Parent Physiological Activity in the Context of Acute Pediatric Pain:
A Pilot Study of Parent Emotional Experience and Regulation

by

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A Thesis
presented to
The University of Guelph

In partial fulfillment of the requirements
for the degree of
Master of Arts
in
Psychology

Guelph, Ontario, Canada

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ABSTRACT

PARENT PHYSIOLOGICAL ACTIVITY IN THE CONTEXT OF ACUTE PEDIATRIC PAIN: A PILOT STUDY OF PARENT EMOTIONAL EXPERIENCE AND REGULATION

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University of Guelph, 2017

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Parent behaviours and responses have been linked to children’s acute pain experience. However, parents’ internal experience, as assessed by physiological activity, in this context remains largely unknown. The current study primarily sought to examine: (1) parent cardiac response (heart rate [HR] and heart rate variability [HRV]) before and after their child’s experience of acute pain; (2) the relations between parent cardiac response and self-reported characteristics; and (3) the associations between parent cardiac response and child outcomes. Children and a primary caregiver (n = 23) participated in this laboratory-based pilot study. Parent HR and HRV were monitored at three different times: during a neutral video, immediately prior to the painful cold-pressor task, and following the cold pressor. Parent trait anxiety, typical emotion regulation strategies, negative emotional state, and state catastrophizing were examined. Child pain intensity, fear, and pain tolerance were assessed. Parents experienced changes in HR and HRV. Non-significant moderate effects were observed between parent HRV and reported traits. Parent HR was inversely associated with parent negative emotional state and differentially associated with child pain outcomes. Findings have implications for incorporating parent physiology in existing models of pain and parent-child interaction frameworks.
Acknowledgements

I would like to express my gratitude to the many individuals that have supported me throughout my Master’s program and have made this a rewarding and positive experience. First, I would like to thank my supervisor, Dr. Meghan McMurtry, for her unwavering dedication and guidance, and for providing me with numerous opportunities to succeed. I cannot thank you enough for the kindness, comfort, and motivation you offered during the challenges over the past two years. Your knowledge and encouragement throughout has fostered my professional growth and has helped me become a better researcher. I also wish to thank my committee member, Dr. Heidi Bailey, for her theoretical and methodological expertise and insight. Your advice and enthusiasm have been invaluable and your assertions regarding the “steps” to understanding physiological processes were encouraging and appreciated. I wish to thank Dr. Christopher Fiacconi for serving on my examination committee and for his expertise on physiological measurement, and Dr. Steve Brown for chairing my defense. Thank you to the members of the Pediatric Pain, Health and Communication Lab for their continuous support and feedback. Many thanks to Rachel Moline for her collaboration in designing and conducting the study, and making this project more manageable and fun. Thanks to Megan G., Tim, Hannah, Megan M., Linda, and Lindsay for their assistance with recruitment, data collection, and data entry.

I would like to gratefully acknowledge the Social Sciences and Humanities Research Council and the Ontario Graduate Scholarship for their financial assistance. Thank you to the Pain in Child Health Strategic Training Initiative for providing various training opportunities and avenues to discuss and disseminate the findings from this project.

Finally, I wish to thank my family and friends for their patience, love, and support. Thank you for encouraging me to have confidence in myself and grounding me to the present moment.
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<td>Confidence Interval</td>
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<td>Cold Pressor Task</td>
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Introduction

Pain is a nearly universal human experience that occurs throughout the lifespan. Children commonly experience pain as a result of required medical procedures (e.g., immunizations, venipunctures; McMurtry et al., 2015). Children receive more than 20 vaccinations before the age of 18 years from routine medical care, and children with chronic illnesses (e.g., diabetes, cancer) undergo many more painful medical procedures (Public Health Agency of Canada, 2006; Taddio, 2013). Properly managing acute pain during medical procedures is needed to reduce potential short- (e.g., distress, suffering, fear) and long-term consequences (e.g., intense memories of pain, greater pain in subsequent procedures, avoidance of medical care; Kennedy, Luhmann, & Zempsky, 2008; Lynch, 2011; McMurtry et al., 2015). Approximately 45% to 90% of young children (15 months to 6 years of age) demonstrate severe distress during immunizations (Jacobson et al., 2001), and such negative experiences can lead to needle fear and avoidance of preventive and medically-required healthcare in adulthood (Taddio et al., 2012; Wright, Yelland, Heathcote, & Shu-Kay, 2009). Approximately 63% of young children and adolescents (i.e., 6 years to 18 years of age) report fear of needles, and 7% to 8% of parents and children report needle fear as the primary reason for immunization non-compliance (Taddio et al., 2012). It follows that a better understanding of the factors that influence child pain outcomes is necessary to reduce and prevent these short- and long-term consequences.

The Individual Pain Experience

Pain is defined as a subjective “unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage” (Merskey & Bogduk, 1994, p. 210). Consequently, pain is not simply a response to a noxious stimulus, since an experience can be reported as painful without any actual tissue damage (Merskey & Bogduk,
Rather, pain is a complex experience that involves sensory discrimination and an emotional response, and these two constructs can vary independently (Craig, 2009). Emotional processing affects both subjective and physiological reactions to pain, and difficulties regulating emotions are associated with higher levels of pain and distress (Keefe, Lumley, Anderson, Lynch, & Carson, 2001; Yoshino et al., 2012). To illustrate, healthy participants report higher ratings of pain intensity and unpleasantness when instructed to view pictures of sad faces, compared to happy and neutral faces (Bayet, Bushnell, & Schweinhardt, 2014; Yoshino et al., 2012). Furthermore, higher state and trait anxiety have been linked to increases in reported pain intensity (Tang & Gibson, 2005).

Children often report fear, anxiety, and distress as a result of painful medical procedures, and these states can influence the amount of pain children experience (Brewer, Gleditsch, Syblik, Tietjens, & Vacik, 2006; Jacobson et al., 2001; Taddio et al., 2012). Consistent with definitions provided by McMurtry et al. (2015), fear can be characterized as an alarm reaction to real or perceived threat; anxiety is a negative emotional state resulting from anticipating future threat; and distress involves an overall unpleasant effect. Higher levels of anticipatory anxiety have been linked to higher levels of postoperative pain and lower levels of pain tolerance (Chieng, Chan, Klainin-Yobas, & He, 2014; Tsao et al., 2004). Anxiety, fear, and pain activate the sympathetic nervous system (i.e., fight or flight), which increases attention to the immediate environment (Walding, 1991). Thus, a child experiencing fear or anxiety is likely to be hyperaware of their own pain signals (Arntz, Dreessen, & De Jong, 1994). Thus, managing children’s distress prior to and during painful medical procedures is relevant to reducing their experience of pain.
The Interpersonal Nature of Pain

Various theoretical models have depicted the interplay among social, biological, and psychological factors that affect the pain experience (Craig, 2014). In the pediatric context, it is imperative to examine the influence of caregivers on pain in children (Birnie, Boerner, & Chambers, 2013; McGrath, 2008). Craig’s (2009) Social Communication Model of Pain considers intrapersonal (e.g., biology, life experience) and interpersonal factors (e.g., social context in which pain occurs) that the suffering individual and observers bring to the pain experience. Consistent with this model, a framework recently suggested by McMurtry, Gorodzinsky, Chorney, & King (in preparation) considers parent and child historical factors (e.g., experience with the pain context), coping strategies, and internal experience that affect procedural interactions, and posits bidirectional communication between parent and child occurring through various pathways (e.g., facial, vocal, verbal, gestures). These verbal and nonverbal methods of communication are influenced by internal physiological activity and regulation (McMurtry, 2013).

The Affective-Motivational Model of Interpersonal Pain Dynamics has been recently offered to integrate emotion and motivation factors that influence the effectiveness of caregiver behaviour (Vervoort & Trost, 2017). Both individuals in pain and observers hold proximal and distal goals, and in the observer, these goals can be categorized as other-oriented or self-oriented. Similarly, the observation of pain can elicit responses aimed towards others’ well-being (e.g., other-oriented) or towards personal well-being (e.g., self-oriented). In parents, attention to both self- and other-oriented goals is required, with the optimal response in acute pain contexts aligned with other-oriented goals (Vervoort & Trost, 2017). This response is largely facilitated
by emotion regulation\(^1\) (ER), which can target aspects of pain-related emotion (e.g., cognitions, response tendencies, physiological responses, observable behavioural responses, emotional states; Vervoort & Trost, 2017). However, it remains unclear which emotion regulation strategy is most effective and under what conditions. These models point to the importance of considering the behaviours and experiences (emotional, internal) of relevant observers (e.g., parents) to understand and effectively manage pediatric pain.

**Parent-Child Interactions During Painful Medical Procedures**

Parents can be a source of comfort and support for their child during painful medical procedures; however, parental presence and behaviour can sometimes be associated with negative child outcomes (Blount et al., 1989; Chambers, Craig, & Bennett, 2002; McMurtry, Chambers, McGrath, & Asp, 2010). Parents’ ability to be supportive can be compromised during procedures as a result of parents’ emotional experience (Karlsson, Englund, Enskär, & Rydström, 2014), and a focus within the pediatric literature has been to explore how parental behaviour affects child coping and distress during painful procedures (e.g., Blount et al., 1989, 1992; Chambers et al., 2002; Chorney et al., 2009; Cohen, Bernard, Greco, & McClellan, 2002; McMurtry et al., 2010; Moon, Chambers, & McGrath, 2011; Wright, Stewart, Finley, Raazi, 2014).

The relations between parent behaviour and child pain outcomes have been investigated using correlational (e.g., Chorney et al., 2009), experimental (e.g., McMurtry et al., 2010), and sequential (e.g., Blount et al., 1989) methodologies. They have been examined during various medical procedures, such as venipunctures (McMurtry et al., 2010), immunizations (Pedro,

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\(^1\) Emotion regulation involves a process to alter the type, intensity, and duration of emotional experience (Gross & Thompson, 2007).
Barros, & Moleiro, 2010), bone marrow aspirations (Cline et al. 2006), dental procedures (Zhou & Humphris, 2014), and laboratory-induced pain (Moon et al., 2011). A recent systematic review examining adult-child interactions during medical procedures found that the most common aspect of the interaction captured was verbal content (98%), followed by gestures (73%; McMurtry et al., in preparation). Physiological indices were included in 9% of the studies examined (n = 5), although only 2% (n = 1) examined parents’ physiological response (McMurtry et al., in preparation). Thus, parents’ physiological response to witnessing their child in pain has largely been understudied, despite its hypothesized role in supporting both verbal and non-verbal responses (McMurtry, 2013).

Observing others in pain activates a threat detection system, which typically results in an automatic aversive response in observers (Yamada & Decety, 2009). Indeed, parents often experience distress and increases in physiological response when viewing their child in pain (Kain et al., 2003; Smith, Shah, Goldman, & Taddio, 2007). Parent distress and catastrophizing about child pain have been linked to greater pain attending behaviours and poor child outcomes (e.g., pain, distress; Caes, Vervoort, Eccleston, Vandenhende, & Goubert, 2011; Goubert, Eccleston, Vervoort, Jordan, & Crombez, 2006). Poor management of negative emotional states has two important implications for the effectiveness of caregiving behaviours: it may increase parents’ self-oriented response (e.g., goal is to reduce distress in the self) and it may be communicated to their child (McMurtry et al., in preparation; Vervoort & Trost, 2017). The cardiovascular system, including measures of heart rate (HR) and heart rate variability (HRV; variation in time between consecutive heartbeats), are commonly examined as physiological correlates of emotional experience and regulation (Appelhans & Luecken, 2006; Constantin, McMurtry, & Bailey, 2016). HR is often examined as a general index of physiological arousal,
and changes in HR from resting is indicative of emotional reactivity towards a stimulus (see Kreibig, 2010 for a review). HR has been included as a measure of observer distress in both acute (Kain et al., 2003; Smith et al., 2007; Vervoort, Trost, Sütterlin, Caes, & Moors, 2014) and chronic pain contexts (Monin et al, 2010). The association between HRV and emotional responding is described in greater detail below. Examining parents’ HR and HRV during parent-child interactions is important given that parents who regulate their own reactions effectively can better respond to their child’s needs (Constantin et al., 2016; Goubert et al., 2005; Perlman, Camras, & Pelphrey, 2008).

**The Autonomic Nervous System and the Vagus Nerve**

The autonomic nervous system (ANS) regulates vital organs of the body, including the heart, and is divided into the sympathetic nervous system (SNS, responsible for energy mobilization) and parasympathetic nervous system (PNS, responsible for restorative functions; Porges, 2003). During periods of safety and stability, the PNS maintains a lower state of physiological arousal as a result of the vagus nerve (Porges, 2003). More specifically, parasympathetic effects decrease heart rate and increase the length between consecutive heartbeats (Thayer, Ahs, Fredrikson, Sollers, & Wager, 2012). In contrast, during states of stress, the sympathetic nervous system (SNS) is activated which increases heart rate and decreases the length between consecutive heartbeats through decreases in vagal activity (Porges, 2003; Thayer et al., 2012). The heart receives input from both the SNS and PNS, which influence heart activity at different speeds (Lane et al., 2009). The sympathetic effects on the heart are relatively slow (i.e., time scale of seconds), while the parasympathetic effects are fast (i.e., time scale of milliseconds) and capable of changing the time between consecutive heartbeats (i.e., heart rate variability; Appelhans & Luecken, 2006; Lane et al., 2009; Thayer et al., 2012). Two naturally
occurring fluctuations in heart rate can be separated into frequency bands: low frequency (0.04-0.15 Hz) and high or respiratory frequency, also known as respiratory sinus arrhythmia (RSA; 0.15-0.40 Hz; Berntson et al., 1997). RSA is largely mediated by parasympathetic activity, whereas the low frequency component is mediated by both the SNS and PNS (Porges, 2007). Moreover, parasympathetic influences on the heart through the vagus are affected by the respiratory cycle (Segerstrom & Nes, 2007). That is, increases in vagal efference occur during exhalation and decelerate heart rate, while decreases in vagal efference occur during inhalation and accelerate heart rate (Beauchaine, 2001). RSA can be used as an index of HRV resulting from parasympathetic input, and high RSA is indicative of greater (high frequency) HRV (Beauchaine, 2001). To describe previous research, the term HRV will be used throughout this paper to refer to vagally-mediated HRV or high frequency HRV (see Appendix A for HRV parameter details).

