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Parental emotion and pain control behaviour when faced with child's pain: the emotion regulatory role of parental pain-related attention-set shifting and heart rate variability

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ABSTRACT

The present study investigated the moderating role of parental pain-related attention-set shifting and heart rate variability (HRV) for parental distress and pain control behaviour when faced with their child's pain. Participants were 54 school children and one of their parents. Parental HRV was assessed at study commencement followed by a cued switching task indexing parental ability to flexibly shift attention between pain-related and neutral attentional sets. In a subsequent phase, parents observed their child perform a CPT task, allowing assessment of parental pain control behavior (indexed by latency to stop their child's CPT performance) and parental distress – assessed via self-report following observation of child CPT performance. Findings indicated that parental *facilitated* attentional shifting (i.e., engage) towards a pain-related attentional set contributed to higher levels of pain control behaviour when faced with increasing levels of chid facial display of pain. Pain control behaviour amongst parents who demonstrated *impeded* attentional shifting to a pain-related attentional set was equally pronounced regardless of low or high levels of child pain expression. Parental ability to shift attention away (i.e., disengage) from a pain related set to a neutral set did not impact findings. Results further indicated that whereas *high* levels of parental HRV buffers the impact of child facial pain display upon parental emotional distress and pain control behaviour, *low* levels of HRV constitute a risk factor for higher levels of parental distress and pain control behaviour when faced with increased child facial pain display. Theoretical/clinical implications and further research directions are discussed.

1. INTRODUCTION

Observing pain in others elicits distress and motivates observers to engage in pain-controlling behaviours [7,8,9,24,67,68]. This dynamic is particularly evident in parent-child dyads. Indeed, findings amongst healthy schoolchildren [7] and children with chronic pain [8] have demonstrated that parental distress when anticipating/observing their child's pain contributes to increased restriction of child pain and painful physical activity. While controlling pain has adaptive value by protecting from further harm, persistent efforts to control child's pain may contribute to increased child disability by diminishing engagement in daily activities [12,38,39,53,54,55,71]. Given the central role of parental emotional distress, parental *emotion regulation ability* is considered fundamental in buffering (or strengthening) the occurrence of distress and pain control behaviours elicited by child's pain displays [25,68,69]. Individual differences in *attention deployment* and resting *heart rate variability* (HRV) have repeatedly been shown to be important factors to regulate emotion across a variety of domains, including personal pain [1,3,22,32,33,50,61,72].

Recently, we provided first evidence on the emotion regulatory role of parental attention deployment within the *interpersonal* pain context [69]. However, findings are preliminary and limited in that findings thus far concern the role of attention that is deployed statically either toward (i.e., engagement) *or* away (i.e., avoidance) from pain. Instead, peoples' ability to *flexibly shift attention* between multiple demands, rather than attentional engagement or avoidance in an all or none response pattern, has been proposed as being essential to successful emotion regulation and goal-directed behaviour [29,30]. Corroborating this notion, evidence has shown that anxious and depressed individuals exhibit a deficient ability to shift attention away from an emotional attentional to a neutral set as well as facilitated attentional shifting from a neutral towards an emotional attentional set [16,19,29]. In the context of personal pain, preliminary evidence suggests that it is difficult to shift attention away from a pain-related to a neutral task [63]. However, whether parental attention-set shifting ability serves a similar emotion regulatory function during their child's pain remains to be examined.

Further research is likewise needed to examine whether the emotion regulatory role of individual differences in (resting) HRV in the context of personal pain translates to the interpersonal pain domain. Specifically, research has demonstrated that lower levels of resting HRV are associated with higher levels of pain unpleasantness [3] and reduced inhibition of fear responses [43,72]. Preliminary evidence suggests parental resting HRV relates to altered parental physiological responding when facing their child's pain [14], yet its precise role for parental self-reported distress and pain-control behaviour elicited by facing child's pain remains to be examined.

The current study examined the moderating role of parental pain-related attention set-shifting and resting HRV upon parental distress and pain control behavior when faced with child's pain. We hypothesized that (1) parental *facilitated* attentional shifting (i.e., engage) from a neutral set towards a child pain-related attention set and parental *reduced* ability to shift attention away (i.e., disengage) from a child pain-related attention set to a neutral attention set, and (2) lower levels of parental resting HRV would strengthen (i.e., moderate) the occurrence of parental distress and pain control behaviour when faced with their child's pain.

2. METHODS

2.1 Participants

The present study is part of a larger study protocol consisting of two parts. The first part aimed at examining the impact of child anxiety and attention control upon child selective attention to pain and its relationship to child Cold Pressor Task (CPT) pain tolerance assessed during children's first CPT performance [see 26]. The second part aimed at examining the impact of parental pain-related attention set shifting upon parental emotional distress and pain control behaviour during the child's second performance of the CPT. The current manuscript reports results about the second and unique part of this larger protocol. Procedures relevant to the first part of the present study occurred *independently* from the methodology described in the current manuscript and are thus not expected to interfere with current results. Participants were recruited from a sample of parents, schoolchildren and adolescents who had consented to be re-contacted following participation in a questionnaire study that aimed at examining child and parental responses to child pain and that took place approximately 5 months earlier [unpublished data]. Exclusion criteria for the child were as follows: (1) suffering from recurrent or chronic pain, (2) developmental delay, (3) having insufficient knowledge of the Dutch language, and (4) not being between the ages of 8-17 years. We aimed at recruiting 50-60 participants based upon power analysis using G*Power indicating that this sample size is sufficient to detect a medium effect (d = .50) with power .80 using $\alpha = .05$, two-tailed. The flow chart of participant recruitment is shown in Figure 1.

The final sample of the present study consisted of 54 parent-child dyads (35 girls; 19 boys; 41 mothers; 13 fathers). All parent-child dyads were of European origin. Parents ranged in age from 35 to 51 years (*M* = 42.67 years, *SD* = 3.52). Most parents (92.6%) were married or co-habiting. In general, parents reported to be in good to very good health (*M* = 1.07, *SD* = 0.82; rated on a 4-point scale with 0=excellent, 1=very good, 2=good, 3=moderate). The majority of parents (86.8%) had received education beyond the age of 18 years.The mean age of the children was 12.1 years (*SD* = 2.39; range 8 to 17 years). Children were recruited from the fifth (7%), sixth (22.6%), seventh (22%), eight (14.5%), ninth (22.6%), tenth (8.1%), and eleventh (3.2%) grade. Parent-child dyads were compensated 30€ for participating in this study. The study was approved by the Ethics Committee of the Faculty of Psychology and Educational Sciences, Ghent University, Belgium.

--INSERT FIGURE 1 ABOUT HERE--

2.2 Study overview

The study protocol consisted of two phases. During the first phase (i.e., at study commencement and before any other child or parent measures were administered), parental resting heart rate variability (HRV) was assessed followed by parents performing a cued switching task indexing parental ability to flexibly shift attention between pain-related and neutral attentional sets [see 29,30]. During the second phase of the study, parents were asked to observe their own child's (second) CPT performance from an adjacent room and parental pain control behavior (i.e., stop behavior; see 2.7.2) was assessed. Subsequent to CPT observation, parents were asked to report on emotional distress they had experienced while observing their child's CPT performance.

