ORIGINAL ARTICLE

The role of infant pain behaviour in predicting parent pain ratings

Rebecca Pillai Riddell PhD C Psych[1,2,3], David B Flora PhD[1], Sara Stevens PhD[1,2],
Saul Greenberg MD FRCPC[4,5], Hartley Garfield MD[4,5]

BACKGROUND: Research investigating how observers empathize or form estimations of an individual experiencing pain suggests that both characteristics of the observer ('top down') and characteristics of the individual in pain ('bottom up') are influential. However, experts have opined that infant behaviour should serve as a crucial determinant of infant pain judgment due to their inability to self-report.

OBJECTIVE: To predict parents' immunization pain ratings using archival data. It was hypothesized that infant behaviour ('bottom up') and parental emotional availability ('top down') would directly predict the most variance in parent pain ratings.

METHODS: Healthy infants were naturalistically observed during their two-, four-, six- and/or 12-month immunization appointments. Cross-sectional latent growth curve models in a structural equation model context were conducted at each age (n=469 to n=579) to examine direct and indirect predictors of parental ratings of their infant's pain.

RESULTS: At each age, each model suggested that moderate amounts of variance in parent pain report were accounted for by models that included infant pain behaviours (R^2=0.18 to 0.36). Moreover, notable differences were found for older versus younger infants with regard to parental emotional availability, infant sex, caregiver age and amount of variance explained by infant variables.

CONCLUSIONS: The results of the present study suggest that parent pain ratings are not predominantly predicted by infant behaviours, especially before four months of age. Current results suggest that recognizing infant pain behaviours during painful events may be an important area of parent education, especially for parents of very young infants. Further work is needed to determine other factors that predict parent judgments of infant pain.

Key Words: *Acute pain; Infant; Parent judgment; Parent rating*

Le rôle du comportement des nourrissons vis-à-vis de la douleur pour prédire les évaluations de la douleur par les parents

HISTORIQUE : Les recherches sur la manière dont les observateurs compatissent avec une personne qui souffre ou dont ils évaluent leur douleur indiquent qu'à la fois les caractéristiques de l'observateur (descendantes) et celles de la personne qui souffre (ascendantes) ont une influence. Cependant, les experts s'entendent pour affirmer que le comportement des nourrissons devrait constituer un déterminant crucial du jugement de la douleur des nourrissons en raison de leur incapacité à la faire eux-mêmes connaître.

OBJECTIF : Prédire l'évaluation que font les parents de la douleur causée par la vaccination au moyen de données d'archives. Il est postulé que le comportement des nourrissons (caractéristiques ascendantes) et la disponibilité affective des parents (caractéristiques descendantes) seraient des prédicteurs directs de la plus grande variabilité des évaluations de la douleur par les parents.

MÉTHODOLOGIE : Les chercheurs ont observé des nourrissons en bonne santé en milieu naturel lors de leur rendez-vous de vaccination à deux, quatre, six ou 12 mois. Ils ont effectué des modèles transversaux des courbes de croissance latentes dans un modèle d'équation structurelle à chaque âge (n=469 à n=579) pour examiner les prédicteurs directs et indirects des évaluations de la douleur des nourrissons par les parents.

RÉSULTATS : À chaque âge, chaque modèle indiquait une variabilité modérée des déclarations des parents, qui incluait les comportements des nourrissons vis-à-vis de la douleur (R^2=0,18 à 0,36). De plus, les chercheurs ont remarqué des différences notables à l'égard de la disponibilité affective des parents envers les nourrissons plus âgés par rapport aux plus jeunes, du sexe des nourrissons, de l'âge de la personne qui s'occupait d'eux et de l'importance de la variabilité expliquée selon les variables des nourrissons.

CONCLUSIONS : D'après les résultats de la présente étude, les évaluations de la douleur par les parents ne sont pas majoritairement tributaires des comportements des nourrissons, particulièrement avant quatre mois. Selon les résultats à jour, il serait important d'apprendre aux parents à reconnaître les comportements de leur nourrisson vis-à-vis de la douleur, surtout s'il est très jeune. D'autres travaux s'imposent pour déterminer les autres facteurs prédictifs de l'appréciation de la douleur du nourrisson par les parents.

Infant health care is often dependent on how accurately parents assess infants' health cues. Previous work has suggested that infant illness reporting and routine infant medical check ups can be predicted by parental variables not directly related to the child's behaviours (1-4). Similar variables are likely crucial to parental pain assessments of their child. Research has also indicated that empathy to the child's pain may be central. Goubert et al (5) discuss what contributes to an individual's "knowing the experience" of another's pain. The 'knowing of the experience of pain' is believed to be influenced by 'top-down' factors (ie, characteristics of the observer such as caregiver age and past pain experiences) and 'bottom-up' factors (ie, characteristics of the individual in pain or contextual factors of the painful event such

as infant pain behaviours or the fact the infant had received a needle). Health care professionals rely heavily on parents' ability to know their own child's pain. It is parents that usually determine pain management both before and after an immunization appointment (6-8). Using archival data from an ongoing longitudinal cohort, the goal of the present study was to examine a convenience subset of 'bottom-up' variables and 'top-down' variables as predictors of parental judgement of infants' pain postimmunization. The Opportunities to Understand Childhood Hurt (OUCH) cohort is a longitudinal sample of parents and healthy infants who were followed over the first year of life during the two-, four-, six- and/or 12-month immunizations (refer to Pillai Riddell et al [9] for a detailed description of the cohort).

[1] Department of Psychology, York University; [2]Department of Psychiatry, Hospital for Sick Children; [3]Department of Psychiatry, University of Toronto; [4]Department of Paediatrics, Hospital for Sick Children; [5]Department of Paediatrics, University of Toronto, Toronto, Ontario
Correspondence: Dr Rebecca Pillai Riddell, The Opportunities to Understand Childhood Hurt (OUCH) Laboratory, York University, Department of Psychology, Faculty of Health, Room 2038, Sherman Health Science Research Centre, Toronto, Ontario M3J 1P3.
Telephone 416-736-2100 ext 20177, fax 416-736-5772, e-mail rpr@yorku.ca

Top-down variables

Parental ability to address child distress: Emotional availability (EA) (10) is a construct that represents how a parent discerns and addresses their child's needs through both overt and covert behaviour. In the context of pain, it is a parent's ability, without being intrusive, to inhibit their own hostility and sensitively structure the parent-infant interaction to manage the needs of their child in distress (9). Parental EA has been shown to have a small but significant relationship with actual infant pain behaviours over the first year of life (9), but the relative contribution to parents' actual infant pain ratings has not been established.

Demographic variables of parent: The archival dataset also included information on parent age and parent education; therefore, they were also included in our analysis. Parent sex could not be included in the analysis at each age due to lack of variability; mothers were primarily the parents providing pain judgements, despite the presence of fathers at 28% to 40% of appointments across the year.

Bottom-up factors

Pain behaviours: Infant pain assessment reviews have posited that behaviours (eg, facial expression, cry and body movement) are paramount in assessing infant pain (7,11,12). Unfortunately, existing work is equivocal regarding the relationship between parent pain ratings and infant pain behaviours, with some showing little relationship (13-17) and others suggesting moderate relationships (18-20). Moreover, all of these studies used smaller sample sizes that often collapsed over large age ranges, precluding more specific developmental analyses. The current study examined the relative contribution of pain behaviours (before the needle, immediately following the needle and 1 min following the needle) in predicting pain judgements using a validated measure of infant pain behaviours (21).

