each individual over time. Also, the mean levels were retained to serve as subject level (level 2) moderators of within subject (level 1) effects. The following variables were used in analyses, where *t* represents time point during the conflict discussion task, and *p* represents person.

1. SCL_{tp} and RSA_{tp} = a person's (*p*) physiological activity (SCL or RSA) associated with each time point (*t*) during the conflict discussion task, centered around the person's average level of physiological activity. These level 1 scores differ from time point to time point and from person to person.
2. $\mathrm{SCL}_{.p}$ and $\mathrm{RSA}_{.p}$= each person's average physiology activity (SCL or RSA), pooled across all conflict task time points. These level 2 values differ from person to person.

2.4.5. Emotion rating data reduction. As SCL and RSA scored for each minute of the 10-minute conflict discussion task via averaging responses for each 60-second epoch within the MindWare software program, CARMA emotion rating responses were also averaged for each 60-second epoch within the 10-min conflict discussion task to parallel this process. Therefore, 10 physiology scores (10 SCL and 10 RSA) and 10 emotion rating scores resulted per participant (i.e., physiology scores and emotion ratings [level 1] were nested within individuals [level 2]). Data were organized in long format, such that each participant had 10 rows of data for each epoch of the conflict discussion task (i.e., minute 1, minute 2, minute 3, etc.). Six participants (4 youth, 2 adults) did not complete the CARMA emotion rating procedure; two participants (1 dyad) were missing a portion (4 epochs) of emotion ratings due to camera technical failure. Of existing usable data, there were no epochs of missing data for emotion ratings (0%).

2.4.6. Power. Regarding preliminary analyses, power analyses using $\alpha = .05$ and power = .80, indicated sufficient power to detect small correlations ($r = .20$) with the $N = 194$ sample size (97 dyads; 194 individual subjects) and high power to detect very small correlations ($r = .06$) when using the total number of observations ($N = 1{,}940$; 194 subjects each with 10 time points), two-tailed (Faul et al., 2007). The sample size ($N = 194$) was sufficient to detect small effects for paired samples t-tests and independent samples t-tests ($d = .20$). Power for multilevel modeling (MLM) can be employed as a function of the type I error rate (α), sample size, and the effect size, but also the sample size of the macro level units of clusters, the sample size of the micro-level units within clusters, and the residual intraclass correlation, after conditioning on a set of covariates (Snijders & Bosker, 2012). For the current study, there were 10 micro-level units (i.e., observations) within 194 clusters (i.e., participants). While there is currently not a formalized consensus on standard or fixed rules for model specification for MLM given variable data structures, the general guidelines, principles, and approach offered by Snijders and Bosker (2012) were utilized. Model fit indices were compared for MLM analyses using a hierarchical build-up procedure to determine the best-fitting models and to test hypotheses.

2.4.7. Preliminary Analyses. Means and standard deviations were calculated for all study variables in caregivers and youth. Bivariate correlations were conducted to examine relations among measures with age in caregivers and youth. Independent samples t-tests were conducted to assess gender differences. Age and gender were retained in subsequent analyses assessing primary aims when related to study variables. To determine that the conflict discussion task successfully elicited physiological responses compared to baseline, paired-samples t-tests were conducted comparing physiological values during the conversation task and the resting baseline. To determine if the conflict discussion task successfully elicited an emotional response in caregivers and youth, a one-sample *t*-test was conducted to determine if emotion ratings differed from zero (i.e., neutral emotion rating). Lastly, intraclass correlation coefficients (ICC) were estimated in the null model predicting emotion ratings accounting for clustering to establish need for multilevel modeling (Pornprasertmanit et al., 2014). The ICC (between-groups variance/total variance) is a proportion that indicates how much of the observed variation in predictions of emotion ratings can be attributed to differences between individuals (i.e., the grouping variable in the present study). Cohen's (1988) guidelines were used to interpret the magnitude of the effect size for correlations (i.e., $r = 0.10$ represents a small effect, $r = 0.30$ a medium effect, and $r \geq 0.50$ a large effect) and *t*-tests (i.e., $d = .20$ a small effect, $d = .50$ a medium effect, and $d = .80$ a large effect). Preliminary analyses were only interpreted if effects were at or above Cohen's (1988) guidelines for a small effect versus reliance on significance, as there were many observations (i.e., 194 subjects with 10 observations) and therefore these tests were overpowered to detect significance.

2.4.8. Hypothesis testing. Numerous studies have assessed physiological synchrony or concordance utilizing a correlational approach (Davis et al., 2018). Benefits to this approach include (a) correlations reflect the average magnitude and direction of correspondence between measures, and (b) can be used with relatively few data points. A drawback to this approach is that correlations do not reflect dynamic changes in concordance. Due to the limitations of correlational analyses, MLM was used. Many studies have employed multilevel modeling techniques to assess physiological synchrony and concordance (see Davis et al., 2018 for a review). MLM increases statistical power by nesting repeated measures within individuals, allows for examination of moderators of concordance simultaneously, models change over time, and provides estimates of moment-to-moment concordance (Davis et al., 2018).

Specifically, SPSS Version 28.0.0.0 software was used to run mixed effects multilevel models examining how measures of physiology predict emotion ratings. Level 1 variables (e.g., emotion rating, physiological activity) reflect observations within individuals across time (i.e., repeated measures), level 2 variables reflect time-invariant features of individuals (i.e., person as the unit of analysis). Full information maximum likelihood (FIML) estimation was used to account for missing data. All tests were conducted at $\alpha = .05$.

Univariate models included covariates (e.g., age, gender), and subject type (parent, child), SCL, and RSA utilizing a build-up procedure where all models were estimated hierarchically. Age, gender, and subject type were first entered into the model as predictors of emotion ratings with fixed effects. SCL and RSA were then entered separately. If main effects were significant or there were hypotheses regarding interactions (e.g., SCL x subject type), these were then entered. All effects were first entered as fixed effects, and if significant and there were hypotheses that these estimates would vary by person, then random effects were examined. Determinations for the final model were based off BIC fit indices and if there were specific hypotheses requiring the testing of more complex models (e.g., interactions). The level-1 models always included fixed (i.e., no pooling) and random (i.e., partially pooled) intercepts and fixed slopes; if tested, random slopes were retained based on model fit and significance.

To test *Aim 1*, physiological-emotional concordance was modeled at level 1 as the effects of the individual's physiological activity on the individual's emotion ratings (See Appendix for MLM equations). To test *Aim 2*, emotion regulation scores (e.g., cognitive reappraisal and emotional suppression on the ERQ, primary control coping, secondary control coping, disengagement coping, involuntary engagement, and involuntary disengagement on the RSQ) were modeled at level 2 as predictors of emotion ratings (i.e., dependent variable), and as predictors of level 1 slopes to determine if emotion regulation measures act as moderators of the hypothesized physiological-emotional association (See Appendix for MLM equations). Hypotheses were supported if physiological measures significantly predicted emotion ratings in youth and in caregivers (i.e., significant slopes reflecting the correspondence of emotions and physiology). Concordance was reflected in a positive prediction of emotion ratings by physiological activity, where higher physiological activity scores correspond to higher emotion ratings. Discordance was reflected in a negative prediction of emotion ratings by physiological activity, such that higher physiological activity scores correspond to lower emotion ratings.

CHAPTER 3

RESULTS

3.1. Preliminary Analyses

Paired samples *t*-tests revealed that SCL, *t*(180) = -10.20, *p* < .001, significantly increased from individuals' (i.e., youth and caregivers) mean resting baseline (*M* = 8.34, *SD* = 7.53) to individuals' mean conflict discussion task level (*M* = 12.12, *SD* = 9.19), *d* = .45, a medium effect. In caregivers, SCL significantly increased from mean resting baseline (*M* = 4.58, *SD* = 4.45) to mean conflict discussion task level (*M* = 7.12, *SD* = 5.32), *t*(89) = -7.27, *p* < .001. In youth, SCL also significantly increased from mean resting baseline (*M* = 12.05, *SD* = 8.10) to mean conflict discussion task level (*M* = 17.07, *SD* = 9.54), *t*(90) = -7.99, *p* < .001. This demonstrates that the conflict discussion task elicited a SNS response in dyads. In participants (i.e., youth and caregivers), RSA approached a significant increase from mean resting baseline (*M* = 5.98, *SD* = 1.24) to mean conflict discussion task level (*M* = 6.07, *SD* = 1.17), *t*(177) = -1.92, *p* = .056, *d* = .07, a negligible small effect. In caregivers, RSA did not differ from mean resting baseline (*M* = 5.31, *SD* = 1.13) to mean conflict discussion task level (*M* = 5.41, *SD* = 1.11), *t*(90) = -1.50, *p* = .14. In youth, RSA also did not differ from mean resting baseline (*M* = 6.68, *SD* = .92) to mean conflict discussion task level (*M* = 6.76, *SD* = .78), *t*(86) = -1.21, *p* = .23. An independent samples *t*-test demonstrated that parents and youth differed in their mean physiological activity during the conflict discussion task. Mean SCL was significantly higher in youth (*M* = 16.96, *SD* = 9.54) than in parents (*M* = 7.00, *SD* = 5.31), *t*(182) = -8.75, *p* < .001. RSA was also significantly different in parents and youth, *t*(180) = -9.58, *p* < .001, where RSA was higher in youth (*M* = 6.79, *SD* = .79) than parents (*M* = 5.43, *SD* = 1.11). Therefore, subject type was included in all MLM models. Means and standard deviations for key study variables are reported for parents in Table 2 and for youth in Table 3.

A one-sample *t*-test demonstrated that the conflict discussion task also successfully elicited an emotional response (i.e., a change in emotion ratings from baseline) from participants, *t*(188) = 2.66, *p* = .008, where ratings (*M* = 5.20, *SD* = 26.76) were overall significantly different from zero (reflecting a small elevation to an overall positive emotion rating), *d* = .19, a small effect. The average emotion rating was near zero, reflecting that the central tendency was somewhat neutral; this was expected, as the emotion rating measurement ranged from -100 to +100. Also as expected, there was substantial variability in mean emotion ratings, with the overall mean emotion rating for the entirety of the task for individual participants ranging from -62.34 (i.e., moderately negative) to +99.10 (i.e., very positive), and the mean distance from the mean (*SD*) being 26.69. For parents, 41.2% rated the task negatively on average and 56.7% rated it positively on average. For youth, 47.4% rated the task as eliciting negative emotions on average, while 48.9% rated it as positive on average. An independent samples *t*-test showed that parents and youth did not significantly differ in their emotion ratings, *t*(186) = .68, *p* = .50, where the mean difference between parents (*M* = +6.51, *SD* = 24.71) and youth (*M* = +3.85, *SD* = 28.77) was 2.67 points on the -100 to +100 scale, demonstrating that parents and youth reported similar mean emotion levels across the task.

Overall averages were followed by minute-by-minute averages to show the progression of emotion ratings across time: minute one (*M* = +4.22, *SD* = 26.01, Range: -61.95, +100.00), minute two (*M* = -2.78, *SD* = 32.28, Range: -86.32, +99.96), minute three (*M* = +.15, *SD* = 33.50, Range: -79.58, +100.00), minute four (*M* = +1.75, *SD* = 34.83, Range: -87.78, +99.49), minute five (*M* = +5.49, *SD* = 33.99, Range: -79.03, +99.92), minute six (*M* = +4.39, *SD* =

35.15, Range: -89.40, +99.08), minute seven (*M* = +4.34, *SD* = 38.94, Range: -98.06, +99.79), minute eight (*M* = +8.16, *SD* = 37.76, Range: -99.51, +97.27), minute nine (*M* = +12.76, *SD* = 36.81, Range: -89.15, +99.74), and minute 10 (*M* = +13.09, *SD* = 38.86, Range: -88.92, +100.00). The minute-by-minute averages demonstrated a consistent pattern where emotion ratings fluctuated around zero (i.e., neutral), and standard deviations and range of emotion ratings remained large, indicating variability in subjects' ratings over time. Overall, the task elicited a wide range of emotional experiences in participants.