2.3 Viewing task stimulus material

2.3.1 Content

The stimulus set for the cued switching task consisted of 3 different pictures of the parents *own* child displaying one of three expressions reflecting three different states; i.e., (1) neutral expression representing no pain, (2) low pain expression representing low levels of pain experience, (3) high pain expression representing high levels of pain experience. For each of these pictures, one of three shapes (i.e., a triangle, circle or square) was superimposed between the eyes of the child, resulting in 9 compound stimuli (i.e., no pain expression, low pain expression and high pain expression presented with either a circle, triangle, or square centred between the eyes).

2.3.2 Preparation

Child pictures were selected by the experimenter from brief videotapes that were created at study commencement. Specifically, children were instructed by the experimenter to look into a camera whilst showing a neutral (no pain) face, and subsequently instructed to act as if they were experiencing a little bit of pain (i.e., *Try to imagine as hard as you can that you are having a little bit of a stomach ache or headache; can you look into the camera and show as if you are now experiencing a little bit of pain?*), or a lot of pain (i.e., *Try to imagine as hard as you can that you are having a lot of a stomach ache or headache; can you look into the camera and show as if you are experiencing a lot of pain?)*. Children were informed that this was done to ensure that the camera was well positioned and able to track their behaviour whilst performing the CPT. Employing pictures of children's posed expressions rather than genuine expressions was based upon pilot-testing indicating high variability in children's pain expressions (including no pain expression) and face position (e.g., child looking down or hair partially covering child's face) which precluded creation of a comparable (i.e., standardized) stimulus set across participating children. The experimenter who instructed the children to display no pain and varying pain states and who subsequently selected the 3 pictures (i.e., 'no pain', 'low pain', and 'high pain' expression) was familiar with the Child Facial Coding System [CFCS; 6,11]. In case the child's expression did not coincide with prototypical expressions of pain, the experimenter insisted on changing facial expressions.

2.3.3 Validity check

At the end of the experiment, parents were asked to make written ratings of each picture of their child on pain intensity using a 0-10 NRS. Pictures of their child were presented on a computer screen. This was done as a validity check to examine whether the categorization of differential facial pain expressions (i.e., no pain, low pain, high pain) corresponded with differential parental pain ratings [see also 64]. This was indeed the case. Specifically, results demonstrated significant differences between parental ratings of their child's pain intensity for the three expression levels ($F(2,52)=369.11$, $p< .0001$). These differences were in the expected direction. Specifically, contrasts indicated that high pain expressive faces were rated significantly more painful (*M*=7.11; *SD*=2.10) than low pain expressive faces (*M*=3.52 , *SD*=1.82; $F(1,53)=281.90$, $p < .0001$). Low pain expressive faces, in turn, were rated significantly more painful than faces expressing no pain (*M*=0.20 , *SD*=0.56 ; $F(1,53)=159.11$, $p < .0001$).

2.4 Switching task

Parents were seated in front of a computer screen at a distance of approximately 60 cm and informed that they had to perform a task whereby they would will see pictures of an unfamiliar child (i.e., during the practice trials) as well as pictures of their own child (i.e., during the test trials). Parents were informed that the pictures of their own child's face were drawn from their child's first performance of the CPT (i.e., pertaining to the first part of this larger investigation; [26]). As such, the stimulus set for each parent was likely to be *personally relevant and task specific* as stimuli consisted of idiosyncratic stimuli, representing child responses to CPT and triggering parental pain expectancies regarding their child's second CPT performance. Instructions for the switching task were presented on the computer screen.

The Attentional Control Capacity for Emotion [ACCE; 29,30] was designed to measure ability to *shift attention* towards and away from emotional attentional sets. A modified version of the ACCE task, the Attentional Control Capacity for Pain (ACCP) was developed for the purpose of the present study. In particular, two modifications were made regarding stimulus materials. First, whereas the original version employed pictures of adult faces showing either an angry, happy or neutral expression; the modified version employed pictures of children showing either a high painful, low painful or no pain face. Second, whereas the faces displayed in the original measure were drawn from persons who were unknown to the participant, the pictures used within our study were pictures of the participants' own child, hence personally relevant for the participant. Validity of the original ACCE task has been demonstrated [30]. A graphical depiction of the ACCP task and trial types is depicted in Figure 2. The ACCP was presented on a computer and required parents to perform one of two judgments on a compound stimulus that consisted of the face of their own child with a shape displayed between their eyes. For the *pain judgment* parents were requested to identify the level of pain intensity of their child, which was no pain, moderate pain, or high pain. For the *shape judgment* they were to identify (by pressing '1', '2' or '3'), the type of shape (i.e., either a circle, square or triangle) that was displayed between the eyes of their child's face. The entire task took about 10 min. The ACCP included three blocks of practice trials (10 shape practice, 10 face practice, and 15 combined practice trials). Each trial started with a cue presented on the computer screen. The cue was presented for 200 ms and then was replaced with the face-shape stimulus on which the participant had to make a judgment. The face-shape combined stimulus was shown until the parent responded or 5 s had expired. A solid bar served as a cue to the parent to attend and respond to the pain expression of the face (pain-related attentional set). A patterned bar served as a cue to the parent to attend and respond to the type of shape displayed between the eyes of their child's face (neutral attentional set).

A series of practice trials were included to ensure participants performed the task correctly. Practice trials also minimize the occurrence of a learning curve and ensure participants' performance remains stable over time. Two blocks of test trials (100 trials per block) followed after the practice trials with time to rest (minimum 10 s) between each block. Given the goal was to assess how parents shift attention between pain-related and neutral attentional sets, we ensured attentional sets shifted frequently, without valence switching as well. Otherwise, attentional set shifting would be confounded with valence switching. Consequently, valence was repeated for six trials until shifting to a different valence. For example, for six sequential trials, the face valence would remain at high pain intensity, while the only thing that shifted was whether the participants were cued to judge the pain level on the face or the shape on the face. Then, the face valence would switch to a low level of pain intensity and remain at that intensity for six trials, etc [see 29,30 for a similar approach].

Switch cost is defined as the length of time (in milliseconds) spent switching from one attentional set and reconfiguring to the other attentional set. Two switch cost scores, pain-neutral (PN) switch cost and neutral-pain (NP) switch cost, were calculated for each level of pain expressiveness (i.e., no pain, moderate pain, high pain). Switch costs constituted the dependent variables in the current study; these were calculated by computing difference scores. To obtain individual differences in PN switch cost, the median response time (RT) for the neutral-neutral (NN) repetition trials was subtracted from the median RT for the pain-neutral (PN) switch trials. To obtain individual differences in NP switch cost, the median response time (RT) for the pain-pain (PP) repetition trials was subtracted from the median RT for the NP switch trials. The different pain expressiveness levels (i.e., no pain, low pain expression, or high pain expression) appeared with approximately the same probability level within each of the four trial types (PN, NP, NN, PP). The same randomized order of trial types was presented to all parents with the limitation of having an approximately equal probability of each of the 12 total unique trial types (e.g., PN trials with high pain, low pain, and no pain faces, etc., range of total trials for each trial type = 12 – 16).