Infant demographic variables: Another limitation of the literature exploring predictors of parental pain judgements is that potentially influential demographic variables (such as infant sex, number of siblings, labour/delivery complications and pregnancy complications) have not been analyzed in a comprehensive manner (17,22) and, yet, have been purported to have a significant impact on parental pain assessment (23). Labour and delivery complications could arguably be considered to be a part of the infant's previous pain or medical experience; thus, it is included as a 'bottom-up' variable. However, it is acknowledged that it could also be considered a 'top-down' variable given that the presence of complications during the birth process would also be a part of the parents', particularly the mother's, experience of their child.

Thus, the current study sought to enhance our evidence-based understanding of parents' pain ratings over the first year of life. Parent pain ratings were obtained after the immunization was complete. Four novel aspects were planned to inform the modelling of parental pain ratings: pain responding was operationalized by pain reactivity (the magnitude of the child's immediate reaction to tissue insult) and pain regulation (the rate of change over the first 2 min postneedle [ie, from the peak pain reaction immediately following the needle to the level of behavioural activity 1 min and 2 min postneedle]); pain reactivity and pain regulation were operationalized via latent factors variables of each structural equation model (ie, the 'intercept' [pain reactivity] and 'slope' [pain regulation]); given that distress behaviours that precede the needle have been shown to be significantly related to postneedle pain behaviours (22), baseline or preneedle infant behaviours were also incorporated into the modelling of parental pain ratings (ie, pain behaviours before the needle were included in each model as an observed variable); and separate structural equation models were created at each of four ages (ie, at two, four, six and 12 months of age). Ultimately, latent growth-curve modelling in a structural equation modelling (SEM) context was completed at each age with infant pain behaviours as a direct predictor of parent pain ratings. Other variables were tested as both direct and indirect predictors of parental pain ratings (ie, as predictors of parental pain ratings and as predictors of infant pain behaviours, respectively). Thus, the analysis set out to address three primary questions:

- What were the direct contributions of infant pain behaviours (baseline, pain reactivity and pain regulation), parental EA and key demographic variables in predicting parental pain ratings?

- What were the indirect contributions of baseline pain scores, parental EA and key demographic variables in predicting parental pain ratings (ie, through predicting infant pain reactivity and pain regulation at each age)?
- When comparing the four age-specific models, were there differences in the inter-relationships of the study variables?

It was hypothesized that the variance of parental pain ratings would primarily be accounted for by infant pain behaviours (baseline, reactivity, regulation), and parental EA would be the next most influential predictor. It was hypothesized that demographic variables and EA would also have an indirect effect in predicting parental pain ratings by directly relating to the infant's pain behaviour. Finally, based on previous quasiexperimental research suggesting that parent pain judgments are more strongly linked to infant behaviours and contextual factors in older infants (3), it was hypothesized that more variance in parental pain ratings would be accounted for by our models of the older infants' parental pain ratings.

METHODS

Participants

The data from the present study are part of an ongoing longitudinal cohort in which caregiver-infant dyads were recruited from three pediatric clinics in the greater Toronto area. The current data were collected at pediatrician clinics between October 2007 and February 2012. Infants were recruited at two, four or six months of age and then followed in a cohort-sequential design (infants were continuously recruited and followed until 12 months of age; subsequent cohort follow-up is occurring at the preschool immunization but is unrelated to the current analysis). A total of 747 different infants were included in the analysis. However, due to the cohort-sequential design, there were different sample sizes at each age (two months, n=492; four months, n=579, six months, n=573 and 12 months, n=469). Caregivers who were able to speak and read English, whose infants had no suspected developmental delays or impairments or chronic illnesses, and who had never been admitted to a neonatal intensive care unit were eligible to participate in the study. All infants were considered to be healthy, from middle-class families and developmentally typical. The withdrawal rate across the infant waves was 3%. The current analysis is cross-sectional and includes all infants who were observed at each age. Table 1 summarizes the demographic characteristics according to age at recruitment.

Procedure

The research ethics boards at both the host university and associated pediatric hospital approved the study protocol. Written informed consent was obtained for each participant. The overall procedure has been published elsewhere (9) and only an overview is provided here. Caregivers with infants receiving immunizations were provided a flyer by the medical receptionist and asked whether they would like to learn more about a longitudinal study. The majority of parents agreed to participate on hearing about the study; however, a small proportion of parents chose not to hear about the study and could not be further approached by research staff. Participating caregivers then completed a demographic information form with the research assistant. Once in the examination room, two video cameras were set up to capture a close-up face shot of the infant, as well as a wide shot to obtain a full view of the caregiver and the child, both before and 5 min postimmunization. At the first opportunity postimmunization, parental pain ratings were obtained orally within the clinic appointment room. Parents were instructed on how to provide pain ratings before the immunization appointment.

Apparatus

Two HV20 HD video camcorders (Canon, USA) were used to videotape the caregiver EA and infant pain behaviours. The camera with the wide-angled lens was mounted on a tripod to capture parent-infant interactions, and the second camera used a handheld tripod and was focused on the infant's face. The recording was continuous from the time the dyads entered the clinic room.

TABLE 1
Demographic variables

Variable	Total sample (n=747)	Recruitment		
		Two months (n=491)	Four months (n=187)	Six months (n=69)
Caregiver age at recruitment, years, mean ± SD	33.5±5.6	33.6±5.0	33.8±7.0	32.6±5.6
Caregiver education level at recruitment (%)				
Graduate school or professional training	30.6	29.8	33.8	28.4
University graduate	39.8	41.6	37.4	32.8
Partial university	4.8	4.9	5.3	2.9
Trade school or community college	16.8	16.0	15.5	25.4
High school graduate	7.3	7.1	7.0	9.0
Some high school	0.5	0.4	0.5	1.5
Junior high school graduate	0.1	–	0.5	–
Less than 7th grade	0.1	0.2	–	–
Infant sex				
Male, %	49.3	50.1	46.0	52.2
Number of siblings, %				
0	56.2	57.2	55.1	52.2
1	33.5	33.2	32.1	39.1
2	8.0	7.0	11.2	7.2
3	2.0	2.2	1.6	1.5
4	0.3	0.4	0	0
Pregnancy/delivery complications, %				
0	27.1	29.2	25.7	16.2
1–2	57.5	57.6	55.6	61.7
3–5	15.4	13.2	18.7	22.1
Pregnancy risk factors, %				
0	62.6	62.7	63.6	58.8
1–3	37.4	37.3	36.4	41.2

No infants were recruited at 12 months of age

Measures

Parent pain judgment: Parent judgment of their infant's pain was scored using the numerical rating scale (24). In this scale, the parental pain rating was obtained using a verbal numerical rating scale that ranged from 0 ('no pain' anchor) to 10 ('worst pain possible' anchor). Parental pain judgment was requested directly after the immunization. This scale has demonstrated reliability and validity with obtaining oral reports of pain, with strong clinical feasibility and utility (25).