According to Porges’ polyvagal theory (1995, 2007), the human ANS evolved in three stages, and each plays a unique role in supporting social processes. The first two systems are responsible for fight, flight, and freeze behaviours. The most recent is the social communication system and is dependent on the ventral vagal complex (VVC), a fast-acting, myelinated vagus nerve that can rapidly activate or prevent its inhibitory influence on cardiac activity (Porges, 1995). The VVC has been labelled the “vagal brake” through its control of cardiac output via the sinoatrial node of the heart; activity of the VVC can result in mobilization by increasing sympathetic activity (i.e., withdrawal of vagal brake), or in self-soothing and calm behavioural states by inhibiting sympathetic influences (i.e., applying the vagal brake; Porges 2007). Signals from the vagus nerve originate in the nucleus ambiguus and exert inhibitory effects on the heart, while vagal afferent fibers originating in the heart provide information to the brain regarding
visceral state (Porges, 2003, 1995). Thus, the vagus can be described as a neural system that engages in bidirectional communication between the peripheral and the central nervous system (Porges, 2003). In examining HRV (particularly at the high frequency or RSA), we are aiming to distally index the functioning of the vagus nerve, given its association with various neural circuits.

**HRV and Social Engagement**

As outlined in the social communication model of pain, one main role of caregivers is to decode children’s pain expression, and this ability may be linked to vagal tone (Craig, 2009, 2014; Porges, 2007). The vagus is anatomically linked to neural structures that control socially relevant behaviours, such as facial expression, head turning, vocalization, and listening (Porges, 2007; Porges et al., 2013). This social engagement system includes two components: (1) special visceral efferent pathways that control the striated muscles of the face, neck, and head; and (2) the myelinated vagus that regulates the heart and bronchi (Porges, 1995, 2007). These two components are linked by interneuronal connections in the nucleus ambiguus, which forms the face-heart connection linking social behaviour to autonomic function (Porges et al., 2013). The social engagement system largely determines emotional expression and the quality of communication. Specifically, the social engagement system functions best in a safe environment, when defense circuits (i.e., fight, flight, freeze behaviour) are inhibited (Porges, 2007). When the defense circuits are activated and threat is perceived, the social engagement system cannot be easily accessed (Porges, 2003). Functioning of the social engagement system parallels vagal influences to the heart, with high resting HRV indicative of calm states and better capacity to access this system (Porges et al., 2013). Therefore, in the pediatric pain context, parents who perceive painful medical procedures as threatening (indexed by changes in HRV from resting to
anticipating child pain) may have difficulties accessing their social engagement system. This is likely to lead to maladaptive parent-child interactions and greater self-oriented responses if decreases in HRV are extreme or do not return to baseline following the discontinuation of threat (Constantin et al., 2016).

**HRV and Appraisal of Threat and Safety**

The neurovisceral integration model posits various cortical and subcortical structures are reciprocally involved in regulating emotional, autonomic, and cognitive processes (Thayer & Lane, 2000), including the prefrontal-subcortical inhibitory circuits (Thayer et al., 2012). The prefrontal cortex supports purposeful and goal-oriented behaviour by controlling subcortical regions, such as the amygdala, that are associated with threat-oriented responses and fear behaviour (Park & Thayer, 2014; Thayer et al., 2012). At rest, the prefrontal cortex inhibits threat responses in the amygdala, and output from this network is transmitted to the sinoatrial node of the heart via the vagus nerve; thus, the model suggests HRV may distally index the functioning of this circuit (e.g., higher prefrontal cortex functioning = higher HRV; Thayer, Hansen, Saus-Rose, Johnsen, 2009; Thayer & Lane, 2000). Indeed, individuals with anxiety disorders experience excessive apprehension and fear in response to their perceptions of threatening stimuli, they have difficulties directing attention away from perceived threat, and they also have lower resting HRV (Aldao & Mennin, 2012; Chalmers, Quintana, Abbott, & Kemp, 2014).

Catastrophizing is described as a tendency to focus on (i.e., ruminate) and exaggerate (i.e., magnify) the threat value of painful stimuli, and negatively evaluate one’s ability to manage such pain (i.e., helplessness; Sullivan et al., 2001). Parents high in pain catastrophizing are likely to appraise child procedural pain as threatening, which results in higher levels of parent distress.
(Caes et al., 2014; Goubert, Vervoort, Sullivan, Verhoeven, & Crombez, 2008). Catastrophizing about child pain is commonly found in parents with high levels of anxiety (Esteve, Marquina-Aponte, & Ramirez-Maestre, 2014; Goubert et al., 2006) and contributes to increases in child-reported fear, postsurgical pain intensity following elective surgery, parent distress, parent fear, and parents’ estimates of child pain (Caes et al., 2014; Esteve et al., 2014; Rabbits, Groenewald, Tai, & Palermo, 2015; Vervoort et al., 2011). The relations between parent catastrophizing about child pain and maladaptive parent and child outcomes have been found in various pain contexts, including lumbar punctures, bone marrow aspirations, finger pricks, and following elective outpatient surgery (Caes et al., 2014; Esteve et al., 2014; Rabbits et al., 2015; Vervoort et al., 2011). Individuals with lower levels of resting HRV are likely to have a predisposition to threat appraisal (Thayer et al., 2012), thus parents with low resting HRV may be especially vulnerable to catastrophizing about child pain, although this link has not been examined in published research.

**HRV and Emotion Regulation**

According to both the polyvagal theory (Porges, 1995; Porges, Doussard-Roosevelt, & Maita, 1994) and the neurovisceral integration model (Thayer & Lane, 2000), measures of HRV can inform our understanding of individuals’ emotional expression and regulation (Appelhans & Luecken, 2006). Two hypotheses have been offered regarding the association between HRV and emotional responding (Butler, Wilhelm, & Gross, 2006). First, resting HRV is indicative of individual differences in the capacity for ER, and second, HRV changes within a person are indicative of current self-regulatory efforts and emotional experience (Butler et al., 2006; Frazier, Strauss, & Steinhauer, 2004; Porges, 1995; Thayer & Lane, 2000). Thus, the link between HRV and ER can be examined at two levels of analysis: the trait or tonic level (i.e.,
resting) and the state or phasic level (i.e., reactivity; Thayer et al., 2012). Although these two indices can be correlated, they are distinct constructs and differentially linked to emotional responding (Cribbett, Williams, Gunn, & Rau, 2011; Salomon, 2005).

**Between-Person Differences in Resting HRV**

High resting HRV is associated with adaptive functioning of the prefrontal-subcortical inhibitory circuits responsible for flexible emotional responding, whereas low resting HRV is linked to hypoactivation in prefrontal regions and hyperactivation in subcortical regions, leading to maladaptive ER (Thayer et al., 2009). In adults, lower levels of resting HRV have been linked to a variety of psychopathologies that are associated with poor emotional and social functioning (e.g., anxiety disorders, depressive disorders; Chalmers et al., 2014; Harris, Sommargren, Stein, Fung, & Drew, 2014). In healthy adults, low resting HRV has been linked to negative affect (Bleil, Gianaros, Jennings, Flory, & Manuck, 2008), emotional lability (Koval et al., 2013), disinhibition (Koenig, Kemp, Feeling, Thayer, & Kaess, 2016), and higher trait and state levels of anxiety (Friedman, 2007). In contrast, high levels of resting HRV are linked to higher positive affect (Koval et al., 2013; Oveis et al., 2009), use of engagement coping strategies (e.g., self-soothing, support seeking; Geisler, Kubiak, Siewert, & Weber, 2013), greater subjective well-being (i.e., better mood, satisfaction with life; Geisler, Vennewald, Kubiak, & Weber, 2010; Geisler et al., 2013), and higher levels of compassion (Stellar, Cohen, Oveis, & Keltner, 2015). High resting HRV in parents is predictive of greater emotionally supportive behaviours (e.g., validating, teaching, expressive encouragement) while responding to children’s negative emotions (Blandon, 2015; Perlman et al., 2008).
Within-Person Differences in HRV Reactivity

Generally, increases in HRV are posited to reflect positive mood states and occur when an individual is relaxed, whereas decreases in HRV reflect negative mood states and occur when responding to a stressor (Porges, 1995; Salomon, 2005; Thayer & Lane, 2000). However, whether increases or decreases in HRV indicate self-regulatory effort may depend on the extent to which the context is perceived as threatening (Park, Vasey, Van Bavel, & Thayer, 2014). Decreases in HRV are posited to be an autonomic and adaptive response to stress, and have been observed in individuals exposed to negative and stressful video clips (El-Sheikh, Hinnant, & Erath, 2011; Frazier et al., 2004), a mental stress test (Houtveen, Rietveld, & De Geus, 2002; Segerstrom & Nes, 2007; Weber et al., 2010), and during worry and fear (Thayer, Friedman, & Borkovec, 1996). Similarly, mothers who are high in sensitivity to child distress experience decreases in HRV while soothing their child following an emotionally challenging procedure (Moore et al., 2009). Alternatively, increases in HRV are hypothesized to indicate self-regulatory effort (i.e., greater prefrontal cortex activity) while engaging in ER or inhibitory behaviour in low-threat contexts. To illustrate, increases in HRV were detected when participants were instructed to eat carrots (i.e., requiring self-control or self-restraint) compared to those participants instructed to eat cookies (Segerstrom & Nes, 2007). Additionally, participants instructed to use ER strategies that require regulation of thoughts (reappraisal) or behaviours (suppression) showed increases in HRV compared to controls (i.e., instructed to interact normally; Butler et al., 2006), although variations in phasic HRV have also been shown to occur as a result of the specific ER strategy utilized (Denson, Grisham, & Moulds, 2011).

To summarize, moderate decreases in HRV in a high threat situation and moderate increases in HRV in a low threat situation requiring self-regulation (or engagement of the
prefrontal cortex) are hypothesized to indicate adaptive emotional responding. Absence of a change in HRV is indicative of a lack of engagement (emotional, cognitive). Further, decreases in HRV when no threat is present (e.g., as is common with anxiety disorders), is a maladaptive emotional response (Chalmers et al., 2014). Lastly, specific emotion regulation strategies are posited to relate to differential changes in HRV (Denson et al., 2011).

**Emotion Regulation Strategies**

Two extensively studied ER strategies include cognitive reappraisal and expressive suppression (Gross & John, 2003). Cognitive reappraisal involves changing the way one thinks about an emotion-inducing stimulus, while expressive suppression involves changing the way one behaves in response to an emotion-inducing stimulus (e.g., inhibiting emotional expression; Gross, 1998). Generally, cognitive reappraisal has been linked with better affective (e.g., experience and express more positive emotions), social (e.g., sharing emotional experience), and physiological (e.g., lower HR) functioning compared to expressive suppression (Cutuli, 2014; Denson et al., 2011). Further, reappraisal and its neural correlates have been linked to increased HRV in response to various emotion-inducing stimuli (Butler, 2006; Denson et al., 2011; Lane et al., 2009; Volokhov & Demaree, 2010). Similarly, high resting HRV predicts the use of reappraisal in response to viewing negatively valenced films compared to emotion suppression (Volokhov & Demaree, 2010). Thus, the association between HRV and ER is likely bidirectional and further complicated by recent views on ER that posit context largely determines which ER strategy is most adaptive (Aldao, 2013). However, it is unclear which strategies parents apply within the pediatric pain context (Vervoort & Trost, 2017), and how it is associated with parent HRV and distress.
HRV and Pain

A recent systematic review highlights the importance of HRV in the pain experience (Koenig, Jarczok, Ellis, Hillecke, & Thayer, 2014). In healthy adults, HRV differentiated categories of pain intensity (Treister, Kliger, Zuckerman, Aryeh, & Eisenberg, 2012), and high resting HRV has been associated with higher pain thresholds and lower pain unpleasantness (Appelhans & Luecken, 2008), whereas pain inductions have been linked to decreases in HRV (Bendixen, Terkelsen, Baad-Hansen, Cairns, & Svensson, 2012). However, research has only recently begun to examine physiological responding in individuals beyond those experiencing pain (e.g., observing caregivers). This is important to explore given the role observers have in shaping the pain experience of children. Preliminary research has demonstrated that anticipating and viewing pain in others results in emotional distress in the observer, evidenced by self-report and physiological measures (Caes et al., 2012; Franck, Allen, Cox, & Winter, 2005; Goubert et al., 2005). For example, increases in heart rate have been found in caregivers witnessing their child’s induction of anesthesia (Kain et al., 2003), and intravenous cannulation (Smith et al., 2007). Further, these increases in HR have been positively associated with children’s preoperative anxiety during anesthesia induction (Kain et al., 2003) and distress following a venipuncture (Smith et al., 2007); these associations are likely to be bidirectional.

To date, only one study has examined parent HRV in the context of pediatric pain (Vervoort, Trost, Sütterlin, Caes, & Moors, 2014). Parents’ HR and HRV reactivity were examined as indices of distress regulation during an attention manipulation task, and prior to their child’s completion of the cold pressor task (CPT). During this task, parents viewed pictures of other people’s children (i.e., who had previously completed the CPT) exhibiting varying levels of pain facial expressions, ranging from no pain or neutral to high pain expression. Parents were
instructed to either focus their eyes on the pain face (i.e., “attend to pain” group), or to focus on the neutral face (i.e., “avoid pain” group). This task differentially affected HR reactivity and self-reported distress depending on parental anxiety. That is, attending to child pain increased general arousal and self-reported distress in parents with low state anxiety, whereas the opposite occurred for parents with high state anxiety. The authors also demonstrated HRV decreased significantly from pre-viewing to post-viewing (Vervoort et al., 2014). Of note, physiological activity was only recorded during the attention manipulation task, and not while parents were interacting with their own child. The vagal system is posited to be more active during social interactions compared to film-viewing paradigms (Butler et al., 2006). Therefore, parents’ physiological activity may differ while they are interacting with their child in the context of acute pain.

