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Caregiver and child distress as predictors of dyadic physiological attunement during vaccination

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Abstract

Objective: Previous research discerned three groups of caregiver-toddler dyads that differed in their physiological co-regulatory patterns, also known as physiological attunement, during routine vaccinations in the second year of life. One group of dyads (80% of sample) displayed an attuned regulatory pattern and two groups of dyads (20% of sample) showed maladaptive attunement patterns (i.e., a lack of attunement or misattunement). The objective of the current study was to examine how well pain-related distress of children and caregivers during vaccination predicted these patterns.

Methods: Caregiver-toddler dyads (N = 189) were part of a longitudinal cohort observed at either 12-, 18-, or 24-month vaccination appointments. Caregiver self-report of worry was assessed before and after the needle and child behavioural pain-related distress was also measured during the vaccination appointment. Logistic regression was used to determine how well these variables predicted caregiver-child physiological attunement patterns, as indexed by high-frequency heart rate variability.

Results: Higher behavioural pain-related distress at various timepoints after the needle were associated with membership in the dyad groups that showed misattunement or lack of attunement. Further, caregivers with higher pre-needle worry and lower post-needle worry had a greater likelihood of belonging to groups that showed a maladaptive attunement pattern.

Discussion: Findings suggest that caregivers who experience distress associated with their toddlers' vaccination experience more difficulty co-regulating with their child during vaccination, and these children are at risk of experiencing higher levels of pain-related distress. This research highlights the need to help caregivers support their children's regulation during vaccination.

Key words: Acute pain, Caregiver-child attunement, Heart rate variability, Pain behaviour, Caregiver worry

1. Introduction

The caregiver-toddler relationship plays a crucial role in shaping and organizing a toddler's capacity to regulate distress across many contexts, including the acute pediatric pain context.[1,2] With the ability to express pain verbally still developing and with limited strategies to regulate themselves, young children rely on their attachment relationship with their primary caregiver to help them regulate pain-related distress.

Within the broader developmental literature, researchers have observed caregiver-toddler dyads working toward a mutually regulated state in distress contexts through moment-to-moment coordination of their biological, affective, and behavioural responses.[3,4] These caregiver-toddler interactions typically involve contingent and reciprocal responses between dyad members (i.e., each dyad member produces and respond to the other's responses).[5] Over time, repeated interactions of mutual regulation with one's caregiver support the toddler's internalization of regulatory skills.[6] Despite the dyadic nature of caregiver-toddler interactions, the caregiver is primarily responsible for facilitating regulation, given a toddler's limited capacity early in life. According to the Self-Regulation Intergenerational Transition Model,[7] a caregiver's self-regulatory capacity influences their ability to effectively structure and support their child's needs, which in turn influences their child's ability to regulate distress. Ideally, the caregiver will be able to regulate their own distress, perceive and understand the distress of their child, and respond sensitively and contingently to their child. However, the caregiver not being able to effectively regulate their own distress may prompt a greater focus on their own distress and hinder their ability to respond to their child's needs.[8,9] The pattern of dynamic and reciprocal responding between caregivers and their children is known as attunement.[10]

1.1 Patterns of physiological attunement in a distress context

Attunement is studied at various biobehavioural levels. Recently, there has been a greater focus on how caregivers and their children regulate their physiological responses in distress contexts as an underlying mechanism of caregiver-child attunement.[11] Regulation of physiological responses helps support one's ability to engage in cognitive and behavioural emotion regulation and respond to one's environment.[12] Several studies have shown that there are varying patterns of both physiological and behavioural regulation that infants and toddlers demonstrate during distressing events,[13–15] and that different patterns are associated with various adaptive (e.g., secure attachment) or maladaptive (e.g., avoidant or resistant attachment, internalizing and externalizing behavioral problems) outcomes for children.[16–19] Given the differing regulatory patterns in young children that can emerge post-distress and the predictive nature of these patterns, it is important to further examine the different patterns of regulatory responses for both toddlers and their caregivers in a distress context. However, a systematic review by our group revealed that much of the research on caregiver-child physiological attunement has focused on interpreting overall relationships between caregiver and child physiological outcomes.[11] Given the variable distress response and regulatory patterns that can emerge, it is important to examine trajectories of caregiver-child co-regulatory patterns.[11,13,20]

Recently, DiLorenzo-Klas and colleagues[21] examined caregiver-child co-regulatory response patterns within an acute pain context (see Figure 1). These authors found that having three latent groups of caregiver-toddler dyads could adequately represent variability in their regulatory responses to pain-related distress over the vaccination appointment (1-minute before needle to 3 minutes after needle), as measured by high-frequency heart rate variability. Specifically, the largest group (80%) demonstrated stable and parallel dyadic regulatory patterns from baseline to post-needle, reflecting an adaptive caregiver-toddler co-regulatory pattern or attunement (i.e.,