Infant pain behaviours: The Modified Behavioral Pain Scale (MBPS) (21) was used to objectively measure infant pain and distress during the immunization appointments. The MBPS uses behavioural indicators (face, cry and body) to determine how much pain an infant is experiencing postprocedure, with higher scores indicating greater distressed behaviours and, therefore, greater pain (0 to 10 scale). The MBPS has been shown to have moderate to high concurrent and construct validity, as well as item-total and inter-rater reliability within the immunization context (21). Data for the MBPS were coded for four 15 s epochs: immediately preceding the first needle (MBPS-B; baseline), immediately following the last needle (MBPS-0), and both 1 min (MBPS-1) and 2 min (MBPS-2) following the needle. Coding was performed by six different coders and managed by one primary coder. Reliability with the primary coder was assessed regularly over the study period. Intraclass correlations assessing inter-rater reliability ranged from 0.93 to 0.96.

For the models, three different pain behaviour indices were derived from the MBPS. First, baseline pain was operationalized by MBPS-B. Second, pain reactivity and pain regulation was based on two latent factors (the intercept [pain reactivity] and slope [pain regulation]) based on three observed variables within the structural equation model. The three observed variables were MBPS-0, MBPS-1, MBPS-2 (see Results section for further detail).

EA: The fourth edition of the Infancy to Early Childhood version of the Emotional Availability Scales (EAS) (10) was used to code EA, a broad construct encompassing factors associated with sensitive and contingent parental responding. The EAS represents a clinical judgment of the quality of caregiving behaviour that occurred during the entire immunization appointment based on established principles of infant mental health (approximately 12 min of footage). Scores were based on footage from the entire immunization appointment both pre- and postimmunization. There were four main caregiver subscales: sensitivity, structuring, nonintrusiveness and nonhostility. These four subscales are summed to form a total EAS score. Total scores can range from 28 to 116. Higher scores reflect more optimal caregiving. The EAS coders were trained by the developer of the scale. There were four EAS coders, and inter-rater reliability was calculated in an ongoing manner on 30 permutations of reliability (ie, between each combination of coder dyad for both subscale and total EAS). Eighteen percent of the entire dataset was either double, triple or quadruple coded to avoid coder drift. Discrepancies between coders were handled via a consensus meeting. Intraclass correlations for the caregiver EAS composite score ranged from 0.83 to 0.92 for each coder with the primary coder.

Demographic variables: Demographic variables were based on parental report using a participant information sheet. The following variables were included in the current analyses: infant sex, number of children in the family, caregiver age, caregiver education, labour/delivery complications and pregnancy complications. The labour/delivery complications score was the sum of all listed complications that the parent endorsed: fetal distress, use of forceps, caesarean section, breech pregnancy, induced labour, premature birth or any physical infant problem complicating labour/delivery. The pregnancy complications score was the sum of maternal prenatal medication use, cigarette exposure, and alcohol and drug exposure. The demographic variables are summarized in Table 1.

RESULTS

Analysis overview

SEM was used to examine the inter-relationships among infant pain behaviours, EA and demographic variables in predicting parent pain judgments. SEM allows for the incorporation of both observed (eg, parent EAS) and latent variables (eg, pain reactivity and pain regulation), and a variable can be both a predictor and an outcome variable within the same model (as was the case for pain reactivity and pain regulation). The model specification was the same at each of the four ages, but the pain behaviours and EA scores from the respective immunization appointment were used. For each model, latent growth modelling within the SEM framework was used to establish pain regulation as the change in MBPS scores across MBPS-0, MBPS-1 and MBPS-2. More specifically, the pain regulation latent variable was a nonlinear slope factor specified using the freed-loading method of fitting a set of linear splines to a nonlinear pattern of change (26). This specification captures the tendency within each age for infants to show a considerable decrease from MBPS-0 to MBPS-1, followed by a smaller change from MBPS-1 to MBPS-2. Pain reactivity was established as the intercept of the line modelling the change in MBPS scores across MBPS-0, MBPS-1 and MBPS-2.

The model examined how much variance of the parent pain ratings was accounted for by baseline pain behaviours, pain reactivity, pain regulation, infant sex, caregiver EA, caregiver age, caregiver education and number of children. Additionally, within the same model, both pain

TABLE 2
Estimates for model 1 (two months of age)

Predictor variable	Unstandardized estimate	SE	P*	Standardized estimate
Pain reactivity outcome				
MBPS-B	0.107	0.013	<0.001	0.286
EAS 2 months	−0.007	0.002	0.004	−0.093
Infant sex	−0.090	0.067	0.179	−0.060
Caregiver age	0.016	0.006	0.011	0.105
Number of children	−0.101	0.037	0.007	−0.103
Pregnancy complications	0.050	0.026	0.049	0.071
Labour complications	−0.001	0.051	0.989	−0.001
Caregiver education	0.052	0.032	0.105	0.089
R^2	0.121			
Pain regulation outcome				
MBPS-B	0.053	0.025	0.039	0.115
EAS 2 months	−0.011	0.005	0.053	−0.117
Infant sex	0.104	0.105	0.320	0.056
Caregiver age	0.000	0.012	0.973	−0.002
Number of children	−0.054	0.069	0.428	−0.046
Pregnancy complications	−0.010	0.050	0.842	−0.011
Labour complications	0.042	0.092	0.645	0.026
Caregiver education	−0.072	0.052	0.170	−0.100
R^2	0.060			
Parental pain rating				
MBPS-B	0.007	0.058	0.899	0.006
Pain reactivity	0.652	0.123	<0.001	0.212
Pain regulation	0.759	0.145	<0.001	0.302
EAS 2 months	0.001	0.010	0.891	0.006
Infant sex	0.250	0.201	0.212	0.054
Caregiver age	0.016	0.023	0.499	0.034
Number of children	0.004	0.148	0.979	0.001
Pregnancy complications	0.130	0.090	0.150	0.059
Labour complications	−0.027	0.166	0.870	−0.007
Caregiver education	0.210	0.108	0.052	0.116
R^2	0.181			

Two-tailed P values; n=492. EAS Emotional Availability Scale; MBPS-B Modified Behavioral Pain Scale – Baseline score

Figure 1) *Determinants of pain ratings at two months of age. Pain rating $R^2=0.181$; reactivity contribution to pain ratings $R^2=0.052$; regulation contribution to pain rating $R^2=0.093$. Dashed lines indicate nonsignificant (P>0.0125) paths. All demographic variables named in the methods section were included in the model; only those with significant relationships (P<0.0125) with one or more endogenous variable are shown in the figure. Emotional Availability = Emotional Availability Scale; Pain-0 Pain immediately postneedle; Pain-1 Pain 1 min postneedle; Pain-2 Pain 2 min postneedle; Pain Baseline = Modified Behavioral Pain Scale – Baseline score;*

and unstandardized estimates are provided for each model in Tables 2 through 9. Only findings relevant to the research questions are described. Statistics were calculated using the MPlus version 7.1 software package.

Model 1: Prediction of parental pain judgements at two months of age
The model fit the two-month data well (CFI = 0.99; RMSEA = 0.02; SRMR = 0.02; see Figure 1 and Tables 2 and 3 for all model estimates and bivariate correlations). Eighteen percent of the variance in parental pain rating was explained in the first model. The majority of the variance in pain ratings was accounted for directly through the pain reactivity and pain regulation factors (5% and 9%, respectively), such that higher initial pain reactivity and slower regulation were associated with higher parent ratings. Caregiver EA, baseline pain behaviours, number of children and caregiver age had indirect relationships with pain ratings by accounting for a significant, albeit small, amount of the variance in pain reactivity, with greater EA associated with lower pain reactivity.