To determine if key study variables differed as a function of gender, gender differences were assessed using independent samples *t*-tests. While gender was evenly distributed in youth (46.4% female; 52.6% male), there were substantially more female caregivers (90%) than male caregivers (10%). Therefore, *t*-tests were conducted separately in caregivers and youth, and differences between female caregivers and male caregivers should be interpreted with caution. In caregivers, there was no effect of gender on emotion ratings, *t*(944) = 1.14, *p* = .26; female caregivers reported similar levels (*M* = +6.87, *SD* = 34.83) to male caregivers (*M* = +3.96, *SD* = 22.50) on average. Female caregivers had lower SCL (*M* = 6.67, *SD* = 5.13) than male caregivers (*M* = 9.71, *SD* = 6.40), *t*(918) = 4.56, *p* < .001, and female caregivers demonstrated higher RSA (*M* = 5.45, *SD* = 1.20) than male caregivers (*M* = 5.18, *SD* = 1.38), *t*(906) = 2.01, *p* = .045. While female caregivers had lower SNS activity and higher PNS activity than male caregivers, this difference should be interpreted with caution due to the limited number of male caregivers. In youth, female youth reported significantly lower (i.e., more negative) emotion ratings during the task (*M* = -2.90, *SD* = 38.73) than male youth (*M* = +11.38, *SD* = 32.91), *t*(6.04) = 914, *p* < .001. The effect of gender for SCL approached significance; female youth (*M* = 16.45, *SD* = 9.97) demonstrated slightly lower levels than male youth (*M* = 17.67, *SD* = 9.41), *t*(906) = 1.89, *p* =

.06. There was a gender difference in RSA: female youth demonstrated significantly higher RSA (*M* = 6.83, *SD* = .84) than male youth (*M* = 6.66, *SD* = 1.01), *t*(850) = 2.60, *p* = .01. Due to these gender differences across the sample, gender was included as a covariate in all MLM analyses.

Bivariate correlation analyses were conducted to assess preliminary associations between continuous covariates (e.g., age), and key study variables physiological measures (e.g., SCL, RSA), emotion ratings, and emotion regulation/coping scores. Correlations are presented separately for parents (Table 2) and youth (Table 3). Age was related to several key variables for parents and youth. For key study variables, parents' emotion ratings significantly correlated with RSA, cognitive reappraisal, and all RSQ factors, but were unrelated to SCL and expressive suppression. Youths' emotion ratings significantly correlated with SCL, expressive suppression, and all RSQ factors, but did not correlate with RSA or cognitive reappraisal.

3.2. Aim 1: Associations Between Physiology and Emotion Ratings

To determine if MLM was appropriate for the structure of the data, the ICC was estimated in the null model with emotion ratings as the dependent variable and the intercept specified as a fixed and random effect, with subject identified as the grouping variable at level 2 (Pornprasertmanit et al., 2014). The ICC indicated that 53% of the observed variation in predictions of emotion ratings was attributed to differences across subjects (i.e., the grouping variable in the present study). This demonstrates that using subject as a grouping provides important information about the variability in emotion ratings, and that allowing for subject grouping via utilization of MLM is appropriate. The null model intercept fixed effect was significant, *t*(188) = 2.67, *p* = .008, indicating that adding a predictor is appropriate, and that the average emotion rating was estimated to be 5.19 with no predictors in the model. The within group variance was significant (estimate = 587.59, SE = 20.25, p < .001), suggesting differences in emotion ratings within subjects. The between groups variance was also significant (estimate = 652.93, SE = 73.47, $p < .001$), suggesting significant differences in emotion ratings across subjects (parents and youth).

3.2.1. SCL models. In the full sample (parents and youth), the final model included covariates (age, gender), subject type, SCL_{tp}, and $\mathrm{SCL}_{.p}$ as fixed effects, and SCL_{tp} random effect. SCL_{tp} was examined as a random effect, as it was expected that the SCL-emotion association may vary across participants. Gender was a significant predictor of emotion ratings (coefficient = -9.70, SE = 4.80, $p = .045$), demonstrating that emotion ratings were lower (i.e., more negative) for females. Contrary to Hypothesis 1a, the fixed effects for SCL_{tp} and $\mathrm{SCL}_{.p}$ were non-significant, indicating that moment-to-moment changes in SCL (SCL_{tp}) did not predict emotion ratings, nor did mean SCL ($\mathrm{SCL}_{.p}$). The within group variance was significant and sufficiently large (estimate = 553.23, SE = 21.16, $p < .001$), indicating significant differences in emotion ratings within participants (parents and youth). As expected, the between groups variance (i.e., SCL_{tp} random effect) was significant (estimate = 31.65, SE = 13.11, $p = .02$), indicating significant variability in the SCL-emotion association across participants (Table 4, Model 1).

To explore if the association between SCL and emotion ratings differed in parents and youth (i.e., subject type predicts the SCL-emotion slope), the interaction between SCL_{tp} and subject type was added to the previous model. The fixed effect of gender remained significant (estimate = -9.70, SE = 4.80, $p = .045$). The fixed effect for SCL_{tp} indicated a significant negative slope (estimate = -5.32, SE = 2.60, $p = .044$), where higher SCL_{tp} (i.e., moment-to-moment increases from an individual’s mean) corresponded to more negative emotion ratings in parents and youth, in support of Hypothesis 1a. Further, subject type predicted the slope of the

SCL-emotion association (estimate = 3.89, SE = 1.54, *p* = .01), demonstrating that the association between SCL_{tp} and emotion ratings differed in parents and youth (Table 4, Model 2). Both within group and between groups variance (*p*'s < .001) were substantially large and significant, indicating variability in emotion ratings within and across subjects.

To interpret the interaction and obtain simple slopes of the SCL-emotion association as a function of subject type (parent or child), separate models were run in parents and in youth. In the final parent model, age, gender, SCL_{tp}, and $\text{SCL}_{.p}$ were included as fixed effects. All predictors of emotion ratings were non-significant (Table 5, Model 1). In contrast, in the parallel youth model, all predictors of emotion ratings were significant (Table 5, Model 2). The final youth model included age, gender, SCL_{tp}, and $\text{SCL}_{.p}$ as fixed effects, and SCL_{tp} as a random effect. Age significantly predicted emotion ratings (coefficient = -4.70, SE = 1.74, *p* = .008), where higher age corresponded to more negative emotion ratings during the conflict task (Figure 1). Female youth reported significantly more negative emotions during the conflict task (coefficient = -12.66, SE = 5.73, *p* = .03). SCL_{tp} was a significant predictor of emotion ratings (Hypothesis 1a), though demonstrated a *positive* slope (coefficient = 2.49, SE = .95, *p* = .01), where higher SCL_{tp} (i.e., moment-to-moment increases from youth's mean SCL) predicted more positive emotion ratings in youth (Figure 2). The within group variance was significant (*p* < .001). The SCL_{tp} variance (i.e., random effect) was significant (*p* = .03), indicating substantial variability in the SCL-emotion slope for youth.

3.2.2. RSA models. In the full sample (parents and youth), the final RSA model included covariates (age, gender), subject type (parent, child), RSA_{tp}, and $\text{RSA}_{.p}$ as fixed effects, and RSA_{tp} as a random effect (Table 6, Model 1). No predictors were significant. The within group variance was significant (estimate = 585.15, SE = 22.32, p < .001), indicating significant variability within individuals (parents and youth). The RSA-emotion association (i.e., random RSA slope) did not demonstrate variability across participants (*p* = .13). To assess if the RSA-emotion association differed between parents and youth, the interaction between RSA and subject type was then entered in the next model (Table 6, Model 2). The interaction was non-significant (*p* = .16), as were all other predictors (*p*'s > .05). The within and between groups variances remained significant (*p*'s < .001). Overall, contrary to Hypothesis 1b, RSA was unrelated to emotion ratings.

3.3. Aim 2: Emotion Regulation and Physiological-Emotion Concordance

3.3.1. Emotion Regulation Questionnaire scales. To test hypothesis 2, covariates (age, gender), subject type, and cognitive reappraisal and expressive suppression scales on the ERQ were estimated as predictors of emotion ratings, as well as the interaction of ERQ scales with physiological variables (SCL, RSA) in parents and youth. In the model including cognitive reappraisal, SCL, and their interaction as fixed effects, all predictors were non-significant (*p*'s > .05), except gender (coefficient = -9.75, SE = 4.80, *p* = .044), indicating more negative emotion ratings for females (Table 7, Model 1). The within group variance was substantial and significant (*p* < .001). In the cognitive reappraisal and RSA model, all predictors were non-significant effects (Table 7, Model 2). The within group variance was again substantial and significant (*p* < .001). In the model including expressive suppression, SCL, and their interaction as fixed effects, all predictors were non-significant (*p*'s > .05), except gender (coefficient = -9.77, SE = 4.80, *p* = .043) (Table 8, Model 1). The within group variance remained significant (*p* < .001). In the expressive suppression and RSA model, all predictors were nonsignificant (*p*'s > .05), while the within and between groups variances were significant (*p*'s < .001) (Table 8, Model 2). Contrary to hypotheses, parent and youth reports of cognitive reappraisal (Hypothesis 2a) and expressive suppression (Hypothesis 2b) use did not predict emotion ratings, nor did they moderate the association between ANS measures and emotion ratings during parent-adolescent conflict. While these specific measures of emotion regulation strategies in response to general emotion states did not predict emotion ratings nor interact with physiological variables in the present study, it is plausible that other well-established, broader coping measures specific to family stress may correspond to in-task emotional experience and physiological-emotional concordance.

3.3.2. Responses to Stress Questionnaire factors. Utilizing the RSQ, a comprehensive measure of conscious, controlled coping strategies and involuntary responses to stress, the five RSQ scales were estimated as predictors of emotion ratings, as well as the interaction of these indices with physiological variables. In the primary control coping and SCL model, the final model included covariates, subject type, SCL_{tp}, $\text{SCL}_{.p}$, and the primary control coping x SCL_{tp} interaction as fixed effects (Table 9, Model 1). There was a significant effect of gender (estimate = -9.53, SE = 4.68, $p = .043$), indicating that females reported more negative emotion ratings. Primary control coping was a significant predictor of emotion ratings (coefficient = 133.76, SE = 43.35, $p = .002$), where increased reported use of primary control coping in response to family stress corresponded to more positive emotion ratings during the in-lab task (Figure 3, Panel A). The interaction was non-significant. The within group and between groups variances were significant ($p < .001$), indicating variability within and across subjects. The primary control coping and RSA final model included covariates, subject type, RSA_{tp}, $\text{RSA}_{.p}$, and primary control coping x RSA_{tp} interaction as fixed effects (Table 9, Model 2). Primary control coping remained a significant predictor of emotion ratings (estimate = 127.23, SE = 42.92, $p = .003$), where increased primary control coping corresponded to more positive emotion ratings. The hypothesized interaction was non-significant ($p > .05$). The within group and between groups variances were both significant (p's < .001). Overall, primary control coping did not alter SCL-emotion or RSA-emotion associations, contrary to Hypothesis 2c, although primary control coping use was a significant predictor of emotion ratings during the conflict task.