- INSERT FIGURE 2 ABOUT HERE -

<u>2.5 Child pain task</u>

The cold pressor task (CPT) with a water temperature of 10°C was used as an experimental pain induction method. Within the current study, children performed the CPT twice; only the second CPT pertained to the aims of the current investigation. For the second CPT, children were requested to hold their right hand to just above the wrist in the cold water.

The cold water in the tank was circulated continuously by a pump to avoid local warming. A second tank with water at room temperature (21°C; +/-1°C) was employed to standardize child skin temperature. Specifically, all children were requested to first immerse their right hand in this second tank for a duration of 2 minutes [see also 56,57]. During subsequent CPT performance, children were asked to hold their hand in the cold water until they heard 'stop' either from their parent (see 2.7.2: measurement of parental pain control behaviour) or after an uninformed ceiling of 4 minutes had elapsed. Children were informed their parent was observing them during CPT performance but were not informed beforehand that their parent would be able to terminate the CPT task. To ensure to not go beyond the child's pain tolerance level, children were informed that they could withdraw their hand from the cold water when they experienced to be no longer able to sustain the pain. Previous studies have demonstrated that cold pressor pain is comparable to various naturally occurring acute pains [5,70].

2.6 Heart Rate Variability (HRV)

Cardiac activity amongst parents was measured at study commencement for later analysis of vagally mediated resting HRV. Vagally mediated resting HRV is a peripheral marker of prefrontal inhibitory control [58,60]. Assessed during resting condition, vagally mediated HRV is operationalized as the cardiorespiratory coupling causing systematic oscillations between cardiac beat intervals and respiratory cycles [23]. High vagally mediated baseline or resting HRV is considered to be indicative of high self- and emotion regulation capacity promoting behavioural and emotional adaptability [2], appropriate social interaction [49], and emotional stability in everyday life [35]. High HRV is positively associated with higher prefrontal inhibitory control over subcortical limbic structures [57] and with efficient allocation of attentional and cognitive resources [58]. Resting HRV, rather than HRV reactivity, was included in the current since resting HRV refers to a persons' *emotion regulation capacity* which is considered particularly relevant in buffering or intensifying distress and pain control behaviours elicited when facing child's pain. HRV reactivity refers to a change in HRV following a stressful event and indexes *emotional reactivity* [45,46].

The recording device consisted of a POLAR RS800CX and a chest strap HR monitor (Polar Electro Oy, Kempe, Finland; sampling rate 1000Hz, for validation see, e.g., [31,40]). Parents were asked to remain silent and seated, and to relax as much as possible during ongoing cardiac activity measurement.

2.7 Pain task measures

For parents, we measured self-reported distress and pain control behaviour. We also measured children's facial expressions of pain whilst the child performed the CPT.

2.7.1 Self-reported parental distress

After observation of their child's CPT performance, parents were requested to rate the extent to which they had experienced distress while viewing their child performing the CPT (i.e., parental *experienced* distress). To this end, parents were instructed to rate four emotion adjectives ('worried', 'upset', 'anxious', 'sad') on an 11-point scale ranging from 'not at all' (0) to 'extremely' (10)). Total scores could range from 0 to 40. This method has previously been used to assess parental distress about their child's pain and has been found to be reliable and valid [see e.g., 8,69]. Cronbach's alpha for experienced parental distress in the current study was .90.

2.7.2 Parental pain control behaviour

Parents observed their child's CPT performance on a monitor streaming video from the adjacent child testing room. Using standardized instructions (see 8,69 for a similar procedure), parents were requested to say 'stop' when they wanted their child to terminate the painful CPT. 'Parental pain control behaviour' was computed by subtracting the time from commencement of the child's CPT performance until the parent terminated the painful task (i.e., the maximum time in seconds). Higher scores (i.e., shorter time to say 'stop') were indicative of higher levels of parental pain control behaviour/ stop behaviour. In case the child terminated the painful CPT before the parent terminated child CPT performance, the parent-child dyad was excluded from the analyses investigating parental pain control behaviour (i.e., stop behaviour) as the latter could not be assessed [see also 69].

2.7.3 Child facial pain expression

The Child Facial Coding System [CFCS;6,11,21] was employed to code children's facial display from video whilst they performed the CPT. The CFCS is an observational coding system that consists of 13 discrete facial actions (e.g., brow lowering, nose wrinkle, nasolabial furrow, lip corner pull, flared nostrils) and that has demonstrated good reliability and validity [6,21]. Facial actions were coded by two trained coders. In line with previous research [69], all 13 facial actions were coded for every second within a 10-second time frame during the following 3 periods: (1) 10 s immediately after the child immersed his/her hand in the cold water, (2) 10 s halfway CPT performance, (3) and 10 s before termination of the CPT. From videotape, the first coder coded all 3 time frames of all child participants. To determine interrater reliability, a random sample of 20% of these videotapes was coded by the second coder. Interrater reliability was calculated according to the formula by Ekman and Friesen [18]. Individual CFCS scores (range 0-23) were calculated following Vervoort et al. [68]. Interrater reliability approached acceptable rates of .80 for overall frequency of child facial pain expressions (i.e., 78 in the current study; range; .73-.95) and of .70 for intensity of child facial pain expressions (i.e., .72 in the current study; range; .59-.94) [see e.g., 6,21,65,66,69].

2.7 Procedure

The parent and child were accompanied by two female experimenters throughout testing. Parent-child dyads were informed that we were interested in parental and child's pain-related thoughts and feelings and how they impact pain experience. Following consent, parent and child were directed to separate rooms. While parents were alone in the room, and before any other child or parent measures were administered, parental baseline or resting HRV was assessed. Next, parents performed the cued switching task. Following the viewing task, parents were provided instructions on stopping the CPT (i.e., pain control behavior) and observed their child's CPT performance. After completion of the CPT, parents were requested to complete the measure of experienced distress. To keep contact with participants to a minimum, the experimenter sat behind a screen when the child performed the CPT and when parents completed the switching task and observed their child's CPT performance. Upon completion of the study, parent- child dyads were informed about deception regarding the use of posed child expressions rather than genuine expressions and fully debriefed about the aims of the current study.

2.8 Data preparation

2.8.1 Switching task

Following Johnson [29,30], individual differences in ACCP were measured by determining the costs of switching from a pain-related attentional set (pain judgment task) to a neutral attentional set (shape judgment task) and from a neutral attentional set to a pain-related attentional set. Typically, more time is needed to switch between different tasks and associated attentional sets than to repeatedly perform the same task. The additional time to switch between different tasks has been labelled switch cost. Only correct responses were used as is typical in reaction time paradigms. Six difference scores were computed resulting in six different switch costs. Specifically, to obtain individual differences in PN switch cost, the median RT for NN repetition trials was subtracted from the median RT for the PN switching trials; this was done for each level of expressiveness (no pain, low pain, high pain) resulting in three PN switch costs; PN_Nopain; PN_Lowpain; PN_Highpain. Following Johnson a mean PN switch cost across emotion intensity levels was calculated for data-analysis. A *higher* PN mean switch cost reflects ‘parental reduced ability to shift attention away (i.e., difficulty to disengage) from child pain-related attention set (i.e., attend to/detect pain) to a neutral (i.e., attend to/detect shape) attentional set’. For brevity and ease of understanding, we will be referring to ‘parental *reduced/facilitated ability disengaging attention away from child pain*’ throughout the remainder of the text. The median RT for PP repetition trials was subtracted from the median RT for NP switch trials to obtain individual differences in NP switch cost. This calculation was done for each level of expressiveness (no pain, low pain, high pain) resulting in three NP switch costs; NP _Nopain; NP _Lowpain; NP _Highpain. For data-analyses, a mean NP switching cost across emotion/pain intensity levels was calculated [see also 29,30]. A *lower* NP switch cost reflects ‘parental facilitated attention shifting (i.e., facilitated engagement) from a neutral attentional set (i.e., attend to/detect shape) to child-pain related attention set (i.e., attend to/detect pain)’. For brevity and ease of understanding, we will be referring to ‘parental *reduced/facilitated attention towards child pain*’ throughout the remainder of the text.