Model 2: Prediction of parental pain judgments at four months of age
The model also fit the four-month data well (CFI = 0.97; RMSEA = 0.05; SRMR = 0.03; see Figure 2 and Tables 4 and 5 for all model estimates and bivariate correlations). This model accounted for 36% parental pain rating variance, with all of the variance accounted for, almost equally, by pain reactivity (17%) and pain regulation (19%). Higher pain reactivity and slower regulation were again associated with higher parent ratings. Baseline pain behaviour indirectly predicted parental pain judgments by positively predicting both pain reactivity and pain regulation.

Model 3: Prediction of parental pain judgments at six months of age
The model also fit the six-month data adequately (CFI = 0.93; RMSEA = 0.07; SRMR = 0.04; see Figure 3 and Tables 6 and 7 for all model estimates and bivariate correlations). Again, pain reactivity and pain regulation (approximately 23% and 11%, respectively) directly accounted for 33% parental pain rating variance, and higher reactivity and slower regulation were associated with higher parent ratings. Baseline pain behaviour indirectly predicted parental pain judgments by positively predicting both pain reactivity and pain regulation.

Model 4: Prediction of parental pain judgments at 12 months of age
The model fit the 12-month data well (CFI = 0.95; RMSEA = 0.06; SRMR = 0.04; see Figure 4 and Tables 8 and 9 for all model estimates

reactivity and pain regulation were simultaneously regressed on the remaining infant and caregiver variables (infant sex, caregiver age, caregiver EAS, caregiver education, pregnancy complications, labour complications and number of children). It is also important to note that, because the slope variable was used to represent regulation, variables that have a positive relationship with pain regulation are associated with slower regulation. Variables that have a negative relationship with pain regulation (ie, the slope variable) are associated with faster rates of regulation. This is because the slope is negative and the further the slope is from 0, the faster the rate that the pain scores are decreasing.

To maximize information used in the analyses, direct maximum likelihood estimation was used so that all cases, including those with missing data, contributed to model estimation. Additionally, adjusted fit statistics and robust SEs were used to account for the non-normal distributions of the variables (27). Goodness of fit was evaluated using the Comparative Fit Index (CFI) (28), the root mean square error of approximation (RMSEA) (29), and the standardized root mean residual (SRMR) (28). CFI values ≥0.95, RMSEA <0.06, and SRMR <0.08 indicate that a model fits the data well (28), although these guidelines should not be used in a strict, absolute sense (30). Finally, to control for multiple comparisons across four separate analyses by age, a Bonferroni-corrected alpha level of 0.05/4 = 0.0125 was used to determine statistical significance within a model. Correlations, standardized estimates
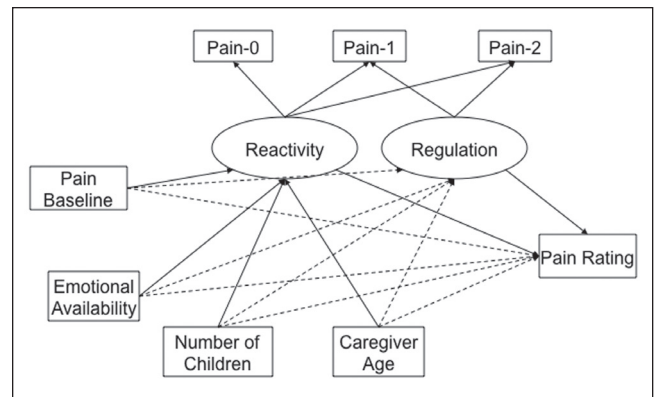
TABLE 3
Descriptive statistics for two-month variables

Variable	1	2	3	4	5	6	7	8	9	10	11
1. MBPS-B	1.00	0.296**	0.182**	0.166**	−0.146**	0.050	0.000	−0.019	0.033	0.012	−0.045
2. MBPS-0	0.296**	1.00	0.277**	0.230**	−0.113*	−0.034	0.063	−0.078	0.038	0.010	0.071
3. MBPS-1	0.182**	0.277**	1.00	0.532**	−0.133**	0.062	0.032	−0.059	0.044	0.085	0.017
4. MBPS-2	0.166**	0.230**	0.532**	1.00	−0135**	0.036	−0.025	−0.011	0.018	−0.026	0.005
5. EAS 2 months	−0.146**	−0.113*	−0.133**	−0.135**	1.00	0.001	0.105*	−0.101*	−0.152**	0.019	0.069
6. Infant sex	0.050	−0.034	0.062	0.036	0.001	1.00	0.024	−0.048	−0.020	0.080	0.040
7. Caregiver age	0.000	0.063	0.032	−0.025	0.105*	0.024	1.00	0.178**	−0.291**	0.040	0.095*
8. Number of children	−0.019	−0.078	−0.059	−0.011	−0.101*	−0.048	0.178**	1.00	0.120**	−0.048	−0.149**
9. Caregiver education	−0.033	−0.038	−0.044	−0.018	0.152**	0.020	0.291**	0.120**	1.00	0.023	0.035
10. Pregnancy risk factors	0.012	0.010	0.085	−0.026	0.019	0.080	0.040	−0.048	−0.023	1.00	0.073
11. Pregnancy/delivery complications	−0.045	0.071	0.017	0.005	0.069	0.040	0.095*	−0.149**	−0.035	0.073	1.00
Mean ± SD	2.97±2.04	8.80±0.76	6.17±2.37	5.64±2.55	92.22±10.32	50.4% Male	33.60±4.95	1.58±0.78	41.3% University Degree	0.41±0.56	1.23±1.07

*Pairwise correlations; n ranged from 408 to 492. *P<0.05; **P<0.01. EAS Emotional Availability Scale; MBPS Modified Behavioral Pain Scale; MBPS-0 Distress immediately postneedle; MBPS-1 Distress 1 min postneedle; MBPS-2 Distress 2 min postneedle; MBPS-B MBPS – Baseline score*
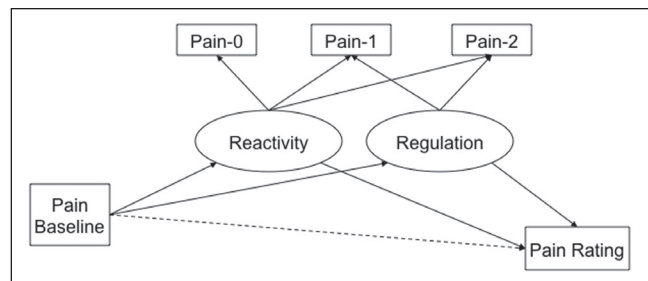

Figure 2) *Determinants of pain ratings at four months of age. Pain ratings $R^2=0.364$; reactivity contribution to pain rating $R^2=0.172$; regulation contribution to pain rating $R^2=0.185$. Dashed lines indicate nonsignificant (P>0.0125) paths. Emotional Availability Scale scores and all demographic variables named in the methods section were included in the model, but are omitted from the figure because none were significant predictors of reactivity, regulation or pain rating (all P>0.0125). Pain-0 Pain immediately post-needle; Pain-1 Pain 1 min postneedle; Pain-2 Pain 2 min postneedle; Pain Baseline = Modified Behavioral Pain Scale – Baseline score*

TABLE 4
Estimates for model 2 (four months of age)