In the secondary control coping model, the final model included covariates, subject type, SCL$_{tp}$, SCL$_{.p}$, and the secondary control coping x SCL$_{tp}$ interaction as fixed effects (Table 10, Model 1). The effect for gender approached significance (coefficient = -8.80, SE = 4.68, p = .062), showing the same effect: females reported more negative emotion ratings. Secondary control coping was a significant predictor of emotion ratings (coefficient = 127.71, SE = 39.26, p = .001, where higher reported use of secondary control coping strategies in response to family stress corresponded to more positive emotion ratings during the in-lab family conflict task (Figure 3, Panel B). In partial support of Hypothesis 2d, the interaction between secondary control coping and SCL approached significance (coefficient = 15.47, SE = 8.43, p = .067), demonstrating that higher reported use of secondary control coping corresponded to a stronger (i.e., steeper slope) SCL-emotion association. The within group and between groups variances were significant (p's < .001), indicating variability within and between subjects. The simple slope for the high secondary control coping group was significant and positive (coefficient = 2.36, SE = 1.01, p = .02), indicating that for those who reported above average secondary control coping use, higher SCL in response to the conflict discussion task corresponded to more positive emotion ratings (Figure 4). The simple SCL-emotion slope for the low secondary control coping group approached significance (coefficient = 2.30, SE = 1.29, p = .075), showing a trend for increases in moment-to-moment SCL predicting higher (i.e., less negative/more positive) emotion ratings for parents and youth reporting low secondary control coping use. The simple slope for the average secondary control coping group was non-significant (coefficient = .027, SE

= .45, $p = .95$). The next model included covariates, subject type, RSA_{tp}, $\text{RSA}_{.p}$, and the secondary control coping x RSA_{tp} interaction as fixed effects (Table 10, Model 2). Secondary control coping remained a significant predictor of emotion ratings (coefficient = 130.34, SE = 38.66, $p < .001$). Secondary control coping did not interact with RSA to predict emotion ratings, nor were there any other significant predictors. The within and between groups variances were significant (p's < .001). In sum, higher reported use of secondary control coping skills predicted more positive emotion ratings during the conflict task. In addition, there was initial evidence that secondary control coping use moderates the association between SCL and emotion ratings, where higher secondary control coping use predicted a stronger positive association (i.e., concordance) between SCL and emotion ratings (Hypothesis 2d).

In the disengagement coping model, the final model included covariates, subject type, SCL_{tp}, $\text{SCL}_{.p}$, and the disengagement coping x SCL_{tp} interaction as fixed effects (Table 11, Model 1). The effect of gender approached significance ($p = .061$), demonstrating the same pattern: more negative emotion ratings for female participants. Disengagement coping was a significant predictor of emotion ratings in the expected direction (estimate = -161.85, SE = 70.99, $p = .024$), where higher reported use of disengagement coping strategies corresponded to more negative emotion ratings during the in-lab conflict task (Figure 3, Panel C). The disengagement coping x SCL_{tp} interaction was non-significant ($p > .05$). The within group and between groups variances were significant (p's < .001). The next model included covariates, subject type, RSA_{tp}, $\text{RSA}_{.p}$, and the disengagement coping x RSA_{tp} interaction as fixed effects (Table 11, Model 2). Disengagement coping was the only significant predictor of emotion ratings, and similarly showed a negative effect (estimate = -159.79, SE = 71.31, $p = .026$). The within group and between groups variances were significant (p's < .001). Overall, reported use of disengagement coping in response to family stress predicted more negative emotion ratings during the laboratory conflict task, though did not predict the physiological-emotion association contrary to Hypothesis 2e.

In the involuntary engagement model, the final model included covariates, subject type, SCL$_{tp}$, SCL$_{.p}$, and the involuntary engagement x SCL$_{tp}$ interaction as fixed effects, and the random effect of SCL$_{tp}$ (Table 12, Model 1). Involuntary engagement significantly predicted emotion ratings (coefficient = -142.29, SE = 43.62, p = .001), where higher reports of involuntary engagement in response to family stress predicted more negative emotion ratings during the laboratory conflict task (Figure 3, Panel D). SCL$_{tp}$ was a significant predictor of emotion ratings (coefficient = 9.28, SE = 3.8, p = .02), where moment-to-moment increases in SCL (i.e., from individuals' mean) during the conflict task corresponded to higher emotion ratings. Further, involuntary engagement was a significant predictor of the SCL-emotion association (coefficient = -33.73, SE = 15.31, p = .034), indicating that for individuals reporting lower involuntary engagement, the SCL-emotion association was stronger (Figure 5). The simple slope for the low involuntary engagement group was significant and positive (coefficient = 4.43, SE = 1.34, p = .001), indicating that for parents and youth reporting low involuntary engagement in response to family stress, higher SCL predicted more positive emotion ratings. In contrast, for the average involuntary engagement group, SCL was not a significant predictor of emotion ratings (p = .36), nor did SCL predict emotion ratings in the high involuntary engagement group (p = .69). The SCL$_{tp}$ between groups variance was significant (estimate = 28.40, SE = 12.45, p = .02), indicating that the SCL-emotion association significantly varied across subjects. The within group variance was significant (p < .001). The next model included covariates, subject type, RSA$_{tp}$, RSA$_{.p}$, and the involuntary engagement x RSA$_{tp}$ interaction as fixed effects (Table 12, Model 2). Involuntary engagement was a significant predictor of emotion ratings (coefficient = -144.29, SE = 42.87, $p < .001$). Involuntary engagement did not moderate the RSA-emotion association. The within and between groups variances both remained significant (p's < .001). Overall, involuntary engagement in response to family stress predicted more negative emotion ratings during the parent-adolescent conflict task. In partial support of Hypothesis 2f, involuntary engagement moderated the SCL-emotion association, where at low reported use of involuntary engagement, subjects demonstrated positive concordance between SCL and emotion ratings.

In the involuntary disengagement model, the final model included covariates, subject type, SCL_{tp}, $SCL_{.p}$, and the involuntary disengagement x SCL_{tp} interaction as fixed effects (Table 13, Model 1). Gender significantly predicted emotion ratings (coefficient = -11.58, SE = 4.73, $p = .015$), where females reported lower emotion ratings. Involuntary disengagement significantly predicted emotion ratings (coefficient = -206.43, SE = 69.46, $p = .003$), where higher reported involuntary disengagement in the face of family stress predicted more negative emotion ratings for parents and youth during the laboratory conflict discussion task (Figure 3, Panel E). The within group and between groups variances were significant (p's < .001). The next model included covariates, subject type, RSA_{tp}, $RSA_{.p}$, and the involuntary disengagement x RSA_{tp} interaction as fixed effects (Table 13, Model 2). Gender remained a significant negative predictor of emotion ratings, with females reporting more negative discussions (coefficient = -9.71, SE = 4.72, $p = 041$). Involuntary disengagement was a significant negative predictor of emotions (coefficient = -202.40, SE = 67.67, $p = .003$). The involuntary disengagement x RSA interaction was non-significant. The within group and between groups variances were significant (p's < .001). Overall, contrary to Hypothesis 2d, involuntary disengagement did not alter the physiological-emotion association, though higher involuntary disengagement in response to family stress did correspond to more negative emotion ratings during the laboratory conflict task.

CHAPTER 4

DISCUSSION

The current study assessed intrapersonal associations (i.e., within individual concordance) between autonomic physiology and emotions ratings, modeling the association of both sympathetic and parasympathetic nervous system measures with self-rated emotions. The present study adds to the long-debated literature regarding the concordance between ANS activity and emotion by assessing associations in both adult caregivers and youth during an ecologically relevant task (i.e., parent-adolescent conflict discussion) and utilizing MLM as a strong within individual methodological approach. Findings addressed several important areas of investigation highlighted by Lougheed and colleagues (2021), including the assessment of underlying biological mechanisms, individual differences, and influences of emotion regulation on within-individual physiological-emotional concordance. A positive association was found between SCL and emotion ratings for youth. However, RSA was unrelated to emotion ratings. Coping strategies and involuntary responses to stress significantly predicted emotional experience during the task. Further, multiple emotion regulation and coping measures were assessed as potential moderators of the physiology-emotion association. Findings supported that involuntary engagement in response to family stress predicted the SCL-emotional association during the parent-adolescent conflict task. Secondary control coping approached significance as a predictor of the SCL-emotional association. No effects were found for expressive suppression, cognitive reappraisal, primary control coping, disengagement coping, or involuntary disengagement as moderators of physiological-emotional associations.

4.1. Aim 1: Physiological-Emotional Associations

4.1.1. Partial evidence for SCL-emotional concordance. When assessed jointly in parents and youth, the association between SCL and emotion was *negative*, where increases in moment-to-moment SCL (i.e., increases from an individual's overall mean) corresponded to more negative emotion ratings, consistent with the direction of the relationship outlined in Hypothesis 1a. Results are consistent with previous research demonstrating increased SNS activity in response to discrete negative emotions (Cacioppo & Berntson, 1997; Kreibig, 2010), and extends to situations measuring both valence (i.e., positive and negative) and intensity (ranging from -100 to +100). There was also evidence of individual variability in the SCL-emotion association (i.e., tested via random slopes indicating significant between groups variance) in the full sample (parents and youth). This aligns with theory and research that emotional concordance may demonstrate substantial individual differences (Brown et al., 2020; Bulteel et al., 2014; Hollenstein & Lanteigne, 2014; Lougheed et al., 2021). Of note, caregiver vs. youth status moderated the SCL-emotion association, and youth and caregivers showed different patterns of results for the SCL-emotion association.

When assessed separately in youth, the SCL-emotion slope was *positive*. Increases in moment-to-moment SCL corresponded to more positive emotion ratings. In a qualitative review, it is notable that EDA (a measure subsuming SCL) was consistently shown to correspond to increased emotions regardless of the emotion type (e.g., anger, anxiety, disgust, embarrassment, fear, affect, amusement, happiness, anticipatory pleasure, pride), although there were a few exceptions where EDA decreased (e.g., sadness without crying, relief) (Cacioppo & Berntson, 1997; Kreibig, 2010; Mauss et al., 2005). In sum, SCL appears to be a unidirectional response most sensitive to level of emotional experience regardless of valence.

While sympathetic arousal is associated with “fight or flight” responses and may reflect an “overactive” SNS response at high levels, EDA (including SCL) also reflects emotional and attentional processing (Braithwaite et al., 2013). Of note, $\mathrm{SCL}_{.p}$ (i.e., mean SCL) effects were non-significant, indicating that participants’ overall SCL across the entire task did not predict emotion ratings, whereas moment-to-moment SCL (i.e., reflecting changes from their mean physiology across time) did predict emotions. It is possible that increases in youths’ SCL from their mean level reflected an increase in active engagement and alertness, which contributed to a more positive emotional experience for youth during those moments of the discussion with their parent about a conflictual topic. It could also demonstrate that youth were challenged by the task demands as reflected by SNS increase, and they were navigating the challenge successfully as reflected by a more positive emotional experience.

Findings did not support an association between physiology and emotion ratings when assessed separately in adult caregivers in multilevel models. Contrary to the present findings, two previous meta-analyses have demonstrated a significant association between emotions and specific physiological measures (e.g., heart rate, blood pressure, SCL) in relation to discrete emotions (e.g., anger, sadness, happiness) (Cacioppo & Berntson, 1997), as well as general physiology (assessed via a physiological composite) in adults (Lench et al., 2011). The methodology in the present study differed from this previous research, which may explain differences in findings. The current conflict task was chosen as an ecologically relevant *stress* induction where parents and youth were instructed to problem solve a recent source of familial conflict. It is possible that parents may have demonstrated a wide range of *discrete emotions* (e.g., anger, happiness) throughout the task. Further, the topics chosen for the task were child-centered, including disagreements regarding youth coming home on time, helping around the house, fighting with siblings, and electronics use. These topics were not tailored to parents' personal difficulties, but rather were more child focused. It is possible that concordance effects were stronger for youth due to nature of the topic (i.e., emphasizing youth behavior).