Group 1: Attuned regulatory pattern). It was deemed adaptive because the caregiver's trajectory matched the child's regulatory trajectory pattern and both trajectories were close to normative baseline HF-HRV levels for healthy adults and toddlers.[22,23] Although the second group (7.9 precent of the sample) also had parallel caregiver-toddler regulatory trajectories, their HF-HRV values were notably lower, indicating that both caregivers and their children were dysregulated from baseline to post-needle (i.e., Group 2: Lack of regulatory attunement). This pattern reflects a lack of regulatory attunement between dyad members, as the caregiver is distressed themselves and unlikely able to help their child regulate distress. The third group (11.1%) demonstrated divergent regulatory trajectories such that caregivers had a stable regulatory trajectory comparable to the normative group, but their toddlers showed an exaggerated withdrawal response (i.e., a steep decrease followed by an increase in HF-HRV values that surpassed their baseline levels; Group 3: Misattuned regulatory pattern). The regulatory responses of these dyads appears to reflect misattunement, whereby the caregiver's attempts at providing external regulatory support are not matched to their toddler's internal state. Thus, the toddler is overly relying on their own internal resources to cope. This research describes the variability in co-regulatory patterns of caregivers and their toddlers in a distress context. However, there is a lack of understanding of the factors that predict the different adaptive and maladaptive attunement patterns.

1.2 Caregiver and child predictors of physiological attunement patterns

Research has shown that measures of observed behavioural distress and physiological regulatory responses can reflect interrelated but also unique aspects of the distress response.[14] In a pain context, toddler behavioural pain-related distress reflects various behaviours (e.g., crying, facial expressions) that signal the toddler's level of distress.[24] The caregiver is meant to interpret these

cues and respond sensitively to the needs of their child. However, in some cases, there is a mismatch between what a child signals and their internal state. For example, young children may express limited behavioural distress and higher physiological dysregulation. In prior research, this pattern has been associated with maladaptive outcomes, including avoidant attachment[18] and greater internalizing behaviors in children.[19] Alternatively, although toddlers may display behaviours to signal distress to their caregiver, caregivers may be unable to respond due to their own dysregulation.[8,25] Thus, identifying whether observed behavioural distress predicts variable patterns of caregiver-child attunement can further elucidate why dyads are demonstrating adaptive versus maladaptive patterns of attunement.

The broader physiological attunement literature has examined how various caregiver factors affect attunement, including caregiver sensitivity and mental health (e.g. depressive symptoms), although much of the evidence is mixed.[11] There is limited but consistent evidence to show that higher parent sensitivity is associated with more concordance between caregiver and child regulatory responses.[26,27] The influence of caregiver worry associated with the distressing event (i.e., state worry) on attunement patterns has yet to be examined. Because co-regulatory patterns may be shaped by the regulatory capacities of the caregiver, an understanding of caregiver's state psychological distress may elucidate whether parent self-regulation and their ability to support their child's regulatory response is at-risk of being compromised. Indeed, previous research has shown that parent-reported state anxiety is associated with less emotional availability,[28,29] as well as greater child pain-related distress.[30,31]

1.3 Present Study

To address these issues, we examined whether caregiver distress (operationalized by reported worry before and after the vaccination) and child distress (operationalized by behavioural pain-

related distress) predict caregiver-toddler cardiac attunement patterns (see Figure 1) in an acute pain context.[21] We examined the separate contributions of caregiver worry and child pain-related distress to caregiver-child attunement patterns. Based on previous research, we hypothesized the following: (1) higher child behavioural pain-related distress would predict a greater likelihood of belonging to one of the two dyad groupings (Group 2 or 3) defined in DiLorenzo-Klas and colleagues[21] that demonstrated maladaptive co-regulatory patterns (i.e., a lack of attunement or misattunement between dyad members) rather than the normative group who showed an adaptive attunement pattern (Group 1), over and above parental worry; and (2) greater caregiver pre-needle and post-needle worry would also predict a greater likelihood of being in either Group 2 or 3 than Group 1, over and above child behavioural pain-related distress.

2. Methods

2.1 Participants

The data are part of a cohort-sequential longitudinal study in which caregiver-toddler dyads were recruited from two pediatric clinics in the greater Toronto area. Dyads were observed during routine vaccinations at 12, 18, and 24 months of age. Participant details and data collection procedures are described in detail elsewhere;[21] a synopsis is presented below. Exclusion criteria were NICU stay during infancy, prematurity (< 37 weeks gestation), suspected or confirmed developmental delay, chronic illness, or caregiver lack of fluency in English. The current analyses were based on a subset of 189 unique dyads with both caregiver and child cardiac data available at either 12 (n = 81), 18 (n = 66), or 24-month (n = 42) vaccination appointments, with a mean age of 17.04 months (SD = 4.80). See Table 1 for participant demographic characteristics. Overall, the toddlers were healthy, from middle-class families, and had caregivers who were well-educated. The subset of dyads included in this study did not

significantly differ from those excluded due to missing data in terms of demographic factors (i.e., caregiver age, education, relation to the child, ethnicity, self-reported mainstream and heritage culture, toddler sex, time since last nap, time since last feed, and number of needles received).

The mean age of primary caregivers was 36 years old (SD = 5.54 years). Most caregivers were born in Canada (58.2%), with the remaining born in Asia (18%), South America (5.3%), Europe (5.8%), Africa (2.1%), Russia (2.1%), United States/Mexico (2.1%), or Australia (1.6%). On average, caregivers reported strong identification with both their heritage culture (i.e., a culture passed down in their family for generations) and mainstream North American culture (i.e., the culture within which they currently live).