**Current Study: Objectives and Hypotheses**

The purpose of the present study was to add to the understanding of parent emotional experience and correlates in the context of their child’s pain. Specifically, we sought to clarify the links between parent physiological activity, characteristics, and child pain outcomes using a cross-sectional design in a laboratory setting. Parents’ physiological activity (i.e., HR, HRV) was monitored during three different 2-minute time blocks: 1) during a neutral film clip (resting); 2) immediately prior to the child’s cold pressor task (pre-CPT); and 3) following the child’s completion of the cold pressor task (recovery). Resting and phasic (i.e., pre-CPT – resting) HR and HRV were examined in relation to parent reported trait anxiety, ER strategies, emotional state (worry, upset, sadness), catastrophizing, and their child’s pain intensity, CPT-related fear, and pain tolerance. Guided by the current literature, the main objectives and hypotheses were as follows:
1. To examine how parent HR and HRV change from resting, to pre-CPT, and recovery.

Given that observing child pain is often viewed as distressing (e.g., Kain et al., 2003), it was hypothesized that parent HR would increase and HRV decrease from resting to pre-CPT. It was also hypothesized that both HR and HRV would return to resting levels during recovery.

2. Broadly, to examine the associations between parent physiological activity and measures of parent self-reported characteristics and states. Specifically:

   1) To investigate resting HRV as an index of ER capacity. It was hypothesized that high resting HRV would be related to lower trait anxiety, lower self-report of expression suppression and higher self-report of cognitive reappraisal as typical ER strategies (as seen in Cutuli, 2014; Friedman, 2007; Lane et al., 2009).

   2) To examine general HR (collapsing HR across resting, pre-CPT, recovery) as a measure of distress (as seen in Smith et al., 2007) in relation to parent self-reported states, including worry, upset, sadness, and catastrophizing about child pain. It was hypothesized that higher HR would be associated with higher state levels of worry, upset, sadness, and catastrophizing.

   3) To examine phasic (pre-CPT minus resting) HR and HRV as an index of emotional reactivity and current self-regulatory efforts, respectively. Consistent with previous research utilizing phasic HR as a measure of emotional distress (e.g., Vervoort et al., 2014), it was hypothesized that increases in HR from resting to pre-CPT would be associated with higher levels of parent worry, upset, sadness, and catastrophizing. Consistent with the polyvagal theory (Porges, 1995) and the neurovisceral integration model (Thayer & Lane, 2000), it was expected
that increases in HRV from resting to pre-CPT would be linked to lower levels of parent negative emotional state and catastrophizing about child pain.

3. To investigate resting and phasic (pre-CPT minus resting) HR and HRV as predictors of parent- and child-rated pain outcomes, and child pain tolerance. Given that greater resting and increases in phasic HRV promote adaptive social and emotional functioning (see Figure 1; Porges, 2003; Thayer & Lane, 2007), it was hypothesized that higher resting HRV, lower resting HR, and phasic increases in HRV would statistically predict lower levels of parent and child report of child pain intensity and fear, and greater levels of pain tolerance, whereas phasic increases in HR would predict poor child outcomes.

4. To investigate parent emotional states (worry, upset, sadness) as statistical predictors of child ratings of pain intensity, CPT-related fear, and pain tolerance. In line with research demonstrating negative child pain outcomes are associated with higher caregiver distress (e.g., Caes et al., 2011; Smith et al., 2007), it was hypothesized that high parental worry, upset, and sadness would statistically predict higher child reports of pain intensity and CPT-related fear, and lower pain tolerance.

5. To examine the interaction between resting HRV and parents’ catastrophizing about child pain as a predictor of parent ratings of child fear and pain intensity. Based on previous research (Rabbitts et al., 2015; Vervoort et al., 2011), it was hypothesized that low resting HRV would be more strongly related to high parental ratings of child fear and pain intensity in parents who are high (vs. low) in catastrophizing.
Methods

Participants

Approval for the current study was obtained from the Research Ethics Board at the University of Guelph (REB#16JN029). Healthy children between 7 and 12 years of age and a primary caregiver were recruited from the community via posters (e.g., libraries, event centres), advertisements (e.g., Kijiji, home school associations), and recruitment from community events. Phone calls were made from an existing contact list of previous participants from the Pediatric Pain, Health, and Communication Lab (PPHC) at the University of Guelph who had not previously participated in the CPT. Families interested in participating were scheduled an appointment time at their convenience.

Inclusionary criteria included the ability to speak, read, and write in English proficiently enough to answer questions. As outlined in the guidelines for the cold pressor task (von Baeyer, Piira, Chambers, Trapanotto, & Zeltzer, 2005), children were excluded if they had a history of: cardiovascular disorder, fainting or seizures, frostbite, Reynaud’s phenomenon, or had an open cut or sore on the hand to be immersed. Children were also excluded if they had a chronic pain condition or major developmental delays. This pilot study is part of a larger project examining verbal and non-verbal aspects of parent-child interactions. Only data related to parent physiological activity, self-reported experiences, and child pain outcomes are reported below. A priori power analyses were conducted for each analysis with alpha set at .05 and power set at .80. Twenty-one participants were needed to conduct the repeated measures ANOVA and 28 participants were required for correlation and simple regression analyses to detect a large effect (Cohen, 1992a). A minimum sample size of 40 parent-child dyads was required to detect a large effect using hierarchical multiple regression with four predictors (Cohen, 1992a).
**Apparatus**

**Cold Pressor Task (CPT).** The CPT (Appendix B) is a laboratory pain task that is used to induce mild to moderate levels of pain by having children submerge their hand and lower arm in cold water (von Baeyer et al., 2005). Water temperature in the cold water tank was maintained at 10°C (± 1°C) and the warm water tank was maintained at 36°C (± 1°C), using a Techne® thermoregulator. Children first washed their hands with soap, then submerged their non-dominant hand in the warm water for two minutes to create a standardized baseline. Next, they were instructed to immerse their hand in cold water, just above the wrist, and to leave it in for as long as they could. Children could remove their arm at any point, thus allowing complete control of the duration of the experience. Pain tolerance was measured by the length of time children keep their arm in the cold water, with a maximum submersion time of 4 minutes (an uninformed ceiling). The CPT allows standardization of the pain stimulus, including location, intensity, and ceiling duration (von Baeyer et al., 2005). Further, a laboratory design provides greater standardization and noise reduction for physiological recordings than is possible with clinical pain. Children’s response to the CPT is predictive of some clinical and real-world outcomes (e.g., acute complaints and school absences; Tsao, Glover, Bursch, Ifekwunigwe, & Zeltzer, 2002), and is most likely comparable to acute clinical pains lasting from a couple minutes to several hours (von Baeyer et al., 2005). This method has been deemed ethically acceptable by researchers, parents, and children and has a rate of adverse events of less than 0.07% (Birnie, Noel, Chambers, von Baeyer, & Fernandez, 2010).

**Electrocardiogram.** Parental HR and HRV activity was recorded throughout the three phases of the study: resting, pre-CPT, and recovery (Appendix C). Parents’ cardiac activity was derived from an electrocardiogram obtained using a BIOPAC™ MP150 unit and a wireless
BioNomadix ECG amplifier acquiring data at 1000 samples per second. Electrodes were placed in a standard Lead II configuration (i.e., an electrode below each collar bone and one ground below the left rib, in an inverted triangle configuration). Data were transmitted to the computer using AcqKnowledge 4.2 software, which was programmed to identify interbeat intervals (IBIs; i.e., time between consecutive heart beats) within the ECG recording. Data were then imported into Kubios HRV specialized analysis software (Standard; version 3.0). HRV guidelines (Berntson et al., 1997; Camm et al., 1996) and the Kubios HRV User’s Guide (Tarvainen, Lipponen, Niskanen, & Ranta-aho, 2017; Tarvainen, Niskanen, Lipponen, Ranta-aho, & Karjalainen, 2014) were followed to quantify HRV.

**Video.** Consistent with previous research (e.g., Paret, Bailey, Roche, Bureau, & Moran, 2015), a neutral film clip was used to acquire resting HR and HRV data. A 2-minute National Geographic Time-Lapse video from YouTube was selected (https://youtu.be/9d8wWcJLnFI).

**Procedure**

Upon arrival to the lab, parent and child were provided with a brief overview of the study before providing parent consent and child assent. One research assistant obtained parent consent, while a second research assistant obtained child assent. Parents were then fitted with the physiological recording equipment and completed the demographic form, State-Trait Anxiety Inventory-Trait, Pain Catastrophizing Scale-Parents-state, and the Emotion Regulation Questionnaire (described in Measures section below). During this time, children played a game with the researcher and were given a juice box to drink prior to completing the CPT, which is recommended to lower the risk of fainting (von Baeyer et al., 2005).
Resting

The first block of the study required parent and child to sit and watch the 2-minute National Geographic Time-Lapse. Next, parents rated their arousal and emotional valence in response to the clips using the Self-Assessment Manikin to determine whether parents viewed the video as neutral. Children washed their hands in preparation for the CPT.

Pre-CPT and CPT

Participants were informed that when the researcher left the room, the CPT would begin once they heard a knock on the window. This knock signaled the child to immerse his/her hand into the warm tank for two minutes. Parent physiological activity was examined during this two-minute interval (i.e., pre-CPT). A second knock on the window informed the child to immerse his/her hand into the cold water bath (CPT; physiological activity was not examined during this block). Throughout, parents were instructed to interact with their child as they normally would. Once the child voluntarily removed his/her arm from the water or the maximum time limit was reached, a researcher recorded the child’s pain tolerance (in seconds) and re-entered the room to complete the final phase of the study.

Recovery

Following the CPT, parent and child completed the Children’s Fear Scale and the Faces Pain Scale-Revised. Parents also completed the Numerical Rating Scales of parent worry, upset, and sadness. Following completion of the questionnaires, parents’ physiological activity was recorded for an additional two minutes while parent and child interacted as usual (defined as the recovery time block).

Next, the physiological equipment was removed, and the participants were given a copy of the consent form. Children received a small toy as a thank you for their participation.
Measures

**Demographics.** Data regarding age, sex, language, ethnic and cultural identity were collected through a demographic information form (Appendix D). Parents also rated their child’s usual response to painful procedures using a numerical rating scale (0 = negative reaction; 10 = positive reaction). Questions were also included to examine parental caffeine and nicotine intake, and cardioactive medication use, as recommended by Quintana and Heathers (2014) when examining cardiac activity.

**State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983).** The STAI (Appendix E) is a 40-item measure of how anxious a person feels at this moment (STAI-State) and a person’s general predisposition to be anxious and perceive situations as threatening (STAI-Trait). Only the STAI-T was used. This scale includes 20 items, with 10 anxiety absent items (e.g., “I am calm”) and 10 anxiety present items (e.g., “I feel nervous and restless”). Items are rated on a 4-point Likert-type scale, ranging from 1 (almost never) to 4 (almost always). Scores can range from 20 to 80, with higher scores indicative of greater anxiety. The STAI-T demonstrates construct validity, internal consistency in clinical and non-clinical samples, and test-retest reliability over a two-month interval (Balsamo et al., 2013; Spielberger et al., 1983).

**Pain Catastrophizing Scale for Parents (PCS-P-state; Durand et al., 2016).** The PCS-P-state (Appendix F) was used as a measure of parents’ catastrophizing thoughts about their children’s pain related to the CPT. The general PCS-P 13-item measure does not specify the context in or painful stimuli regarding which the catastrophizing about child’s pain occurs (Goubert, Vervoort, Cano, & Crombez, 2009). Thus, as is recommended for acute procedural pain and consistent with previous research (Caes et al., 2014; Goubert et al., 2009; Vervoort et
al., 2011), a situation-specific measure was used. Consistent with the methods outlined by Durand et al. (2016), one item that in previous research loaded highly on its respective factor was used from each subscale of the PCS-P, including rumination (“At this moment, to what extent do you keep thinking about how much pain your child might experience during the cold pressor task?”), magnification (“At this moment, to what extent do you think something serious might happen to your child because of the pain?”), and helplessness (“At this moment, to what extent do you think you will not be able to endure the cold pressor task, because of the pain of your child?”). Items are rated on an 11-point numerical rating scale ranging from 0 (not at all) to 10 (very much), and scores can range from 0 to 30. The PCS-P-state was administered before children completed the CPT, thus measuring parents’ catastrophizing thoughts about their child’s upcoming pain. The full PCS-P demonstrates construct validity (Goubert et al., 2006), predictive validity, and Cronbach’s alpha for the PSC-P-state has been found to range from .80 to .86 (Caes et al., 2014; Durand et al., 2016; Goubert et al., 2009; Vervoort et al., 2011).

Emotion Regulation Questionnaire (ERQ; Gross & John, 2003). The ERQ (Appendix G) is a 10-item measure that examines typical use of two emotion-regulation strategies: cognitive reappraisal (“I control my emotions by changing the way I think about the situation I’m in”) and expressive suppression (“I control my emotions by not expressing them”). Items are rated on a 7-point Likert-type scale ranging from 1 (strongly disagree) to 7 (strongly agree). Scores on the cognitive reappraisal subscale can range from 6 to 42 and scores on the expressive suppression scale from 4 to 24. Higher scores are indicative of greater levels of reappraisal and suppression. The ERQ demonstrates internal consistency, test-retest reliability over a three-month interval, and construct validity (Gross & John, 2003).

Self-Assessment Manikin (SAM; Morris, 1995). The SAM (Appendix H) was used to
measure valence and arousal in response to the video presented during the resting block. The scales range from 1 (happy, stimulated) to 9 (unhappy, relaxed), and a score is provided for both dimensions.

