A Multi-Method Approach to Understand Parent Behaviors during Child Acute Pain

Kaytlin L. Constantin, MA[1*], Rachel L. Moline, MA[1], Lindsay Labonte, BA[1], & C. Meghan McMurtry PhD[1,2,3]

[1] Department of Psychology, University of Guelph, Guelph, ON, Canada
[2] Pediatric Chronic Pain Program, McMaster Children's Hospital, Hamilton ON, Canada
[3] Department of Paediatrics, Schulich School of Medicine & Dentistry, Western University, London ON, Canada

Address correspondences and reprint requests to: Kaytlin L. Constantin, MA. Department of Psychology, University of Guelph, 87 Trent Lane, University of Guelph, Guelph, ON N1G 2W1, (519) 824 -4120 Ext. 52342 kaytlin@uoguelph.ca.

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Abstract

Objective: Parent behaviors strongly predict child responses to acute pain; less studied are the factors shaping parent behaviors. Heart rate variability (HRV) is considered a physiological correlate of emotional responding. Resting or "trait" HRV is indicative of the capacity for emotion regulation, while momentary changes or "state" HRV is reflective of current emotion regulatory efforts. This study aimed to examine: 1) parent state HRV as a contributor to parent verbal behaviors before and during child pain; and 2) parent trait HRV as a moderator between parent emotional states (anxiety, catastrophizing) and parent behaviors. **Methods:** Children 7 to 12 years of age completed the cold pressor task (CPT) in the presence of a primary caregiver. Parents rated their state anxiety and catastrophizing about child pain. Parent HRV was examined at 30-second epochs at rest ("trait HRV"), before ("state HRV-warm"), and during their child's CPT ("state HRV-cold"). Parent behaviors were video recorded and coded as coping-promoting or distress-promoting. **Results:** Thirty-one parents had complete cardiac, observational, and self-report data**.** A small to moderate negative correlation emerged between state HRV-cold and CP behaviors during CPT. Trait HRV moderated the association between parent state catastrophizing and distress-promoting behaviors. **Conclusions:** Parents experiencing state catastrophizing were more likely to engage in distress-promoting behavior if they had low trait HRV. This novel work suggests parents who generally have a low (vs. high) HRV, reflective of low capacity for emotion regulation, may be at risk of engaging in behaviors that increase child distress when catastrophizing about their child's pain.

Keywords: acute pediatric pain, parent-child, behaviors, psychophysiology, heart rate variability

Introduction

Needle procedures, such as vaccinations and venipunctures, are common sources of pain and fear for children (McMurtry et al., 2015). Pain is defined as "an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage" (Raja et al., 2020), and fear is defined as an alarm reaction in response to immediate threat; pain and fear have a bidirectional association (McMurtry et al., 2015). Poorly managed child pain and fear during needle procedures can contribute to a host of individual and societal costs, including unnecessary suffering, longer procedure time, and vaccine hesitancy, which compromises herd immunity (Kennedy et al., 2008; McLenon & Rogers, 2019; McMurtry et al., 2015). Parent behaviors during children's needle procedures are important and account for up to 53 to 64% of the variance in child pain outcomes (Campbell et al., 2017; Cohen et al., 2002; Mahoney et al., 2010; Martin et al., 2013; Racine et al., 2016). Parent verbal behaviors are often categorized as conducive to child coping ("coping-promoting") or child distress ("distress-promoting"; Blount et al., 1989, 2003; Taylor et al., 2011). While the importance of examining parent verbal behaviors has been established, less research has examined the processes underlying parent behaviors in response to child acute, or short-lasting, pain, which may contribute to the development of caregiver interventions to support children during acute pain (Caes et al., 2016).

The Affective-Motivational Model of Interpersonal Pain Dynamics (Vervoort & Trost, 2017) suggests that understanding the factors contributing to parent behaviors is essential in understanding the effectiveness of caregiving behaviors. According to this model, parental behaviors in response to child pain are downstream from pain-related emotions. Emotions are generated from cognitive appraisals (e.g., catastrophizing) and result in subjective states (e.g., anxiety), somatic responses (e.g., cardiovascular activity), as well as action tendencies and expressive behavior (Gross & Thompson, 2007; Vervoort & Trost, 2017). Viewing another person in pain activates a threat detection system and two commonly experienced states that are characterized by appraisals of threat include anxiety (i.e., anticipation of future threat)[1] and catastrophizing (i.e., focus on and magnification of the threat value of painful stimuli, and to negatively evaluate one's ability to manage such pain; Boerner et al., 2015; Esteve et al., 2014; McMurtry et al., 2015). Parents often experience anxiety during their child's pain, which can lead parents to engage in behaviors, such as discouraging brave behavior, failing to praise brave behavior, and attending to child displays of anxiety, that inadvertently exacerbates child distress behavior, fear, and pain (Bearden et al., 2012; Bernard & Cohen, 2006; Dahlquist & Pendley, 2005; Evans et al., 2016; Smith et al., 2007). Parents high in state catastrophizing about child pain are likely to appraise child procedural pain as threatening and engage in higher levels of maladaptive parent behaviors that associate with negative child outcomes (e.g., "distress-promoting", pain-controlling; Boerner et al., 2016; Caes et al., 2011; Caes et al., 2014; Goubert et al., 2008). However, other work demonstrates that parent anxiety and catastrophizing are unrelated to parent behaviors (e.g., Birnie et al., 2016; Caes et al., 2014b; Frank et al., 1995), which suggests that threat-oriented states do not inevitably result in maladaptive parent behaviors and highlights the need to examine moderators that may buffer the impact of parent anxiety and catastrophizing on behaviors. According to the model put forth by Vervoort and Trost (2017), emotion regulation is key to understanding these mixed findings given that emotion regulation is theorized to facilitate adaptive parent behaviors, although this has been largely overlooked in

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[1] The term "anxiety" will be used when referring to parent anxiety and fear for simplicity and for consistency with extant literature.

published literature (see Vervoort et al., 2014, 2019 for exceptions). Existing literature demonstrates emotion regulation serves to buffer the effects of viewing one's child in pain on subsequent parent distress and behaviors (Vervoort et al., 2019). Moreover, research demonstrating parental distress mediates the association between parent catastrophizing about child pain and maladaptive parent behaviors further illustrates the relevance of examining one's ability to regulate difficult emotions as a moderating factor (Caes et al., 2011).

Heart rate variability (HRV), defined as the variation in time between consecutive heartbeats, offers promise to further understand parent emotion regulation (Appelhans & Luecken, 2006), although few have endeavored to explore parent HRV in pediatric pain. Both theory and empirical findings illustrate that the heart receives input from the prefrontal-subcortical inhibitory circuits involved in threat detection and regulation and this can be measured through vagally-mediated HRV (Thayer et al., 2012; Thayer & Lane, 2000). As such, HRV is thought to be informative to understanding both anxiety and catastrophizing (Koenig et al., 2016; Thayer et al., 2012). A distinction can be made between HRV during rest and HRV in response to a particular event, both of which are implicated in emotion regulation (Laborde et al., 2018). To date, extant research has largely focused on resting HRV and according to leading theories on HRV in psychophysiology (e.g., Porges [2001] Polyvagal Theory, and Thayer & Lane's [2000] Neurovisceral Integration Model) and a large body of empirical work (e.g., see Balzarotti et al., 2017; Smith et al., 2020 for reviews), a higher level of resting HRV is indicative of better capacity for emotion regulation and as such, is hereby termed trait HRV. Low trait HRV relates to emotional lability and state and trait anxiety, whereas high trait HRV relates to greater health and well-being (Chalmers et al., 2014; Friedman, 2007; Geisler et al., 2010, 2013; Koval et al., 2013). HRV in response to a particular event, hereby termed state HRV, can inform an individual's current emotion regulation effort (Laborde et al., 2017), although there is less agreement on the meaning of state HRV in relation to emotion regulation (Balzarotti et al., 2017). Recent theory suggests the extent to which increases or decreases in state HRV reflect adaptive self-regulatory effort depends on the situational demands and whether a stressor requires engaging in physical activity (Laborde et al., 2018). Specifically, a smaller decrease or an increase in HRV is viewed as adaptive in situations that require engaging the prefrontal cortex and purposeful, goal-oriented behaviors, rather than physical activity (Laborde et al., 2018).