4.1.2. No evidence of RSA-emotional concordance. In contrast with Hypothesis 1b, moment-to-moment RSA (RSA_{tp}) and mean RSA ($\text{RSA}_{.p}$) were unrelated to emotion ratings in all models. While it was anticipated that increased PNS activity would reflect effective self-regulation in response to stress and correspond to more positive emotion ratings, PNS activity also decreases during challenge or threat to engage with and adapt to environmental demands (Beauchaine, 2001; Porges, 2007). While there is a rich literature on SCL as a specific index of SNS responsivity, RSA has only more recently been gaining more attention in research, as many researchers opt for more easily obtained heart related ANS measures (e.g., heart rate, blood pressure) (see Kreibig, 2010 for a review). A qualitative review showed inconclusive patterns or no changes for PNS measures in conjunction with some discrete emotions (e.g., disgust, fear, contentment, pride), and a varied pattern across others (e.g., increased HRV in response to amusement, decreased HRV in response to anger, anxiety, embarrassment) in adults (Kreibig, 2010). In real-life experiences, as was mimicked in the task in the current study, it was expected that caregivers and adolescents may experience a wide range of discrete emotions. RSA should continue to be assessed using these paradigms that more closely reflect daily experiences.

Parasympathetic activity is also thought to be integrated into the social engagement system, which can rapidly mobilize or calm individuals to foster either defensive or social behaviors (Porges, 2007). Therefore, it is plausible that other factors may contribute to the RSA-emotion association (e.g., parenting, relationship quality in parent-adolescent dyad). For example, in a study of children exposed to social engagement (e.g., free play, dyadic teaching task) and social disengagement (e.g., parental separation) tasks, HRV was only altered during social disengagement for healthy controls (Shahrestani et al., 2014). Further, children at risk for or diagnosed with a psychological disorder in the sample did not show any change in HRV for any tasks compared to baseline (Shahrestani et al., 2014). Other studies have also shown that PNS activity is altered with clinical samples, where low resting PNS activity and excessive PNS reactivity to emotional challenges have been found to correspond to dysregulated self-regulatory functions (see Beauchaine & Thayer, 2015 for a review) and decreased RSA has been shown to correspond to higher externalizing and internalizing symptoms (Graziano & Derefinko, 2013). In the present study, all subjects were participating in a socially engaging task, which may not have altered RSA, a measure thought to vary as a function of social engagement. Participants were also sampled across the general population with varying life histories and clinical diagnoses. This could mask potential differences in RSA relationships for specific subgroups where dysregulation of parasympathetic regulatory function may be expected.

RSA has also been shown to change with development of physiological systems (Hinnant et al., 2017), and is affected by posture, respiration rate, and physical activity (Grossman & Taylor, 2007; Kreibig, 2010). The present study required back and forth dialogue during the dyadic task, which may have limited the ability to detect a reliable and consistent parasympathetic signal, as talking and movement can alter RSA. It is possible that RSA is a "noisier" measure of physiological activity and moderated by many other factors, and therefore did not produce a reliable discernable signal. These methodological and moderating factors should be considered in future research.

4.1.3. Summary of SNS and PNS concordance. Different patterns emerged for SNS and PNS measures in the present study. Several inherent features of the ANS may contribute to variability in the present study and previous findings (Berntson et al., 1991; Kreibig, 2010; Quigley & Barrett, 2014). First, while SNS and PNS branches of the ANS can function reciprocally, researchers often fail to consider that uncoupled activation is possible and a common occurrence (e.g., one branch is activated, while the other is not). For example, different modes of control (e.g., *reciprocal* in which there is a one unit increase in SNS and one unit decrease in PNS activity, versus *uncoupled* in which there is a one unit increase in SNS and no change in PNS activity) can produce variable ANS responses. Also, proximity to one's physiological limit can impose floor and ceiling effects on ANS activity (Hinnant et al., 2017). Further, emotions can change without concomitant changes in ANS activity, and vice versa (see Kreibig, 2010 for a review). Research requires additional consideration of response specificity within individuals taking these ANS features into account.

4.2. Aim 2: Effects of Emotion Regulation, Coping, and Involuntary Stress Responses

While assessment of self-regulation strategies has been identified as an area of high importance for understanding concordance in emotion and physiology (Lougheed et al., 2021), emotion regulation has predominantly been examined in studies of adults. This research has used non-specific composites of physiological measures (Brown et al., 2020; Butler et al., 2014; Dan-Glauser & Gross, 2013), or passive viewing of film clips with explicit emotion regulation instructions (Peters et al., 2014; Shiota & Levenson, 2012). In youth, emotion regulation ability has been inferred from patterns of physiological-emotional responding, though not empirically assessed as a moderator of the physiological-emotional association (Hastings et al., 2009; Lanteigne et al., 2014; Smith et al., 2011). The present study quantitatively assessed emotion regulation scales as potential moderators of the physiological-emotional association using two measures: the ERQ assessing the specific domains of cognitive reappraisal and expressive suppression in response to emotions, and the RSQ assessing factors including primary control coping, secondary control coping, disengagement coping, involuntary engagement, and involuntary disengagement in response to family stress. Findings indicated partial support for the hypotheses. Specific indices of emotion regulation on the ERQ did not predict emotion ratings or physiology, nor did they alter the physiological-emotional association (Hypotheses 2a-2b). Broader factors of coping and involuntary responses to stress on the RSQ predicted emotion ratings during the laboratory task. Further, secondary control coping (Hypothesis 2d) and involuntary engagement (Hypothesis 2f) moderated the physiological-emotional association.

4.2.1. Cognitive reappraisal and expressive suppression: no effects. The cognitive reappraisal and expressive suppression scales did not predict emotion ratings, nor were they associated with physiology-emotion rating slopes. One study also used the ERQ self-report and cognitive reappraisal was unrelated to adults' physiological-emotional coherence while viewing positive and negative films (Brown et al., 2020). It is possible that the ERQ was unrelated to the physiological-emotional association because it is a measure of typical or trait-like responses to emotions, while the present study assessed physiology and emotions specifically during parent-adolescent conflict. It is possible that youth and caregivers' specific use of suppression or reappraisal in response to emotions is distinct from strategies used during dyadic conflict.

Previous research demonstrating a moderating role for expressive suppression and cognitive reappraisal experimentally manipulated regulation strategies (versus self-report) with adults. For example, in a study where participants were instructed to not display any emotions, expressive suppression reduced concordance (as assessed via cross-correlations) across emotional experience, emotional expression, and an ANS composite while independently viewing emotional images (Dan-Glauser & Gross, 2013). Another study demonstrated that instructions to suppress emotional expression disrupted concordance for both positive and negative emotional experiences with ANS measures, while individuals instructed to reappraise demonstrated variable patterns of concordance between emotional expressions and ANS measures (Butler et al., 2014). Given the state of current research, findings appear strongest for the active use of expressive suppression in the moment (i.e., instructions to not show emotion) corresponding to weaker physiological-emotional associations. There is no strong consensus for the specific use of cognitive reappraisal in altering the physiological-emotional association yet.

4.2.2. Coping and involuntary stress responses predict emotional experience. The present study is the first to assess how primary control coping, secondary control coping, disengagement coping, involuntary engagement, and involuntary disengagement affected physiological-emotional associations using the RSQ. Higher reported use of primary control coping (e.g., problem solving, and emotional modulation and expression) and secondary control coping (e.g., acceptance, cognitive reappraisal, positive thinking, and distraction) predicted more positive self-reported emotional experience during the conflict task in parents and youth. This aligns with a body of work demonstrating that primary and secondary control coping strategies tend to be adaptive responses to stressors (see Compas et al., 2017 for a meta-analysis and review). These findings also have clinical implications. If parents and youth are advised to use primary and secondary control coping strategies during conflict, the interaction may result in more positive emotional experiences (e.g., Compas et al., 2010).

Higher reported use of disengagement coping, and higher levels of involuntary engagement and involuntary disengagement predicted more negative emotional experiences during the conflict task for parents and youth. Similarly, interventions can work with families to target strategies to orient away from stress (e.g., denial, avoidance) as well as automatic involuntary responses to stress (e.g., impulsive actions, automatic negative thoughts, heightened physiological or emotional arousal) to replace with more helpful and adaptive strategies like problem solving, communication skills, relaxation skills, mindfulness, and distress tolerance.

4.2.3. Involuntary engagement alters SNS-emotion association. In support of Hypothesis 2e, involuntary engagement predicted the slope of the SCL-emotion association, where at low levels of involuntary engagement, increases in SCL corresponded to more positive emotion ratings. This provides initial evidence that concordance, or a positive association between SNS activity and emotions may be an adaptive response. This also aligns with previous research where greater coherence between physiological measures and emotion ratings corresponded to better well-being and life satisfaction and lower symptoms of depression and anxiety in adults (Brown et al., 2020). Further, higher involuntary engagement predicted more negative emotion ratings, indicating that individuals reporting more involuntary rumination, intrusive thoughts, emotional and physiological arousal, and impulsive action, reported more negative emotional experiences during the parent-adolescent conflict task. The present findings demonstrate that concordance is *stronger* for those demonstrating more adaptive automatic responses to stress.

4.2.4. Secondary control coping and SNS-emotion association. In partial support of Hypothesis 2d, secondary control coping predicted the slope of the SCL-emotion association, though this effect approached significance (and therefore, this finding should be interpreted with caution). Results suggested that at high levels of reported secondary control coping use, increases in moment-to-moment SCL (from individuals' average) predicted more positive emotion ratings. As secondary control coping strategies are generally considered to be adaptive (Compas et al., 2017), this finding implies that increases in SNS activity and higher use of acceptance, cognitive reappraisal, positive thinking, and distraction predict more positive emotional experiences during parent-adolescent conflict. This finding also lends support to the literature demonstrating that concordance is *stronger* for those demonstrating more adaptive coping strategies, and therefore concordance may be adaptive.

Emotion dysregulation is an important correlate of psychopathology. Some posit that concordance may only occur when intense emotional experiences are not regulated (e.g., in clinical populations) (Lougheed et al., 2021). While the present findings indicate that concordance may be adaptive, it is likely that the context in which physiological-emotional associations are measured is essential. For example, individuals with snake phobia showed greater coherence between physiology and affective experience than individuals without a snake phobia *in response to snake films* (Schaefer et al., 2014). Additionally, in a sample of mother-daughter dyads, adolescents with depression *who displayed the most aversive behavior* demonstrated within-person concordance (i.e., simultaneous physiological [i.e., RSA] dysregulation and behavioral dysregulation) during a conflict discussion task (Crowell et al., 2014). In sum, the advantage of a strong physiological-emotional association likely depends on the context and population.

4.3. Strengths, Limitations, and Future Directions

4.3.1. Methodological considerations. While experimental stimuli have varied (e.g., discrete emotional images, emotional induction), there appears to be consensus that context is essential to consider in assessing physiological-emotional associations. The present findings are the first to assess within individual physiological-emotional concordance utilizing a parent-adolescent conflict discussion task. The present study takes an important step in assessing concordance in a more realistic daily experience for parents and youth. While the task was not standardized, it was a topic rated as relevant by parents and youth. Yet, families vary in how conflictual, stressful, or negative their interactions tend to be, and there was large variability in how negatively participants rated the laboratory task as well. According to mean emotion rating results, some participants found the task quite aversive and rated it negatively, while others rated the experience as positive on average.