**Children’s Fear Scale (CFS; McMurtry, Noel, Chambers, & McGrath, 2011).** The CFS (Appendix I) is a one-item measure of children’s fear during a painful procedure. The scale includes a row of five sex and age neutral faces, and the rater must indicate which face matches his/her level of fear, ranging from 0 (no fear) to 4 (extreme fear). In the original work, the CFS demonstrated interrater reliability and temporal stability (for a single procedure) over a two-week period, as well as construct validity (McMurtry et al., 2011). Further, a recent clinical practice guideline recommended the use of the CFS when assessing for children’s pain-related fear during vaccinations (Taddio et al., 2015), and the CFS has also been used in the context of the CPT (e.g., Boerner, et al., 2015; Noel, Chambers, McGrath, Klein, & Stewart, 2012). Parents also completed the CFS in order to provide a rating of how much fear they believe their child experienced.

**Faces Pain Scale-Revised (FPS-R; Hicks, von Baeyer, Spafford van Korlaar, & Goodenough, 2001).** The FPS-R (Appendix J) is a one-item measure of children’s pain intensity, ranging from no pain to severe pain. This measure consists of six facial expressions, and can be rated on a scale of 0 (no pain) to 10 (very much pain). Children are asked to identify the face that reflects their pain experience. The FPS-R is an appropriate measure of procedure-related pain for children aged 4 to 12 years of age (Hicks et al., 2001; Stinson, Kavanagh, Yamada, Gill, & Stevens, 2006). The FPS-R demonstrates test-retest reliability and construct validity, with strong positive correlations with a visual analogue scale of child pain ($r = .93$; Hicks et al., 2001). This scale has been recommended by a recent clinical practice guideline (Taddio et al., 2015), and for
use in clinical trials as a self-report measure of pain (Stinson et al., 2006). Parents also completed the FPS-R in order to provide a rating of how much pain they believed their child was feeling (as seen in Boerner et al., 2015).

**Numerical Rating Scale (NRS).** To assess parent specific emotions or emotional state in response to their child’s completion of the cold pressor task, parents provided ratings indicating their level of worry, upset, and sadness (Appendix K). The rating system consists of an 11-point numerical rating scale, ranging from “not at all” (score of 0) to “extremely” (score of 10). Although these emotion adjectives have been combined into a composite distress score in previous research (e.g., Batson, Fultz, & Schoenrade, 1987; Caes et al., 2011; Vervoort et al., 2014), these emotions have been shown to be associated with different patterns of physiological responding (Kreibig, 2010; Thayer et al., 1996) and thus were examined separately in the current study.

**Results**

**Analytic Strategy**

As a result of difficulties with recruitment and timeline for completion of the master’s, the total sample size of the study included 29 dyads, rather than the desired sample size of 40 parent-child dyads. In addition to describing findings in terms of traditional statistical significance testing, results will also be discussed using effect sizes and 95% confidence intervals (CI). Effect sizes for correlations are reported based on Cohen’s conventions (1992b). Correlations representing moderate effects (i.e., $r \geq .30$) will be highlighted given the reduced power. Of the 29 parent-child dyads, three parents participated with more than one child and thus were excluded from the analyses. One participant who had consumed nicotine two hours prior to the visit and was taking cardioactive medication was excluded from all analyses due to extreme
HR and HRV values ($z_{skewness} = 1.49$ to $3.66$). Thus, the final sample consisted of 23 dyads for analyses. The demographic characteristics of the sample are presented in Table 1.

To test Hypothesis 1, three repeated measures ANOVAs were conducted to compare parent HR and HRV during resting, pre-CPT, and recovery. To examine Hypothesis 2, zero-order correlations were conducted to examine the relations between: 1) resting HRV, trait anxiety, and ER (i.e., reappraisal, suppression); 2) general HR and parent reported states (worry, upset, sad, catastrophizing); and 3) phasic (i.e., pre-CPT – resting) HR and HRV and parent reported states (worry, upset, sad, catastrophizing). Hypothesis 3 was explored by first conducting bivariate correlations between resting HR and HRV, phasic HR and HRV, parent and child ratings of child fear and pain intensity, and child pain tolerance. Significant correlations were further explored with simple regression analyses, entering physiological measures as predictors of child pain-related outcomes. To test Hypothesis 4, bivariate correlations between parent emotional state (worry, upset sad) and child rated pain intensity, fear, and child pain tolerance were conducted. Significant relations were followed up using multiple regression to predict child pain outcomes. Hypothesis 5 sought to examine the moderating effect of parent catastrophizing about child pain on the relation between resting HRV and parent-rated fear and pain intensity. However, given the small sample size and associated lack of power, moderation analyses were not conducted. Bivariate correlations were conducted instead to examine the associations among these variables.

As noted previously, a priori power analyses were conducted to determine the sample size required in each statistical analysis to detect a large effect at the .05 level with power set at .80. A sample of 21 participants was needed for the repeated measures ANOVA (i.e., Hypothesis #1; Cohen, 1992a). For correlations and simple regression (i.e., Hypothesis #2, #3, &
#4), 28 participants were needed. Finally, a minimum sample size of 40 parent-child dyads was required to conduct hierarchical multiple regression with three (i.e., Hypothesis #5) and four predictors (i.e., Hypothesis #4; Cohen, 1992a).

Data for all analyses were examined for violations of parametric assumptions. Continuous variables were assessed for normality using $z_{skewness}$ (skewness/$SE$), with any $z_{skewness}$ score $\geq 1.96$ considered significantly skewed at $p < .05$ (Field, 2013). Variables that were significantly skewed were examined using non-parametric analyses (e.g., Spearman’s rank correlations instead of Pearson’s). The within-subjects sphericity assumption for the one-way repeated measures ANOVA was verified using Mauchly’s test; when this assumption was violated, Mauchly’s test is reported. The assumption of normally distributed residuals, independent errors, and collinearity were verified in the regression analyses (Field, 2013).

Data Preparation

The software program Statistical Package for the Social Sciences (SPSS v. 24) was used to manually enter the raw data from the self-report and physiological measures (further information presented below). Before analyses were performed, the final database was screened for missing data ($n = 23$). The first five participants did not complete the STAI-Trait form given that this measure was added to the questionnaire package at a later time.

**ECG recordings.** Recordings were visually inspected for ectopic heartbeats; no participants breached the convention of 5% threshold for ectopic beats relative to total beats (Allen, Chambers, & Towers, 2011). A threshold-based artifact correction algorithm was used to correct visually identified artifacts, which replaces artifact beats using cubic spline interpolation (Tarvainen et al., 2014). As is recommended, the lowest possible correction level was selected for each data segment that required editing (Tarvainen et al., 2017). One waveform required
more than 10% of segment (i.e., recovery block) editing, and was excluded from analyses (Peltola, 2012). Two cardiac measures were derived including: HR to provide a measure of general autonomic arousal and emotional reactivity, and HRV as an index of current parent ER and ER capacity. HR and HRV scores were calculated for the resting, pre-CPT, and recovery blocks. Phasic measures of HR and HRV (represented by $\Delta = \text{change score}$) were also computed by subtracting a person’s average during resting from his/her average during pre-CPT (i.e., $\Delta = \text{pre-CPT} - \text{resting}$); thus, positive values reflect HR or HRV increases from resting to pre-CPT.

HR was quantified as beats per minute and HRV was quantified using both time- and frequency-domain methods. The time-domain measure (i.e., statistical calculation) of HRV was computed by the root mean square of successive differences (RMSSD) between R-R (i.e., interbeat) intervals\(^2\), which provides numerical estimates for HRV in milliseconds (Goedhart, Van der Sluis, Houtveen, Willemsen, & de Geus, 2007). RMSSD values were squared ($\text{ms}^2$) and natural-log (ln) transformed because values were skewed. The frequency-domain measure of HRV was computed based on the following procedure (Goedhart et al., 2007; Tarvainen et al., 2014). RR intervals were first detrended with a smoothness-prior method (i.e., high-pass filter) to remove the very low frequency component ($< 0.04 \text{ Hz}$). Next, power spectral density analysis was performed using the Fast-Fourier Transform (i.e., provides information on how the variance in HR is distributed as a function of frequency), with a high frequency (HF) band set at 0.15-0.40 Hz. HF-HRV was natural-log (ln) transformed because absolute values were skewed and are reported in squared milliseconds ($\text{ms}^2$; see Appendix L for summary of physiological measures).

It is a widely-held standard among physiological researchers to report the natural logarithm of

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\(^2\) R refers to the peak of the QRS complex [combination of the Q wave, R wave, and S wave] in the ECG wave.
HRV (e.g., Goedhart et al., 2007).

External factors that can influence HRV, such as caffeine and nicotine intake, and cardioactive medication use (e.g., antidepressants, antipsychotics, benzodiazepines, antihypertensives; Quintana & Heathers, 2014) were examined. Bivariate correlations revealed that these factors were unrelated to HR and HRV in the current sample.

Descriptive Statistics, Reliability of the Study Instruments, and Film Manipulation Check

Descriptive statistics and reliability estimates for the study measures are presented in Table 2. Internal consistencies of each measure were assessed by coefficient alphas and were considered acceptable if they were above the threshold of .70 (Nunnally, 1978). All measures demonstrated acceptable levels of internal consistency, except for the PCS-P (α = .52). Although not uncommon for scales with a small number of items, it is lower than what has been previously found (e.g., Durand et al., 2016). Thus, findings from the PCS-P-state should be interpreted with caution. The PCS-P-state (zSkewness = 2.06), parent ratings of child fear (zSkewness = 3.62), parent ratings of upset (zSkewness = 4.10) and sadness (zSkewness = 5.33) exceeded the recommended z-score cutoff of 1.96 for skewness (Field, 2013).

Means, standard deviations, and the range of HR and HRV measures are presented in Table 3. Descriptive statistics for the phasic measures of HR and HRV are reported in Table 4. Phasic RMSSD (zKurtosis = 2.22) was greater than the z-cut-off of 1.96 for kurtosis (Field, 2013). Similar to past research (e.g., Werner et al., 2015), participants rated the film clip neutral to slightly positive (M = 3.35, SD = 1.27), and relaxing (M = 6.87, SD = 1.66). Bivariate correlations indicated parent ratings of children’s typical reaction to painful medical procedures (M = 4.60, range = 0 to 9.5; 0 = negative reaction, 10 = positive reaction) was moderately associated with resting HR (r = -.30, p > .05, 95% CI [-.53, .13]), HF-HRV (r = .32, p > .05,
95% CI [-.11, .65]), and RMSSD ($r = .29, p > .05, 95\% \text{ CI} [-.14, .63])

**Objective 1.1: Exploring HR Activity during Resting, Pre-CPT, and Recovery**

A one-way repeated measures ANOVA was conducted to examine differences in parent HR between the three different blocks of the laboratory visit. There was a significant effect of block on HR ($F(2, 42) = 14.03, p < .001$, partial $\eta^2 = .40$; see Figure 2). Post hoc tests using Tukey’s LSD revealed that HR pre-CPT was significantly higher than HR during resting ($M_{\text{difference}} = 4.51, SE = .95, p < .001, 95\% \text{ CI} [2.55, 6.48]$). Similarly, HR during recovery was significantly higher than HR during resting ($M_{\text{difference}} = 2.26, SE = .64, p < .01, 95\% \text{ CI} [.93, 3.59]$). Finally, HR during pre-CPT was significantly higher compared to during recovery ($M_{\text{difference}} = 2.26, SE = .94, p > .05, 95\% \text{ CI} [.31, 4.20]$). The three 2-minute blocks were broken down into 30 second intervals to plot the changes within each block and can be seen in Figure 3.

**1.2 Exploring HF-HRV and RMSSD Activity during Resting, Pre-CPT, and Recovery**

A one-way repeated measures ANOVA was conducted to examine differences in parent HF-HRV between the three blocks of the laboratory visit. There was a significant effect of time on HF-HRV ($F(2, 42) = 4.28, p < .05$, partial $\eta^2 = .17$; see Figure 4). Tukey LSD post hoc tests revealed that HF-HRV pre-CPT was not significantly different from HF-HRV during resting ($M_{\text{difference}} = -.32, SE = .19, p > .05, 95\% \text{ CI} [-.72, .08]$). Similarly, HF-HRV did not significantly change from pre-CPT to recovery ($M_{\text{difference}} = .17, SE = .16, p > .05, 95\% \text{ CI} [-.16, 0.51]$). However, HF-HRV during recovery was significantly lower than HF-HRV during resting ($M_{\text{difference}} = -.50, SE = .16, p < .05, 95\% \text{ CI} [-.83, -0.16]$).

A one-way repeated measures ANOVA was conducted to examine differences in parent RMSSD during the three different blocks of the laboratory visit. There was no significant effect of time on RMSSD ($F(2, 42) = .73, p > .05$, partial $\eta^2 = .03$; see Figure 5).
Objective 2.1: Examining the Associations between Resting HRV, Trait Anxiety, and Emotion Regulation

Pearson correlation coefficients and 95% CIs are reported in square brackets in Table 5. No significant correlations were reported between resting HF-HRV, RMSSD and trait anxiety and ER (i.e., cognitive reappraisal, emotion suppression); however, moderate effects were observed. Higher resting HRV (HF-HRV, RMSSD) was associated with lower trait anxiety, and higher HF-HRV was negatively related to expressive suppression. Correlations between self-report measures indicated trait anxiety was negatively associated with cognitive reappraisal.

2.2 Examining the Associations Between General HR, Emotional State (Worry, Upset, Sad), and Parent Catastrophizing about Child Pain

Correlation coefficients and 95% CIs are reported in square brackets in Table 6. Moderate to large negative effects were observed between general HR and parent worry, sadness, and upset. No significant associations were found between HR and catastrophizing about child pain. Catastrophizing demonstrated a strong positive association with worry, but it was not associated with parent upset or sadness.

2.3 Examining the Associations between Phasic HR and HRV, Emotional State (Worry, Upset, Sad), and Parent Catastrophizing about Child Pain

No significant correlations were observed between the phasic measures and parent state measures (see Table 6).