Trait HRV has been implicated in the inhibition of fear responses (Wendt et al., 2015) and deemed an important factor in regulating emotions in both personal and interpersonal pain contexts (Constantin, et al., 2017; Koenig et al., 2016; Vervoort et al., 2014, 2019), whereas much less is known about how state HRV may relate to threat-oriented states and behaviors. Preliminary work on parent trait HRV demonstrates an association with past experiences with pain (Constantin et al., 2017) and pain control behaviors (Vervoort et al., 2019). Initial work also demonstrates that parent state HRV decreases when viewing pictures of children displaying varying levels of facial expressions of pain (Vervoort et al., 2014) and immediately before their child's completion of the cold pressor task (Constantin et al., 2017). Missing from the literature is a foundational understanding of how parent HRV, as a correlate of emotion regulation, relates to parent verbal behaviors and responses that are commonly observed during child acute pain. Specifically, it is unclear how trait HRV, a relatively well-established indicator of emotion regulation, may act to buffer the association between parent threat-oriented states and behaviors that relate to increases in child distress. There is also no research that has explored the pattern of parent HRV before and during their child's pain and whether this pattern of responding relates to parent behaviors measured concurrently. Examining state HRV may be particularly informative in the interpersonal pain context as it can provide continuous information about emotional states without disrupting the dyadic interactions, a core component of gathering ecologically valid interpersonal data, and may help to understand a mechanism through which parents engage in distress- or coping-promoting behaviors (Thorson et al., 2018).

Methods

The goal of this cross-sectional, laboratory-based study is to investigate the potential role of both state and trait HRV in shaping parent behaviors in response to their child's completion of the cold pressor task (CPT). Specifically, we examined: 1) state HRV as an index of momentary emotion regulatory effort in relation to parent coping-promoting (CP) and distress-promoting (DP) behaviors at 30 second intervals before (two time points) and during child pain; and 2) trait HRV, indexing parent capacity for emotion regulation, as a moderator between parent states (anxiety, catastrophizing) and behaviors during child pain. We hypothesized that: i) low parent state HRV would relate to greater concurrent rates of DP behaviors, whereas high state HRV would relate to greater concurrent rates of CP behaviors; and ii) trait HRV would moderate the association between parent states (anxiety, catastrophizing) and behaviors.

Sample Recruitment

The data for this article were collected as part of a larger study examining verbal and non-verbal aspects of parent-child interactions that are presented in two other empirical papers. The present paper examines a distinct set of research questions regarding the role of parent HRV in relation to parent self-reported states and behaviors. Participants were drawn from a pool of 56 children (28 girls, 28 boys) between 7 and 12 years of age and one of their parents, recruited from the community. Interested families were contacted via phone by a research assistant who were informed that the study was examining parent and child experiences during child acute pain and were screened for inclusionary and exclusionary criteria. Inclusionary criteria for both child and parent included the ability to speak, read, and write in English proficiently enough to answer questions. Parents were included if they were a primary caregiver; there were no other parental criteria. Consistent with CPT guidelines (Von Baeyer et al., 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.

Apparatus

Cold Pressor Task (CPT)

The CPT is a laboratory pain task used to induce mild to moderate levels of pain comparable to acute clinical pains, such as needle procedures, lasting from a couple minutes to several hours (Von Baeyer et al., 2005). The CPT has the advantage of standardizing the pain stimulus that is not possible during needle procedures. Children completed the CPT by submerging their non-dominant hand in a warm water tank [36°C (± 1°C)] for two minutes to create a standardized baseline. Next, they were instructed to immerse their hand in a cold-water tank [10°C (± 1°C)] and to leave it in for as long as they could or until they reached the four-minute maximum submersion time. Participants were not informed of the ceiling time. A Techne© thermoregulator (Techne Inc., Burlington, United States) maintained water temperatures. This method has been deemed ethically acceptable by researchers, parents, and children and has low rates of adverse events (< 0.07%; Birnie et al., 2010). The duration of time children kept their hand in the cold water ranged from 21 seconds to 240 seconds (M = 148 seconds, SD = 98 seconds), which is comparable to other published work (e.g., Birnie et al., 2016).

Electrocardiogram

Parental cardiac activity was recorded continuously for later analysis of HRV. 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 inverted triangle configuration (i.e., electrodes below each collar bone, one ground below the left rib). AcqKnowledge 4.2 software was programed to identify interbeat intervals (IBIs; time between consecutive heart beats) within the ECG recording. Data were then imported into Kubios HRV specialized analysis software (Premium; version 3.3) and HRV was analyzed according to HRV guidelines (Camm et al., 1996) and the Kubios HRV User's Guide (Tarvainen et al., 2014). Consistency in the length of HRV recording across time points is recommended when comparing HRV (Laborde et al., 2017). As such, HRV was calculated for four separate 30-sec time points: resting (first 30 secs of neutral video), before child pain termed "warm1" (first 30s of the warm water tank) and "warm 2" (last 30s of the warm water tank), and during child pain "cold" (first 30s after the child immerses their hand in the cold water tank). Trait HRV was measured during the resting time point; all subsequent time points represent indicators of state HRV. In order to examine parent HRV and behaviors concurrently, 30 second epochs were used given: 1) existing recommendations that each measurement be equivalent in time (Laborde et al., 2017), 2) the variability in time that children kept their hand immersed in the cold water and; 3) a minimum of a 30-second HRV recording can be used to estimate HRV at the high frequency (e.g., Baek et al., 2015). A continuous 30 second time frame is consistent with published work in pediatric pain examining behavioral and cardiac responding in infants (Waxman et al., 2020)

Procedure

Approval for the current study was obtained from the University of Guelph's Research Ethics Board. A visual overview of the study procedures is depicted in Figure 1. Parent and child were given a brief overview of the study upon arrival, before providing parent consent and child assent. Parents were fitted with the ECG and completed the demographic form, State-Trait Anxiety Inventory-State, and the Pain Catastrophizing Scale-Parents-State. Children were given a juice box to drink prior to completing the CPT (Von Baeyer et al., 2005). The dyad watched a two-minute minute National Geographic Time-Lapse to acquire trait HRV data. Next, the dyad sat one to three feet apart, facing each other, and were instructed to interact as they normally would. Participants were given an auditory signal for the child to immerse their hand into the warm water tank for two minutes. A second signal indicated when the child was to immerse their hand into the cold-water tank. The CPT ended once the child voluntarily removed their arm from the water or the four-minute time limit was reached. Parent and child interactions were video recorded during the CPT. After the data were collected, transcripts of the parent-child interactions were assembled for each of the parent-child dyads. The data were then coded using the CAMPIS-R.

Measures

Demographics

Parents reported on their own and their child's demographic information. Parental caffeine, nicotine, and medication use were also measured as they are external factors that can influence HRV (Laborde et al., 2017).