2.8.2 Heart rate and Heart rate variability analysis

In line with recommendations by the Task Force [56] a 300 s recording was used from the total HR recording for later HRV analyses. Frequency domain methods were employed to calculate HRV. Interbeat interval time series were screened on the occurrence of measurement artifacts [4]. Linear interpolations using ARTiiFACT software (Version 2.03; www.artiifact.de) substituted erroneous intervals. In line with Vervoort et al. [68], the high frequency spectrum (0.15-0.4 Hz) within the frequency domain was extracted via Fast-Fourier-Transformation resulting in calculated high frequency spectrum power in ms^2 (i.e., HF*abs*).

2.9 Plan of statistical analyses

To investigate (1) *the impact of children’s facial expression of pain and the moderating role of parental attention-set shifting*, a series of separate univariate ANCOVAs were performed with children’s facial display of pain and parental attention-set shifting (i.e., either

PN switch cost or NP switch cost) entered as covariates and with either parental self-reported distress, or pain control behaviour entered as dependent variable. To investigate (2) *the impact of children's facial expression of pain upon the outcome measures and the moderating role of parental HRV*, a similar set of univariate ANCOVAs was performed but with HF*abs* and children's facial expression of pain entered as covariates. In the case of significant correlations between child age and any of the outcome variables or significant differences between boys and girls or mothers and fathers, ANCOVAs will also control for the impact of these significant socio-demographic variables impacting outcomes.

In the case of significant interaction effects of child facial expressiveness and the moderator variable upon the outcome measures, additional moderation analyses were performed allowing to interpret the significant interaction effect – i.e., whether the association between the predictor variable (child facial expressiveness) and outcome variable (parental self-reported distress / parental pain control behaviour) was significant at high (+ 1SD) or low (- 1 SD) or both levels of the moderator variable (i.e., NP/PN switch cost or HF*abs*). Moderation analyses was performed following the procedure outlined by Holmbeck [28], and reported in detail elsewhere [69]. Greenhouse-Geisser corrections (with adjusted degrees of freedom, or NDf) were performed, in case of violation of the sphericity assumption (Mauchly's test of sphericity was $p < .05$). Effect sizes using the Partial Eta Squared index (η_p^2) were reported with values of 0.01 indicating small effect size, 0.06 indicating medium effect size and 0.14 indicating large effect size [13;41].

3. RESULTS

3.1 Participant characteristics and preliminary analyses

Mean scores, standard deviations, observed range, correlations, and number of valid cases for each measure are shown in Table 1. Missing values were either due to children who had removed their hand from the cold water before their parent terminated the CPT, thus resulting in missing values for parental control behaviour (*N*=9), to equipment failure during HRV measurement (*N*=7), or because recording of child facial pain expression was missing (*N*=1). The 9 children who removed their arm out of the cold water before being stopped by their parent did not differ from the remainder of the sample of children in terms of age ($t(52)= -.66$, ns) or sex (χ^2 (1)= .02, ns).

To reduce the likelihood of outliers for ACCP switching cost parameters, median reaction times (RTs) were used to compute all ACCP scores for each participant. In addition, ACCP data were screened for RTs shorter than 130 ms (none met this criterion) and longer than 3 * interquartile range above the 75th percentile (none met this criterion). In addition, excessively low accuracy scores were screened by excluding accuracy scores at 3 * interquartile range below the 25th. Nine participants met this criterion for more than four trial types with one participant demonstrating zero accuracy for NP/PN switching trials; hence precluding calculation of NP/PN switch cost for this one participant. As *p*-values and effect sizes for primary analyses did not substantively change when the remaining 8 participants were excluded, we opted to include the data of the remaining 8 participants in the analysis with NP and PN switch costs.

Pearson Correlation analyses (see Table 1) revealed both switch costs were significantly positively correlated with each other. None of the other variables correlated significantly with the switching parameters. Parental HRV was also not significantly correlated with child facial expression of pain or any of the outcome variables. However, in line with expectations, child facial pain expression and both of the outcome measures were positively correlated with each other. Findings further indicated there were no significant correlations between child age and any of the independent variables or outcome variables (all $r \leq |.21|$, ns) except for parental HRV which was significantly negatively correlated with child age ($r = -.36$, $p<.05$).

One sample t-tests indicated NP and PN switch cost parameters were both significant indicating the ACCP task placed a significant demand on task-switching processes ($M_{\text{NP swith cost}}$=626.11; *SD*=301.34; $M_{\text{PN swith cost}}$=569.22; *SD*=219.76; both $t \geq 15.13$, $p<.0001$). NP switch cost was slightly higher than PN switch cost, suggesting disengaging a pain-related set and engaging a neutral set placed a lower demand on attention-set shifting ability than the reverse switch, however, paired samples t-test indicated the difference between NP and PN switch cost failed to reach significance ($t(52)=1.80$, ns). NP switch cost was significantly higher for fathers than for mothers indicating that the cost to switch attention from a neutral attentional set towards a pain-related attentional set is higher for fathers (*M*=801.22; *SD*=273.82) than for mothers (*M* =569.20; *SD*=290.63; $t(51)= -2.53$, $p<.05$). None of the other measures differed between boys and girls (all $t \leq .89$, ns) or between mothers and fathers (all $t \leq .99$, ns).

3.2 Effects of facing child's pain: the moderating role of parental attention-set shifting

3.2.1. The moderating role of NP switch cost

Analysis of *parental self-reported distress* revealed a significant effect of child facial expressiveness with higher levels of child pain expression being associated with higher levels of parental self-reported distress ($F(1,52)=4.71$, $p<.05$, η_p^2 =.16). No significant NP switch cost, nor a significant NP switch cost x child facial pain expressiveness interaction effect was observed (both $F \leq 2.17$, ns).

The analysis with *parental pain control behaviour* revealed a significant interaction between child facial pain expression and parental NP switch cost ($F(1,44)=5.39$, $p< .05$, η_p^2 = .12). To interpret this interaction, separate ANOVAs were performed with parental pain control behaviour as the dependent variable and high or low values of parental NP switch cost entered as a covariate. As shown in Figure 3, findings indicated, in line with expectations, that increasing levels of child pain expression were associated with higher levels of pain control behaviour for parents who demonstrated *low levels* of NP switch cost ($F(1,43)=10.33$, $p < .005$).