Predictor variable	Unstandardized estimate	SE	P*	Standardized estimate
Pain reactivity outcome				
MBPS-B	0.157	0.015	<0.001	0.292
EAS 4 months	−0.007	0.004	0.111	−0.062
Infant sex	−0.005	0.077	0.950	−0.002
Caregiver age	0.002	0.009	0.838	0.010
Number of children	−0.057	0.054	0.291	−0.043
Pregnancy complications	−0.074	0.040	0.064	−0.081
Labour complications	0.030	0.065	0.644	0.017
Caregiver education	−0.065	0.048	0.179	−0.082
R^2	0.114			
Pain regulation outcome				
MBPS-B	0.124	0.022	<0.001	0.276
EAS 4 months	−0.005	0.005	0.261	−0.059
Infant sex	0.080	0.085	0.350	0.048
Caregiver age	0.007	0.008	0.418	0.045
Number of children	−0.090	0.063	0.153	−0.082
Pregnancy complications	0.004	0.039	0.916	0.005
Labour complications	0.069	0.076	0.360	0.046
Caregiver education	−0.035	0.042	0.404	−0.053
R^2	0.108			
Parental pain rating				
MBPS-B	0.011	0.056	0.843	0.008
Pain reactivity	0.914	0.089	<0.001	0.373
Pain regulation	1.241	0.171	<0.001	0.422
EAS 4 months	−0.008	0.010	0.420	−0.030
Infant sex	0.289	0.181	0.110	0.059
Caregiver age	−0.020	0.016	0.196	−0.047
Number of children	0.107	0.118	0.362	0.033
Pregnancy complications	−0.015	0.090	0.868	−0.007
Labour complications	−0.168	0.169	0.320	−0.038
Caregiver education	−0.049	0.096	0.609	−0.025
R^2	0.364			

Two-tailed P values; n=579. EAS Emotional Availability Scale; MBPS-B Modified Behavioral Pain Scale – Baseline score

and bivariate correlations). Pain reactivity (24%) and pain regulation (7%) explained 34% of the variance in parental pain rating in the same directions as at the younger infant ages. In addition, infant female sex also directly positively predicted pain ratings, although weakly. Caregiver EA had an indirect relationship with pain ratings by accounting for a significant, but small, amount of the variance in both pain reactivity and pain regulation, such that greater EA was associated with lower reactivity and better regulation. Baseline pain behaviour indirectly predicted parental pain judgments by positively predicting pain reactivity. Finally, number of children also had significant but weak indirect and direct effects on pain ratings, such that parents with more children had infants with quicker regulation and lower pain ratings.

DISCUSSION

The goal of the current study was to examine the relative ability of 'top-down' and 'bottom-up' variables to predict parental pain ratings of their infant's immunization pain, at two-, four-, six- and 12-month appointments. Using archival data, available predictors of parental pain ratings (infant pain behaviours [baseline, pain reactivity, pain regulation], caregiver EA and influential demographic variables) were tested. The use of age-specific analyses and advanced model estimation techniques applied to our large data set enabled definitive commentary on the role of these variables in predicting parental pain ratings. When predicting pain ratings directly from the variables, the

available top-down factors did not have significant predictive value. It was the bottom-up variables (ie, infant pain reactivity and infant pain regulation) that accounted for the most variance in pain ratings across

TABLE 5
Descriptive statistics for four-month variables

Variable	1	2	3	4	5	6	7	8	9	10	11
1. MBPS-B	1.00	0.996**	0.991**	0.992**	−0.013	−0.005	−0.011	−0.054	−0.059	0.005	0.038
2. MBPS-0	0.996**	1.00	0.993**	0.993**	−0.009	−0.003	−0.014	−0.048	−0.063	0.011	0.035
3. MBPS-1	0.991**	0.993**	1.00	0.993**	−0.016	0.005	−0.010	−0.063	−0.073	0.016	0.038
4. MBPS-2	0.992**	0.993**	0.993**	1.00	−0.016	−0.003	−0.014	−0.054	−0.068	0.009	0.039
5. EAS 4 months	−0.013	−0.009	−0.016	−0.016	1.00	0.049	0.082*	−0.035	0.020	0.014	0.017
6. Infant sex	−0.005	−0.003	0.005	−0.003	0.049	1.00	0.051	−0.062	−0.006	0.000	0.050
7. Caregiver age	−0.011	−0.014	−0.010	−0.014	0.082*	0.051	1.00	0.217**	−0.227**	0.036	0.121**
8. Number of children	−0.054	−0.048	−0.063	−0.054	−0.035	−0.062	0.217**	1.00	−0.160**	−0.039	−0.140**
9. Caregiver education	0.059	0.063	0.073	0.068	−0.020	0.006	0.227**	−0.160**	1.00	0.024	0.029
10. Pregnancy risk factors	0.005	0.011	0.016	0.009	0.014	0.000	0.036	−0.039	−0.024	1.00	0.036
11. Pregnancy/delivery complications	0.038	0.035	0.038	0.039	0.017	0.050	0.121**	−0.140**	−0.029	0.036	1.00
Mean ± SD	3.90±19.53	9.58±19.12	6.05±19.96	5.93±20.20	111.22±61.39	47.7% Male	33.71±5.61	1.57±0.76	41.7% University degree	0.40±0.56	1.27±1.10

*Pairwise correlations; n ranged from 521 to 579. *P<0.05; **P<0.01. EAS Emotional Availability Scale; MBPS Modified Behavioral Pain Scale; MBPS-0 Distress immediately postneedle; MBPS-1 Distress 1 min postneedle; MBPS-2 Distress 2 min postneedle; MBPS-B MBPS – Baseline score*
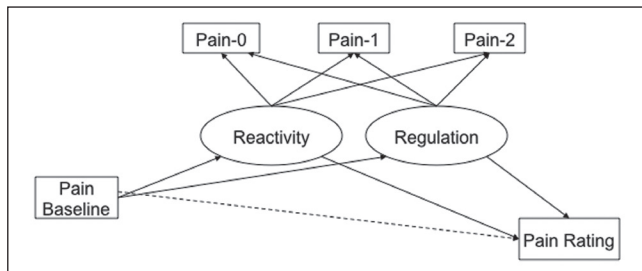

Figure 3) *Determinants of pain ratings at six months of age. Pain rating $R^2=0.331$; reactivity contribution to pain rating $R^2=0.226$; regulation contribution to pain rating $R^2=0.114$. Dashed lines indicate nonsignificant (P>0.0125) paths. The Emotional Availability Scale scores and all demographic variables named in the methods section were included in the model, but are omitted from the figure because none were significant predictors of reactivity, regulation or pain rating (all P>0.0125). Pain-0 Pain immediately postneedle; Pain-1 Pain 1 min postneedle; Pain-2 Pain 2 min postneedle; Pain Baseline = Modified Behavioral Pain Scale – Baseline Score*

TABLE 6
Estimates for model 3 (six months of age)