Objective 3: Resting and Phasic HR and HRV as Predictors of Child Pain, Fear, and Pain Tolerance

Correlation coefficients and 95% CIs are reported in Table 7. No significant correlations were observed, although a moderate effect was found as follows. Decreases in parent phasic
HRV (RMSSD) were associated with lower parent ratings of child fear. Given that no significant correlations were observed between the variables of interest, regression analyses were not conducted.

Correlation coefficients and 95% CIs are reported in Table 7. A positive association was found between parent ΔHR and child ratings of fear, such that increases in parent HR from resting to pre-CPT were associated with higher levels of child-rated fear.

**Objective 4: Regression Analyses Predicting Child Rated Pain, Fear, and Pain Tolerance Based on Parent Emotional State (i.e., Worry, Upset, Sad)**

Correlation coefficients and 95% CIs are reported in Table 8. Parent ratings of worry, upset, and sadness were not significantly related to child pain. Similarly, no significant findings emerged with child fear, although a moderate positive correlation emerged between parental upset and child fear. Finally, worry, upset, and sad were not significantly related to child pain tolerance. Given the previous pattern of findings, no regression analyses were conducted.

**Objective 5: Parent Catastrophizing about Child Pain as a Moderator Between Resting HRV and Parent Ratings of Child Pain and Fear.**

The moderation analyses could not be conducted given the small sample size, the low reliability of the catastrophizing measure, and the lack of significant correlations between both resting HF-HRV and RMSSD and parent ratings of child pain intensity and fear. However, correlation analyses between these variables indicated that parent catastrophizing about child pain was positively related to parent perception of child CPT-related fear ($r_s = .53$, 95% CI [.15, .77]).
Discussion

The goal of the current study was to contribute to existing knowledge of parent internal experience and correlates in context of their child’s acute pain. Specifically, this investigation aimed to: (1) examine how parent HR and HRV changes from resting, prior to child pain, and following child pain; (2) clarify how parent physiological activity is associated with parent self-reported trait characteristics and states; and (3) explore the relations between parent physiological activity and child pain outcomes. A further goal was to explore how parent self-reported emotional states and cardiac activity while anticipating their child’s pain would predict child pain outcomes. Understanding these relations can clarify parents’ emotional experience in the context of pediatric acute pain, and inform how they are regulating their emotions. This is the first investigation to examine both HR and HRV in parents in the context of an acute pain task, and the associations with parent traits, states, and child pain outcomes. Ultimately, the goal of this line of research is to contribute to existing models of pain and parent-child interaction frameworks and inform clinical practice to reduce parent and child distress during painful medical procedures.

Parent HR and HRV in the Context of Acute Pain

The first objective of this investigation sought to clarify how HR and HRV change over the three study blocks. As hypothesized and consistent with previous findings (e.g., Kain et al., 2003), parents demonstrated increases in HR from resting to immediately before their child’s cold pressor task, likely indicating emotional reactivity to the anticipation of their child’s pain. Following the CPT, parents’ HR did not return to resting and remained significantly higher compared to HR at rest. However, it is important to note that although parents did experience significant increases in HR compared to resting, their mean values were lower (e.g., 70 to 80
bpm) than what has been typically observed in clinical settings (e.g., 90 to 100 bpm; Kain et al., 2003, Smith et al., 2007). Thus, it is possible that parents did not perceive the CPT to be as threatening or distressing as a venipuncture or anesthesia induction.

Given that HRV has not been examined while parents are interacting with their child before and after acute pain, both frequency- and time-domain measures were examined. It was predicted that parent HRV would decrease from resting to pre-CPT, and return to baseline during recovery; this was partially supported. HF-HRV demonstrated a general trend of decreasing from resting, to pre-CPT, and to recovery, although significant differences were only observed when comparing HF-HRV during resting and recovery. A decrease in HRV is typically indicative of an autonomic response to stress; thus, decreases in parent HRV while anticipating child pain is consistent with our predictions. However, parent HR remained elevated and HRV lower during recovery when parent and child interacted normally, compared to resting. Of note, decreases in HRV does not necessarily indicate parents experienced negative emotions; indeed, previous findings have demonstrated decreases in HRV in response to both positive and negative film clips (Frazier et al., 2004). Vervoort and colleagues (2014) demonstrated similar decreases in parent HRV (both HF-HRV and RMSSD) from resting to post-viewing (i.e., after viewing neutral and pain faces of children other than their own). In contrast, our results only revealed a nonsignificant trend suggesting decreases in RMSSD from resting to recovery. This finding is surprising given the strong correlations observed between HF-HRV and RMSSD ($r = .79$ to $.89$) and research indicating both are equivalent indices of HRV (Goedhart et al., 2007). Thus, exploring these associations in a larger sample and utilizing other frequency-domain methods (e.g., autoregressive models) may help clarify the pattern of findings.
Parent HRV and HR in Relation to Self-Reported Parent Traits and States

A second aim of the study was to clarify how parent physiological activity is linked to parent self-reported trait characteristics and states in the acute pain context. It was hypothesized that high resting HRV would be linked to lower trait anxiety, expressive suppression and higher cognitive reappraisal. No significant associations emerged with reappraisal, although moderate negative trends were found between resting HRV and both trait anxiety and expressive suppression. These relations are in line with our predictions and current literature indicating higher resting HRV is associated with greater emotional well-being (e.g., Geisler et al., 2013; Thayer et al., 2012). Although not a primary goal of the current study, relevant findings emerged in examining the associations with the self-report trait measures. Trait anxiety was inversely related to cognitive reappraisal. This is consistent with research indicating reappraisal as a coping strategy that is generally associated with greater emotional well-being compared to suppression (Cutuli, 2014).

In examining the association between parent reported states and HR, it was hypothesized that higher general HR (i.e., collapsing across blocks) would be associated with higher state levels of worry, upset, sadness, and catastrophizing. Contrary to our hypothesis, parent HR was inversely related to parent levels of emotional state. That is, higher HR was associated with lower ratings of worry, upset, and sadness. This may be in part due to the temporal nature of the procedure, and that emotional states were measured following children’s completion of the CPT and once the threat and experience of their child’s pain had passed. Thus, parents with higher mean HR may have experienced greater relief following the CPT. Another potential explanation for this inverse association is that HR could be indicative of an empathic response from parents.

Correlations in which $r \geq .30$ were described in the results section.
(Mehrabian, Young, & Sato, 1998); research demonstrates that viewing others in pain tends to activate neural circuits associated with the emotional experience of pain (vs. sensory experience), which provides us with a basis for understanding how others feel during pain (Singer et al., 2004). Finally, the increase in HR may reflect general arousal associated with excitement and the dyad viewing the experience as a challenge rather than a threat (Kreibig, 2010). This notion is supported by the restricted range observed in parent ratings of emotions, particularly ratings of worry (range = 0 to 4) and sadness (range = 0 to 3). Relatedly, low HR may be associated with modest emotion endorsement whereas high HR may be associated with the denial of emotion, which may indicate parents with higher HR may lack insight into their own emotional experience. Having parents rate positive (e.g., excitement, empathy) and negative emotions at multiple time points (e.g., at rest, before pain, following pain) in future research, may further clarify these associations.

Phasic measures of parent HR and HRV (i.e., pre-CPT minus resting) were also examined in relation to parent reported states. It was predicted that increases in HRV from resting would be related to lower levels of parent worry, upset, sadness, and catastrophizing about child pain, while increases in HR from resting to pre-CPT would be associated with higher levels of parent negative emotional states. No significant relations were observed between parent phasic HR and HRV and reported states, which is surprising considering phasic measures are posited to reflect current emotional responding. The association between parent resting HR and children’s typical response to painful medical procedures may help to clarify this finding. Specifically, parents who rated children’s response to painful procedures as negative (vs. positive) had higher HR at rest. Thus, parents who are likely to experience greater distress during child pain (e.g., based on children’s typical response to pain) may present with a heightened state
of physiological arousal at rest and may therefore not experience significant changes in arousal before the procedure. This highlights the importance of viewing parent physiological responding and child pain experiences as a bidirectional association, and taking into consideration previous pain experiences.

The pattern of relations between the self-reported states revealed that, consistent with extant literature (e.g., Caes et al., 2011, 2014), parent catastrophizing about child pain prior to their child’s CPT was significantly and strongly related to higher levels of parent worry, although not entirely overlapping ($r = .50$). Catastrophizing was unrelated to upset and sadness, which is consistent with the notion that worry, sadness, upset and catastrophizing are distinct constructs.

**The Association Between Parent HR and HRV in Relation to Child Pain Outcomes**

To clarify whether parent internal experience and regulation are related to child pain outcomes, resting and phasic HR and HRV were examined in relation to parent- and child-ratings of pain intensity, CPT-related fear, and pain tolerance. It was predicted that higher resting HRV and low resting HR, and increases in HRV from resting to pre-CPT, would be associated with lower levels of pain intensity and CPT-related fear (child, parent report), and greater levels of pain tolerance, whereas the opposite pattern would emerge with increases in HR. Various moderate effects were present and partially in line with our hypotheses.

First, parents who experienced greater increases in HR from resting to pre-CPT had children who provided higher ratings of fear. This is consistent with our hypothesis that increases in HR while parents anticipate child pain would be associated with poorer child pain outcomes and is in line with other findings (Kain et al., 2003). This, in addition to the findings above, speaks to the importance of considering both resting and phasic HR, and their relevance in
capturing different aspects of parent internal experience. With respect to HRV and child pain outcomes, trends emerged with parent ratings of child fear. Decreases in phasic HRV (RMSSD) were associated with lower parent ratings of child fear. Relevant to note are the floor effects that were observed with both parent and child ratings of fear, suggesting the procedure was not viewed as highly fear-inducing and that high scores reflect moderately experienced emotion.

**Parent Emotional States and Child Pain Outcomes**

The fourth objective of the study sought to explore the hypothesis that higher parent emotional states (worry, upset, sad) would predict higher child reports of pain intensity and CPT-related fear, and lower pain tolerance. Contrary to what was predicted, parent emotional states were not significantly correlated with child ratings of pain intensity, fear, or pain tolerance, although moderate effects were present. Parental ratings of upset were associated with child fear, which is in line with past research demonstrating an association between aspects of emotional distress and child pain outcomes (e.g., Caes et al., 2014). However, caution is warranted given the range restriction in both ratings of fear and upset. These findings lend support to the examination of parent worry, upset, and sadness separately in this context, given the differential associations with parent emotions and child fear.

**The Relations between Parent Resting HRV, Catastrophizing about Child Pain, and Parent Rated Child Pain and Fear**

The final objective sought to explore parent catastrophizing as a moderator between resting HRV and child pain outcomes; however, given the small sample size and the lack of association between HRV and child pain outcomes, moderation analyses were not conducted. Correlation analyses revealed parents high in catastrophizing perceived their child to be more fearful during the CPT. This finding is consistent with and contributes to research demonstrating
parent catastrophizing about their child’s pain is positively associated with their own fear and their child’s report of fear (Vervoort et al., 2011).

**Strengths, Limitations, and Methodological Considerations**

A major strength of this investigation was utilizing a laboratory pain task that permitted the acquisition of parent HRV recordings during resting, prior to their child’s experience of pain, and following child pain. Given that HRV recordings require a minimum of one minute for each time point (Camm et al., 1996), capturing parents’ HRV activity at different time points is challenging during clinical pain. Two measures of HRV were included, which is a recommended procedure for HRV data analysis (Laborde, Mosley, & Thayer, 2017) and adds to the literature on the extent to which these two indices overlap. Additionally, the controlled laboratory environment enables high internal validity, standardization of the pain stimulus and cleaner physiological recordings (i.e., reducing noise, movement artifacts) than is possible with clinical pain. Further, our estimate of child pain tolerance ($M = 159.13$ seconds, $SD = 98.57$) is comparable to recent research utilizing the CPT with a similar age group by Birnie and colleagues (2016; $M = 132.10$, $SD = 102.72$) and Schinkel and colleagues (2016; $M = 192.69$ second, $SD = 84.50$). The multi-method, multi-informant nature of this study is another notable strength. Parent emotional experience during their child’s acute pain was examined using both physiological recordings and self-reported data, thus informing how physiological and emotional processes are associated in the context of pediatric acute pain. Further, this is the first study to examine these relations throughout a laboratory pain task, which can inform the utility of this type of task in simulating clinical pain (e.g., do parents show similar patterns of HR and HRV throughout lab-induced pain compared to pain associated with medical procedures?). Despite the novelty of this investigation, several limitations should be acknowledged.
A limitation of the current investigation is the difficulties with recruitment that resulted in a small sample size, insufficient power to conduct the planned analyses, and wide 95% confidence intervals that were observed with the moderate correlations. Lack of diversity within the sample is also a concern. Most the sample consisted of White/European participants, reporting high levels of educational attainment. Further, to meet the assumption of independence, parents were removed if they participated with more than one child, which resulted in five parent-child dyads being excluded from the analyses. Another aspect of the current investigation to be considered is the painful stimulus employed. The findings from the current study may not generalize to clinical pain, such as needle-pokes as parent responses may differ in a clinical context. As noted, parent HR was lower than what has been observed during clinical pain (e.g., Kain et al., 2003). Anecdotally, many parents and children described the CPT as a challenge as opposed to a threatening or fear-inducing situation, even if they reported a fear of needles. On average, children rated their fear in response to the CPT as a .57 out of 4 (range = 0 to 2), while parents perceived their child’s fear in response to the CPT as a .52 out of 4 (range = 0 to 3), which is lower than what has been found during procedural pain ($M = 1.08, SD = 1.15$ for child ratings; $M = 1.77, SD = 1.18$ for parent ratings; McMurtry et al., 2011). As noted above, a restricted range was also observed with parent ratings of emotions, indicating parents did not experience high levels of worry, upset, or sadness. The CPT also differs from clinical pain in other ways in that parent and child historical procedural experience (as outlined by McMurtry et al., in preparation) that affects responses to the current painful procedure are not typically present in a laboratory setting. That is, the CPT is a novel experience for most children and they may never complete or choose to participate in this pain task again. In contrast, children have prior experience with needles and they will also be required to receive numerous needles throughout
their lifetime. Similarly, children are given complete control of the pain stimulus during the CPT (i.e., can remove their hand at any point), which is not possible during clinical pain, and may have affected how painful or fear-inducing they rated their experience to be.