State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983)

The 20 item STAI –State was used to capture parent state anxiety. Items are rated on a 4-point Likert-type scale, and scores can range from 20 to 80, with higher scores indicating higher anxiety. Scores in our sample ranged from 24 to 51. The STAI-S demonstrates construct validity and internal consistency (Spielberger et al., 1983). The measure showed strong reliability in our sample (α = .90).

Pain Catastrophizing Scale for Parents (PCS-P-state; Durand et al., 2016)

The PCS-P-state measured parents' catastrophizing thoughts about their children's upcoming pain related to the CPT as per Durand and colleagues (Durand et al., 2016). Items are rated on an 11-point numerical rating scale, and can range from 0 to 30, with higher scores indicating increased catastrophizing. In our sample, scores ranged from 0 to 17. The full PCS-P demonstrates construct validity, predictive validity, and internal consistency (Caes et al., 2014; Durand et al., 2016; L. Goubert et al., 2009). Cronbach's alpha in our sample was .60.

Child Adult Medical Procedure Interaction Scale and -Revised (CAMPIS, CAMPIS-R; Blount et al., 1990)

The CAMPIS-R is an observational scale used to assess adult and child behaviors during painful procedures (Blount et al., 1997). In the CAMPIS-R, parent behaviors include: adult distress-promoting (DP), adult coping-promoting (CP), and adult neutral. Only parent DP and CP behaviors were examined in this study. Adult CP behaviors include: humor directed to child, nonprocedure-related talk to the child, and command to engage in coping strategy. Adult DP behaviors include: criticism, reassuring comment, giving control to the child, apology, and empathy. The CAMPIS-R is a well-established assessment measure of parent-child interactions having acceptable to excellent psychometric properties (Bai et al., 2018). Coding of parent behaviors was based on verbatim transcripts of the interactions between parent and child during the CPT.

Data Preparation

To meet the assumption of independence for study analyses, 11 dyads in which parents participated with a second child were removed from analyses. This resulted in a dataset of 45 dyads, which was screened for missing data (Table 1). Eight video recordings were unable to be used due to: missing video (*n* = 3), dyad speaking a language other than English (*n* = 3), and unintelligible transcripts (i.e., more than 20% of the entire transcript was transcribed as 'unintelligible'; *n* = 2). Missing values also resulted from equipment failure during HRV recording (*n* = 3 for full segment, *n* = 3 partial recording[2]) and administration error with the STAI-state (*n* = 1). Thirty-one parents had complete cardiac, observational, and self-report data available. When participants were missing data on a given variable for a specific analysis, their data were excluded from the corresponding analysis only. As a result of the missing values, degrees of freedom vary across analyses.

ECG Recordings

Recordings were visually inspected for artifacts. A threshold-based 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 (Tarvainen et al., 2017). Consistent with existing research on pediatric pain (e.g., Vervoort et al., 2019; Waxman et al., 2020), HRV was quantified using a frequency-domain method (Goedhart et al., 2007; Tarvainen et al., 2014). Power spectral density analysis was performed using the Fast Fourier Transform, with a high frequency (HF) band set at 0.15-0.40 Hz. HRV was natural-log (ln) transformed because absolute values were skewed and are reported in squared milliseconds (ms^2). Analyses were also completed with a time-domain measure of

[2] The missing values due to technical artifacts occurred during the following time points in three participants: rest (*n* = 1), warm 1 (*n* = 2), cold (*n* = 1).

HRV (the root mean square of successive differences [RMSSD] between interbeat intervals) and are reported in the Supplemental Appendix (as per recommendations by Laborde et al., 2017). RMSSD values were squared (ms^2) and natural-log (ln) transformed. ECG-derived respiration was computed and the respiration frequency for all participants were within the average range (i.e., 0.15 Hz to 0.40 Hz).

Transcription and Behavioral Coding with the CAMPIS

The video recordings of the parent-child dyads were transcribed verbatim from the time the child placed their hand in the warm water tank until the first 30 seconds following immersion into the cold water. Prior to coding, the transcripts were reviewed by a research assistant to confirm their accuracy; any disagreement between the transcriber and checker was resolved through consensus.

Two coders were trained to recognize all 16 of the parent verbal behaviors from the CAMPIS using didactic methods and practiced using sample transcriptions from another data set (REB approval secured for this purpose). Both coders attended a CAMPIS training, in which each code was discussed and defined within the context of the cold pressor task. Once coders were familiar with all 16 of the adult verbal behavior codes, they practiced coding using sample transcripts from a previous study until 80% interrater reliability was achieved. Next, the coders practiced coding data from the current study. Primary and secondary coders were compared with a “gold standard” third coder who was previously trained in the CAMPIS coding scheme, to ensure accuracy to the CAMPIS. After coding three transcripts from the current study data, the primary and secondary coder both achieved 94.74% percent agreement with the “gold standard” third coder and 89.47% percent agreement with each other.

Continuous event coding was used to code each instance of parent verbal behaviors from the time the child placed their hand in the warm-water tank until the completion of the CPT; no verbal interaction occurred during the resting period due to the nature of the task. Parent behaviors were first coded according to the 16 adult verbal behavior codes from the CAMPIS (Blount et al., 1989) and later grouped according to the CP and DP codes as outlined in the CAMPIS-R. To examine concurrent parent behaviors and HRV activity, 30-second segments of the interaction were used to calculate rates of parent CP and DP behaviors during: warm 1, warm 2, and cold, as described above. The primary coder coded all transcriptions, and the secondary coder coded a random 20% of the transcripts, that was randomly selected using an online number generator (Research Randomizer). Strong interrater reliability on the double coded 20% was achieved (percent agreement for DP behaviors = 87%; percent agreement for CP behaviors = 94%; overall Cohen's kappa = .83). The secondary coder's codes were used in analyses in the case of disagreements between codes.

Analysis Plan

Descriptive statistics and bivariate correlations between all study variables were calculated for descriptive purposes. Partial correlations controlling for parent trait HRV in the association between parent state HRV and behaviors were conducted given that the magnitude of a psychophysiological response is dependent on the baseline level (Berntson et al., 1994). To examine the moderating effects of trait HRV on the relations between parent states (catastrophizing, anxiety) and behaviors (CP, DP), four moderation analyses were performed using the PROCESS Macro (Hayes, 2013). Parent states (anxiety, catastrophizing) were entered as predictor variables, trait HRV was entered as the moderator, and parent behaviors were entered as the outcome variables. The predictor and moderator variables were mean centered to decrease multicollinearity between the interaction term and its corresponding main effects. Simple slopes analyses were conducted for interaction effects significant at $p < .10$ level, in which the relation between parent states and behaviors were examined within high (i.e., +1 *SD*) and low (-1 *SD*) groups of trait HRV.

Results

Participants

Forty-five parent-child dyads were retained for analyses[3]. The parent sample consisted mainly of White/European (95.6%) mothers ($N = 44$), with a mean age of 42.00 years (range = 32 to 50 years, $SD = 4.36$) that have completed college/university (36.6%), a graduate education (33.3%), or a professional degree (20%). A sample size of 30 participants is recommended to detect a large effect size at 80% power for multiple regression with two predictors (Cohen, 1992a). Data for all analyses were examined for violations of parametric assumptions and compensating techniques applied (i.e., Spearman's rank correlations for skewed or kurtotic variables). External factors that can influence HRV, such as caffeine consumption, nicotine intake, and cardioactive medication use (Quintana & Heathers, 2014) were examined. Participants who had recently consumed nicotine and were taking medications presented with higher HRV ($r = .32$ to $.43$, $p < .05$). However, controlling for medication and nicotine use did not change the pattern of results and thus were not controlled for in analyses. Effect sizes for correlations are reported based on Cohen's guidelines (Cohen, 1992b).