For parents demonstrating *high levels* of NP switch costs (i.e., parents who showed reduced attentional shifting to pain), parental pain control behaviour did not vary as a function of child facial pain expressiveness; $F(1,44)=.31$, ns); their level of pain control behaviour was equally pronounced regardless of whether their child was facially expressing low or high levels of pain. While these findings suggest a buffering role for reduced attentional shifting to child pain, the pattern of findings displayed in Figure 3 suggest some caution is needed when drawing such conclusion. In particular, additional analysis *within* the group of parents who had 'low pain expressive children' showed that low levels of NP switch cost (i.e., reflecting facilitated attention to pain) were associated with *lower* levels of parental pain control behaviour compared to parents who demonstrated high levels of NP switch cost ($F(1,44)=4.43$, $p<.05$; dotted line in Figure 3). Analyses *within* the group of parents who had 'high pain expressive children' showed parental NP switching cost did not impact parental pain control behaviour ($F(1,44)=.56$, ns).

- INSERT FIGURE 3 ABOUT HERE –

3.2.2. The moderating role of PN switch cost

The analyses with child facial pain expressiveness and PN switch cost as independent variables and *parental self-reported distress* and *parental pain control behaviour* only revealed a significant positive effect of child facial pain expressiveness (both $F\geq4.02$, $p<.05$, $\eta_p^2 \geq .08$). There were no significant main effects of PN switch cost nor a significant PN switch cost x child facial pain expressiveness interaction effect for both outcome measures (all $F\leq3.80$, ns).

3.3 Effects of facing child's pain: the moderating role of parental HRV

Analysis of *parental self-reported distress* revealed a significant interaction between child facial pain expression and parental HRV ($F(1,46)=5.29$, $p< .05$, $\eta_p^2 =.11$). Separate ANOVAs (depicted in Figure 4) with parental distress as the dependent variable and high or low values of parental HRV indicated, in line with expectations, that increasing levels of child pain expression were associated with higher levels of parental distress but only for parents who demonstrated *low* HRV ($F(1,46)=10.88$, $p< .005$). Increasing child pain display no longer contributed to parental distress for parents demonstrating *high* HRV $F(1,46)=2.48$, ns), suggesting a buffering role of high levels of HRV when faced with heightened child pain display. Indeed, additional analyses within the group of parents who had 'high pain expressive children' indicated significantly lower levels of parental distress for parents demonstrating high levels of HRV compared to parents demonstrating low levels of HRV ($F(1,46)=8.11$, $p<.01$; dotted line in Figure 4). Analyses *within* the group of parents who had 'low pain expressive children' revealed no significant effect of parental HRV ($F(1,46)=.000$, ns).

- INSERT FIGURE 4 ABOUT HERE –

Analysis of parents' *pain control behaviour* also revealed a significant interaction between child facial pain expression and parental HRV ($F(1,38)=7.91$, $p< .01$, $\eta_p^2 =.19$). Separate ANOVAs for parents with low and high levels of HRV echoed analyses with self-reported parental distress as dependent variable. Specifically, findings (see Figure 5) indicated that higher child pain expressiveness was significantly associated with higher parental pain control behaviour, but only at low levels of HRV ($F(1,38)=14.06$, $p< .001$), and not at high levels of HRV ($F(1,38) =2.9$, ns). Further, additional analyses within the group of parents who had 'high pain expressive children' indicated significantly lower levels of parental actual pain control behaviour for parents demonstrating high levels of HRV compared to parents demonstrating low levels of HRV ($F(1,38)=6.60$, $p<.05$; dotted line in Figure 5), hence attesting to the role of higher levels of HRV in buffering parents from engaging in actual pain control behaviour when faced with high child pain display. Analyses *within* the group of parents who had ‘low pain expressive children’ revealed no significant effect of parental HRV ($F(1,38)=1.60$, ns).

- INSERT FIGURE 5 ABOUT HERE -

4. DISCUSSION

The current study investigated the moderating role of parental pain-related attention set-shifting and resting HRV for parental emotional distress and pain control behavior when faced with their child’s pain. Results of the present study indicated, in line with expectations, that parental *facilitated* attentional shifting to child pain contributed to higher levels of pain control behaviour (but not self-reported parental distress) when faced with increasing levels of child facial display of pain. Pain control behaviour for parents who demonstrated *reduced* attentional shifting to child pain was equally pronounced regardless of whether their child expressed low or high levels of pain. Counter to expectations, no effects for parental ability to disengage from child pain were observed. With regard to parental resting HRV, findings indicated that whereas *high* levels of parental HRV buffers the impact of child facial pain display upon parental distress and pain control behaviour, *low* levels of parental HRV constitute, in line with expectations, a risk factor for higher levels of parental distress and pain control behaviour when being faced with increased levels of child facial pain display.

To the best of our knowledge, the current study is the first to demonstrate that parental attention set shifting, particularly parental ability to shift attention away from a neutral attentional set *towards* a pain-related attentional set, may be key in understanding affective-motivational and associated behavioral outcomes when facing another in pain. As such, the present findings corroborate and extend earlier work on the role of attention set shifting towards emotional stimuli. In particular, using a similar switching task paradigm, Johnson [29,30] demonstrated that facilitated attentional shifting towards an emotional attentional set contributed to less successful emotion regulation (i.e., increased frustration) whilst performing a stressful task [26] and increased avoidance behaviour reflected by reduced task persistence [29,30]. Our findings extend these previous findings and suggest that the ability to shift attention *towards* pain, is likely also important in understanding interpersonal pain dynamics.

Drawing upon the notion that facilitated attention towards threat constitutes a survival mechanism as well as a risk factor for problematic outcomes when generalized [51], the observed pattern may likewise initially be adaptive. Specifically, parental facilitated attention shifting towards child pain may facilitate quick processing of child bottom-up cues (i.e., child facial pain expression) thereby allowing rapid and accurate decoding of child's pain and instigating care attuned to pain-related child needs. However, while caution is needed since the present study did not entail a clinical population, it is possible that in the context of persistent or chronic pain, a similar pattern may contribute to enhanced processing of child pain-related cues and associated persistent efforts to control child's pain thereby contributing to increased child disability by diminishing engagement in valued daily activities [38,68,71].

At present, however, it is premature to draw firm conclusions on the (potentially maladaptive) function of facilitated attention to pain. Specifically, while parental facilitated attentional shifting to child pain contributed to parental pain control behaviour when faced with child's pain, no impact was observed for parental subjective experience of distress. Furthermore, parental *reduced* attentional shifting to child pain contributed to similar levels of parental pain control behaviour regardless whether their child expressed high or low levels of pain. While such findings may reflect diminished responsiveness to child bottom-up cues (i.e., pain expression) by more top-down regulation, and accordingly suggest a buffering role for reduced attentional shifting to pain, additional analyses as well as anxiety literature suggest some caution may be needed here. Specifically, the notion that reduced attention to emotional material may not always be adaptive is in line with Borkovec and Sibrava's [52] theory of clinical anxiety and empirical inquiry [29] suggesting a core aspect of clinical anxiety is cognitive avoidance of negative stimuli. In the current study, parents who exhibited the most cognitive avoidance (i.e., high NP switch cost) demonstrated significantly more pain control behavior even with very low pain exhibited on their child's face. This pattern may reflect 'miscarried' helping behaviour (i.e., increased parental pain control when child need for help is low [17,20,57,68]) and may suggest perhaps an unhealthy hyper-reactivity to their child's pain due to their tonic cognitive avoidance. However, drawing further conclusions on the function of parental attention-set shifting requires further research incorporating child-pain outcomes and a broader range of parental caregiving responses [10,65,71].