Predictor variable	Unstandardized estimate	SE	P*	Standardized estimate
Pain reactivity outcome				
MBPS-B	0.185	0.017	<0.001	0.348
EAS 6 months	−0.002	0.005	0.741	−0.015
Infant sex	0.059	0.093	0.525	0.025
Caregiver age	0.016	0.011	0.146	0.068
Number of children	−0.039	0.064	0.549	−0.024
Pregnancy complications	−0.025	0.040	0.525	−0.024
Labour complications	0.025	0.079	0.754	0.012
Caregiver education	0.008	0.046	0.857	0.009
R^2	0.136			
Pain regulation outcome				
MBPS-B	0.110	0.021	<0.001	0.296
EAS 6 months	−0.010	0.005	0.034	−0.123
Infant sex	0.146	0.093	0.114	0.088
Caregiver age	0.005	0.010	0.624	0.028
Number of children	−0.041	0.074	0.579	−0.036
Pregnancy complications	0.003	0.042	0.937	0.004
Labour complications	0.021	0.080	0.791	0.015
Caregiver education	0.036	0.046	0.437	0.055
R^2	0.129			
Parental pain rating				
MBPS-B	−0.038	0.054	0.484	−0.034
Pain reactivity	0.965	0.076	<0.001	0.455
Pain regulation	0.929	0.186	<0.001	0.308
EAS 6 months	−0.004	0.010	0.712	−0.015
Infant sex	0.174	0.188	0.354	0.035
Caregiver age	−0.032	0.019	0.093	−0.064
Number of children	0.025	0.125	0.840	0.007
Pregnancy complications	0.124	0.085	0.144	0.056
Labour complications	−0.098	0.159	0.537	−0.023
Caregiver education	−0.021	0.085	0.809	−0.010
R^2	0.331			

*Two-tailed P values; n=573. EAS Emotional Availability Scale; MBPS-B Modified Behavioral Pain Scale – Baseline score

the year. However, although infant pain behaviour (ie, the bottom-up variables) were the relatively best predictors, there was considerable variance in parental pain ratings that was left unaccounted for. Moreover, the amount of variance accounted for was notably less in the youngest infants. Finally, it was also interesting to note that preneedle pain behaviours consistently predicted infant pain behaviour postneedle, but did not directly predict parent pain ratings. Results are discussed in order of the research questions.

Addressing the first research question, there was considerable unexplained variance that was not determined by what are considered to be 'gold standard' indicators by expert clinicians and researchers, namely infant pain behaviours. In essence, models that included facial expression, body movement and cry accounted for approximately 18% of the variance in two- and four-month-olds and approximately 36% of the variance in six- and 12-month-olds. These models also included demographic variables and caregiver EA. Contrary to our hypotheses, EA and baseline pain behaviours were never a direct predictor of parental pain ratings, while demographic factors (more children, female sex) showed a very small, albeit significant, direct positive relationship at 12 months of age (confirming our hypotheses). Other OUCH cohort analyses have suggested that EA is stable over the first year of life and has significant but low-magnitude relationships with infant pain behaviour and parent pain management behaviour (9,31,32). The current study now confirms that EA only has indirect relationships with parents' actual pain assessments of

their infant (see below for discussion of indirect relationships in our model). More research must be performed to better understand factors influencing parental pain assessment and management. For example, previous research involving older children has suggested that parents'

TABLE 7
Descriptive statistics for six-month variables

Variable	1	2	3	4	5	6	7	8	9	10	11
1. MBPS-B	1.00	0.356**	0.318**	0.378**	−0.070	0.104*	−0.003	−0.089*	0.003	−0.083*	−0.053
2. MBPS-0	0.356**	1.00	0.385**	0.320**	−0.200**	0.067	0.057	−0.046	0.005	−0.020	−0.029
3. MBPS-1	0.318**	0.385**	1.00	0.463**	−0.056	0.113**	0.058	−0.058	0.029	0.006	−0.040
4. MBPS-2	0.378**	0.320**	0.463**	1.00	−0.129**	0.081	0.001	−0.033	0.047	−0.056	−0.017
5. EAS 6 months	−0.070	−0.200**	−0.056	−0.129**	1.00	−0.022	−0.027	−0.090*	−0.045	−0.038	−0.003
6. Infant sex	0.104*	0.067	0.113**	0.081	−0.022	1.00	0.047	−0.031	0.003	0.038	0.023
7. Caregiver age	−0.003	0.057	0.058	0.001	−0.027	0.047	1.00	0.118**	−0.226**	0.014	0.097*
8. Number of children	−0.089*	−0.046	−0.058	−0.033	−0.090*	−0.031	0.118**	1.00	0.205**	−0.079	−0.154**
9. Caregiver education	−0.003	−0.005	−0.029	−0.047	0.045	−0.003	0.226**	−0.205**	1.00	−0.059	−0.061
10. Pregnancy risk factors	−0.083*	−0.020	0.006	−0.056	−0.038	0.038	0.014	−0.079	−0.059	1.00	0.080
11. Pregnancy/delivery complications	−0.053	−0.029	−0.040	−0.017	−0.003	0.023	0.097*	−0.154**	−0.061	0.080	1.00
Mean ± SD	3.17±2.22	8.34±1.18	4.79±2.58	4.33±2.60	112.75±64.35	48.3% Male	33.50±4.93	1.54±0.73	41.2% University degree	0.42±0.58	1.35±1.13

*Pairwise correlations; n ranged from 490 to 573. * P<0.05; ** P<0.01. EAS Emotional Availability Scale; MBPS Modified Behavioral Pain Scale; MBPS-0 Distress immediately postneedle; MBPS-1 Distress 1 min postneedle; MBPS-2 Distress 2 min postneedle; MBPS-B MBPS – Baseline score*
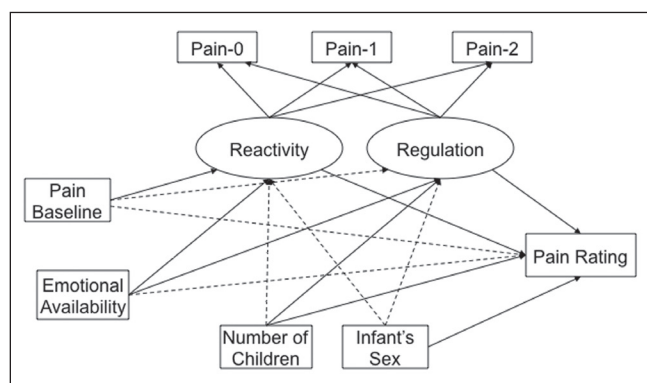

Figure 4) *Determinants of pain ratings at 12 months of age. Pain rating R^2=0.338; reactivity contribution to pain rating R^2=0.239; regulation contribution to pain rating R^2=0.070. Dashed lines indicate nonsignificant (P>0.0125) paths. All demographic variables named in the methods section were included in the model; only those with significant relationships (P<0.0125) with one or more endogenous variable are shown in the figure. Emotional Availability = Emotional Availability Scale; Pain-0 Pain immediately postneedle; Pain-1 Pain 1 min postneedle; Pain-2 Pain 2 min postneedle; Pain Baseline = Modified Behavioral Pain Scale – Baseline score*

TABLE 8
Estimates for model 4 (12 months of age)