2.2 Procedures

Approval to collect data was obtained through the research ethics review board of the participating university. Caregivers were approached prior to their child's vaccination appointment. If caregivers agreed to participate, informed consent was obtained, and caregivers were asked to fill out a short demographic form before the appointment. During the vaccination appointment, caregivers held their toddlers as part of the vaccination process and video and cardiac data were simultaneously collected before and after the needle. Both caregivers and toddlers were connected to mobile monitoring devices to measure their high-frequency heart rate variability and heart rate. Based on methods from previous longitudinal studies that examined caregiver-infant dyads during vaccination,[13] toddlers and their caregivers were examined for 1 minute prior to the needle and up to three minutes after the needle. Technologies from Mindware and Noldus were used to synchronize video and cardiac data during the vaccination appointment and were used for data coding or editing procedures. Procedures allowed for naturalistic observation of participants with minimal interference from the research team except for

videotaping and cardiac monitoring. All participating caregivers were provided with a sheet outlining evidenced-based pain management strategies at each vaccination appointment.[32]

2.3 Measures

2.3.1 Demographic information

Caregivers reported demographic information for themselves (i.e., age, education, relation to child) and their child (i.e., age, sex, ethnicity). Caregivers were also asked to provide two separate ratings adapted from the Vancouver Index of Acculturation.[33] They reported the extent to which they believe their way of life reflects their self-reported heritage culture, as well as the extent to which their way of life reflects mainstream 'North American or Canadian culture'. The ratings were on a scale of 0 to 10, with a higher score reflecting greater identification with self-reported or mainstream culture. Variables that are known to affect cardiac indictors were also collected.[34,35]

2.3.2 Child pain behaviours

The Face, Legs, Activity, Cry, and Consolability (FLACC) scale was used to measure child pain behaviour during the vaccination appointment.[36] The degree of pain-related distress is measured with five types of pain behaviours (face, legs, activity, cry, and consolability) during 15-second epochs from one minute pre-needle to three minutes post-needle. Each item is scored with a scale from 0 to 2, resulting in a total score between 0 and 10 for each epoch. For ease of comparison and interpretation across measures used in the current study, 15-second epochs were averaged over one-minute phases. Four phases were used for the current analyses, including baseline (FLACC Baseline; 60 to 1 second before the first needle), one minute immediately after the last needle (FLACC Post 1; 1 to 60 seconds after the last needle), two minutes after the last needle (FLACC Post 2; 61 to 120 seconds after the last needle), and three minutes after the last needle

(FLACC Post 3; 121 to 180 seconds after the last needle). The FLACC scale has evidenced moderate to high validity and strong interrater reliability in the acute pain context.[24] High pain-related distress is considered in the 7 to 10 range, moderate pain in the 4 to 6 range, low/mild pain in the 1 to 3 range, and scores of 0 represent no pain-related distress. All coders in the current study were trained by an experienced primary FLACC coder and were blind to the study hypotheses. A total of 20% of the sample was reliability-coded throughout the coding process. Interrater reliability was high (intraclass correlations between 0.9 and 0.93).

2.3.3 Caregiver ratings of self-worry

Using a validated numerical rating scale in a pain context,[37] caregiver perceptions of their own worry level were assessed on a scale from 0 to 10. Parents were asked to rate worry levels immediately before and following the immunization procedure (i.e., “On a scale from 0 to 10, how worried about the needle are you right now on a scale from 0 ‘no worry at all’ to 10 ‘the most worry possible’?”).

2.3.4 High-frequency heart rate variability

High-frequency heart rate variability (HF-HRV) is the variation in time between heart beats and reflects a measure of parasympathetic activity.[38] Under resting conditions, the parasympathetic nervous system maintains homeostasis in the body by controlling the heart via the vagus nerve.[39] Increased parasympathetic influence (i.e., a state of "rest-and-digest") is reflected in higher values of HF-HRV. Individuals with higher HF-HRV at rest have shown to have a greater capacity to regulate distress.[40] However, in the face of a distressing event, temporary withdrawal of parasympathetic influence elicits autonomic arousal and allows for active coping (i.e., flight or fight response).[39,41] The withdrawal response is captured through decreasing HF-HRV. Of note, an excessive or prolonged withdrawal response reflects

inflexibility of the autonomic system (i.e., poor ability to regulate distress and adaptability to changing situations) which is associated with poorer long-term mental health outcomes.[42] Since HF-HRV is an index of regulatory capacity, it can provide unique insights on children's responses to distress in a needle pain context.