Descriptive Statistics, Bivariate and Partial Correlations Between Study Variables

Means, standard deviations, and correlations for study variables are presented in Table 2 (see Table S1 for means, standard deviations and correlations with RMSSD). Rates/30 seconds

[3] As indicated in "data preparation", sample size will vary based on the analysis.

of parent behavior ranged from 0 to 0.27 for CP behaviors and from 0 to 0.17 for DP behaviors across all time points. Parent trait HRV ranged from 2.21 to 7.99 and state HRV ranged from 2.46 to 7.71. The first aim of the study was to examine parent state HRV, CP, and DP behaviors while controlling for trait HRV. Partial correlations are reported in Table 3 (see Table S2 for partial correlations with RMSSD)[4]. No correlations observed between parent HRV and behaviors during the warm water bath (i.e., warm 1, warm 2) reached significance, although a small to moderate positive association emerged between parent CP behaviors during the first 30 seconds of the warm water tank and HRV during the cold water (r = .30, p = .090). In contrast, the small to moderate association during the cold water CPT (r = -.35, p = .047) suggests that parents with lower HRV engaged in greater CP behaviors.

Moderation Analyses

Parent trait HRV was examined as a moderator between state anxiety and DP and CP behavior (see Table 4; see Table S3 for RMSSD). Analyses for the first moderation model indicated no significant main effect of anxiety, trait HRV, or an anxiety x trait HRV interaction effect on DP behaviors. Similarly, analyses for the second moderation model indicated no significant main effect of anxiety, trait HRV, or an anxiety x trait HRV interaction effect on CP behaviors.

Trait HRV was examined as a moderator between parent state catastrophizing and DP and CP behaviors (see Table 4; see Table S3 for moderation analyses with RMSSD). Analyses for the third moderation model indicated no significant main effect of catastrophizing or trait

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[4] Parent CP behaviours during the first 30 seconds of the warm water submission (warm 1) positively related to RMSSD during the last 30 seconds of the warm water submersion (r = .45, p = .010) and cold water submersion (r = .46, p = 009). Parent RMSSD and CP behaviours during cold water submersion were negatively associated (r = -.43, p = .014).

HRV on DP behaviors. A significant catastrophizing x trait HRV interaction effect was observed on DP behaviors. Simple slopes analysis revealed that the association between catastrophizing and DP behaviors was strongest among individuals with low levels of HRV ($t = 2.57$, $p = .015$; see Figure 2). Analyses for the fourth moderation model indicated no significant main effect of catastrophizing, trait HRV, or a catastrophizing x trait HRV interaction effect on CP behaviors. Of note, while a similar pattern of results were obtained with RMSSD, the third moderation model did not reach significance at $p < .05$ for the interaction effect ($p = .09$) or in predicting parent DP behaviors overall ($p = .06$).

Discussion

Parent behaviors are strong predictors of child acute pain outcomes, yet there is a lack of work examining possible factors driving these behaviors. The current work contributes to our understanding of parent responses to child acute pain by examining potential mechanisms through which parent states relate to their behaviors using a multimethod approach. This is the first study to explore parent HRV, a psychophysiological index of emotion regulation, and behaviors concurrently throughout children's pain.

A first aim of this study was to examine whether state HRV corresponds to parent verbal behaviors before and during child pain. Parent state HRV did not correlate with DP behaviors; while unexpected, this is consistent with work that failed to find a direct correlation between parent HRV and pain control behavior (Vervoort et al., 2019). Also inconsistent with our hypothesis was a small to moderate relation between low parent state HRV during their child's pain and greater CP behaviors. It is possible that modest decreases in parent HRV in the moment may be adaptive in the immediate pain context. A reduction in HRV is an expected response to threat (Porges, 2003) and the degree and duration of this decrease may need to be considered in order to understand how this may translate to behaviors (Park et al., 2014). This finding should also be understood in the context of the pain stimulus. Parents may not perceive the CPT to be as threatening or distressing as a venipuncture or anesthesia induction. Indeed, mean levels of parent state anxiety were in the "no to low anxiety" range (Spielberger et al., 1983). As such, moderate HRV decreases might facilitate parent CP behaviors in low-threat pain contexts, such as when children experience everyday bumps or bruises. It may also be that parents with high HRV during the cold water CPT may have been more attuned to their child's emotional experience and needs. If the CPT was not viewed as a threatening context, then parents may not deem it necessary to provide CP verbalizations. Future work with larger samples could examine the aforementioned associations using more advanced statistics, including cross-lagged path analysis to examine reciprocal and concurrent associations. Future work may examine phasic measures of HRV to determine how the degree of change from resting to anticipating, viewing, and recovering from witnessing one's child in pain relates to parent behaviors and responses measured concurrently to better understand the meaning of state HRV. For example, it is possible that parents who experienced the greatest *change* or decrease in HRV from resting to the CPT and experienced challenges returning to rest, may be at greater risk of experiencing distress and engaging in DP behaviors. A limitation of the current study is that this was not explored since HRV was not extracted following the CPT given that parent behaviors were only coded during the CPT and the aim of this investigation was to examine parent HRV and behaviors concurrently. Examining parent HRV and behaviors following the painful stimuli would further our understanding of parent emotion regulatory efforts in relation to their actions.

A second aim of this study was to examine trait HRV as a moderator in the association between parent states and behaviors. Trait HRV is viewed as an index for the capacity for emotion regulation and as such, lends itself well to be considered as a parental risk or resource variable that may serve to buffer or strengthen the association between how parents are feeling in the moment and their subsequent behaviors. Parental trait HRV did not moderate the association between anxiety and verbal behaviors, nor between catastrophizing and CP behaviors. However, parents experiencing state catastrophizing were significantly more likely to engage in distress-promoting behavior if they had low (vs. high) trait HRV. This finding suggests that parents who generally have low HRV, indicative of less capacity for emotion regulation, may be particularly susceptible to engaging in DP behaviors when catastrophizing about their child's pain. This is consistent with prominent HRV theories that claim in a state of stress, an individual with low HRV has difficulty expressing social cues and emotions (Porges, 2003). This novel work is consistent with the Affective Motivational Model (Vervoort & Trost), suggesting that low levels of HRV, indicative of lower capacity for emotion regulation, may serve as a risk factor for parents, such that they may be more likely to engage in behaviors that increase child distress during acute pain. These findings have the potential for both theoretical and clinical implications, although future work replicating these findings is needed before any conclusive statements can be drawn, particularly in light of the differences in the level of statistical significance between the two HRV parameters.

Theoretical models of pain (e.g., Affective-Motivational Model of Interpersonal Pain Dynamics, Social Communication Model of Pain; Craig, 2009) recognize the role of parents in shaping their child's pain experience and the factors contributing to parent responses; however, parent physiology as a contributor to parent responses has been neglected. This preliminary work speaks to the need for parent physiology to be recognized in existing social pain models more clearly. Clinically, the present results suggest that interventions aimed at parent HRV, including relaxation techniques, mindfulness, and biofeedback training, may be particularly useful when targeting parent behaviors that promote child distress (Goessl et al., 2017). Moreover, a number of prominent psychological interventions that target emotion regulation, such as mindfulness meditation, have been shown to result in quantifiable increases in HRV (e.g., Adler-Neal et al., 2020). Therefore, HRV may not only serve as an important indicator of a parent's capacity to regulate their own distress in the face of their child's pain, but also to monitor the effectiveness of treatments that are aimed to reduce parent distress.