Further research is also needed to examine why no effects were observed for parental ability to disengage from pain. According to attentional control theory [19], particularly the ability to disengage attention from emotional stimuli is considered critical for successful emotion regulation. Indeed, anxiety and depression literature has demonstrated that reduced ability to shift attention away from emotional stimuli and towards neutral stimuli contributes to higher anxiety [19], reduced task persistence [30] and increased ruminative thoughts [16,34]. To the best of our knowledge, only one study in the context of personal pain examined attention set shifting between pain-related and neutral tasks with findings indicating it is difficult to shift attention away from a pain-related attentional set [63], however its impact upon pain or emotion outcomes was not examined. The current findings on the role of parental ability to disengage attention from child pain towards a neutral set are the first in their kind; replication studies are needed to ascertain its precise role.

The current study is, to the best of our knowledge, also the first to demonstrate the importance of examining parental resting HRV as determinant of parental emotion regulation and associated goal-directed behavior. The role of HRV has been well documented across various domains including personal pain, with research findings consistently demonstrating low HRV constitutes a risk factor for emotion regulation deficits reflected by a stronger tendency to ruminate [42], less affective stability [35] and less cognitive/attentional control [58]. Our findings corroborate preliminary findings [see 14] indicating that observer (i.e., parental) resting HRV is also important in understanding interpersonal pain dynamics. Yet, current findings extend earlier findings by demonstrating that whereas low levels of parental resting HRV constitute a vulnerability factor for increasing levels of parental distress and pain control behaviour when faced with increasing child facial pain display, high levels of parental resting HRV serve a buffering role in this relationship. Accordingly, the current findings attest to the importance of assessing for parental resting HRV in the context of observing their child in pain as it may provide critical insight into which parents (and children) are most at risk for deleterious outcomes.

Notably, findings on the role of low vs. high resting HRV largely echoed those observed for facilitated vs. reduced attentional shifting towards pain, hence suggesting HRV and attention-set shifting may serve a similar regulatory function and may thus be conceptually linked. Such notion is in line with the Neurovisceral Integration Model [2,58,59] which posits that attention set shifting and emotion regulation ability can be physiologically indexed by vagally mediated HRV. Supporting the Neurovisceral Integration Model, findings have shown that HRV serves as a peripheral proxy for prefrontal modulation via inhibitory processes that are related to attentional shifts such that lower HRV contributes to inefficiency of attentional regulation as well as deficits in emotion regulation [44,59]. Accordingly, one would expect HRV and attention-set shifting being associated with each other. However, this was not the case in the current study. Possibly, HRV assessment amongst parents *whilst* viewing their child in pain may be better related to attention-set shifting in the context of pain, yet further research is warranted here.

Several study limitations deserve consideration. First, this study used experimental pain; the findings of this lab-based study should be applied cautiously to parents of children with clinical pain. In addition, sample size is relatively low for some of the analyses. Replication amongst clinical and larger samples is needed. Second, the majority of parents in the current study were mothers (76%) with findings thus mostly representing mother-child interactions. Further research examining potential mother-father differences is needed [37]. Third, for 17% of the parent-child dyads, parental pain control behaviour could not be assessed since these children withdrew their hand earlier on. These children possibly constituted the most fearful ones. Hence, findings from the present study may not generalize to parental responses in the context of high fearful children. Fourth, stimuli consisted of child posed expressions which may slightly differ from genuine ones. [27,36,62]. However, identifiable differences are low and mostly related to temporal dynamics of expression [15,27,47,48], rather than specific facial actions. Since stimuli used in the current study were evaluated as corresponding to a pain expression prototype following facial coding criteria [11] and that parents responded to still photographs, their posed nature is rather unlikely to strongly limit the representativeness of observed findings. Finally, parental HRV was assessed when parents arrive at the laboratory anticipating pain in their child. Therefore, the extent to which parental HRV reflects a true baseline remains debatable. Including a control group (non-pain task) may shed light on the extent to which the current findings are specific to the pain context [see also 14]. These limitations notwithstanding, the current findings attest to the importance of further examining parental attention-set shifting ability and HRV within an interpersonal pain context to advance understanding of parental emotional responding and caregiving behavior.

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FIGURE LEGENDS

Figure 1: Flow chart of participant recruitment

Figure 2: Schematic of the attentional control capacity for pain (ACCP) task.

Figure 3: Mean *parental pain control behaviour* as a function of child facial pain expressiveness during CPT performance and low (-1*SD* below the mean) and high (+1*SD* above the mean) levels of parental NP switch cost * $p < .01$; *** $p < .005$

Figure 4: Mean *parental self-reported distress* as a function of child facial pain expressiveness during CPT performance and low (-1*SD* below the mean) and high (+1*SD* above the mean) levels of parental HRV (HF_{abs}) ** $p < .01$; *** $p < .005$

Figure 5: Mean *parental pain control behaviour* as a function of child facial pain expressiveness during CPT performance and low (-1*SD* below the mean) and high (+1*SD* above the mean) levels of parental HRV (HF_{abs}) * $p < .05$; **** $p < .001$