Some hypothesize that concordance may only occur in high intensity, single-emotion states (e.g., a pure fear response) that are rarely encountered in modern-day society, which is most often comprised of lower intensity, mixed-emotion states (Friedman et al., 2014). Some research has indeed demonstrated increased coherence for more emotionally intense films as compared to those that are less emotionally intense (Brown et al., 2020). Though it is also suggested that real-life experiences, particularly with social elements, may be more successful in eliciting a stress response as compared to passive image or film viewing (Dickerson & Kemeny, 2004), and that emotion inductions must be potent enough to supersede typical ANS-mediated physiological changes (Cui et al., 2015; Quigley & Barrett, 2014; Woltering et al., 2015). Future studies could incorporate sufficiently emotional or stressful tasks, beyond passive image or film viewing, to assess physiological-emotional associations in real-life scenarios in which stressors and emotions typically occur. Furthermore, the present study assessed moment-by-moment emotions ratings during the task using video mediated recall procedures. Only two studies have utilized this VMR technique previously (Butler et al., 2014; Mauss et al., 2005). This procedure minimizes recall errors and allows for the measurement of covert, internal emotions versus behavioral observations and should continue to be incorporated in research.

The present study assessed the concurrent relations (i.e., no time lag) between ANS measures and emotion ratings, as emotions were assessed retrospectively where participants were instructed to rate their emotion *during that moment* in the video. Similarly, some *intra*individual research (e.g., Cui et al., 2021) and *inter*individual research (e.g., Suveg et al., 2016) have assessed concurrent associations. Other studies have used a time lag assessing *intra*individual measures (Brown et al., 2020; Dan-Glauser & Gross, 2013; Mauss et al., 2005; Sze et al., 2010), and *inter*individual measures, as one individual's emotional or physiological response was purportedly dependent upon their partner's response (e.g., Cui et al., 2015; Woltering et al., 2015). Of note, one study quantitatively assessed time lags between physiological measures and emotions and determined that different physiological measures had different best-fitting time lags (Butler et al., 2014). Currently, there is no standard for the most accurate time lag to capture associations between various ANS measures and emotions (Hollenstein & Lanteigne, 2014). The heterarchical organization of the nervous system is essential to consider for these determinations (Quigley & Barrett, 2014). As experiences are constructed by the central nervous system, there are many temporal dependencies, but little consensus on their linear progression. It may be that emotional experiences are constructed simultaneously over time from multiple avenues. Determining the appropriateness of using time lags, and if so, which time lag to use, are important areas of research to elucidate the presence of concordance.

The present study adds to the literature by assessing physiological-emotional concordance along a continuum of positive and negative emotional experience. Previous research has often taken the absolute value of bipolar emotional experience rating scales (i.e., ranging from negative to positive) based on expectations that physiological arousal will occur in response to greater emotionality regardless of valence (Brown et al., 2020; Butler et al., 2014; Sze et al., 2010). Despite this fairly common practice, Lougheed et al. (2021) called for researchers to retain the valence of emotional experience to deepen understanding of both positive and negative emotional experiences and physiology, as crucial information can be missed by solely assessing arousal (i.e., regardless of valence). Future studies could empirically investigate potential differences in concordance by valence or intensity by comparing results gleaned from emotion ratings ranging from negative to positive with the absolute value of emotion ratings (i.e., emotional intensity). To determine if concordance is adaptive or maladaptive and in which circumstances, it will be beneficial to consider emotional valence in these relationships.

As highlighted above, the ANS coordinates a multitude of complementary and opposing functions and findings are mixed across individual ANS measures. While coordination of the SNS and PNS facilitates flexibility in meeting environmental demands, a common misconception is that SNS activation causes PNS activation or inactivation, when in fact the neurotransmitters modulating the responses of each of these systems vary (i.e., SNS via norepinephrine and PNS via acetylcholine) and many physiological measures represent coactivation in target organs served by both systems (Levenson, 2014). There is also evidence of fractionation between cardiovascular (e.g., RSA) and electrodermal (e.g., SCL) response systems (Lacey, 1967). The present study assessed SNS and PNS indices in separate models, although some research has begun to assess associations between SNS and PNS measures within individuals (Cui et al., 2021). Associations within physiological subsystems (i.e., comparing two physiological measures) is an important area for future research. It can delineate how ANS patterns correspond to outcomes and lend support for continued emphasis in research to parse apart which emotional response patterns are adaptive versus maladaptive.

4.3.2. Gender. While specific hypotheses were not made about gender differences, lower emotion ratings for females were consistent, where female youth reported more negative emotions during the task. Research has shown that emotional content in parent-child interactions specifically can vary by gender, where parents reference more emotional language and more frequently describe sadness and disliking with girls than boys (Adams et al., 1995; Fivush et al., 2000; Knothe & Walle, 2018), and women tend to report more frequent and intense emotional experiences than men (Bradley et al., 2001). In addition, female youth had higher RSA during the conflict task than males. Some studies have found that ANS measures do not vary by sex (Haag et al., 2019; Jenness et al., 2019), while other research has shown sex differences (Koenig et al., 2017; Ordaz & Luna, 2012). Gender differences for caregivers were not interpreted due to the predominance of female caregivers. Gender should continue to be included in future work, and it is essential to contextualize interpretations of gender differences within a framework incorporating biological differences, psychological development, and cultural and social context (Chaplin, 2015).

4.3.3. Age. Importantly, age was included in all models in the present study. As youth transition from childhood to adolescence, the parent-child relationship involves continual renegotiation of relational qualities. In the present sample, younger youth (ages 9-12) reported more positive emotions, while older youth (ages 14-15) reported more negative emotions. This aligns with a meta-analysis demonstrating that conflict affect (i.e., emotional intensity of disagreements) increases from early- to mid-adolescence (Laursen & Collins, 1998). It is important to note that increased conflict is not maladaptive per say but is arguably functional for child development given changing expectations for behavior and roles (see Smetana & Rote, 2019 for an extensive review). Age is also essential to consider the development of physiological systems. While the present study controlled for overall levels of physiological responding (via person-centered physiological scores), ANS measures have been shown to differ with age (Cohen et al., 2020; Gray et al., 2018; Hinnant et al., 2017). This highlights that age should continue to be considered in models assessing physiological-emotional associations, as age and development affect parent-child relationships and may affect physiology.

4.3.4. Clinical implications. Two core transdiagnostic features of psychopathology, and key targets for multiple interventions, are emotional and physiological dysregulation. Significant within individual variability in emotional experience was consistent across models in the present study, as in previous research, indicating the potential presence of moderators (Van Doren et al., 2021; Butler et al., 2014). Some research has begun to assess physiological-emotional associations in conjunction with internalizing and externalizing problems (Hastings et al., 2009; Lanteigne et al., 2014), though more rigorous methodology is needed. Assessment of relevant moderators, including adverse childhood experience and/or trauma, is an important area of future research. Lastly, research has begun to examine the *inter*individual (i.e., between parent and adolescent) associations between emotions (Henry et al., 2022) and physiology (Gruhn, 2020; Vreeland, 2020) in dyads, though the assessment of both emotions and physiology in parent-adolescent dyads will provide a deeper understanding of these processes, which may yield insight that can be applied to family interventions. Understanding the clinical relevance of physiological-emotional concordance could provide a useful biomarker of risk or resilience in youth and caregivers.

4.4. Conclusion

In conclusion, emotional concordance has been contemplated for decades. Empirical studies have shown that theorized associations between emotional experience and autonomic physiology are often not found or are complex. The present study took an important next step in assessing the concordance of emotion and physiology during an ecologically relevant parent-adolescent conflict discussion task across multiple autonomic nervous system measures. This work expanded on the often theorized, but infrequently empirically supported, notion of positive concordance of emotional and physiological measures as a typical response during stressful and emotional situations. Evidence was found for SCL-emotional concordance in youth, and RSA was unrelated to emotional experience in the present study. The moderating role of various facets of emotion regulation, coping, and involuntary stress responses on emotional-physiological concordance were assessed. Low levels of reported involuntary engagement in response to stress and high levels of reported secondary control coping were associated with SCL-emotional concordance (i.e., increases in SCL corresponded to more positive emotions), providing initial evidence that concordant responses may be adaptive. Findings provide an important foundation for understanding emotional concordance during parent-adolescent conflict in adult caregivers and for the first time, emotional concordance in youth, using a within individual, comprehensive statistical approach. The foundational question of how individual processes of emotion regulation affect physiological-emotional concordance can inform interventions at both the individual and family levels.

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TABLES

Table 1

Demographic Characteristics of Study Participants

	Youth	Caregivers
Age at assessment, *M* (SD)	12.22 (1.68)	42.04 (6.98)
Sex, *n* (%)		
Female	45 (46.4)	87 (89.7)
Male	51 (52.6)	10 (10.3)
Ethnicity, *n* (%)		
Hispanic or Latino/a	5 (5.2)	2 (2.1)
Not Hispanic or Latino/a	90 (92.8)	94 (96.4)
Race, *n* (%)		
Asian	5 (5.2)	4 (4.1)
Black or African American	15 (15.5)	15 (15.5)
White	70 (72.2)	73 (75.3)
More than one race	5 (5.2)	3 (3.1)
Other	2 (2.1)	2 (2.1)
Household income, *n* (%)		
$15,000 or under	--	3 (3.1)
$15,000 - $29,999	--	6 (6.2)
$30,000 - $44,999	--	14 (14.4)
$45,000 - $59,999	--	12 (12.4)
$60,000 - $74,999	--	15 (15.5)
$75,000 - $89,999	--	5 (5.2)
$90,000 - $104,999	--	7 (7.2)
$105,000 - $119,999	--	6 (6.2)
$120,000 - $134,999	--	5 (5.2)
$135,000 - $149,999	--	6 (6.2)
$150,000 or more	--	17 (17.5)
Parent relation, *n* (%)		
Mother	--	81 (84)
Father	--	8 (8.2)
Adoptive parent	--	4 (4)
Stepparent	--	2 (2)
Other	--	1 (1)

Note. The sample included 97 youth and 97 caregivers.

Table 2

Descriptive Data and Correlations for Parents

Variable	*M* (*SD*)	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Age	42.04 (6.98)	--										
2. Emotion Rating	6.56 (33.75)	.04	--									
3. SCL	7.00 (5.37)	-.007	-.04	--								
4. RSA	5.43 (1.22)	-.11***	-.08*	.02	--							
5. Cognitive reappraisal	29.82 (6.02)	-.10**	.17***	.03	.14***	--						
6. Expressive Suppression	12.77 (5.25)	-.04	-.04	-.07*	-.03	.17***	--					
7. Primary control coping	.22 (.04)	-.09**	.12***	-.02	.13***	.13***	-.33***	--				
8. Secondary control coping	.25 (.04)	-.07*	.23***	-.04	.05	.32***	.33***	.11***	--			
9. Disengagement coping	.13 (.02)	.10**	-.12***	.12***	-.07*	-.03	.24***	-.56***	-.30***	--		
10. Invol. engagement	.24 (.05)	.13***	-.19***	.02	-.07*	-.35***	-.18***	-.43***	-.70***	.10**	--	
11. Invol. disengagement	.16 (.03)	-.02	-.16***	-.06	-.13***	-.13***	.10**	-.56***	-.37***	.31***	.11***	--

Note. Invol. = involuntary.