Parent trait HRV moderated the association between parent catastrophizing and distress-promoting behaviors, whereas trait HRV did not moderate the association between parent anxiety and distress-promoting behaviors. This may be understood as reflecting the varying degree of specificity measured in each construct. That is, the measure of parent catastrophizing about child pain examined parent thoughts regarding their child's completion of the CPT, whereas parent's emotional response, captured through the STAI, was measured by having parents rate how they feel in the moment (e.g., the amount to which they feel tense, afraid, nervous, worried), without reference to the child's pain and occurred once their child's pain had passed. As such, future research would benefit from endeavours asking parents to rate their anxiety while they anticipate their child's pain, getting ratings of fear/negative affect during their child's pain, or by cuing them to reflect on their emotional experience while their child was in pain.

A strength of this investigation was utilizing a laboratory pain task that permitted the acquisition of parent HRV recordings during resting, prior to and during their child's experience of pain. The controlled laboratory environment provides high internal validity, standardization of the pain stimulus, and cleaner physiological recordings (i.e., reducing noise, movement artifacts) than is possible with clinical pain. This novel work is the first to investigate parent physiological responding and behaviors concurrently in the context of parent-child interactions and child acute pain. The multi-method approach in capturing parents' experience at several time points uniquely contributes to existing work on parent responses and behaviors in response to their child's completion of the CPT. Parent responding during their child's acute pain was captured using physiological recordings, in addition to self-report and behavioral data, thus contributing to understanding on how parent physiological activity may contribute to or interact with their subjective states and verbal behaviors.

This study provides unique insights into the role of parent HRV in relation to their behaviors, although limitations offer directions for future work in this area. Although the CPT enables strong internal reliability, these findings may not translate to clinical pain, such as needle procedures, as parent responses may differ in a clinical context. For example, 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 work in a clinical setting, such as a needle procedure, may help to clarify the lack of associations observed in parent self-reported experiences and behaviors in the context of experimental pain. Similarly, children's behaviors were not examined in this study although is an area worthy of further investigation given that parent's appraisal of threat will relate to their child's pain expression. The lack of diversity within the sample is a concern as the majority of dyads consisted of White/European participants, reporting high levels of educational attainment. Another limitation is the internal consistency of the parent pain catastrophizing scale, despite past work that has demonstrates adequate reliability (alpha = .7; Durand et al., 2016) The low observed Cronbach's alpha is likely related to the low number of items in the scale as opposed to poor interrelatedness (Tavakol & Dennick, 2011); the 6-item (vs. 3-item) PCS-P state measure was added following commencement of this study and increased Cronbach's alpha to .82. This was not included in the current paper as only 15 participants completed all six items, although this speaks to the relevance of replication in future work and exploring these associations with the 6-item state pain catastrophizing measure. The sample size in the present study may have contributed to underpowered analyses; however, our sample is comparable to other published work with a similar methodology (Bai et al., 2017; Perlman et al., 2008) and presents an initial step in understanding parent behavioral and physiological responses to child pain. The inclusion of multiple autonomic nervous system indices, beyond HRV, may enhance the specificity in emotive responses. Similarly, studying parent and child nonverbal behaviors is likely to be fruitful given that literature suggests nonverbal signals (e.g., vocal prosody) can be traced to activity from the autonomic nervous system (Eckland et al., 2019), parent physiology may indirectly relate to child outcomes through verbal and nonverbal avenues (Thorson et al., 2018), and children's nonverbal expressions of pain (e.g., facial expression) are bidirectionally associated with parent verbal and nonverbal responses (Constantin et al., 2018; Vervoort & Trost, 2017).

The current study extends existing knowledge on parent responses to child pain in relation to parent behaviors during children's completion of the cold pressor task. Results offer initial support for the use of parent HRV to glean unique information regarding parent experiences of child pain that may not be captured through self-report methods. Future work would benefit from examining these associations in a larger, diverse sample and in clinical settings (e.g., needle procedures), using multiple psychophysiological indices.

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Table 1

Reasons for cardiac, observational, and self-report data not being usable from a sample of 45 parent-child dyads

Cardiac data		Observational data		Self-report data[a]	
Equipment failure	3	Missing video	3	Procedural Error[a]	1
Technical artifacts (partial)	3[b]	Speaking another language	3		
		Unintelligible transcripts	2		
Number retained:	39	Number retained:	37	Number retained:	44
Number of participants with complete cardiac, observational, and self-report data:				31	

Note. [a]The STAI-State was the only self-report measure with a procedural error; [b]Participants with technical artifacts are missing (partial) cardiac data at a specific time point: rest ($n = 1$), warm 1 ($n = 2$), cold ($n = 1$).

Table 2

Means, standard deviations, and correlations with confidence intervals (n = 31 to 44)

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11
1. Trait HRV	5.84	1.30											
2. Anxiety	29.08	7.40	-.27 [-.55, .06]										
3. Catastroph.	4.82	4.09	-.10 [-.39, .22]	.21 [-.09, .48]									
4. W1_HRV	5.99	1.33	.69** [.49, .83]	-.19 [-.47, .13]	-.15 [-.44, .17]								
5. W1_CP[a]	0.02	0.05	-.07 [-.39, .27]	.02 [-.32, .36]	.01 [-.33, .35]	-.05 [-.37, .28]							
6. W1_DP[a]	0.01	0.01	.24 [-.09, .53]	-.04 [-.39, .26]	.14 [-.29, .36]	.05 [-.37, .28]	-.25 [-.53, .09]						
7. W2_HRV	5.57	1.24	.73** [.54, .85]	-.21 [-.48, .09]	.07 [-.27, .39]	.77** [.61, .88]	-.15 [-.44, .17]	.09 [-.24, .40]					
8. W2_CP	0.07	0.07	-.15 [-.47, .20]	.33* [.00, .59]	-.03 [-.35, .30]	-.23 [-.53, .13]	-.09 [-.40, .24]	.27 [-.07, .54]	-.07 [-.40, .27]				
9. W2_DP[a]	0.00	0.01	.06 [-.28, .36]	-.16 [-.46, .18]	-.29 [-.56, .04]	.19 [-.15, .49]	.22 [-.12, .51]	.13 [-.22, .46]	-.12 [-.43, .20]	-.26 [-.54, .07]			
10. Cold_HRV	5.64	1.21	.71** [.52, .84]	-.20 [-.43, .20]	-.06 [-.36, .25]	.68** [.47, .82]	.17 [-.20, .46]	.06 [-.25, .36]	.69** [.49, .82]	-.19 [-.49, .17]	.01 [-.33, .35]		
11. Cold_CP	0.02	0.03	-.13 [-.46, .22]	.05 [-.27, .38]	-.13 [-.43, .21]	-.05 [-.39, .30]	.07 [-.27, .39]	.14 [-.29, .36]	-.17 [-.46, .20]	.24 [-.09, .52]	.02 [-.32, .36]	-.34* [-.61, -.01]	
12. Cold_DP[a]	0.02	0.04	-.13 [-.46, .22]	.01 [-.33, .35]	-.01 [-.35, .33]	-.06 [-.36, 28]	.11 [-.23, .42]	-.27 [-.55, .06]	-.18 [-.48, .16]	-.24 [-.52, .09]	.16 [-.18, .46]	-.08 [-.40, .26]	-.05 [-.39, .30]

Note. Sample size range is due to pairwise deletion. Trait HRV = log transformed heart rate variability at rest (reported in ms^2); Anxiety = state anxiety; Catastroph. = state catastrophizing; W1 = first 30 second block of the warm water tank; W2 = final 30 second block of the warm water; Cold = first 30 seconds after child immersed his/her hand in the cold water tank; CP = coping-promoting behavior; DP = distress-promoting behavior. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$.
[a]Spearman's rank correlation coefficient.