Cardiac measures were collected using Mindware wireless monitors (MW 1000A) with a sampling rate of 500 Hz. Three electrocardiograph (ECG) electrodes were placed on caregivers and their toddlers including one electrode placed over the right clavicle, one electrode placed under the rib cage on the left side, and a ground electrode placed under the rib cage on the right side. Mindware software (BioLab 3.3) was used to acquire ECG data during the vaccination appointment. The data were processed offline using Mindware HRV 3.1.5. The software uses an algorithm to identify each R wave. HF-HRV was calculated from spectral analysis of the RR intervals (i.e., the intervals between successive heart beats or R waves).[43] Frequency bands within the range of spontaneous respiration (0.24-1.04 Hz for toddlers and 0.15-0.40 for adults) [22,43] were used. Data were edited for artifacts due to misidentification of R waves by the software or equipment failure in the clinic (e.g., device malfunction, electrodes fell off participant). Decisions to exclude data due to artifact were made in consultation with the primary coder on an epoch-by-epoch basis. Editing of artifacts was less than 5% across the sample.

All coders were trained to edit cardiac data by an experienced primary coder. A total of 20% of data files were double-coded for reliability throughout the coding process. Unreliable codes (i.e., intraclass correlation below 0.9) were consensus coded and reviewed by the primary coder. Overall, the interrater reliability between the coders was high (intraclass correlations between 0.96 and 0.99).

HF-HRV was calculated for 30-second epochs from 1 minute pre-needle to three minutes post-needle. For analyses purposes, 30-second epochs were averaged for every minute pre- and post-needle (i.e., Baseline [60 seconds to 1 second pre-needle], Post 1 [1 to 60 seconds post-needle], Post 2 [61 to 120 seconds post-needle], and Post 3 [121 to 180 seconds post-needle]).[21] Our methods are consistent with Task Force guidelines on HRV standards of measurement that suggest approximately 1 minute of data is needed at minimum to identify the high-frequency components of HRV.[44]

2.4 Analysis plan

Distinct groups of caregiver-toddler dyads were formed according to growth mixture models (GMM) of the simultaneous HRV trajectories of caregivers and toddlers.[21] Group membership served as the dependent variable in the current analyses. In our previous study,[21] demographic characteristics (e.g., child sex, child age, caregiver relation to child) were not significantly associated with group membership and are not included in the current analyses. The predictors, caregiver self-worry pre- and post-needle and FLACC variables, were checked for outliers, and correlations among predictors were examined to ensure there was no evidence of multicollinearity. We also plotted FLACC scores by group membership to examine the child pain-related responses of these groups (see Figure 2).

Multinomial logistic regression was used to examine how well child behavioural distress and parent worry pre- and post-needle predict the group membership patterns of caregiver-child attunement during vaccination. Child behavioural distress variables (FLACC scores) were entered first in the model, as they were hypothesized to have a greater influence on physiological attunement compared to parent variables. Caregiver pre- and post-needle worry ratings were

subsequently entered to examine how caregiver factors predict attunement patterns above and beyond the child pain variables.

3. Results

3.1 Preliminary analyses

Descriptive statistics for study variables are provided in Table 2. Correlations among predictors are in Table 3; all predictors were weakly to moderately correlated (r = .01 to .60), and there were no evident outliers.

3.2 Displaying Child behavioural pain scores according to dyad co-regulatory group membership

Figure 2 shows child behavioural distress, measured with FLACC, graphed according to the caregiver-child HF-HRV regulatory trajectories. On average, Group 1 (attuned regulatory pattern) showed low pain-related behavioural distress at baseline (M = 2.01), followed by an increase to moderate pain levels immediately after the needle (M = 5.76), and a return to near-baseline levels by the third minute following the needle (M = 2.33). Regarding the two maladaptive dyadic regulatory patterns, Group 2 (lack of regulatory attunement) demonstrated mild pain-related distress at baseline (M = 2.55) and a subsequent increase in pain-related distress at a moderate-to-high level immediately after the needle (M = 6.80). Mean FLACC scores for Group 2 decreased to a moderate level by the third minute post-needle (M = 4.73). Group 3 (misattuned regulatory pattern) showed mild-to-moderate pain-related distress at baseline (M = 3.15) and a steep increase to a high level of pain-related distress immediately after the needle (M = 7.63), which decreased to a low-to-moderate level by the third minute post-needle (M = 3.43).

3.3 Predicting dyad co-regulatory group membership

Results from the multinomial regression are in Table 4. Group 1 (attuned regulatory pattern) was chosen as the reference category because it is the largest and demonstrated a stable HF-HRV co-regulatory response. Post 1 (χ^2 (2) = 6.90, p = .03) and Post 3 (χ^2 (2) = 5.89, p = .043) FLACC scores, as well as parent ratings of pre- (χ^2 (2) = 5.80, p = .045) and post-needle (χ^2 (2) = 11.66, p = .003) self-worry significantly contributed to the model's ability to predict group membership.

Baseline, Post 1, and Post 2 FLACC scores did not significantly predict the odds of membership in Group 2 (lack of regulatory attunement) rather than Group 1 (attuned regulatory pattern). A higher FLACC score during the third minute post-needle was significantly associated with an increased likelihood of being in Group 2 versus Group 1, OR = 1.41, p = .020. Higher ratings of parent self-worry pre-needle predicted greater odds of being in Group 2 versus Group 1, OR = 1.24, p = .044, while lower parent self-worry post-needle was significantly associated with a greater likelihood of being in Group 2 versus Group 1, OR = 0.719, p = .036.