*$p < .05$

**$p < .01$

***$p < .001$

Table 3

Descriptive Data and Correlations for Youth

Variable	*M* (*SD*)	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Age	12.22 (1.68)	--										
2. Emotion Rating	3.69 (36.65)	-.22***	--									
3. SCL	16.95 (9.70)	-.17***	.10**	--								
4. RSA	6.76 (.92)	-.05	-.01	-.01	--							
5. Cognitive reappraisal	25.90 (7.15)	-.04	.06	.09**	-.10**	--						
6. Expressive Suppression	14.40 (9.97)	.18***	-.08*	.06	.02	.11**	--					
7. Primary control coping	.18 (.05)	-.25***	.19***	.08*	-.8*	.15***	-.38***	--				
8. Secondary control coping	.25 (.05)	-.02	.16***	.14***	.15	.36***	.04	.18***	--			
9. Disengagement coping	.16 (.03)	.09**	-.15***	-.01	.18***	-.12***	.32***	-.59***	-.41***	--		
10. Invol. engagement	.24 (.04)	.09**	-.18***	-.06	.04	-.34***	.01	-.50***	-.72***	.23***	--	
11. Invol. disengagement	.18 (.03)	.18***	-.13***	-.28***	-.03	-.24***	.19***	-.53***	-.57***	.30***	.38***	--

Note. Invol. = involuntary.
*$p < .05$
**$p < .01$
***$p < .001$

Table 4

Multilevel Models of Emotion Ratings with SCL

Model	Independent variable	PE	SE	*p*
Model 1	Fixed effects	--	--	--
	Intercept	38.13	30.37	.21
	Subject type	-10.85	12.54	.39
	Age	-.08	.39	.84
	Gender	-9.70	4.80	.045
	SCL	.97	.76	.21
	Mean SCL	.15	.26	.56
	Random effects	--	--	--
	Residual	553.23	21.16	<.001
	Intercept	647.55	74.38	<.001
	SCL	31.65	13.11	.02
Model 2	Fixed effects	--	--	--
	Intercept	37.87	30.37	.21
	Subject type	-10.70	12.54	.40
	Age	-.08	.39	.84
	Gender	-9.70	4.80	.045
	SCL	-5.32	2.60	.044
	Mean SCL	.15	.26	.56
	SCL x Subject type	3.89	1.54	.01
	Random effects	--	--	--
	Residual	552.45	21.01	<.001
	Intercept	647.78	74.39	<.001
	SCL	29.25	12.10	.02

Note. PE = parameter estimate; SE = standard error; SCL = skin conductance level. Emotion ratings were the dependent variable for each model.

Table 5

Multilevel Models of Emotion Ratings with SCL Separately in Parents and Youth

Model	Independent variable	PE	SE	*p*
Model 1:	Fixed effects	--	--	--
Parents	Intercept	-4.18	23.51	.86
	Age	.18	.37	.62
	Gender	2.42	8.46	.78
	SCL	-.92	.87	.29
	Mean SCL	-.21	.50	.68
	Random effects	--	--	--
	Residual	587.64	29.11	<.001
	Intercept	558.73	91.60	<.001
Model 2:	Fixed effects	--	--	--
Youth	Intercept	77.06	23.36	.001
	Age	-4.70	1.74	.008
	Gender	-12.66	5.73	.03
	SCL	2.49	.95	.01
	Mean SCL	.16	.30	.60
	Random effects	--	--	--
	Residual	535.89	29.28	<.001
	Intercept	648.18	105.94	<.001
	SCL	30.14	14.18	.03

Note. PE = parameter estimate; SE = standard error; SCL = skin conductance level. Emotion ratings were the dependent variable for each model.

Table 6

Multilevel Models of Emotion Ratings with RSA

Model	Independent variable	PE	SE	*p*
Model 1	Fixed effects	--	--	--
	Intercept	43.73	31.56	.17
	Subject type	-5.94	12.26	.63
	Age	-.09	.38	.82
	Gender	-8.70	4.77	.07
	RSA	.43	1.29	.74
	Mean RSA	-2.05	2.06	.32
	Random effects	--	--	--
	Residual	585.15	22.32	<.001
	Intercept	622.00	72.68	<.001
	RSA	46.69	31.04	.13
Model 2	Fixed effects	--	--	--
	Intercept	41.42	31.60	.19
	Subject type	-5.26	12.28	.67
	Age	-.07	.38	.85
	Gender	-8.50	4.80	.08
	RSA	5.48	3.60	.13
	Mean RSA	-1.96	2.06	.34
	RSA x Subject type	-3.26	2.32	.16
	Random effects	--	--	--
	Residual	597.64	21.58	<.001
	Intercept	620.58	72.66	<.001

Note. PE = parameter estimate; SE = standard error; RSA = respiratory sinus arrhythmia. Emotion ratings were the dependent variable for each model.

Table 7

Multilevel Models of Emotion Ratings with Physiology and ERQ Cognitive Reappraisal Scale

Model	Independent variable	PE	SE	*p*
Model 1: SCL and CR	Fixed effects	--	--	--
	Intercept	37.75	30.42	.22
	Subject type	-10.70	12.56	.40
	Age	-.07	.39	.85
	Gender	-9.75	4.80	.044
	Cognitive reappraisal	-.001	.01	.94
	SCL	.66	.39	.09
	Mean SCL	.16	.26	.55
	CR x SCL	.007	.006	.19
	Random effects	--	--	--
	Residual	590.51	20.90	<.001
	Intercept	643.28	74.32	<.001
Model 2: RSA and CR	Fixed effects	--	--	--
	Intercept	40.75	31.68	.20
	Subject type	-4.96	12.32	.69
	Age	-.06	.38	.87
	Gender	-8.48	4.78	.08
	Cognitive reappraisal	-.004	.01	.77
	RSA	.99	1.17	.40
	Mean RSA	-1.94	2.06	.35
	CR x RSA	-.01	.008	.12
	Random effects	--	--	--
	Residual	597.49	21.57	<.001
	Intercept	620.10	72.60	<.001

Note. ERQ = Emotion Regulation Questionnaire; PE = parameter estimate; SE = standard error; CR = cognitive reappraisal. Emotion ratings were the dependent variable for each model.

Table 8

Multilevel Models of Emotion Ratings with Physiology and ERQ Expressive Suppression Scale

Model	Independent variable	PE	SE	*p*
Model 1: SCL and ES	Fixed effects	--	--	--
	Intercept	37.46	30.43	.22
	Subject type	-10.55	12.57	.40
	Age	-.07	.39	.86
	Gender	-9.77	4.80	.043
	Expressive suppression	-.003	.01	.83
	SCL	.63	.40	.11
	Mean SCL	.16	.26	.54
	ES x SCL	.007	.005	.21
	Random effects	--	--	--
	Residual	590.56	20.90	<.001
	Intercept	643.10	74.30	<.001
Model 2: RSA and ES	Fixed effects	--	--	--
	Intercept	40.37	31.68	.20
	Subject type	-4.77	12.33	.70
	Age	-.06	.38	.88
	Gender	-8.48	4.78	.08
	Expressive suppression	-.005	.01	.67
	RSA	.10	1.18	.40
	Mean RSA	-1.94	2.06	.35
	ES x RSA	-.01	.008	.13
	Random effects	--	--	--
	Residual	597.54	21.57	<.001
	Intercept	619.73	72.57	<.001

Note. ERQ = Emotion Regulation Questionnaire; PE = parameter estimate; SE = standard error; CR = cognitive reappraisal; ES = expressive suppression. Emotion ratings were the dependent variable for each model.

Table 9

Multilevel Models of Emotion Ratings with Physiology and RSQ Primary Control Coping Factor

Model	Independent variable	PE	SE	*p*
Model 1: SCL and PCC	Fixed effects	--	--	--
	Intercept	-6.06	32.83	.85
	Subject type	-1.26	12.60	.92
	Age	.04	.38	.92
	Gender	-9.53	4.68	.043
	Primary control	133.76	43.35	.002
	SCL	.48	1.81	.79
	Mean SCL	.13	.26	.62
	PCC x SCL	1.07	9.64	.91
	Random effects	--	--	--
	Residual	587.54	20.85	<.001
	Intercept	610.17	70.98	<.001
Model 2: RSA and PCC	Fixed effects	--	--	--
	Intercept	.54	33.89	.99
	Subject type	4.22	12.43	.74
	Age	.04	.37	.91
	Gender	-8.27	4.70	.08
	Primary control	127.23	42.92	.003
	RSA	6.41	4.69	.17
	Mean RSA	-2.31	2.02	.26
	PCC x RSA	-28.52	22.81	.21
	Random effects	--	--	--
	Residual	595.75	21.63	<.001
	Intercept	593.38	70.10	<.001

Note. RSQ = Responses to Stress Questionnaire; PE = parameter estimate; SE = standard error; PCC = primary control coping. Emotion ratings were the dependent variable for each model.

Table 10

Multilevel Models of Emotion Ratings with Physiology and RSQ Secondary Control Coping Factor

Model	Independent variable	PE	SE	*p*
Model 1:	Fixed effects	--	--	--
SCL and	Intercept	-1.02	31.83	.97
SCC	Subject type	-7.60	12.23	.54
	Age	.009	.38	.98
	Gender	-8.80	4.68	.062
	Secondary control	127.71	39.26	.001
	SCL	-3.21	2.15	.14
	Mean SCL	.09	.26	.72
	SCC x SCL	15.47	8.43	.067
	Random effects	--	--	--
	Residual	586.32	20.81	<.001
	Intercept	606.44	70.57	<.001
Model 2:	Fixed effects	--	--	--
RSA and	Intercept	1.52	32.94	.96
SCC	Subject type	-2.14	11.98	.86
	Age	.004	.37	.99
	Gender	-7.34	4.68	.12
	Secondary control	130.34	38.66	<.001
	RSA	6.43	5.57	.25
	Mean RSA	-2.11	2.01	.30
	SCC x RSA	-23.03	22.00	.30
	Random effects	--	--	--
	Residual	595.98	21.64	<.001
	Intercept	583.81	69.14	<.001

Note. RSQ = Responses to Stress Questionnaire; PE = parameter estimate; SE = standard error; SCC = secondary control coping. Emotion ratings were the dependent variable for each model.

Table 11

Multilevel Models of Emotion Ratings with Physiology and RSQ Disengagement Coping Factor

Model	Independent variable	PE	SE	*p*
Model 1: SCL and DC	Fixed effects	--	--	--
	Intercept	45.99	30.21	.13
	Subject type	-3.35	12.79	.80
	Age	.01	.38	.98
	Gender	-8.94	4.75	.061
	Disengagement	-161.85	70.99	.024
	SCL	-2.20	2.17	.33
	Mean SCL	.18	.26	.48
	DC x SCL	17.63	13.55	.19
	Random effects	--	--	--
	Residual	586.93	20.83	<.001
	Intercept	625.95	72.66	<.001
Model 2: RSA and DC	Fixed effects	--	--	--
	Intercept	48.95	31.52	.12
	Subject type	2.30	12.59	.86
	Age	.01	.38	.97
	Gender	-7.77	4.76	.10
	Disengagement	-159.79	71.31	.026
	RSA	-1.52	5.31	.77
	Mean RSA	-1.83	2.05	.37
	DC x RSA	15.59	35.98	.67
	Random effects	--	--	--
	Residual	596.29	21.65	<.001
	Intercept	607.06	71.58	<.001

Note. RSQ = Responses to Stress Questionnaire; PE = parameter estimate; SE = standard error; DC = disengagement coping. Emotion ratings were the dependent variable for each model.

