Remembering the pain of surgery 1 year later: a longitudinal examination of anxiety in children’s pain memory development

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Abstract

Children who develop greater negatively-biased recall of pain (i.e., recalled pain is higher than the initial pain report) following surgery are at risk for developing chronic pain; therefore, identifying risk factors for the development of biased pain memories is important. Higher anxiety has been implicated in the development of greater negatively-biased recall of pain; however, studies have not examined anxiety at multiple time points before and after a surgery and its relationship to children’s postsurgical pain memories after 1 year. This prospective study examined a cohort of 237 children and adolescents undergoing major surgery. Anxiety sensitivity, pain catastrophizing, and pain anxiety were assessed at baseline, 48 to 72 hours after surgery, and at 6- and 12-month follow-ups. Pain intensity at rest, movement-evoked pain intensity, and pain unpleasantness were assessed daily in hospital. Memories for pain were elicited via telephone 1-year post surgery. Findings revealed that children who had higher levels of anxiety at baseline and 48 to 72 hours after surgery developed greater negatively-biased recall of pain intensity 12 months after surgery. Specifically, higher anxiety sensitivity at baseline and greater tendencies to catastrophize about pain at baseline and in the immediate acute recovery phase were most strongly linked to greater negatively-biased recall of pain. Greater negatively-biased recall of pain was related to higher pain intensity at 6 and 12 months post surgery. Findings support conceptual models of anxiety and pain memory biases and can inform intervention efforts to reduce anxiety in the pre- and post-op periods to minimize negative biases in pain memories.

Keywords: Pain, Surgery, Memory, Anxiety, Adolescents, Children

1. Introduction

Chronic pain in adolescence has been coined a “modern public health disaster,” yet we know little about the mechanisms by which acute pain becomes chronic. One risk factor may involve a memory bias. Pain experiences in childhood and adolescence are remembered long after they end. These memories leave a lasting impression on the developing child and set the stage for future pain experiences. Pain memories can be accurate or biased. Children who develop more negatively-biased recall of pain (recalled pain is higher than the initial pain report) are at heightened risk of developing fears of medical care and higher pain and distress at subsequent pain experiences. Pain memories have been implicated in the development of chronic pain. A recent study of adolescents undergoing spinal fusion/pectus repair revealed that more negatively-biased memories of pain 2 to 4 months after surgery predicted higher reports of pain 2 months later, specifically when pain is at risk of becoming chronic. Given the rising prevalence and debilitating impact of pediatric chronic pain, greater understanding of underlying mechanisms, such as pain memory, is timely.

Identifying youth at risk of developing greater negatively-biased recall of pain is a high priority since remembering pain as more intense than it was predicts greater subsequent pain intensity. Pain-specific (pain anxiety and pain catastrophizing) and general anxiety factors (anxiety sensitivity) have been posited as risk factors for pain memory biases. Theoretical models posit that individuals with high levels of general anxiety selectively attend to and encode threatening information, which subsequently leads to overestimation in pain recall. Empirical research with 8 to 12 year olds revealed that higher trait and state anxiety, and anxiety sensitivity, predicted more negatively-biased recall of cold pressor pain intensity 2 weeks later. Similarly, higher levels of pain catastrophizing among adolescents before major surgery were linked to greater negatively-biased recall of pain 2 to 4 months later. Nevertheless, the roles of other general and pain-specific anxiety factors on children’s longer-term recall of postsurgical pain have not been investigated. Furthermore, the role of anxiety in children’s pain memory biases...
has not been prospectively examined at multiple time points before and after a painful event. This is important for informing intervention efforts aimed at modifying factors that lead to biased pain memories over time. This study aimed to fill these gaps. Youth undergoing major general and orthopaedic surgeries known to lead to a 15% to 20% 1-year incidence of chronic pain were prospectively followed for 1 year. Anxiety risk factors were assessed at multiple time points over the follow-up period, and their relationship with pain memories was examined 1 year after surgery. We hypothesized that youth with higher levels of pain-related anxiety constructs (catastrophizing, pain anxiety, and anxiety sensitivity) would develop greater negatively-biased recall of postsurgical pain. We did not have specific hypotheses regarding the time points at which the various anxiety factors would be related to pain memories, or which aspects of recall (ie, sensory vs affective, pain at rest vs during movement) would be most susceptible to bias. We expected that pain at 6 and 12 months post surgery would be related to 12-month negative memory biases.

2. Method

The present article reports results from a larger study examining risk factors for chronic postsurgical pain in children and youth, which has not yet been published. The methods below pertain only to the aim of this article, which was to examine the influence of general and pain-specific anxiety-related factors on children’s pain memory biases 1 year after surgery.

2.1. Participants

Patients aged 8 to 17 years undergoing either orthopedic surgery (ie, osteotomy, plate insertion tibial/femur, and surgery for scoliosis) or general surgery (ie, thoracotomy, thoracoabdominal, Nuss/Ravitch, sternotomy, laparotomy, laparoscopic-assisted; colectomy, ileostomy, J-pouches), and their parents were eligible to participate in this study. Children were excluded if (1) they had a documented developmental or cognitive impairment or disability, (2) they had a diagnosis of cancer, (3) they did not speak or read English, or (4) their parent or guardian did not speak or read English.