Baseline, Post 2, and Post 3 FLACC scores did not significantly predict greater odds of membership in Group 3 (misattuned regulatory pattern) instead of Group 1 (attuned regulatory pattern). However, higher FLACC scores immediately after the needle (Post 1) were associated with a greater likelihood of being in Group 3 versus Group 1, OR = 1.73, p = .024. Higher ratings of parent self-worry pre-needle predicted greater odds of being in Group 3 versus Group 1, OR = 1.22, p = .041. Lastly, lower parent ratings of self-worry post-needle are significantly associated with a higher likelihood of being in Group 3 versus Group 1, OR = 0.68, p = 0.012.

4. Discussion

The goal of the current study was to investigate the relative contributions of caregiver distress (self-reported worry before and after the needle) and toddler distress during the vaccination

appointment (behavioural pain-related distress) in predicting caregiver-toddler physiological attunement patterns during vaccination. This study builds on previous work[21] that discerned three latent groups of dyads that demonstrated different attunement patterns in an acute pain context. DiLorenzo-Klas and colleagues[21] showed that the largest group (i.e., Group 1) demonstrated attunement with a stable and parallel pattern of HF-HRV from baseline to post-needle. The second group of dyads showed a parallel but low pattern of HF-HRV from baseline to post-needle, indicating both dyad members are dysregulated, and the caregiver is unlikely able to respond in a reciprocal and supportive manner (i.e., lack of attunement). Finally, the third group showed diverging regulatory patterns, whereby the caregiver showed a stable regulatory response but the child mounted an excessive withdrawal response right after the needle. This pattern reflects misattunement between dyad members, as the caregiver's attempts to provide regulatory support did not reflect their child's internal regulatory state.

The current study is unique in investigating whether child and caregiver distress during the vaccination appointment are associated with differences in physiological attunement patterns. In addition to graphically describing toddler pain scores that were associated with each of the three dyadic regulatory patterns, the current study confirmed hypotheses that both caregiver and child pain-related distress differentiated the dyads that demonstrated an attuned regulatory response from those who did not.

Consistent with our first hypothesis, dyads with maladaptive attunement patterns had higher behavioural pain-related distress compared to the attuned group of dyads, though these findings emerged at specific time points post-needle. Specifically, higher pain-related behavioural distress during the third minute post-needle was associated with a greater likelihood of being in Group 2 (lack of regulatory attunement) versus Group 1 (attuned regulatory pattern), indicating that the

children in Group 2 continued to experience considerable pain-related distress by the third minute post-needle. This result is consistent with their HF-HRV trajectory which suggests an inflexible parasympathetic response (i.e., stable, low HF-HRV with no withdrawal response) and reduced capacity for regulation.

Contrary to expectations, there were no significant differences in behavioural pain-related distress between dyads showing an attuned regulatory pattern (Group 1) versus dyads showing lack of regulatory attunement (Group 2) at any other time points. One possible explanation is that there is typically little variability in distress responses immediately after the needle,[13] whereas pain regulatory responses more distal to the needle will differ due to individual (e.g., child's pain threshold, regulatory capacity) and external factors (e.g., parent support).[45] It was more unexpected that there were no significant differences between Groups 1 (attuned regulatory pattern) and 2 (lack of regulatory attunement) in terms of behavioural pain-related distress at baseline, as Group 2's HF-HRV values suggest lower parasympathetic influence (i.e., internal dysregulation) leading up to the needle. Research has shown that behavioural pain-related distress is more closely linked to a heart rate that reflects more of a sympathetic or arousal response, whereas HF-HRV captures more regulatory activity because it is an index of the parasympathetic system.[46] Thus, before a distressing event, toddlers in Group 2 (lack of regulatory attunement) maintain a baseline level of arousal. However, consistent with previous research, the low levels of baseline HF-HRV suggest that the toddlers will be slower in recovering from the stressor, which is also predictive of later challenges with regulation and behavioural problems.[47] Further, these results suggest that toddlers in Group 2 (lack of regulatory attunement) were signalling distress; however, their caregivers where unable to regulate

themselves (i.e., they had stable, low HF-HRV values) which affected their ability to attune to the child's needs in a sensitive manner to support their regulatory response.[48]

There was a different pattern of results for dyads with a misattuned regulatory pattern (Group 3) when examining pain-related behavioural distress as a predictor of caregiver-child co-regulatory patterns. Higher behavioural pain-related distress immediately after the needle was significantly associated with a greater likelihood of being in Group 3 (misattuned regulatory pattern) versus Group 1 (attuned regulatory pattern). This result reflects the pattern of HF-HRV responding of toddlers in Group 3, as they mounted an excessive withdrawal response followed by a steep increase in HF-HRV that surpassed their baseline levels. Based on the patterns of HF-HRV and behavioural pain-related distress responses, toddlers in Group 3 (misattuned regulatory pattern) demonstrated an overarousal response. Despite displaying normative baseline and regulatory responses (i.e., steady declines to low-to-moderate pain-related distress by the third minute post-needle) that were similar to Group 1 (attuned regulatory pattern), the excessive withdrawal response may reflect parasympathetic dysfunction. Previous research has linked overarousal or excessive vagal withdrawal with emotional lability and later mental health outcomes such as panic, anxiety, and mood challenges.[49,50] Toddlers in Group 3 (misattuned regulatory pattern) were signalling distress to their caregivers. However, although caregivers appeared regulated enough to respond to their child, they may not have responded in an attuned and supportive way to scaffold an adaptive regulatory response (e.g., the use of distress-promoting behaviours such as verbal reassurance can increase child pain-related distress),[51] reflecting misattunement between dyad members.