Table 3

Partial correlations between state HRV, CP and DP behaviors with confidence intervals controlling for trait HRV (n = 31 to 44)

Variable	1	2	3	4	5	6	7	8
1. W1_HRV								
2. W1_CP[a]	-.01							
	[-.37, .35]							
3. W1_DP[a]	-.12	-.24						
	[-.46, .25]	[-.55, .13]						
4. W2_HRV	.54**	-.14	-.12					
	[.22, .75]	[-.48, .23]	[-.46, .25]					
5. W2_CP	-.16	-.09	.32	.06				
	[-.49, .21]	[-.44, .28]	[-.06, .61]	[-.31, .41]				
6. W2_DP[a]	.28	.22	.14	-.11	-.27			
	[-.09, .58]	[-.15, .54]	[-.23, .48]	[-.44, .26]	[-.57, .10]			
7. Cold_HRV	.36**	.30	-.16	.35**	-.11	.04		
	[.00, .63]	[-.07, .60]	[-.49, .21]	[.03, .60]	[-.44, .26]	[-.32, .39]		
8. Cold_CP	.05	.06	.16	-.11	.22	.01	-.35*	
	[-.31, .40]	[-.31, .41]	[-.21, .49]	[-.44, .26]	[-.15, .54]	[-.35, .37]	[-.60, -.03]	
9. Cold_DP[a]	.02	.11	-.25	-.13	-.26	.15	-.14	-.06
	[-.34, 38]	[-.26, .44]	[-.13, .55]	[-.47, .24]	[-.11, .57]	[-.22, .48]	[-.48, .23]	[-.41, .31]

Note. Sample size range is due to pairwise deletion. Trait HRV = log transformed heart rate variability at rest (reported in ms^2); W1 = first 30 second block of the warm water tank; W2 = final 30 second block of the warm water; Cold = first 30 seconds after child immersed his/her hand in the cold water tank; CP = coping-promoting behavior; DP = distress-promoting behavior. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$. [a]Spearman's rank correlation coefficient.

Table 4

Summary of regression analysis with the measures of trait HRV, state anxiety, catastrophizing and their interaction term as predictors of parent behaviors

Predictor Variable	*b (SE)*	*t*	*p*	95% confidence interval for *b*	
				Lower bound	Upper bound
		Criterion = Distress-Promoting Behaviors[a]			
Anxiety (centered)	.0006 (.00)	0.67	p = .51	-.0013	.0026
Trait HRV (centered)	-.0021 (.01)	-0.37	p = .72	-.0140	.0097
Anxiety X Trait HRV	-.0013 (.00)	-1.65	p = .11	-.0028	.0003
		Criterion = Coping-Promoting Behaviors[a]			
Anxiety (centered)	-.0002 (.00)	-0.28	p = .78	-.0016	.0012
Trait HRV (centered)	-.0051 (.00)	-1.24	p = .22	-.0136	.0033
Anxiety X Trait HRV	.0006 (.00)	1.13	p = .27	-.0005	.0017
		Criterion = Distress-Promoting Behaviors[b]			
Catastrophizing (centered)	.0016 (.00)	1.07	p = .29	-.0014	.0046
Trait HRV (centered)	-.0055 (.00)	-1.12	p = .27	-.0155	.0045
Catastrophizing X Trait HRV	-.0026 (.00)	-2.26	$p < .05$	-.0049	-.0002
		Criterion = Coping-Promoting Behaviors[b]			
Catastrophizing (centered)	-.0005 (.00)	-0.43	p = .67	-.0028	.0018
Trait HRV (centered)	-.0030 (.00)	-0.79	p = .43	-.0107	.0047
Catastrophizing X Trait HRV	.0005 (.00)	0.52	p = .61	-.0013	.0022

Note. [a]n = 32; [b]n = 33; R^2 = .15 for model 1; R^2 = .07 for model 2; R^2 = .24 for model 3; R^2 = .03 for model 4.

Figure 1

Timeline of study procedure. HRV: heart rate variability; CPT: cold pressor task; ECG: electrocardiogram; CAMPIS-R: Child-Adult Medical Procedure Interaction Scale-Revised; STAI-S: State-Trait Anxiety Inventory-State; PCS-P: Pain Catastrophizing Scale for Parents - State

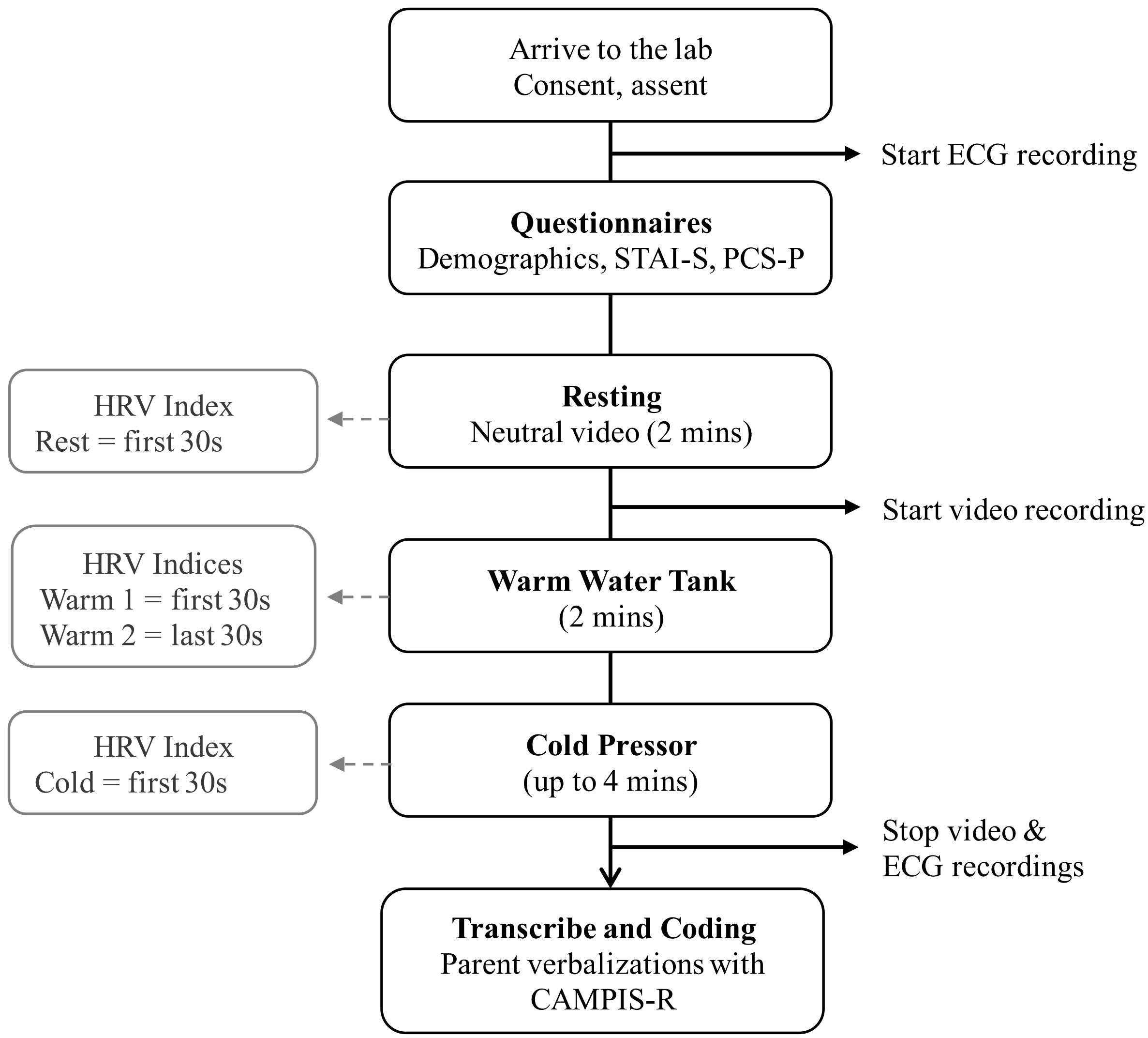


Figure 2

Parent trait HRV as moderator of the relation between parental catastrophizing about child pain and DP behaviours.