**Future Research**

This study applied a laboratory pain task to investigate parents’ internal experience in the context of child acute pain using a community sample. Replication of the current study using a larger and more diverse sample will clarify how parent physiological response is associated with reported states and child pain outcomes. Also, clarifying how frequency- and time-domain methods of quantifying HRV differ in their association with parent states and child pain outcomes in the acute pain context is needed. To further clarify the observed associations with phasic HRV and parent and child variables, it may be relevant to consider and/or control for resting HRV. That is, individuals with higher resting HRV (compared to lower resting HRV) have a greater capacity for HRV reactivity (Geisler et al., 2013); thus, examining the interaction between resting and phasic HRV in predicting parent and child outcomes may further clarify the current results. The current study employed a multi-method examination of parent experience in the context of pediatric pain; however, other indicators of parent emotional experience may also be explored in relation to these measures. This includes aspects of both verbal and non-verbal communication, including parent vocalizations and facial expressions. Other psychophysiological measures, such as electrodermal recordings or saliva samples, could also be applied to gain greater understanding of parents’ physiological profile in this context. Further, as recently indicated by Vervoort and Trost (2017) there are various regulatory strategies that parents may employ to cope with their child’s painful experience, and only two ER strategies were examined in this study. Future research is required to examine parents’ ER strategies, and
to clarify which strategies are most often employed, how they relate to observable parent behaviours, as well as whether they interact with child ER strategy and child pain coping behaviours. It has been suggested that individuals with higher resting HRV are more effective at applying ER strategies in general (e.g., Aldao & Mennin, 2012); thus, higher HRV may not be associated with a specific ER strategy but rather how the strategy is utilized.

Lastly, examining parent and child HR and HRV concurrently in the context of acute pain would clarify whether children experience similar increases in HR and decreases in HRV as parents experienced in this study, and how it relates to their emotional experience. The current study removed parent-child dyads from the analyses if the parent participated with a second or third child; however, differences in parent reactions depending on which child is present would be an interesting factor to explore in a larger sample (e.g., how do parent responses and behaviours vary as a function of which child is present).

Conclusions

The existing research on parents' physiological activity in the pediatric acute pain context is limited, despite the observed connections between cardiac activity and emotional experience and regulation. The current pilot study generated knowledge on parents' HR and HRV activity throughout their child's completion of a laboratory pain task, and how this activity is linked to parent characteristics and child pain outcomes. The following are offered as preliminary conclusions that should be further explored: First, parents experienced increases in HR while anticipating child pain and decreases in HF-HRV following their child's pain, indicative of an emotional response before and after their child's CPT. Second, parents with higher resting HRV experienced higher HR and decreased HF-HRV, indicative of an emotional response before and after their child's CPT. Third, parents with higher resting HRV reported higher reported trait anxiety and expressive suppression. Further, with respect to parent reports of emotional state, parents with higher general arousal (indexed by HR) reported lower negative emotional state, parents with higher general arousal (indexed by HR) reported lower negative emotional state, parents with higher general arousal (indexed by HR) reported lower negative emotional state, parents with higher general arousal (indexed by HR) reported lower negative emotional state.
emotions during the procedure, although parents who experienced greater increases in HR had children with higher levels of fear. Taken together, parents with higher HR reported very low levels of negative emotions and parents who demonstrated decreases in HRV provided very low ratings of child fear. This may indicate that higher HR and decreases in HRV were not associated with distress but rather excitement and/or that these parents had less insight (e.g., extremely low ratings may reflect the denial of emotions) into their own and their child’s emotional experience throughout the CPT.

Only recently has HRV been recognized as an important variable to examine in individuals not only experiencing pain, but also observing those in pain (Constantin et al., 2016). Thus, findings from the current investigation provide preliminary evidence on the usefulness of examining HR and HRV as indices of emotional experience and regulation in the pediatric pain context. These results elucidate how these physiological indices relate to parent reported characteristics and child pain outcomes, thereby informing existing biopsychosocial models of pain and parent-child interaction frameworks.
References


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doi:10.1016/j.biopsycho.2005.08.009


doi:10.1016/j.biopsycho.2013.02.013


Table 1

**Demographic Characteristics of the Sample (n = 23)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (SD)</th>
<th>n (Frequency in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent Age (years)</td>
<td>42.39 (4.02)</td>
<td></td>
</tr>
<tr>
<td>Parent Sex (female)</td>
<td>22 (95.7%)</td>
<td></td>
</tr>
<tr>
<td>Parent Ethnicity (White/European)</td>
<td>21 (91.3%)</td>
<td></td>
</tr>
<tr>
<td>Marital Status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>21 (91.3%)</td>
<td></td>
</tr>
<tr>
<td>Divorced/Separated</td>
<td>1 (4.3%)</td>
<td></td>
</tr>
<tr>
<td>Never Married</td>
<td>1 (4.3%)</td>
<td></td>
</tr>
<tr>
<td>Highest Level of Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete high school</td>
<td>2 (8.7%)</td>
<td></td>
</tr>
<tr>
<td>Some college/university</td>
<td>1 (4.3%)</td>
<td></td>
</tr>
<tr>
<td>Completed college/university</td>
<td>9 (39.1%)</td>
<td></td>
</tr>
<tr>
<td>Completed graduate education</td>
<td>6 (26.1%)</td>
<td></td>
</tr>
<tr>
<td>Professional degree</td>
<td>5 (21.7%)</td>
<td></td>
</tr>
<tr>
<td>Caffeine Consumption in the past 2 hours (Yes)</td>
<td>8 (34.8%)</td>
<td></td>
</tr>
<tr>
<td>Less than ¾ cup</td>
<td>4 (22.2%)</td>
<td></td>
</tr>
<tr>
<td>1 cup</td>
<td>3 (11.1%)</td>
<td></td>
</tr>
<tr>
<td>1 ½ cup</td>
<td>1 (3.7%)</td>
<td></td>
</tr>
<tr>
<td>Nicotine Consumption in the past 2 hours (Yes)</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Cardioactive Medication (Yes)</td>
<td>3 (13.0%)</td>
<td></td>
</tr>
<tr>
<td>Child Age (years)</td>
<td>9.48 (1.73)</td>
<td></td>
</tr>
<tr>
<td>Child Sex (female)</td>
<td>11 (47.8%)</td>
<td></td>
</tr>
<tr>
<td>Child Ethnicity (White)</td>
<td>21 (91.3%)</td>
<td></td>
</tr>
<tr>
<td>Child typical reaction to painful medical procedures</td>
<td>4.63 (2.11)</td>
<td></td>
</tr>
<tr>
<td>(0 - negative, 10 - positive)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2

Descriptive Statistics and Reliability Estimates of the Measures of Anxiety, Pain Catastrophizing, Emotion Regulation, Emotional State (Worry, Upset, Sad), Children’s Fear (parent and child rated), Children’s Pain Intensity (parent and child rated), Pain Tolerance, Valence/Arousal (n = 23)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean</th>
<th>SD</th>
<th>Actual Range</th>
<th>Potential Range</th>
<th>Coefficient Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAI-Trait Anxiety&lt;sup&gt;a&lt;/sup&gt;</td>
<td>34.78</td>
<td>7.09</td>
<td>24-51</td>
<td>20-80</td>
<td>.84</td>
</tr>
<tr>
<td>PCS-P State Catastrophizing</td>
<td>5.48</td>
<td>3.75</td>
<td>0-16</td>
<td>0-30</td>
<td>.52</td>
</tr>
<tr>
<td>ERQ Suppression</td>
<td>9.45</td>
<td>4.38</td>
<td>4-19</td>
<td>4-24</td>
<td>.76</td>
</tr>
<tr>
<td>ERQ Reappraisal</td>
<td>32.52</td>
<td>6.82</td>
<td>16-42</td>
<td>7-42</td>
<td>.91</td>
</tr>
<tr>
<td>NRS Worry</td>
<td>1.35</td>
<td>1.27</td>
<td>0-4</td>
<td>0-10</td>
<td>--</td>
</tr>
<tr>
<td>NRS Upset</td>
<td>1.22</td>
<td>2.13</td>
<td>0-9</td>
<td>0-10</td>
<td>--</td>
</tr>
<tr>
<td>NRS Sad</td>
<td>.43</td>
<td>.84</td>
<td>0-3</td>
<td>0-10</td>
<td>--</td>
</tr>
<tr>
<td>CFS Child Fear (parent)</td>
<td>.52</td>
<td>.79</td>
<td>0-3</td>
<td>0-4</td>
<td>--</td>
</tr>
<tr>
<td>CFS Child Fear (child)</td>
<td>.57</td>
<td>.59</td>
<td>0-2</td>
<td>0-4</td>
<td>--</td>
</tr>
<tr>
<td>FPS-R Pain Intensity (parent)</td>
<td>3.37</td>
<td>1.97</td>
<td>0-6</td>
<td>0-10</td>
<td>--</td>
</tr>
<tr>
<td>FPS-R Pain Intensity (child)</td>
<td>2.87</td>
<td>1.69</td>
<td>0-6</td>
<td>0-10</td>
<td>--</td>
</tr>
<tr>
<td>Pain Tolerance (seconds)</td>
<td>159.13</td>
<td>98.57</td>
<td>27-240</td>
<td>1-240</td>
<td>--</td>
</tr>
<tr>
<td>SAM-Arousal</td>
<td>6.87</td>
<td>1.66</td>
<td>4-9</td>
<td>1-9</td>
<td>--</td>
</tr>
<tr>
<td>SAM-Valence</td>
<td>3.35</td>
<td>1.27</td>
<td>1-5</td>
<td>1-9</td>
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</tr>
</tbody>
</table>

Note. STAI = State-Trait Anxiety Inventory; PCS-P State = Pain Catastrophizing Scale-Parents State Version; ERQ Suppression = Emotion Regulation Questionnaire Expressive Suppression subscale; ERQ Reappraisal = Emotion Regulation Questionnaire Cognitive Reappraisal subscale; NRS = Numerical Rating Scale; CFS = Children’s Fear Scale; FPS-R = Faces Pain Scale-Revised; Pain Tolerance = Pain Tolerance during the Cold Pressor Task; SAM-Arousal = Self-Assessment Manikin Arousal (higher scores = calm/bored); SAM-Valence = Self-Assessment Manikin Valence (higher scores = unhappy/sad). For each measure, higher scores indicate higher levels of the construct, with exceptions as noted for the SAM.<sup>a</sup> n = 18 due to missing data for trait anxiety.
Table 3

*Descriptive Statistics of HR, HF-HRV, and RMSSD during Resting, Pre-CPT, and Recovery (n = 23)*

<table>
<thead>
<tr>
<th></th>
<th>Resting</th>
<th></th>
<th></th>
<th>Pre-CPT</th>
<th></th>
<th></th>
<th>Recovery¹</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>Range</td>
<td>M</td>
<td>SD</td>
<td>Range</td>
<td>M</td>
</tr>
<tr>
<td>HR</td>
<td>75.91</td>
<td>9.89</td>
<td>61.83-97.05</td>
<td>80.37</td>
<td>10.96</td>
<td>61.90-103.99</td>
<td>78.67</td>
</tr>
<tr>
<td>HF-HRV</td>
<td>6.06</td>
<td>0.81</td>
<td>4.55-7.36</td>
<td>5.75</td>
<td>1.10</td>
<td>3.26-7.24</td>
<td>5.51</td>
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<tr>
<td>RMSSD</td>
<td>6.79</td>
<td>0.82</td>
<td>4.94-8.06</td>
<td>6.72</td>
<td>0.87</td>
<td>4.39-8.50</td>
<td>6.59</td>
</tr>
</tbody>
</table>

*Note.* HR = heart rate (reported in beats per minute); HF-HRV = log transformed HF-HRV (reported in ms²); RMSSD = log transformed RMSSD (reported in ms²).

¹*n = 22* given one data segment that required more than 10% editing.
Table 4

*Descriptive Statistics of the Phasic Measures of HR, HF-HRV, and RMSSD (n = 23)*

<table>
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<tr>
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<th>Pre-CPT – Resting</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>ΔHR</td>
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<td>ΔHF-HRV</td>
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<td>ΔRMSSD</td>
<td>0.07</td>
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*Note. Δ = change score reflecting pre-CPT minus resting; HR = heart rate; HF-HRV = log transformed HF-HRV (reported in ms\(^2\)); RMSSD = log transformed RMSSD (reported in ms\(^2\)).*
Table 5

*Bivariate Correlations Between Resting HR, HF-HRV, RMSSD, Trait Anxiety, and Emotion Regulation (n = 23)*

<table>
<thead>
<tr>
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<tr>
<td>1. Resting HR</td>
<td></td>
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</tr>
<tr>
<td>2. Resting HF-HRV</td>
<td>- .41*</td>
<td></td>
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<td></td>
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<tr>
<td>3. Resting RMSSD</td>
<td></td>
<td>- .66**</td>
<td>.89**</td>
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<td></td>
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<tr>
<td>4. STAI-Trait Anxiety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- .37</td>
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<tr>
<td>5. ERQ Reappraisal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- .61**</td>
</tr>
<tr>
<td>6. ERQ Suppression</td>
<td></td>
<td></td>
<td></td>
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<td>.09</td>
</tr>
</tbody>
</table>

*Note.* Resting HR = heart rate during resting (reported in beats per minute); Resting HF-HRV = log transformed HF-HRV (reported in ms$^2$) during resting; Resting RMSSD = log transformed RMSSD (reported in ms$^2$) during resting; STAI = State-Trait Anxiety Inventory; ERQ Reappraisal = Emotion Regulation Questionnaire Cognitive Reappraisal subscale; ERQ Suppression = Emotion Regulation Questionnaire Expressive Suppression subscale. 95% CI reported in square brackets.

a\(n = 18\) due to missing data for trait anxiety.