Finally, consistent with our second hypothesis, we found that higher caregiver worry before the needle was associated with a greater likelihood of displaying patterns of misattunement or lack

of attunement (Groups 2 and 3) compared to a more adaptive attunement pattern (Group 1). These findings are consistent with models such as the Self-Regulation Intergenerational Transition Model[7] which suggest that caregivers must be able to regulate their own emotional reactions in order to model adaptive regulatory strategies and to respond to their child's distress in way to support their regulation. Therefore, caregivers' ability to regulate their own emotions precedes their ability to organize and engage sensitive caregiving behaviours to aid with their child's distress regulation.

Contrary to expectations, lower caregiver worry after the needle was associated with a greater likelihood of being in one of the same groups that reported higher worry before the needle (i.e., Group 2 or 3: lack of regulatory attunement or misattuned regulatory pattern). This finding was unexpected given that these dyads were less attuned and the toddlers in these groups displayed less optimal reactivity or regulatory responses. One possible explanation is that some caregivers in these groups might have resorted to using a response-focused regulatory strategy (i.e., avoidance and suppression of emotion), which is often used to regulate a distress response when earlier efforts have failed, instead of using an early antecedent regulatory strategy (e.g., reappraisal) before the event.[52] It is possible that, before the procedure, caregivers in Group 2 and 3 (lack of regulatory attunement or misattuned regulatory pattern) experienced anticipatory feelings of distress, which then affected their ability to attune to their child's needs and support their regulation from pain-related distress. Consequently, their reduced report of worry post-needle may reflect attentional avoidance to reduce their prolonged distress associated with their child's needle procedure.

4.2 Limitations

The findings of the current study should be interpreted in the context of some limitations

that offer directions for future research. The current study examined a low-risk sample (i.e., highly educated families with healthy toddlers) and analyses were limited by the small sample sizes of dyads in Groups 2 (n = 15) and Group 3 (n = 21). Further work is needed to explore additional caregiver and child factors that may support or hinder attunement between dyads. For example, it would be informative to examine whether certain distress-promoting caregiver behaviours and lower parent emotional availability predict lack of attunement or misattunement patterns between caregivers and their children, as previous research has shown that parent insensitive behaviours predict greater pain-related distress.[53] Further, the current study did not examine trait characteristics of caregivers and children (e.g., caregiver trait anxiety or child temperament), and the transactional development of these factors to predict attunement patterns. Previous work in young children has demonstrated early child-directed effects on caregivers, whereby early temperamental risk predicts changes in maternal responses to child distress and increases in maternal trait anxiety.[54]

4.3 Conclusions and clinical implications

The current results showed that caregiver and child factors are associated with differences in the co-regulatory experience of caregivers and their toddlers during vaccination. Our findings suggest that caregivers who report psychological distress before vaccination are less connected to their toddlers in terms of their physiological regulatory responses and their toddlers experience greater pain-related distress. These caregivers likely lack the capacity to regulate themselves or offer resources to support their children's regulation from distress. Consequently, they resort to maladaptive regulatory strategies, such as suppressing or avoiding their distress, as these same caregivers reported lower worry after the needle compared to the attuned group of dyads.

Early vaccination procedures are a common source of pain, fear, and distress for young children which can lead to elevated anxiety, fear, and pain associated with needles in the future, as well as avoidance of other health care. An important precursor to understanding how to best support children in acute pain contexts is understanding the factors that shape these early experiences. It is widely acknowledged that caregivers play an important role in providing external regulatory support for their children during painful experiences. Identifying how caregivers support their children within the routine vaccination context is important given the importance of the first few years of life for laying the foundation of child regulation skills. The findings from this study help to identify caregivers who may or may not be attuned to their child's needs, and how caregivers' own distress can hinder attunement leading to greater pain-related distress experienced by their toddlers. From a clinical perspective, encouraging caregivers to be mindful of their own arousal and worry pre-needle and providing support to help their distress regulation prior to the vaccination may enhance their capacity to shift focus to their children's needs and help their children's distress regulation. Future directions should include efforts to educate primary health care professionals to screen for parents who may require more support in helping their child regulate during vaccination.

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Figure 1. Latent groups of caregiver and toddler concurrent high-frequency heart rate variability (HF-HRV) (adapted from DiLorenzo-Klas et al., 2023). HF-HRV, a common index used to measure parasympathetic activity, reflects one's regulatory response to distress. Group 1: Attuned Regulatory Pattern, Group 2: Lack of regulatory attunement, Group 3: Misattuned regulatory pattern.