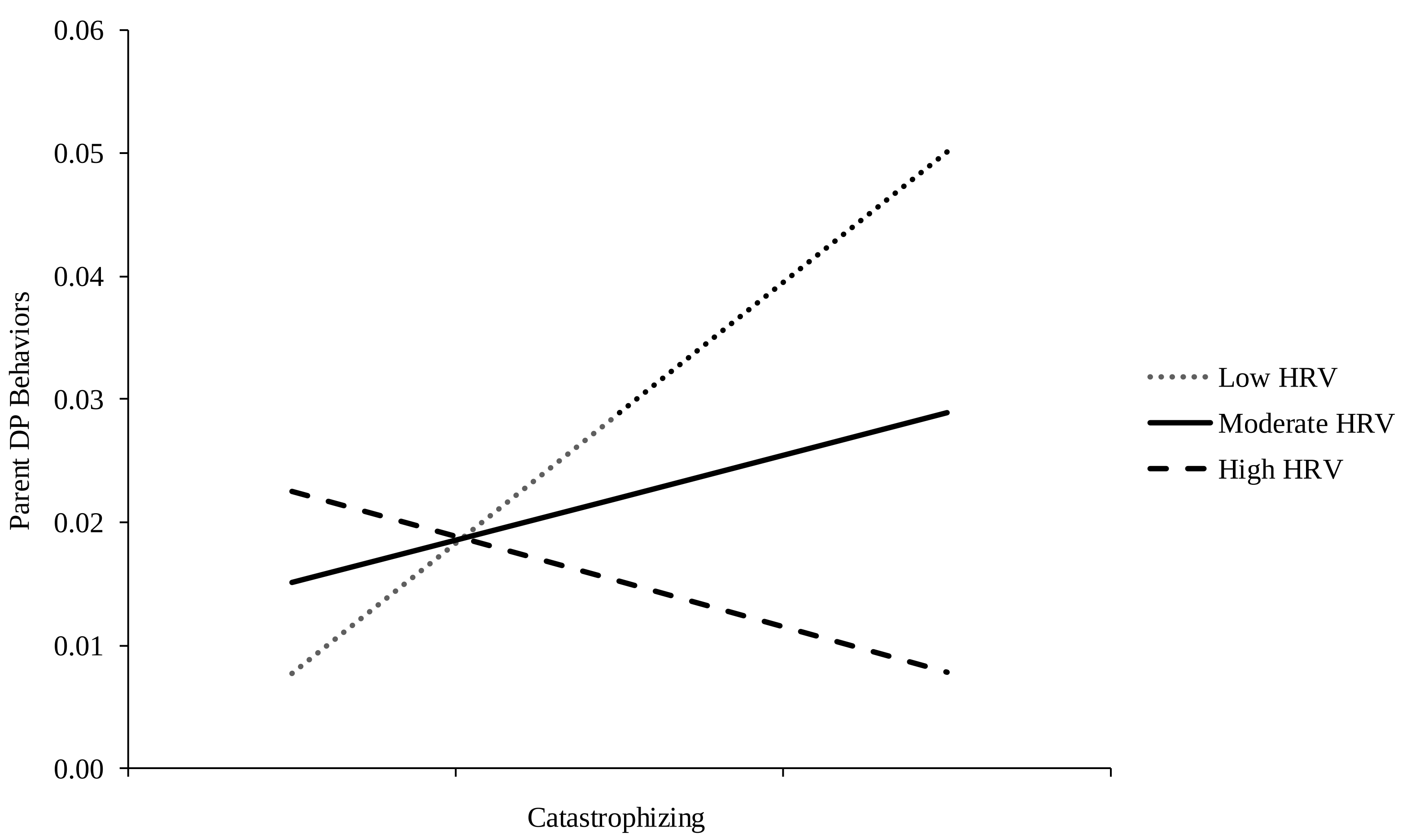


Table S1

Means, standard deviations, and correlations with confidence intervals with RMSSD and study variables (n = 31 to 44)

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11
1. Trait RMSSD	6.84	1.19											
2. Anxiety	29.08	7.40	-.33* [-.58, .-02]										
3. Catastroph.	4.82	4.09	.04 [-.27, .34]	.21 [-.09, .48]									
4. W1_ RMSSD	6.86	1.32	.75** [.57, .86]	-.27 [-.53, .05]	-.08 [-.38, .24]								
5. W1_CP[a]	0.02	0.05	-.14 [-.46, .21]	.02 [-.32, .36]	.01 [-.33, .35]	-.03 [-.37, .32]							
6. W1_DP[a]	0.01	0.01	.13 [-.22, .45]	-.04 [-.39, .26]	.14 [-.29, .36]	-.01 [-.35, .33]	-.25 [-.53, .09]						
7. W2_ RMSSD	6.57	1.12	.80** [.65, .89]	-.35* [.04, .60]	.13 [-.21, .43]	.85** [.73, .92]	.21 [-.13, .51]	-.06 [-.39, .28]					
8. W2_CP	0.07	0.07	-.17 [-.46, .20]	.33* [.00, .59]	-.03 [-.35, .30]	-.34 [-.01, .62]	-.09 [-.40, .24]	.27 [-.07, .54]	-.30 [-.60, .04]				
9. W2_DP[a]	0.00	0.01	-.09 [-.42, .26]	-.16 [-.46, .18]	-.29 [-.56, .04]	.03 [-.37, .32]	.22 [-.12, .51]	.13 [-.22, .46]	.10 [-.25, .42]	-.26 [-.54, .07]			
10. Cold_RMSSD	6.46	1.05	.68** [.47, .82]	-.36* [-.43, .20]	-.07 [-.36, .25]	.83** [.70, .91]	.28 [-.06, .56]	.00 [-.34, .34]	.80** [.65, .89]	-.31 [-.59, .03]	.03 [-.37, .32]		
11. Cold_CP	0.02	0.03	.07 [-.28, .40]	.05 [-.27, .38]	-.13 [-.43, .21]	-.13 [-.43, .21]	.07 [-.27, .39]	.14 [-.29, .36]	-.11 [-.43, .24]	.24 [-.09, .52]	.02 [-.32, .36]	-.27 [-.56, -.08]	
12. Cold_DP[a]	0.02	0.04	-.30 [-.46, .22]	.01 [-.33, .35]	-.01 [-.35, .33]	-.18 [-.50, 18]	.11 [-.23, .42]	-.27 [-.55, .06]	-.18 [-.48, .16]	-.24 [-.52, .09]	.16 [-.18, .46]	-.15 [-.46, .20]	-.05 [-.39, .30]

Note. Sample size range is due to pairwise deletion. Trait RMSSD = log transformed heart rate variability at rest measured by the root mean square of successive differences (reported in ms^2); Anxiety = state anxiety; Catastroph. = state catastrophizing; W1 = first 30 second block of the warm water tank; W2 = final 30 second block of the warm water; Cold = first 30 seconds after child immersed his/her hand in the cold water tank; CP = coping-promoting behavior; DP = distress-promoting behavior. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. *indicates $p < .05$. ** indicates $p < .01$. [a]Spearman's rank correlation coefficient.