Table 12

Multilevel Models of Emotion Ratings with Physiology and RSQ Involuntary Engagement Factor

Model	Independent variable	PE	SE	*p*
Model 1:	Fixed effects	--	--	--
SCL and	Intercept	59.86	30.39	.050
InvEng	Subject type	-6.55	12.24	.59
	Age	.06	.38	.88
	Gender	-7.96	4.69	.09
	Invol. engagement	-142.29	43.62	.001
	SCL	9.28	3.83	.020
	Mean SCL	.13	.25	.62
	InvEng x SCL	-33.73	15.31	.034
	Random effects	--	--	--
	Residual	550.38	21.16	<.001
	Intercept	609.88	70.56	<.001
	SCL	28.51	12.51	.023
Model 2:	Fixed effects	--	--	--
RSA and	Intercept	64.45	31.56	.043
InvEng	Subject type	-.80	12.02	.95
	Age	.07	.37	.85
	Gender	-6.67	4.69	.16
	Invol. engagement	-144.29	42.87	<.001
	RSA	-7.64	6.08	.21
	Mean RSA	-2.22	2.01	.27
	InvEng x RSA	34.49	24.61	.16
	Random effects	--	--	--
	Residual	595.64	21.63	<.001
	Intercept	584.04	61.15	<.001

Notes. PE = parameter estimate; SE = standard error; Invol. = involuntary; InvEng = involuntary engagement. Emotion ratings were the dependent variable for each model.

Table 13

Multilevel Models of Emotion Ratings with Physiology and RSQ Involuntary Disengagement Factor

Model	Independent variable	PE	SE	*p*
Model 1: SCL and InvDis	Fixed effects	--	--	--
	Intercept	69.17	31.55	.030
	Subject type	-5.46	12. 38	.66
	Age	-.06	.38	.87
	Gender	-11.58	4.73	.015
	Invol. disengagement	-206.43	69.46	.003
	SCL	1.63	2.41	.50
	Mean SCL	-.005	.26	.98
	InvDis x SCL	-5.81	14.38	.69
	Random effects	--	--	--
	Residual	587.49		<.001
	Intercept	612.63		<.001
Model 2	Fixed effects	--	--	--
	Intercept	74.55	32.93	.025
	Subject type	-.61	12.12	.96
	Age	-.07	.37	.86
	Gender	-9.71	4.72	.041
	Invol. disengagement	-202.40	67.67	.003
	RSA	-8.94	6.43	.16
	Mean RSA	-2.68	2.03	.19
	InvDis x RSA	58.16	38.06	.13
	Random effects	--	--	--
	Residual	595.50	21.63	<.001
	Intercept	592.44	70.03	<.001

Notes. RSQ = Responses to Stress Questionnaire; PE = parameter estimate; SE = standard error; Invol. = involuntary; InvDis = involuntary disengagement. Emotion ratings were the dependent variable for each model.

FIGURES

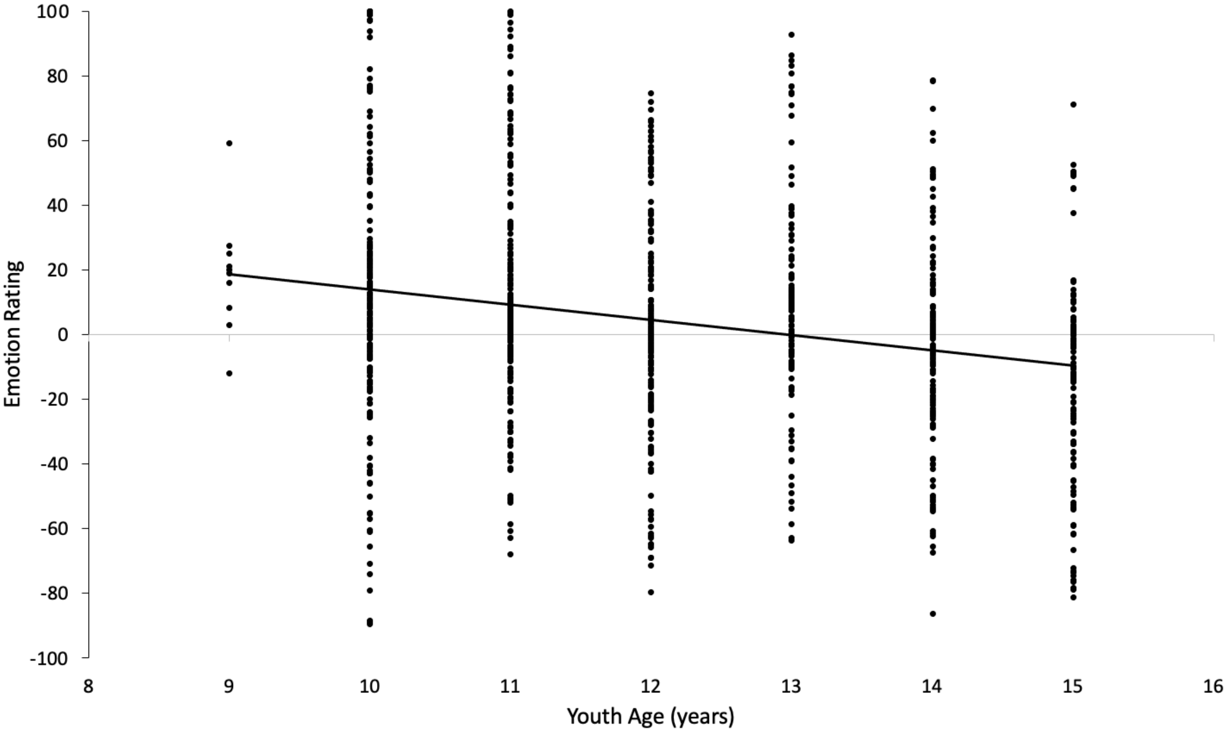

Figure 1. Emotion ratings by youth age.

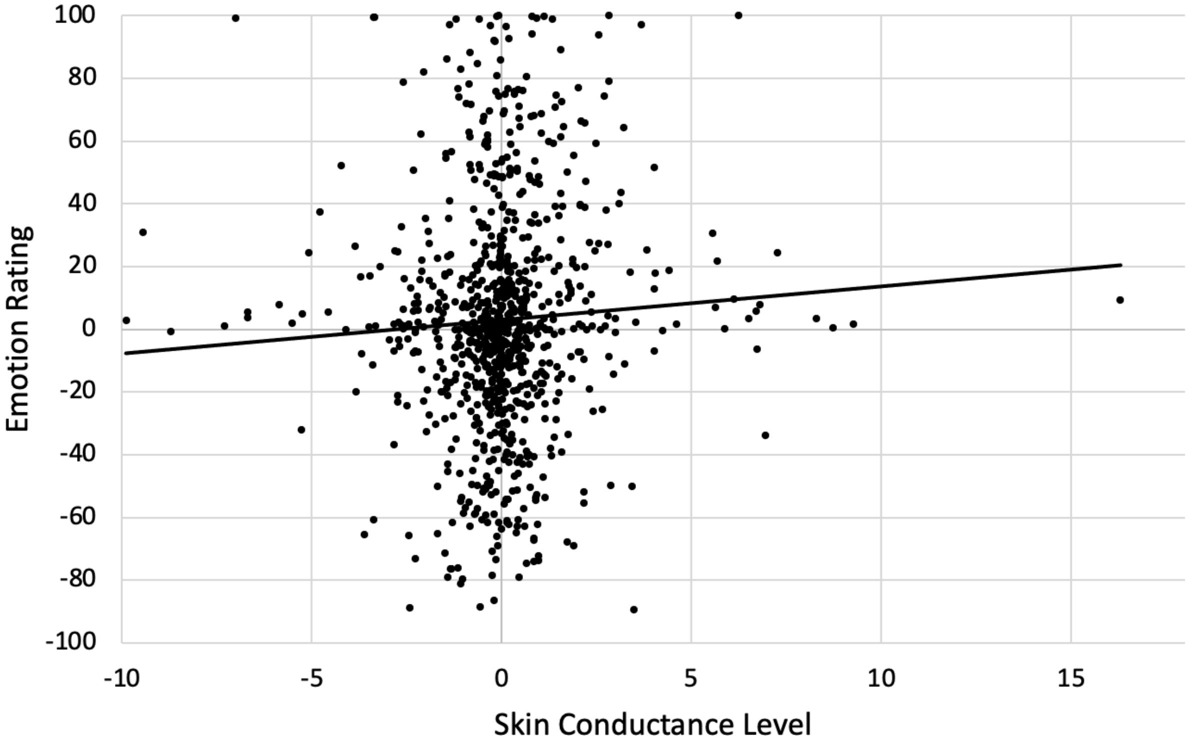

Figure 2. Emotion ratings vs. skin conductance level in youth.

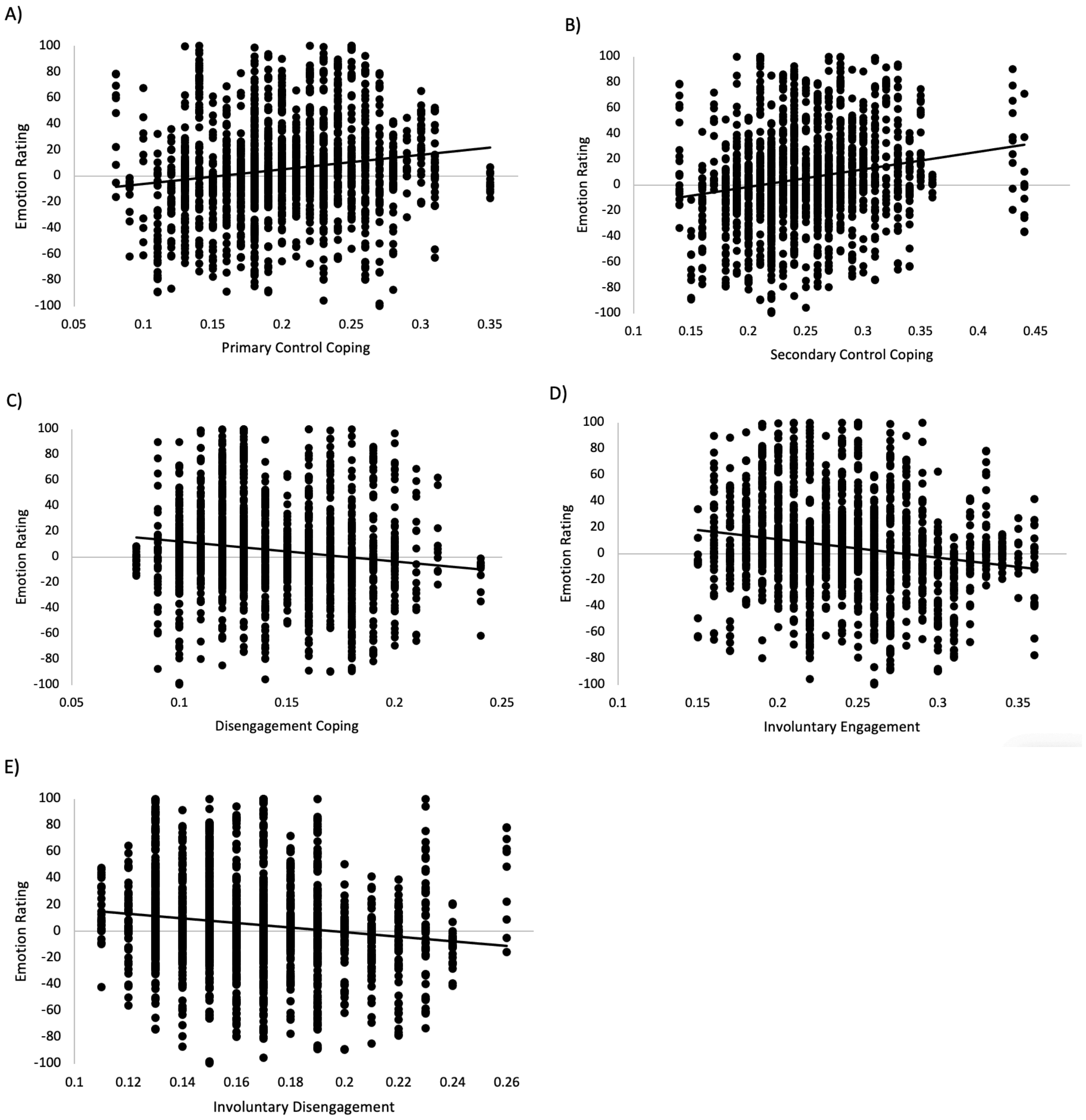

Figure 3. Coping strategies and involuntary responses to stress predicting emotion ratings. A) Primary control coping, B) Secondary control coping, C) Disengagement coping, D) Involuntary engagement, E) Involuntary disengagement.