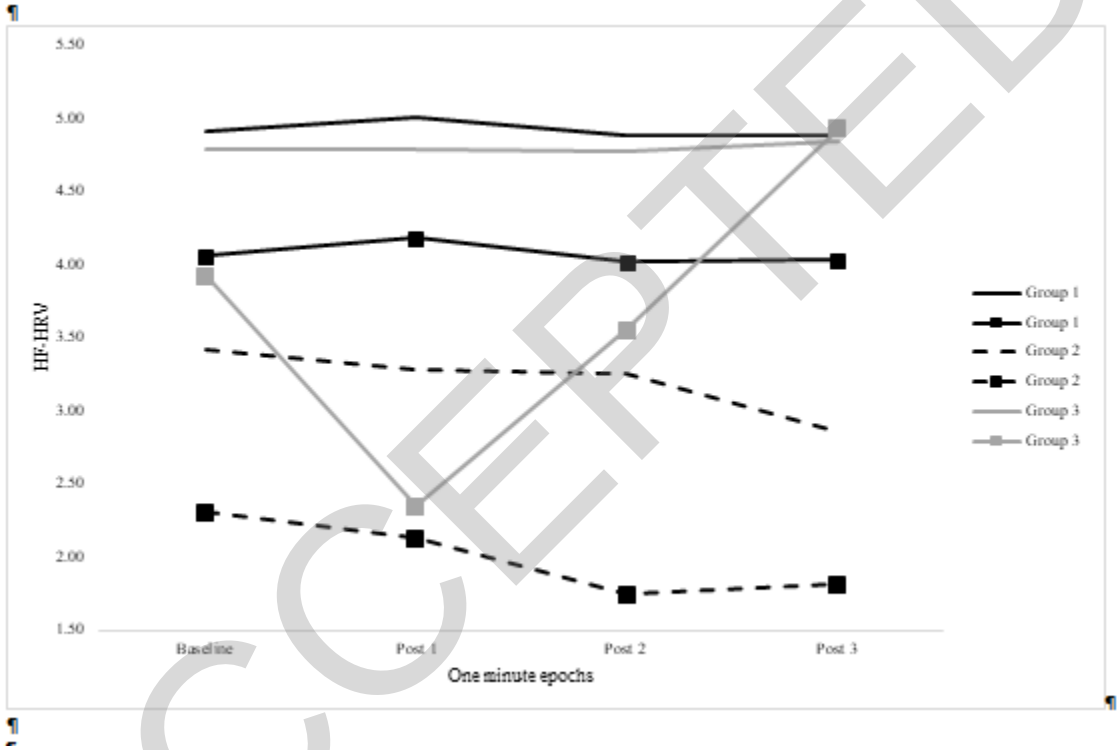

Figure 2. Child pain-related distress scores according to dyad co-regulatory group membership. Pain-related distress scores, measured with the Face, Legs, Activity, Cry and Consolability (FLACC) scale, were calculated post-hoc using the exported class membership variable. Group 1: Attuned Regulatory Pattern, Group 2: Lack of regulatory attunement, Group 3: Misattuned regulatory pattern.

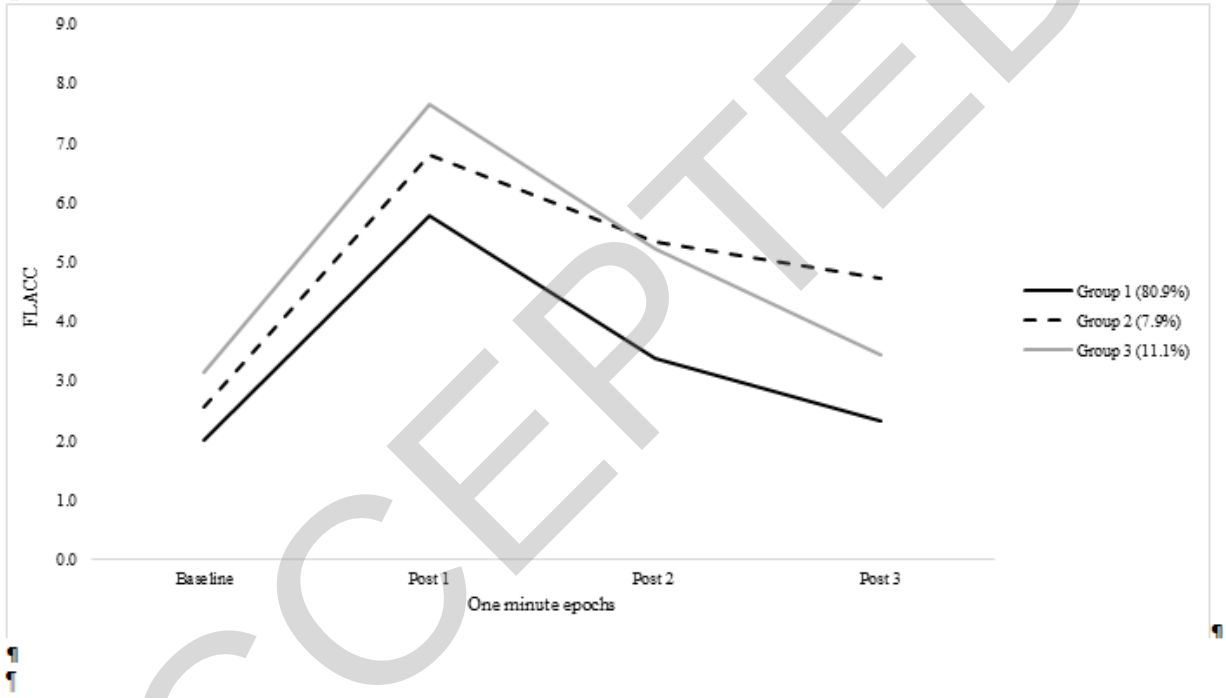

Table 1. Demographic and personal characteristics.