	Unstandardized			Standardized
Predictor variable	estimate	SE	P*	estimate
Pain reactivity outcome				
MBPS-B	0.152	0.018	<0.001	0.293
EAS 12 months	−0.015	0.005	0.002	−0.138
Infant sex	0.061	0.106	0.561	0.026
Caregiver age	0.006	0.008	0.492	0.028
Number of children	0.001	0.060	0.981	0.001
Pregnancy complications	−0.058	0.057	0.310	−0.052
Labour complications	−0.148	0.095	0.117	−0.071
Caregiver education	0.000	0.052	0.993	0.000
R^2	0.131			
Pain regulation outcome				
MBPS-B	0.059	0.024	0.015	0.145
EAS 12 months	−0.015	0.005	0.006	−0.176
Infant sex	0.101	0.108	0.348	0.054
Caregiver age	0.016	0.009	0.085	0.098
Number of children	−0.237	0.074	<0.001	−0.193
Pregnancy complications	−0.048	0.049	0.328	−0.055
Labour complications	−0.036	0.091	0.695	−0.022
Caregiver education	0.014	0.054	0.802	0.018
R^2	0.112			
Parental pain rating				
MBPS-B	−0.008	0.047	0.860	−0.008
Pain reactivity	0.989	0.084	<0.001	0.480
Pain regulation	0.610	0.154	<0.001	0.231
EAS 12 months	−0.001	0.010	0.919	−0.005
Infant sex	0.618	0.193	<0.001	0.126
Caregiver age	−0.029	0.016	0.066	−0.069
Number of children	0.341	0.132	0.010	0.105
Pregnancy complications	0.069	0.092	0.451	0.030
Labour complications	−0.272	0.170	0.109	−0.063
Caregiver education	0.041	0.095	0.667	0.021
R^2	0.339			

*Two-tailed P values; n=469. EAS Emotional Availability Scale; MBPS-B Modified Behavioral Pain Scale – Baseline score

own experiences with surgery accounts for more variance in their estimations of the helpfulness of pain medication for their child than the child's actual experiences (18). Thus, research exploring other 'top-down' factors, such as parental needle fears and parental pain experience with needles, would likely be fruitful future lines of inquiry.

Previous research has clearly shown that infant pain behaviours are important to both professional and parental assessments of infant pain (22). Because behavioural observations of infants are considered to be crucial to understanding their subjective experience (7), this finding suggests that parental pain ratings may be largely based on factors outside of what experts would consider to be integral to accurate pain assessment. The present study stands alone in its use of latent factors representing the initial peak pain response and the rate of change of infant pain scores in predicting parental pain ratings. Using the growth curve of three pain scores over the immunization appointment increased the reliability of our measurement and findings. Given the clear link between the assessment and management of infant pain and the primary role that parents play in shaping pain responses over childhood, more research should investigate other factors determining parental pain ratings.

With regard to the second research question, supporting initial postulations, indirect relationships were found that helped clarify the interrelationships between a caregiver and infant in pain. Baseline

TABLE 9
Descriptive statistics for 12-month variables

Variable	1	2	3	4	5	6	7	8	9	10	11
1. MBPS-B	1.00	0.325**	0.286**	0.281**	−0.014	0.058	−0.006	−0.079	−0.016	0.026	−0.004
2. MBPS-0	0.325**	1.00	0.395**	0.336**	−0.017	0.037	−0.001	0.004	0.011	−0.078	−0.054
3. MBPS-1	0.286**	0.395**	1.00	0.543**	−0.036	0.035	0.034	−0.110*	−0.063	−0.023	−0.052
4. MBPS-2	0.281**	0.336**	0.543**	1.00	−0.015	0.081	0.013	−0.101*	−0.011	−0.073	−0.020
5. EAS 12 months	−0.014	−0.017	−0.036	−0.015	1.00	0.000	0.052	−0.113*	−0.035	−0.067	−0.038
6. Infant sex	0.058	0.037	0.035	0.081	0.00	1.00	0.042	−0.026	−0.052	0.015	0.007
7. Caregiver age	−0.006	−0.001	0.034	0.013	0.052	0.042	1.00	0.205**	−0.224**	0.036	0.103*
8. Number of children	−0.079	0.004	−0.110*	−0.101*	−0.113*	−0.026	0.205**	1.00	0.201**	−0.091	−0.156**
9. Caregiver education	0.016	−0.011	0.063	0.011	0.035	0.052	0.224**	−0.201**	1.00	0.042	0.070
10. Pregnancy risk factors	0.026	−0.078	−0.023	−0.073	−0.067	0.015	0.036	−0.091	−0.042	1.00	0.100*
11.Pregnancy/delivery complications	−0.004	−0.054	−0.052	−0.020	−0.038	0.007	0.103	−0.156	−0.070	0.100*	1.00
Mean ± SD	3.45±2.29	8.27±1.19	5.63±2.49	4.79±2.59	113.82±68.69	48.2% Male	33.59±5.84	1.57±0.76	40.7% University degree	0.41±0.57	1.26±1.06

*Pairwise correlations; n ranged from 418 to 469. *P<0.05; **P<0.01. EAS Emotional Availability Scale; MBPS Modified Behavioral Pain Scale; MBPS-0 Distress immediately postneedle; MBPS-1 Distress 1 min postneedle; MBPS-2 Distress 2 min postneedle; MBPS-B Modified Behavioral Pain Scale – Baseline score*

pain scores never directly predicted pain ratings, but did generally predict pain reactivity and pain regulation. This suggests that parents' evaluations of their infants' pain does not take into account the child's preneedle distress but confirmed the relationship between baseline pain and postneedle pain responses (9,22). Baseline infant pain behaviour predicted higher infant pain behaviours postneedle. This also suggests that parents and health professionals should strive to reduce distress before administering infant immunizations. Indeed, previous work from this cohort has found that soothing behaviours and distraction behaviours have a significant, albeit small, effect on reducing needle-related distress in infants (33,34). Moreover, baseline distress should be incorporated into postneedle evaluations of infant pain.

Contrary to our hypotheses, caregiver EA only had an indirect relationship with parent pain rating at two and 12 months of age. Moreover, demographic variables indirectly predicted parent pain rating only at two and 12 months of age. At two months of age, higher pain reactivity was associated with older parents and fewer children in the family. At 12 months of age, the more children in the infant's family, the quicker the rate of regulation. Further research needs to explore why these differences in EA and the role of demographic variables appear to play a role only at these ages. When examining the sample as a whole, the two- and 12-month immunizations have been shown to have the highest pain behaviours over the year (9). It is speculated that infant level of distress may be an influential factor when examining the interrelationships between parent and infant behaviours (35).

With regard to the third research question relating to developmental differences, in addition to what has been noted above in terms of direct and indirect relationships with parental pain rating, a striking difference was observed in the amount of variance accounted for in our models. In early infancy (two months of age), only 18% of the variance was accounted for by pain reactivity and pain regulation factors, with this figure almost doubling in later infancy (33% to 36%; four, six and 12 months of age). This naturalistic observational work validates earlier quasiexperimental work on caregiver pain judgments, suggesting age biases that favour the older infant (16). The current study clearly shows that parents depend even less on gold-standard indicators when infants are younger. Delving into the inter-relationships within our models, an interesting pattern is discerned when examining the change in the relative contributions of pain reactivity and pain regulation in determining parental pain ratings. The change reflects a developmental shift in whether parents attend to the child's immediate reaction to tissue insult or to the child's capacity to self regulate or modulate the pain. At two months of age, pain regulation contributes to almost double the amount of variance in pain ratings relative to pain reactivity. At 12 months of age, after a gradual shifting through four and six months of age, pain reactivity accounts for more than three times the amount of variance in parental pain ratings when compared with pain regulation. These findings suggest another important area of improving parental assessment skill would be to teach parents to attend to initial pain reactivity in even the youngest of infants undergoing immunization.