*\(p < .05\), **\(p < .01\).*
Table 6

Bivariate Correlations Between General HR and Phasic (Δ) HR, HF-HRV, RMSSD, Emotional State (Worry, Sad, Upset), and Parent Catastrophizing about Child Pain (n = 23)

<table>
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<th>6</th>
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<td>1. General HR&lt;sup&gt;a,c&lt;/sup&gt;</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2. ΔHR&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[-.22, .57]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. ΔHF-HRV&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.13</td>
<td>-.27</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[-.29, .51]</td>
<td>[-.61, .16]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. ΔRMSSD&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-.01</td>
<td>-.36</td>
<td>.79**</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>[-.42, .40]</td>
<td>[-.67, .06]</td>
<td>[.56, .91]</td>
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<tr>
<td>5. NRS-Worry&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-.41</td>
<td>.02</td>
<td>.09</td>
<td>-.04</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[-.70, .02]</td>
<td>[-.40, .43]</td>
<td>[-.33, .48]</td>
<td>[-.44, .38]</td>
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</tr>
<tr>
<td>6. NRS-Sad&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-.60**</td>
<td>-.10</td>
<td>.10</td>
<td>.22</td>
<td>.49*</td>
<td>.73**</td>
<td></td>
</tr>
<tr>
<td>7. NRS-Upset&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-.52*</td>
<td>-.10</td>
<td>.10</td>
<td>.22</td>
<td>.49*</td>
<td>.73**</td>
<td></td>
</tr>
<tr>
<td>8. PCS-Catastrophizing&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-.24</td>
<td>.01</td>
<td>-.04</td>
<td>.01</td>
<td>.50*</td>
<td>-.17</td>
<td>.04</td>
</tr>
</tbody>
</table>

Note. Δ = change score reflecting pre-CPT minus resting; General HR = combined heart rate during resting, pre-CPT, and recovery; ΔHR = phasic heart rate; ΔHF-HRV = phasic HF-HRV; ΔRMSSD = phasic RMSSD; NRS = Numerical Rating Scale; PCS-P State = Pain Catastrophizing Scale-Parents State Version. 95% CI reported in square brackets.

<sup>a</sup>Pearson’s correlation coefficient; <sup>b</sup>Spearman’s correlation coefficient; <sup>c</sup>n = 22 given one data segment that required more than 10% editing.

*p < .05, **p < .01.
Table 7

*Bivariate Correlations Between Resting and Phasic (Δ) HR, HF-HRV, RMSSD, Parent Ratings of Child Fear and Pain, Child Ratings of Fear and Pain, and Child Pain Tolerance (n = 23)*

<table>
<thead>
<tr>
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<th>1</th>
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<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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<tbody>
<tr>
<td>1. Resting HR^a</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>2. Resting HF-HRV^a</td>
<td>-.41*</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3. Resting RMSSD^b</td>
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<td>-.04</td>
<td>-.02</td>
<td>-.38</td>
<td>-.44</td>
<td>-.02</td>
<td>-.40</td>
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<td>.21</td>
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</tr>
<tr>
<td>5. ΔHF-HRV^a</td>
<td></td>
<td></td>
<td>-.22</td>
<td>.57</td>
<td>-.53</td>
<td>-.28</td>
<td>-.60</td>
<td>.18</td>
<td>-.61</td>
<td>.16</td>
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<td>6. ΔRMSSD^b</td>
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<td>-.11</td>
<td>-.22</td>
<td>-.36</td>
<td>.79**</td>
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<tr>
<td>7. CFS Child Fear</td>
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<td>-.15</td>
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<tr>
<td>(parent)^b</td>
<td></td>
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<td>8. CFS Child Fear</td>
<td>-.29</td>
<td>.01</td>
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<td>.44*</td>
<td>-.13</td>
<td>-.10</td>
<td>.02</td>
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<td>(child)^c</td>
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<tr>
<td>9. FPS-R Pain</td>
<td>.10</td>
<td>-.16</td>
<td>-.08</td>
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<td>.06</td>
<td>.05</td>
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<td>intensity (parent)^d</td>
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<tr>
<td>10. FPS-R Pain</td>
<td>-.11</td>
<td>-.20</td>
<td>-.02</td>
<td>.02</td>
<td>.06</td>
<td>.08</td>
<td>-.16</td>
<td>.49*</td>
<td>.10</td>
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<tr>
<td>intensity (child)^c</td>
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<td>11. Child Pain</td>
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<td>.27</td>
<td>.21</td>
<td>-.08</td>
<td>.17</td>
<td>.16</td>
<td>.01</td>
<td>-.05</td>
<td>-.18</td>
<td>-.40</td>
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</tr>
</tbody>
</table>

*Note. Δ = change score reflecting pre-CPT minus resting; Resting HR = heart rate during resting; Resting HF-HRV = log transformed HF-HRV during resting; Resting RMSSD = log transformed RMSSD during resting; ΔHR = phasic heart rate; ΔHF-HRV = phasic HF-HRV; ΔRMSSD = phasic RMSSD; CFS = Children’s Fear Scale; FPS-R = Faces Pain Scale-Revised; Pain Tolerance = Pain Tolerance during the Cold Pressor Task. 95% CI reported in square brackets.

^aPearson’s correlation coefficient; ^bSpearman’s correlation coefficient.

*p < .05, **p < .01.
Table 8

Bivariate Correlations Between Pre-CPT HR, Emotional State (Worry, Upset, Sad), Child Pain Intensity, Fear, and Pain Tolerance (n = 23)

<table>
<thead>
<tr>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. NRS-Worry&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. NRS-Upset&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td>.49*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[.10, .75]</td>
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</tr>
<tr>
<td>3. NRS-Sad&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.28</td>
<td></td>
<td>.73**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td>[-.15, .62]</td>
<td>[.45, .88]</td>
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</tr>
<tr>
<td>4. FPS-R Pain Intensity (child)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-.15</td>
<td></td>
<td>.02</td>
<td></td>
<td>-.00</td>
</tr>
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<td></td>
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<td>[-.53, .28]</td>
<td>[-.43, .40]</td>
<td>[.41, .41]</td>
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<tr>
<td>5. CFS Child Fear (child)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.03</td>
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<td>.26</td>
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<td></td>
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<td>[-.39, .44]</td>
<td>[-.01, .70]</td>
<td>[-.17, .61]</td>
<td>[.10, .75]</td>
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<tr>
<td>6. Pain Tolerance&lt;sup&gt;a&lt;/sup&gt;</td>
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<td></td>
<td>.16</td>
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<td>-.40</td>
</tr>
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<td></td>
<td></td>
<td>[-.28, .53]</td>
<td>[-.27, .54]</td>
<td>[-.17, .61]</td>
<td>[-.70, .01]</td>
</tr>
</tbody>
</table>

Note. Pre-CPT HR = heart rate during pre-CPT; NRS = Numerical Rating Scale; FPS-R = Faces Pain Scale-Revised; CFS = Children’s Fear Scale; Pain Tolerance = Pain Tolerance during the Cold Pressor Task. 95% CI reported in square brackets.

<sup>a</sup>Pearson’s correlation coefficient; <sup>b</sup>Spearman’s correlation coefficient.

* p < .05, ** p < .01.
Figure 1. A model depicting the hypothesized role of parent HRV in the pediatric pain context. **Resting HRV** is indicative of self-regulatory capacity, such that high HRV is associated with an adaptive autonomic system and self-regulation (SR), while low HRV is associated with a rigid autonomic system and poor SR. **Phasic HRV** is indicative of self-regulatory effort in response to an environmental demand. When threat is perceived (see high threat), the vagal brake withdraws, heart rate (HR) increases and heart rate variability (HRV) decreases. This has been linked to higher negative affect and a lessened ability to socially engage. It is expected that this will contribute to higher parental negative emotions and catastrophizing about child pain, and poor parent-child interactions prior to, during, and following painful procedures. When low threat is perceived (see low threat), the vagal brake is active via parasympathetic inputs, resulting in low HR and high HRV. This has been linked to higher social engagement, and use of adaptive emotion regulation (ER) strategies. It is hypothesized that this will contribute to lower negative emotions and catastrophizing about child pain, and thus promote adaptive parent-child interactions prior to, during, and following painful procedures.

Increases in HR and decreases in HRV may occur via 3 different routes (Thayer et al., 2009):
1. Indirect activation by decreased inhibition in other cortical areas, leading to an increase in sympathetic activity.
2. A decrease in parasympathetic activity.
3. Direct activation of sympahtoexcitatory neurons leading to an increase in sympathetic activity.
**Figure 2.** HR activity during resting, pre-CPT and recovery (2 minute intervals). Bars represent standard error. Asterisks indicate significant differences between blocks, *$p < .05$.  

![Graph showing HR activity during resting, pre-CPT and recovery](image-url)
Figure 3. HR activity during resting, pre-CPT and recovery (30 second intervals). B = baseline, C = pre-CPT, R = Recovery. Bars represent standard error.
Figure 4. HF-HRV activity during resting, pre-CPT and recovery (2 minute intervals). Bars represent standard error. Asterisks indicate significant differences between blocks, *$p < .05$. 
Figure 5. RMSSD activity during resting, pre-CPT and recovery (2 minute intervals). Bars represent standard error.
### Appendix A

**HRV Parameters from the Cited Literature**

<table>
<thead>
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<th>Author(s)</th>
<th>Year</th>
<th>HRV Parameter</th>
<th>Construct Measured</th>
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</thead>
<tbody>
<tr>
<td>Aldao &amp; Mennin</td>
<td>2012</td>
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<td>2008</td>
<td>HF-HRV</td>
<td>Pain sensitivity</td>
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<td>Bendixen et al.</td>
<td>2012</td>
<td>HF-HRV, RMSSD, SDNN</td>
<td>Pain intensity</td>
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<td>Blandon</td>
<td>2015</td>
<td>HF-HRV</td>
<td>Emotional response</td>
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<td>Bleil et al.</td>
<td>2008</td>
<td>HF-HRV</td>
<td>Parasympathetic cardiac autonomic function</td>
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<td>Butler et al.</td>
<td>2006</td>
<td>HF-HRV</td>
<td>Emotional reactivity &amp; regulation</td>
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<td>Chalmers et al.*</td>
<td>2014</td>
<td>RMSSD, SDNN, pNN50, SDANN, HF-HRV</td>
<td>Vagal function</td>
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<td>Cribbett et al.</td>
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<td>Emotional responding</td>
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<td>Denson et al.</td>
<td>2011</td>
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<td>Emotion regulation &amp; mental load</td>
</tr>
<tr>
<td>El-Sheikh et al.</td>
<td>2011</td>
<td>Peak-to-valley method</td>
<td>Parasympathetic nervous system activity</td>
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<td>Frazier et al.</td>
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<td>HF-HRV</td>
<td>Emotional response</td>
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<td>Friedman</td>
<td>2007</td>
<td>HF-HRV</td>
<td>Self-regulation</td>
</tr>
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<td>Geisler et al.</td>
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<td>HF-HRV</td>
<td>Self-regulation</td>
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<td>HF-HRV</td>
<td>Emotion regulation, social engagement</td>
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<td>Harris et al.*</td>
<td>2014</td>
<td>HF-HRV, SDNN, RMSSD, pNN50</td>
<td>Autonomic nervous system activity</td>
</tr>
<tr>
<td>Koenig et al.*</td>
<td>2014</td>
<td>HF-HRV, RMSSD, SDNN</td>
<td>Flexible autonomic regulation</td>
</tr>
<tr>
<td>Koenig et al.*</td>
<td>2016</td>
<td>HF-HRV, peak-to-valley method</td>
<td>Emotion regulation</td>
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<td>Koval et al.</td>
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<td>Emotion regulation</td>
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<td>2009</td>
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<td>Inhibitory control</td>
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<td>Moore et al.</td>
<td>2009</td>
<td>RSA (Porges method)</td>
<td>Regulation of social interaction, behaviour, emotion, and attention</td>
</tr>
<tr>
<td>Oveis et al.</td>
<td>2009</td>
<td>HF-HRV</td>
<td>Emotional responding</td>
</tr>
<tr>
<td>Park et al.</td>
<td>2014</td>
<td>HF-HRV</td>
<td>Self-regulation</td>
</tr>
<tr>
<td>Porges et al.</td>
<td>2013</td>
<td>RSA (Porges method)</td>
<td>Social engagement</td>
</tr>
<tr>
<td>Salomon</td>
<td>2005</td>
<td>MSD</td>
<td>Vagal tone</td>
</tr>
<tr>
<td>Segerstrom &amp; Nes</td>
<td>2007</td>
<td>RMSSD</td>
<td>Self-regulation</td>
</tr>
<tr>
<td>Stellar et al.</td>
<td>2015</td>
<td>Peak-to-valley method</td>
<td>Vagal tone</td>
</tr>
<tr>
<td>Thayer et al.</td>
<td>1996</td>
<td>HF-HRV, MSD</td>
<td>Vagal tone</td>
</tr>
<tr>
<td>Thayer et al.*</td>
<td>2012*</td>
<td>HF-HRV, RMSSD</td>
<td>Prefrontal cortex activity</td>
</tr>
<tr>
<td>Thayer et al.</td>
<td>2009</td>
<td>HF-HRV</td>
<td>Executive function and prefrontal cortex activity</td>
</tr>
<tr>
<td>Treister et al.</td>
<td>2012</td>
<td>HF-HRV</td>
<td>Pain intensity</td>
</tr>
<tr>
<td>Name</td>
<td>Year</td>
<td>Measures</td>
<td>Domain</td>
</tr>
<tr>
<td>----------------------</td>
<td>------</td>
<td>------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Vervoort et al.</td>
<td>2014</td>
<td>RMSSD, HF-HRV</td>
<td>Emotion Regulation</td>
</tr>
<tr>
<td>Volokhov &amp; Demaree</td>
<td>2010</td>
<td>HF-HRV</td>
<td>Emotion Regulation</td>
</tr>
<tr>
<td>Weber et al.</td>
<td>2010</td>
<td>HF-HRV, RMSSD</td>
<td>Autonomic regulation</td>
</tr>
</tbody>
</table>

*Note.* MSD = mean squared differences; HF-HRV = high frequency heart rate variability; RMSSD = root mean square of successive differences; SDNN = standard deviation of the N-N intervals; pNN50 = percentage of successive normal sinus RR intervals more than 50 ms; SDANN = standard deviation of the average N-N interval; RSA = respiratory sinus arrhythmia.