Table S2

Partial correlations between state RMSSD, CP and DP behaviors with confidence intervals controlling for controlling for trait RMSSD (n = 31 to 44)

Variable	1	2	3	4	5	6	7	8
1. W1_RMSSD								
2. W1_CP[a]	.17 [-.20, .50]							
3. W1_DP[a]	-.12 [-.46, .25]	-.24 [-.53, .13]						
4. W2_RMSSD	.64** [.40, .80]	.45** [.11, .70]	-.21 [-.53, .16]					
5. W2_CP	-.33 [-.62, .03]	-.11 [-.45, .26]	.30 [-.07, .60]	-.26 [-.57, .11]				
6. W2_DP[a]	.12 [-.25, .46]	.21 [-.16, .53]	.14 [-.23, .48]	.23 [-.14, .55]	-.28 [-.58, .09]			
7. Cold_RMSSD	.65** [.41, .80]	.46** [.12, .70]	-.09 [-.44, .28]	.57** [.30, .75]	-.26 [-.57, .11]	.10 [-.25, .42]		
8. Cold_CP	-.27 [-.57, .10]	.08 [-.29, .43]	.13 [-.24, .47]	-.27 [-.57, .10]	.25 [-.12, .56]	.03 [-.33, .39]	-.43* [-.68, -.08]	
9. Cold_DP[a]	.02 [-.34, 38]	.08 [-.29, .43]	-.24 [-.55, .13]	-.15 [-.48, .22]	-.30 [-.60, .07]	.13 [-.23, .47]	-.04 [-.39, .32]	-.02 [-.38, .34]

Note. Sample size range is due to pairwise deletion. Trait RMSSD = log transformed heart rate variability at rest measured by the root mean square of successive differences (reported in ms^2); W1 = first 30 second block of the warm water tank; W2 = final 30 second block of the warm water; Cold = first 30 seconds after child immersed his/her hand in the cold water tank; CP = coping-promoting behavior; DP = distress-promoting behavior. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. *indicates $p < .05$. ** indicates $p < .01$. [a]Spearman's rank correlation coefficient.

Table S3

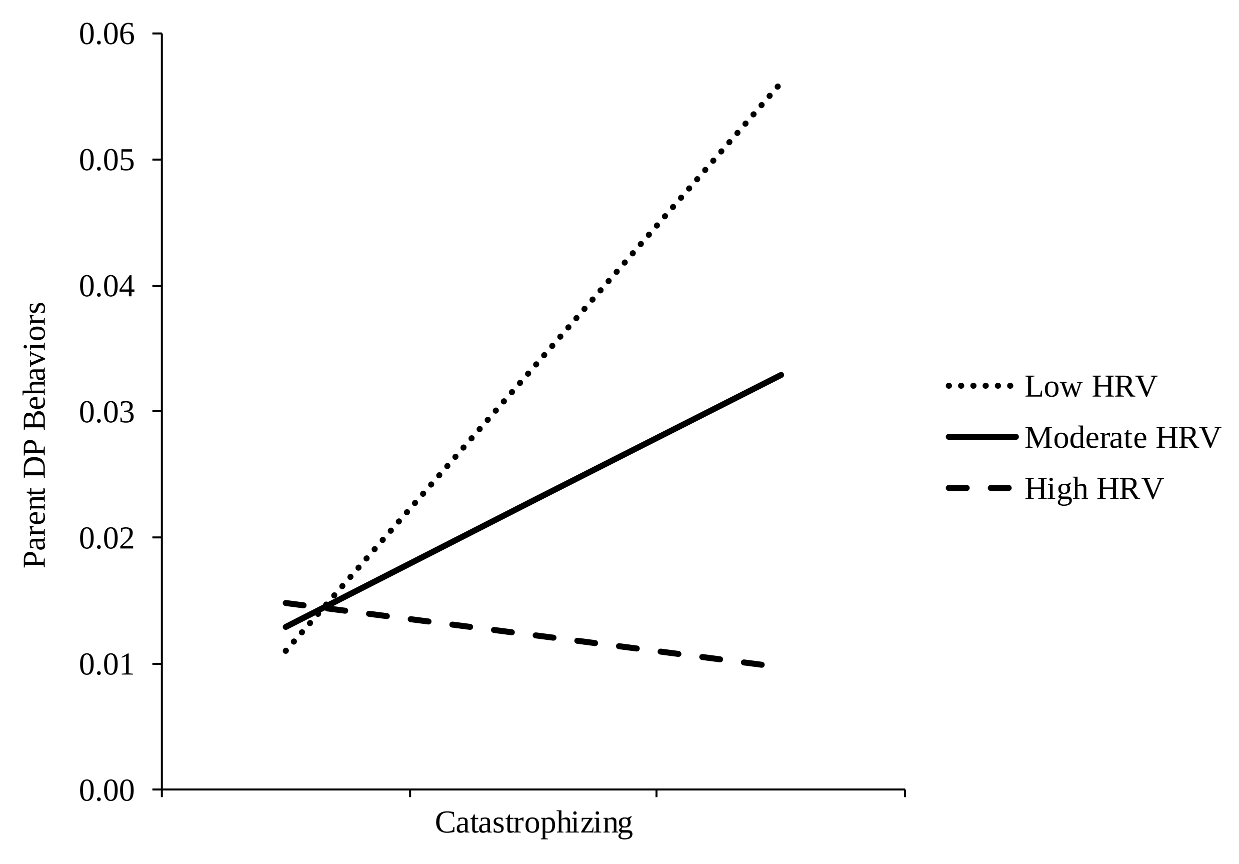
Summary of regression analysis with the measures of trait HRV (RMSSD), state anxiety, catastrophizing and their interaction term as predictors of parent behaviors

Predictor Variable	*b (SE)*	*t*	*p*	95% confidence interval for *b*	
				Lower bound	Upper bound
		Criterion = Distress-Promoting Behaviors[a]			
Anxiety (centered)	.0007 (.00)	.65	p = .52	-.0015	.0028
Trait HRV (centered)	-.0058 (.01)	-.91	p = .37	-.0290	.0073
Anxiety X Trait HRV	-.0003 (.00)	-.37	p = .71	-.0033	.0015
		Criterion = Coping-Promoting Behaviors[a]			
Anxiety (centered)	.0002 (.00)	-0.22	p = .82	-.0017	.0014
Trait HRV (centered)	-.0012 (.00)	0.27	p = .79	-.0082	.0106
Anxiety X Trait HRV	-.0002 (.00)	-.35	p = .73	-.0015	.0011
		Criterion = Distress-Promoting Behaviors[b]			
Catastrophizing (centered)	.0023 (.00)	1.59	p = .12	-.0007	.0054
Trait HRV (centered)	-.0089 (.01)	-1.69	p = .10	-.0197	.0019
Catastrophizing X Trait HRV	-.0025 (.00)	-1.75	p = .09	-.0053	.0004
		Criterion = Coping-Promoting Behaviors[b]			
Catastrophizing (centered)	-.0006 (.00)	-0.55	p = .58	-.0029	.0017
Trait HRV (centered)	-.0016 (.00)	0.41	p = .68	-.0066	.0098
Catastrophizing X Trait HRV	.0009 (.00)	0.81	p = .42	-.0013	.0031

Note. [a]n = 32; [b]n = 33; R^2 = .08 for model 1; R^2 = .01 for model 2; R^2 = .22 for model 3; R^2 = .03 for model 4.

Figure S1

Parent trait HRV (RMSSD) as moderator of the relation between parental catastrophizing about child pain and DP behaviours.



Note. Simple slopes analysis were probed as the moderation model was significant at $p < .10$ and revealed a similar trend as HF-HRV in that the association between catastrophizing and DP behaviors was strongest among individuals with low levels of HRV ($t = 2.41$, $p = .02$).