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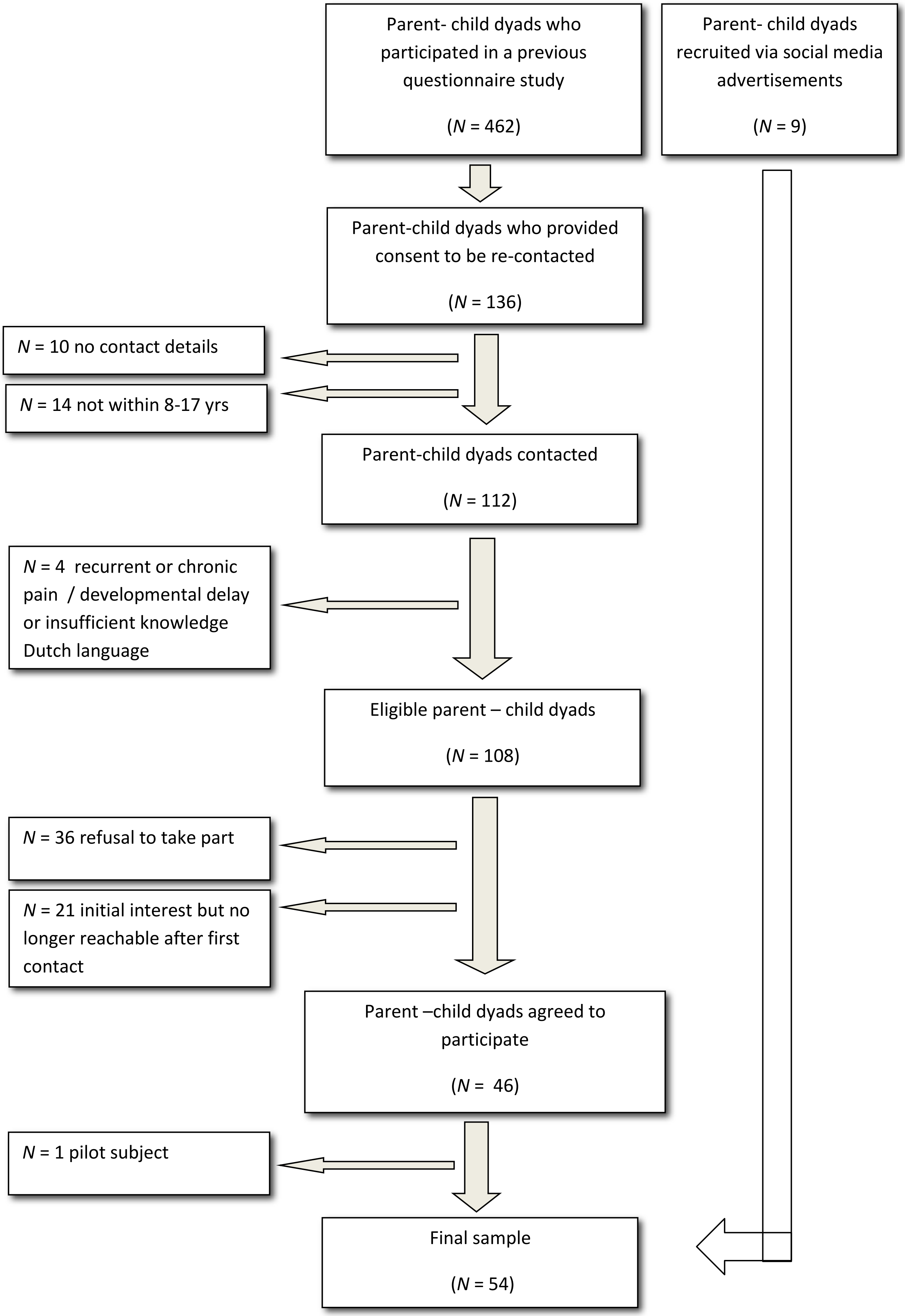

Parent- child dyads who participated in a previous questionnaire study
(N = 462)
Parent- child dyads recruited via social media advertisements
(N = 9)
Parent-child dyads who provided consent to be re-contacted
(N = 136)
N = 10 no contact details
N = 14 not within 8-17 yrs
Parent-child dyads contacted
(N = 112)
N = 4 recurrent or chronic pain / developmental delay or insufficient knowledge Dutch language
Eligible parent – child dyads
(N = 108)
N = 36 refusal to take part
N = 21 initial interest but no longer reachable after first contact
Parent –child dyads agreed to participate
(N = 46)
N = 1 pilot subject
Final sample
(N = 54)

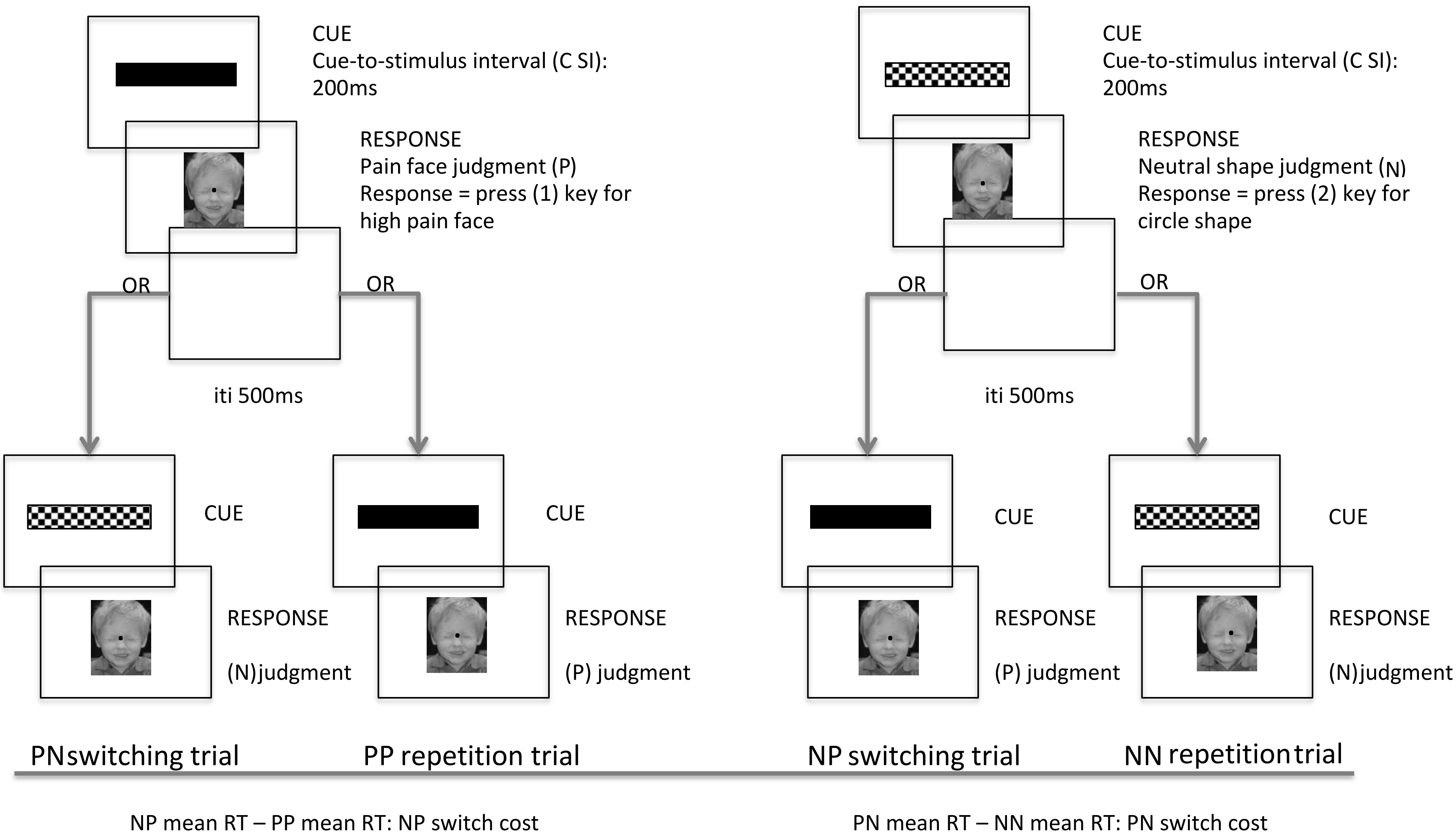

CUE
Cue-to-stimulus interval (C SI):
200ms
RESPONSE
Pain face judgment (P)
Response = press (1) key for
high pain face
OR
OR
iti 500ms
CUE
RESPONSE
(N)judgment
CUE
RESPONSE
(P) judgment
PNswitching trial
PP repetition trial
CUE
Cue-to-stimulus interval (C SI):
200ms
RESPONSE
Neutral shape judgment (N)
Response = press (2) key for
circle shape
OR
OR
iti 500ms
CUE
RESPONSE
(P) judgment
CUE
RESPONSE
(N)judgment
NP switching trial
NN repetition trial
NP mean RT – PP mean RT: NP switch cost
PN mean RT – NN mean RT: PN switch cost