Despite the large sample size and unique age-specific analyses, the generalizability of these findings to high-risk samples has yet to be determined. However, the results from the present study do provide both researchers and clinicians with important normative data regarding the process of parental judgment in a primary care setting in which future higher risk participants can be compared.

SUMMARY

Immunization pain is an optimal clinical paradigm for improving our general understanding of parental report in health care settings across the first year of life. It applies a well-recognized noxious stimulus in a generally standardized procedure that is witnessed by both parent and health professional. Despite the use of variables hypothesized to be involved in parental immunization pain assessments, much of the variance in parental pain assessments remains unexplained. Therefore, the present study implies that parent pain judgments are heavily influenced by factors unrelated to the infants' pain behaviour. Parental personal experiences with needles, psychopathology, catastrophizing and types of mundane stress levels have all been shown to significantly influence parental perceptions of their child's pain experience (18,19) and must be explored in greater depth for their determining role in infant pain judgments. Moreover, important developmental differences have been elucidated that highlight the need to take a sharper developmental lens within infancy.

REFERENCES

1. Horton R, Din Osmun L, Pillai Riddell R, Stevens B, Greenberg S. Maternal relationship style, pediatric health care utilization and infant health. Pediatr Child Health 2010;15:432-6.
2. Balda RC, Guinsburg R. Perceptions of neonatal pain. Neoreviews 2007;8:e533-42.
3. Pillai Riddell R, Craig KD. Judgemnet of infant pain: Impact of caregiver identity and infant age. J Pediatr Psychol 2007;32:501-11.
4. Breau LM, McGrath PJ, Stevens B, et al. Judgement of pain in the neonatal instensive care setting: A survey of direct care staffs' perception of pain in infants at risk of neurological impairment. Clin J Pain 2006;22:122-9.
5. Goubert L, Craig KD, Vervoort T, et al. Facing others in pain: The effects of empathy. Pain 2005;118:283-5.
6. Chambers CT, McGrath PJ. Pain measurement in children. In: Ashburn MA, Rice L, eds. The Management of Pain. New York: Churchill Livingstone, 1998:625-34.
7. Steven BJ, Pillai Riddell RR, Oberlander TE, Gibbins S. Assessment of pain in neonates and infants. In: Anand KJ, Stevens BJ, McGrath P, eds. Pain in Neonates and Infants, 3rd edn. Edinburg: Elsevier Limited, 2007:67-90.
8. McGrath PJ, Finley GA, Ritchie J. Parent's role in pain assessment and management. IASP Newsletter 1994; March/April:3-4.
9. Pillai Riddell R, Campbell L, Flora DB, et al. The relationship between caregiver sensitivity and infant pain behaviors across the first year of life. Pain 2011;152:2819-26.
10. Biringen Z. The emotional availability (EA) scales, 4th edn. 2008. <http://www.emotionalavailability.com/> (Accessed September 1, 2012).
11. Pillai Riddell R, Lisi D, Campbell L. Pain assessment in neonates: Premature and full-term. In: Schmidt RF, Gebhart GF, eds. Encyclopedia of Pain, 2nd edn. Heidelberg: Springer; 2013.
12. Blount RL, Piira T, Cohen LL, Cheng PS. Pediatric procedural pain. Behav Mod 2006;30:24-49.
13. Cohen LL. Reducing infant immunization distress through distraction. Health Psychol 2002; 21:207-11.
14. McClellan CB, Cohen LL, Joseph KE. Infant distress during immunization: A multimethod assessment. J Clin Psychol Med S 2003;10:231-8.
15. Reissland N, Harvey H, Mason J. Effects of maternal parity, depression and stress on two-month-old infant expression of pain. J Reprod Infant Psyc 2012;30:363-6.
16. Goubert L, Vervoort T, Cano A, Crombez G. Catastrophizing about their children's pain is related to higher parent-child congruency in pain ratings: An experimental investigation. Eur J Pain 2009;13:196-201
17. Kelly AM, Powell CV, Williams A. Parent visual analogue scale ratings of children's pain do not reliably reflect pain reported by children. Pediatr Emerg Care 2002;18:159-62.
18. Pillai Riddell RR, Lilley CM, Craig KD. Predicting parental attitudes toward the helpfulness of postoperative analgesic medication. J Child Health Care 2004;33:185-200.
19. Pillai Riddell RR, Stevens BJ, Cohen LL, Flora DB, Greenberg S. Predicting maternal and behavioural measures of infant pain: The relative contribution of maternal factors. Pain 2007;133:138-49.
20. Stein PR. Indices of pain intensity: Construct validity among preschoolers. Pediatr Nur 1995;21:119-23.
21. Taddio A, Nulman I, Koren BS, Stevens B, Koren G. A revised measure of acute pain in infants. J Pain Symptom Manag 1995;10:456-63.
22. Pillai Riddell R, Racine N. Assessing pain in infancy: The caregiver context. Pain Res Manag 2009;14:27-32.
23. Rosenbloom E, Goldman M, Konki N, Edelman S, Baram W, Kozer E. Parental sex and age: Their effect on pain assessment of young children. Pediatric Emergency Care 2011;11:266-9.
24. Jensen MP, Karoly P, O'Riordan EF, Bland Jr F, Burns RS. The subjective experience of acute pain: An assessment of the utility of 10 indices. CJP 1989;5:153-9.
25. Jensen M, Karoly P. Self-report scales and procedures for assessing pain in adults. In: Turk, D, Melzack R, eds. Handbook of Pain Assessment. New York: Guilford Press, 2001:15-34.
26. Bollen, KA, Curran, PJ. Latent Curve Models: A Structural Equation Perspective. New York: Wiley, 2006.
27. Yuan KH, Bentler PM. Three likelihood-based methods for mean and covariance structure analysis with nonnormal missing data. In: Sobel ME, Becker MP, eds. Sociological Methodology. Washington DC: ASA, 2000:165-200.
28. Steiger JH. EzPATH: A supplementary module for SYSTAT and SYSGRAPH. Evanston: SYSTAT, 1989.
29. Hu L, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Struct Equ Modeling 1999;6:1-55.
30. Marsh HW, Hau K, Wen Z. In search of golden rules: Comment on hypothesis-testing approaches to setting cutoff values for fit indexes and dangers in overgeneralizing Hu and Bentler's (1999) findings. Struc Equ Modeling 2004;11:320-41.
31. Din Osmun L, Pillai Riddell R, Flora D. Infant negative affect at 12 months of age: Caregiver and infant predictors. J Pediatr Psychol 2014;39:23-34.
32. Racine N, Pillai Riddell R, Garfield H, Greengberg S. A longitudinal examination of verbal reassurance during infant immunization: Occurrence and examination of emotional availability as a potential moderator. J Ped Psych 2012;37:935-44.
33. Campbell L, Pillai Riddell R, Garfield H, Greenberg S. A cross-sectional examination of the relationships between caregiver proximal soothing and infant pain over the first year of life. Pain 2013;154:813-23.
34. Lisi D, Campbell L, Pillai Riddell R, Garfield H, Greenber S. Naturalistic parental pain management during immunizations during the first year of life: Observational norms from the OUCH cohort. Pain 2013;154:1245-53.
35. Ahola Kohut S, Pillai Riddell R, Flora DB, Oster H. A longitudinal analysis of the development of infant facial expressions in response to acute pain: Immediate and regulatory expressions. Pain 2012;153:2458-65.