* = review paper or meta-analysis.
Appendix B

Cold Pressor Task

Instructions: “(Child’s name), this is where you are going to put your arm in the water. To get ready, could you wash your hands with soap right up to here (point to mid-forearm)? Now, which hand do you write with? OK, could you put your other hand in this warm water and leave it there for a couple of minutes. This is so everybody’s hand will be the same temperature. We’ll tell you when it’s time to put your arm in the cold water. You’ll put it in all at once, right up to here (show point above wrist to indicate depth of immersion). Lay your hand face up on this armrest. Once you’ve put your hand in, we’d like you to leave it in for as long as you can, even if it is uncomfortable. But you can take your arm out if it gets too uncomfortable or hurts too much to leave it in. I’m going to leave the room. You can call me any time. Remember to leave your hand in the water as long as you can, and then take it out when it hurts too much. Do you have any questions about what you’ll be doing?” (adapted from von Baeyer et al., 2005).
Appendix C

Timeline of Procedure

- Arrive at appointment
  - Questionnaires: Demographics, STAI-T; PCS-P state; ERQ

- 2 mins: Resting during neutral video (Block 1)
  - Start ECG Recordings

- Pre-CPT
  - 2 mins: warm water (Block 2)
  - 4 mins: cold water (max)

- 2 mins: Recovery normal interaction (Block 3)
  - Questionnaires: CFS, FPS-R, NRS-parent emotions

- Debrief
  - Stop ECG Recordings
Appendix D

Demographic and Basic Information

DEMOGRAPHIC INFORMATION

We would like to find out some basic information about you and your child.

1. What is your relationship to the child (circle one)?
   ☐ Mother
   ☐ Father
   ☐ Stepmother
   ☐ Stepfather
   ☐ Other_____________________

2. Please indicate your current age______ (years) and ______ gender ______

3. Please indicate your ethnicity (check all that apply):
   ☐ Aboriginal/First Nations/Metis
   ☐ White/European
   ☐ Black/African/Caribbean
   ☐ Southeast Asian (e.g., Chinese, Japanese, Korean, Vietnamese, Cambodian, Filipino, etc.)
   ☐ Arab (Saudi Arabian, Palestinian, Iraqi, etc.)
   ☐ South Asian (East Indian, Sri Lankan, etc.)
   ☐ Latin American (Costa Rican, Guatemalan, Brazilian, Columbian, etc.)
   ☐ West Asian (Iranian, Afghan, etc.)
   ☐ Other (please specify):

4. Please indicate your highest education (check one):
   ☐ Some high school
   ☐ Completed high school
   ☐ Some college/university
   ☐ Apprenticeship training and trades
   ☐ Completed college/university
   ☐ Some graduate education
   ☐ Completed graduate education
   ☐ Professional degree

5. Please indicate your current marital status (check one):
   ☐ Married
   ☐ Divorced/Separated
   ☐ Remarried
   ☐ Widowed
   ☐ Never Married
   ☐ Other (please specify): _______________________

If applicable, please provide the following information about your spouse/partner (#6-8):

6. Please indicate your Spouse's/Partner's Current Age: ______ (years)
7. Please indicate your Spouse's/Partner's highest education (check one):
   □ Some high school
   □ Completed high school
   □ Some college/university
   □ Apprenticeship training and trades
   □ Completed college/university
   □ Some graduate education
   □ Completed graduate education
   □ Professional degree

8. Please indicate your Spouse/Partner's Race/Ethnicity (check all that apply):
   □ Aboriginal/First Nations/Metis
   □ White/European
   □ Black/African/Caribbean
   □ Southeast Asian (e.g., Chinese, Japanese, Korean, Vietnamese, Cambodian, Filipino, etc.)
   □ Arab (Saudi Arabian, Palestinian, Iraqi, etc.)
   □ South Asian (East Indian, Sri Lankan, etc.)
   □ Latin American (Costa Rican, Guatemalan, Brazilian, Columbian, etc.)
   □ West Asian (Iranian, Afghani, etc.)
   □ Other (please specify): ____________________________________________

9. Research has found that consuming caffeine, nicotine, and certain medications influences the activity of the heart. So, we would like to know the following:

a) Have you consumed caffeine in the past 2 hours? _____ No          _____ Yes

   i. If yes, please indicate the approximate amount (check one):
      a) Less than 6 fl oz (3/4 cup) □
      b) 8 fl oz (1 cup) □
      c) 12 fl oz (1 ½ cups) □
      d) 16 fl oz (2 cups) □
      e) More than 20 fl oz (2 ½ cups) □

b) Have you consumed nicotine in the past 2 hours? _____ No          _____ Yes

c) Are you currently taking cardioactive medication? _____ No          _____ Yes (check all that apply)
   a) Antidepressants (e.g., Prozac, Zoloft) □
   b) Antipsychotics (e.g., Clozaril, Risperdal) □
   c) Benzodiazepines (e.g., Valium, Ativan) □
   d) Antihypertensives (e.g., Lozol, Diuril) □
10. Please indicate how your child typically reacts to painful medical procedures, such as vaccinations and venipunctures (please mark below):

<table>
<thead>
<tr>
<th>Negative Reaction</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Neutral</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Positive Reaction</th>
<th>10</th>
</tr>
</thead>
</table>

**CHILD INFORMATION**

Please answer the following about the child who is participating in our study today.

1. **Child’s Age:** ____ (years)

2. **Child’s Gender:** ______

3. **Child’s Date of Birth:** ______ (month) ______ (year)

4. Please indicate your **child’s ethnicity** (check all that apply):
   - [ ] Aboriginal/First Nations/Metis
   - [ ] White/European
   - [ ] Black/African/Caribbean
   - [ ] Southeast Asian (e.g., Chinese, Japanese, Korean, Vietnamese, Cambodian, Filipino, etc.)
   - [ ] Arab (Saudi Arabian, Palestinian, Iraqi, etc.)
   - [ ] South Asian (East Indian, Sri Lankan, etc.)
   - [ ] Latin American (Costa Rican, Guatemalan, Brazilian, Columbian, etc.)
   - [ ] West Asian (Iranian, Afghani, etc.)
   - [ ] Other (please specify): __________________________

Does your child have any **chronic illnesses or other medical conditions** (circle one):
   - [ ] No
   - [ ] Yes

If yes, please list the illnesses and/or medical conditions:

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
Appendix E

State-Trait Anxiety Inventory (STA-Trait Form)

Instructions
A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you generally feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel. For each item please use the following scale.

<table>
<thead>
<tr>
<th>Almost Never</th>
<th>Sometimes</th>
<th>Often</th>
<th>Almost Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

1. I feel pleasant ................................................................. 1 2 3 4
2. I feel nervous and restless ................................................. 1 2 3 4
3. I feel satisfied with myself .................................................. 1 2 3 4
4. I wish I could be as happy as others seem to be .......................... 1 2 3 4
5. I feel like a failure .............................................................. 1 2 3 4
6. I feel rested ................................................................. 1 2 3 4
7. I am “calm, cool, and collected” .......................................... 1 2 3 4
8. I feel that difficulties are piling up so that I cannot overcome them ... 1 2 3 4
9. I worry too much over something that really doesn’t matter ............. 1 2 3 4
10. I am happy ............................................................................ 1 2 3 4
11. I have disturbing thoughts ....................................................... 1 2 3 4
12. I lack self-confidence ........................................................... 1 2 3 4
13. I feel secure ........................................................................ 1 2 3 4
14. I make decisions easily .......................................................... 1 2 3 4
15. I feel inadequate .................................................................. 1 2 3 4
16. I am content ......................................................................... 1 2 3 4
17. Some unimportant thought runs through my mind and bothers me .... 1 2 3 4
18. I take disappointments so keenly that I can’t put them out of my mind ... 1 2 3 4
19. I am a steady person .................................................................. 1 2 3 4
20. I get in a state of tension or turmoil as I think over my recent concerns
    and interests ........................................................................ 1 2 3 4
Appendix F

Pain Catastrophizing Scale for Parents-State (PCS-P-state)

Please indicate the extent to which you are experiencing the following thoughts regarding your child’s completion of the cold pressor task by marking an X in the boxes below.

1. At this moment, to what extent do you keep thinking about how much pain your child might experience during the cold pressor task?

2. At this moment, to what extent do you think something serious might happen to your child because of the pain?

3. At this moment, to what extent do you think you will not be able to endure the cold pressor task, because of the pain of your child?
Appendix G

Emotion Regulation Questionnaire (ERQ)

Instructions and Items

We would like to ask you some questions about your emotional life, in particular, how you control (that is, regulate and manage) your emotions. The questions below involve two distinct aspects of your emotional life. One is your emotional experience or what you feel like inside. The other is your emotional expression, or how you show your emotions in the way you talk, gesture, or behave. Although some of the following questions may seem similar to one another, they differ in important ways. For each item, please answer using the following scale:

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Neutral</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Strongly Agree</th>
<th>7</th>
</tr>
</thead>
</table>

1. ___ When I want to feel more positive emotion (such as joy or amusement), I change what I’m thinking about.
2. ___ I keep my emotions to myself.
3. ___ When I want to feel less negative emotion (such as sadness or anger), I change what I’m thinking about.
4. ___ When I am feeling positive emotions, I am careful not to express them.
5. ___ When I’m faced with a stressful situation, I make myself think about it in a way that helps me stay calm.
6. ___ I control my emotions by not expressing them.
7. ___ When I want to feel more positive emotion, I change the way I’m thinking about the situation.
8. ___ I control my emotions by changing the way I think about the situation I’m in.
9. ___ When I am feeling negative emotions, I make sure not to express them.
10. ___ When I want to feel less negative emotions, I change the way I’m thinking about the situation.
Appendix H

The Self-Assessment Manikin (SAM)

Please use the following scale to rate how you felt during the video clip by marking the circle with an X.

Excited
Stimulated

Calm
Bored

Happy
Joyful

Neutral

Unhappy
Sad
Appendix I

Children’s Fear Scale (CFS)

Instructions for children: “These faces are showing different amounts of being scared. This face [point to left-most face] is not scared at all, this face is a little bit more scared [point to second face from left], a bit more scared [sweep finger along scale], right up to the most scared possible [point to the last face on the right]. Have a look at these faces and choose the one that shows how scared you were during the cold pressor.” (McMurtry et al., 2011).

Instructions for parents: “These faces are showing different levels of fear. This face [point to the left-most face] shows no fear at all, this faces shows a little bit more [point to second face from left], a bit more [sweep finger along scale], right up to extreme fear [point to the last face on the right]. Have a look at these faces and choose the one that shows how much fear you think your child felt during cold pressor.”
Appendix J

The Faces Pain Scale-Revised (FPS-R)

Instructions for children: “These faces show how much something can hurt. This face [point to left-most face] shows no pain. The faces show more and more pain [point to each from left to right] up to this one [point to right-most face] - it shows very much pain. Point to the face that shows how much you hurt during the cold pressor.” (Hicks et al., 2001).

Instructions for parents: “These faces show how much something can hurt. This face [point to left-most face] shows no pain. The faces show more and more pain [point to each from left to right] up to this one [point to right-most face] - it shows very much pain. Point to the face that shows how much pain you think your child experienced during the cold pressor.”
Appendix K

Numerical Rating Scale (NRS)

On a scale of 0 to 10, how **worried** were you **during** your child’s completion of the cold pressor?

<table>
<thead>
<tr>
<th>Not at all</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Extremely</th>
</tr>
</thead>
</table>

On a scale of 0 to 10, how **upset** were you **during** your child’s completion of the cold pressor?

<table>
<thead>
<tr>
<th>Not at all</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Extremely</th>
</tr>
</thead>
</table>

On a scale of 0 to 10, how **sad** were you **during** your child’s completion of the cold pressor?

<table>
<thead>
<tr>
<th>Not at all</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Extremely</th>
</tr>
</thead>
</table>
## Appendix L

Summary of HR and HRV Measures and Interpretation

<table>
<thead>
<tr>
<th>Construct (HR)</th>
<th>Parameter</th>
<th>Score (as described in-text)</th>
<th>Meaning</th>
</tr>
</thead>
</table>
| **Heart Rate (HR)** | Beats per minute | Resting HR  
Pre-CPT HR  
Recovery HR  
General HR = resting + pre-CPT + recovery  
*Phasic HR (change score)*:  
$\Delta HR = $ pre-CPT HR – resting HR | High HR = physiological arousal  
Increase in HR = emotional response |
| **Heart Rate Variability (HRV)** | *Time-domain:* lnRMSSD (ms$^2$) | Resting RMSSD  
Pre-CPT RMSSD  
Recovery RMSSD  
*Phasic RMSSD (change score)*:  
$\Delta RMSSD = $ pre-CPT RMSSD – resting RMSSD | High resting = capacity for emotion regulation  
Increase in HRV = self-regulation during low threat  
Decrease in HRV = Self-regulation during high threat |
|  | *Frequency-domain:* lnHF-HRV(m$^2$) | Resting HF-HRV  
Pre-CPT HF-HRV  
Recovery HF-HRV  
*Phasic HF-HRV (change score)*:  
$\Delta HF-HRV = $ pre-CPT HF-HRV – resting HF-HRV | View RMSSD: HF-HRV and RMSSD are posited to be equivalent indices |