FIGURE 3

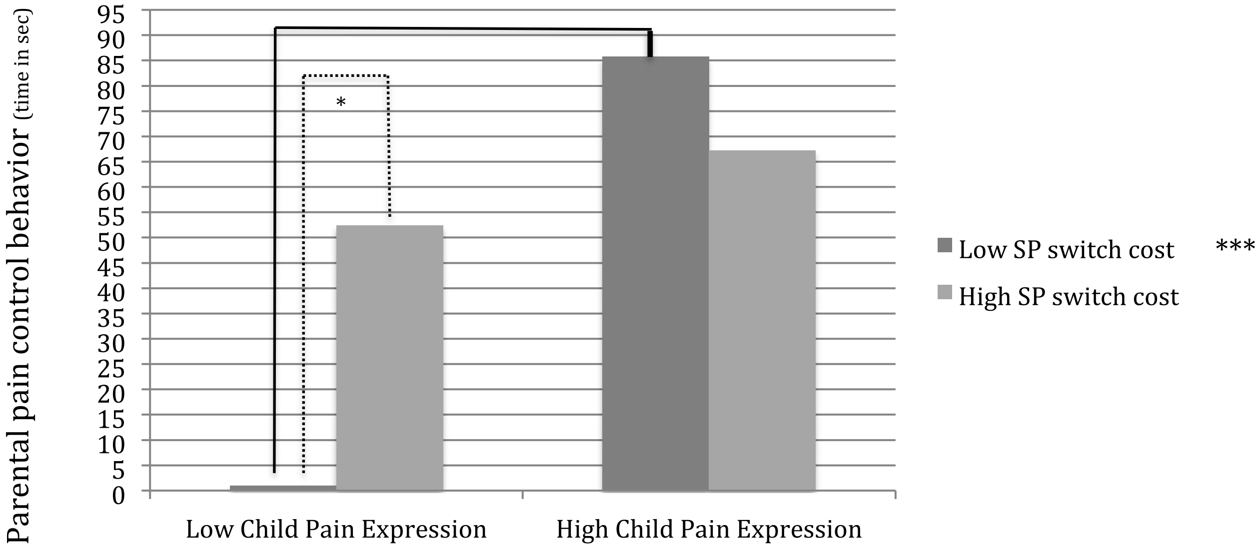
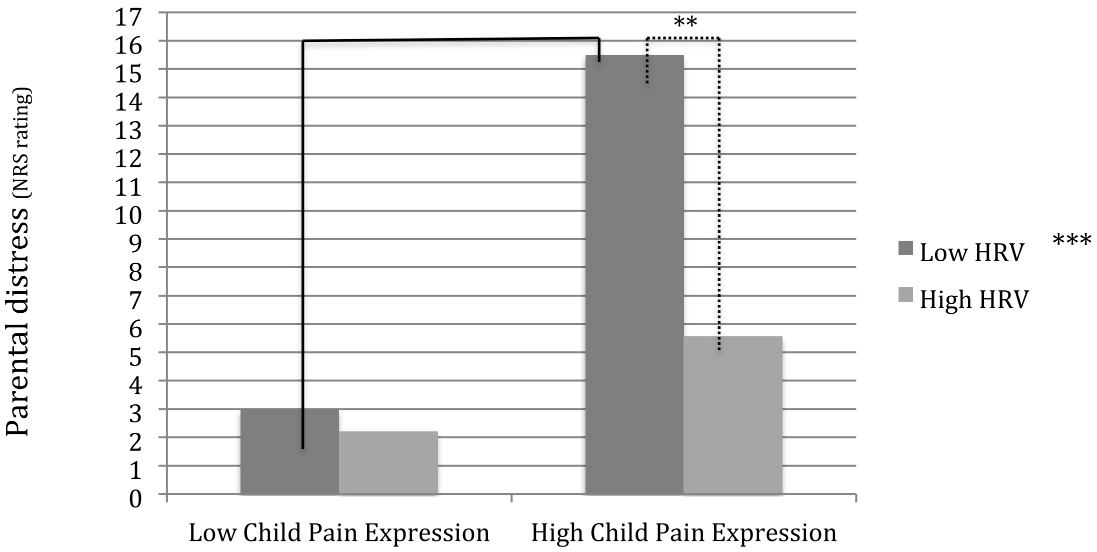
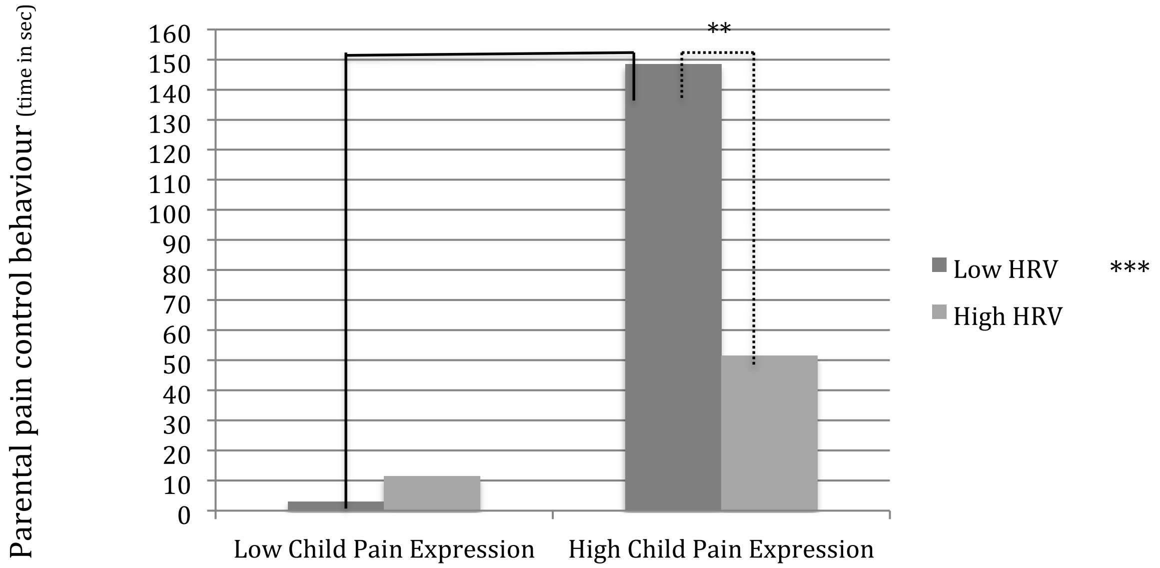

Parental pain control behavior (time in sec)
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
*
Low Child Pain Expression
High Child Pain Expression
Low SP switch cost
High SP switch cost
***

FIGURE 4



Parental distress (NRS rating)
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
**
Low HRV
High HRV
***
Low Child Pain Expression
High Child Pain Expression

FIGURE 5


Parental pain control behaviour (time in sec)
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
**
Low Child Pain Expression
High Child Pain Expression
Low HRV
***
High HRV