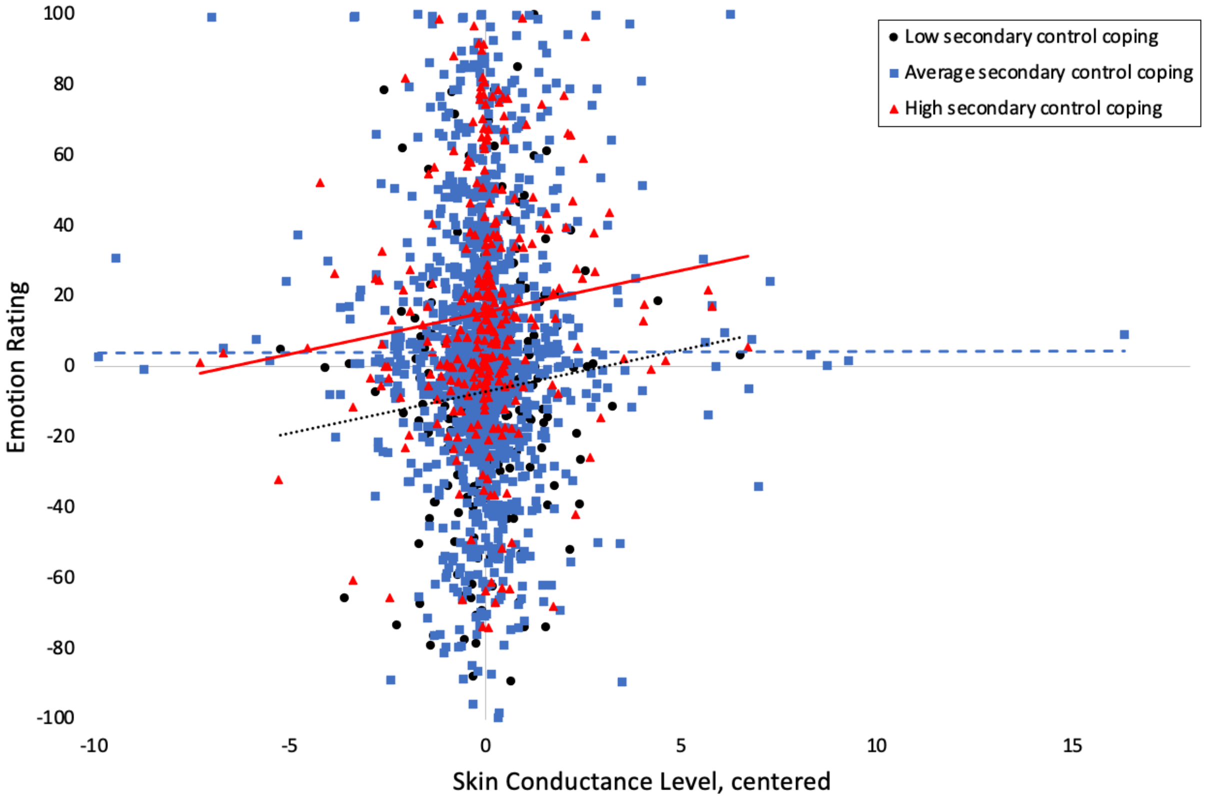

Figure 4. Emotion ratings vs. skin conductance level by secondary control coping use.

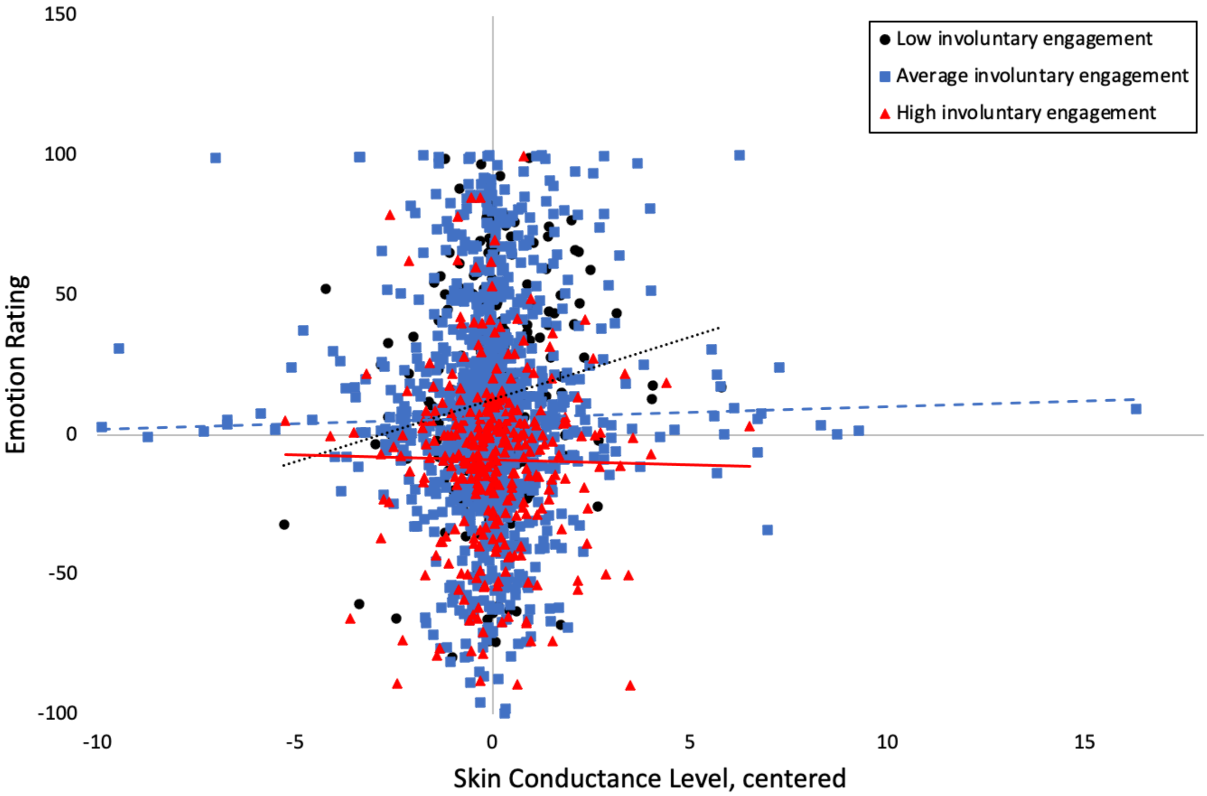

Figure 5. Emotion ratings vs. skin conductance level by involuntary engagement.

APPENDIX

Null model

$$E_{tp} = \beta_{0t} + e_{tp}$$

Example 1: Multilevel model predicting emotion scores with physiology and covariates

Level 1 equation:

$$E_{tp} = \beta_{0p} + \beta_{1p}SCL_{tp} + e_{tp}$$

E_{tp}: person's p emotion score at each time point t
SCL_{tp}: SCL score per time point, per person; centered around the person's mean ($SCL_{.p}$)
β_{0p}: intercept of the DV in person p
β_{1p}: slope term for the association between DV and level-1 SCL
e_{tp}: random error term for the level-1 equation

***Level 2 equations*:**

$$\beta_{0p} = \gamma_{00} + \gamma_{20}SCL_{.p} + \gamma_{30}SubjType + \gamma_{40}Age + \gamma_{50}Gender + u_{0p}$$
$$\beta_{1p} = \gamma_{10} + u_{1p}$$

γ_{00}: overall intercept (grand mean of DV across all groups when all predictors = 0)
γ_{10}: overall slope term between DV and level-1 SCL predictor
γ_{20}: slope term for the association between DV and level-2 $SCL_{.p}$
γ_{30}: slope term for the association between DV and subject type
γ_{40}: slope term for the association between DV and age
γ_{50}: slope term for the association between DV and gender
u_{0p}: random error term for the intercept
u_{1p}: random error term for the slope

Mixed model:

$$E_{tp} = \gamma_{00} + \gamma_{10}SCL_{tp} + \gamma_{20}SCL_{.p} + \gamma_{30}SubjType + \gamma_{40}Age + \gamma_{50}Gender + u_{0p} + u_{1p}SCL_{tp} + e_{tp}$$

$$e_{tp} \sim N(0, \sigma_e^2)$$
$$u_{0p} \sim N(0, \tau_{00})$$
$$u_{1p} \sim N(0, \tau_{11})$$
$$\begin{bmatrix} u_{0p} \\ u_{1p} \end{bmatrix} \sim MVN\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \tau_{00} & \\ \tau_{10} & \tau_{11} \end{bmatrix}\right)$$

Example 2: Multilevel model predicting emotion scores with physiology, covariates, and emotion regulation, coping, or involuntary response to stress measure

Level 1 equation:

$$E_{tp} = \beta_{0p} + \beta_{1p}SCL_{tp} + e_{tp}$$

E_{tp}: person's *p* emotion score at each time point *t*

SCL_{tp}: SCL score per time point, per person; centered around the person's mean ($SCL_{.p}$)

β_{0p}: intercept of the DV in person *p*

β_{1p}: slope term for the association between DV and level 1 SCL

e_{tp}: random error term for the level 1 equation

***Level 2 equations*:**

$$\beta_{0p} = \gamma_{00} + \gamma_{20}SCL_{.p} + \gamma_{30}SubjType + \gamma_{40}Age + \gamma_{50}Gender + \gamma_{60}ER + u_{0p}$$

$$\beta_{1p} = \gamma_{10} + \gamma_{11}ER_{1p} + u_{1p}$$

γ_{00}: overall intercept (grand mean of DV across all groups when all predictors = 0)

γ_{10}: overall slope term between DV and level-1 SCL predictor

γ_{11}: the effect of emotion regulation on the SCL-emotion slope

ER_{1p}: emotion regulation/coping level 2 score for person *p*

γ_{20}: slope term for the association between DV and level 2 $SCL_{.p}$

γ_{30}: slope term for the association between DV and subject type

γ_{40}: slope term for the association between DV and age

γ_{50}: slope term for the association between DV and gender

γ_{60}: slope term for the association between DV and emotion regulation/coping score

u_{0p}: random error term for the intercept

u_{1p}: random error term for the slope

Mixed model:

$$E_{tp} = \gamma_{00} + \gamma_{10}SCL_{tp} + \gamma_{11}ER_{1p}SCL_{tp} + \gamma_{20}SCL_{.p} + \gamma_{30}SubjType + \gamma_{40}Age + \gamma_{50}Gender + \gamma_{60}ER + u_{0p} + u_{1p}SCL_{tp} + e_{tp}$$

$e_{tp} \sim N(0, \sigma_e^2)$

$u_{0p} \sim N(0, \tau_{00})$

$u_{1p} \sim N(0, \tau_{11})$

$$\begin{bmatrix} u_{0p} \\ u_{1p} \end{bmatrix} \sim MVN\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \tau_{00} & \\ \tau_{10} & \tau_{11} \end{bmatrix}\right)$$