Toddler variables:	*n* = 189
Age in months, M (SD)	17.04 (4.80)
Age by appointment, n (%)	
12 months	81 (42.9)
18 months	66 (34.9)
24 months	42 (22.2)
Sex, male (%)	55.0
Minutes since last feed, M (SD)	102.22 (71.46)
Minutes since last nap for toddler, M (SD)	137.38 (101.53)
Number of needles toddler received, Mode (range)	1 (1-3)
Caregiver variables:	*n* =189
Age in years, M (SD)	36 (5.54)
Relationship to toddler, n (%)	
Mother	163 (86.2)
Father	24 (12.7)
Other	2 (1.1)
Education, n (%)	
Graduate school/professional training	92 (48.7)
University graduate	60 (31.7)
Partial university (at least 1 year)	5 (2.6)
Trade school/community college	26 (13.8)
High School Graduate	2 (1.1)
Missing	4 (2.1)
Country at Birth, n (%)	
Canada	110 (58.2)
Asia	34 (18)

South America	10 (5.3)
Europe	11 (5.8)
Africa	4 (2.1)
Russia	4 (2.1)
United States/Mexico	4 (2.1)
Australia	3 (1.6)
Missing	9 (4.8)
Acculturation status, M (SD)	
Way of life reflects heritage culture	7.78 (2.13)
Way of life reflects mainstream North American/Canadian Culture	6.33 (2.83)

Table 2. Study variable descriptive statistics.

	Mean	SD	Range
Group 1 – Attuned Regulatory Pattern (80.1%)			
FLACC Baseline	2.01	2.41	0-9.75
FLACC Post 1	5.76	2.39	0-10.00
FLACC Post 2	3.37	2.67	0-9.00
FLACC Post 3	2.33	2.54	0-8.46
Parent pre-needle worry	2.38	2.40	0-10.00
Parent post-needle worry	2.10	2.50	0-9.00
Group 2 – Lack of Regulatory Attunement (7.9%)			
FLACC Baseline	2.56	2.46	0-8.25
FLACC Post 1	6.80	2.18	0.5-8.75
FLACC Post 2	5.33	2.93	0-8.75
FLACC Post 3	4.73	3.13	0-9.75
Parent pre-needle worry	2.73	3.26	0-8.00
Parent post-needle worry	1.80	2.46	0-7.00
Group 3 – Misattuned Regulatory Pattern (11.0%)			
FLACC Baseline	3.15	2.72	0-8.00
FLACC Post 1	7.63	1.07	4.50-9.00
FLACC Post 2	5.23	1.98	0.50-8.25
FLACC Post 3	3.43	2.43	0-8.50
Parent pre-needle worry	3.19	3.63	0-10.00
Parent post-needle worry	1.71	2.26	0-7.00

Abbreviations: FLACC = Face, Legs, Activity, Cry, and Consolability Scale.

Table 3. Correlations among predictors.

	1.	2.	3.	4.	5.	6.
1. FLACC Baseline	_	.37*	.39*	.39*	.17*	.25*
2. FLACC Post 1		_	.55*	.42*	.03	.22*
3. FLACC Post 2			_	.60*	.01	.29*
4. FLACC Post 3				_	.01	.34*
5. Parent pre-needle self-worry					_	.48*
6. Parent post-needle self-worry						_

Note. *$p < .05$; FLACC = Face, Legs, Activity, Cry, and Consolability scale.

Table 4. Caregiver worry and child pain-related distress as predictors of group membership

Predictor	*B*	*SE B*	OR	*p*
Lack of regulatory attunement (Group 2) vs. Attuned regulatory pattern (Group 1):				
FLACC Baseline	-0.07	0.13	0.93	.574
FLACC Post 1	0.08	0.19	1.08	.689
FLACC Post 2	0.12	0.19	1.13	.532
FLACC Post 3	0.34*	0.15	1.41	.020
Parent pre-needle self-worry	0.22*	0.12	1.24	.044
Parent post-needle self-worry	-0.33*	0.16	0.72	.036
Misattuned regulatory pattern (Group 3) vs. Attuned regulatory pattern (Group 1):				
FLACC Baseline	0.04	0.10	1.04	.672
FLACC Post 1	0.55*	0.24	1.73	.024
FLACC Post 2	0.11	0.16	1.11	.503
FLACC Post 3	0.09	0.13	1.10	.522
Parent pre-needle self-worry	0.20*	0.10	1.22	.041
Parent post-needle self-worry	-0.39*	0.15	0.68	.012

Note. *$p < .05$; Model χ^2 (12) = 37.09, $p < 0.001$; FLACC = Face, Legs, Activity, Cry and Consolability Scale