2.2. Measures

2.2.1. The Numerical Rating Scale

The Numerical Rating Scale (NRS) is a 11-point verbally administered scale that measures the subjective experience of pain intensity (I), movement-evoked pain (M), or pain unpleasantness (U). The NRS-I ranged from 0 (no pain at all) to 10 (worst possible pain). The NRS-U ranged from 0 (not at all unpleasant/horrible/yucky) to 10 (most unpleasant/horrible/yucky). The NRS has excellent reliability and validity, and has been validated for acute postsurgical pain in children aged 7 to 17 years.46

2.2.2. Childhood Anxiety Sensitivity Index

The Childhood Anxiety Sensitivity Index (CASI) is an 18-item scale that measures the extent to which the symptoms of anxiety (eg, increased heart rate, shortness of breath, and racing thoughts) are feared because of the belief that they will have harmful somatic, psychological, and/or social consequences. Each item is rated on a scale of 1 (none) to 3 (a lot). Total scores range from 18 to 54 with higher scores indicative of greater anxiety sensitivity. The CASI has very good internal consistency ($\alpha = 0.87$), satisfactory test–retest reliability ($r = 0.76$), and adequate construct validity. Internal consistency for this study was very good T0 ($\alpha = 0.864$), T1 ($\alpha = 0.872$), T2 ($\alpha = 0.850$), and T3 ($\alpha = 0.856$).

2.2.3. Pain Catastrophizing Scale—Children

The 13-item Pain Catastrophizing Scale—Children (PCS-C) is a child version of the PCS that measures the thoughts and feelings children may experience when they are in pain, including unrealistic beliefs that the current situation will lead to the worst possible pain outcome, negative thoughts about the future and self, and “an exaggerated negative ‘mental set’ brought to bear during actual or anticipated pain experience” (p. 53). Each item is rated on a 5-point scale ranging from 0 (not at all) to 4 (all the time). The PCS-C yields a total score and 3 subscale scores assessing (1) rumination, (2) magnification, and (3) helplessness. The PCS-C has excellent internal consistency ($\alpha = 0.90$) and strongly correlates with pain intensity ($r = 0.49$) and disability ($r = 0.50$). Internal consistency for this study was excellent at T0 ($\alpha = 0.935$), T1 ($\alpha = 0.942$), T2 ($\alpha = 0.926$), and T3 ($\alpha = 0.932$).

2.2.4. Child Pain Anxiety Symptoms Scale

The Child Pain Anxiety Symptoms Scale (CPASS) is a 20-item scale that measures the fear and anxiety-related thoughts, feelings, behaviors, and physical sensations that accompany the experience and anticipation of pain. It is a modified version of the adult PASS that can be administered to children as young as 8 years old. Each item is rated on a scale of 0 (never) to 5 (always), and overall scores range from 0 to 100 with higher scores indicative of greater pain-related anxiety. The CPASS has excellent internal consistency ($\alpha = 0.89-0.903$) and strong construct validity. Internal consistency for this study was excellent at T0 ($\alpha = 0.920$), T1 ($\alpha = 0.941$), T2 ($\alpha = 0.925$), and T3 ($\alpha = 0.932$).

2.2.5. Pain memory interview

Similar to previous research with adolescents undergoing spinal fusion and pectus repair, youth completed a memory interview that probed their recall of the postsurgical pain experience while in hospital. First, youth were asked to think back to their in-hospital experience (ie, the first day after surgery and during their entire hospital stay) and then rate the pain intensity (NRS-I), pain unpleasantness (NRS-U), and movement-evoked pain intensity (NRS-M) as they remembered experiencing these using the same scales previously administered at those time points. The pain intensity questions probed both the pain intensity at rest (stem: when you were resting quietly but not sleeping) and while moving about (stem: when you moved around in your bed or tried to walk).

2.3. Procedure

The study was reviewed and approved by the Research Ethics Boards at The Hospital for Sick Children (SickKids) (REB file # 1000019644) and the Human Participants Review Committee at York University (Certificate # 2010–276). Children and their parents were recruited to participate either at the preoperative assessment clinic or by telephone if they did not attend the preoperative clinic. Parents provided consent to participate, and children provided assent for their participation. This prospective study involved 4 assessment time points over the course of...
a year: preoperative (T0), in-hospital recovery (T1), and 6 (T2) and 12 (T3) months after surgery.

### 2.3.1. Preoperative assessment

The baseline assessment included administration of child questionnaires that assessed previous and current pain experiences, as well as relevant psychological and emotional functioning. The order of questionnaire administration was randomized within subjects to minimize fatigue and order effects. The child’s preoperative medication use (analgesics and others) was obtained from the parents and confirmed by the patient’s hospital medical record.

### 2.3.2. Intraoperative anaesthetic management

Each patient received a general anaesthetic in accordance with SickKids clinical practice. The following intraoperative factors were recorded from the surgical and anaesthetic records: duration of surgery, analgesic/anaesthetic regime including use of epidural/regional anaesthetic techniques, and systemic opioids (ie, opioids given for the surgical procedure).

### 2.3.3. In-hospital postoperative assessment

Pain intensity scores (NRS-I), movement-evoked pain scores (NRS-M), and pain unpleasantness scores (NRS-U) were obtained daily by a research assistant. Daily NRS scores from the first 3 postoperative days of hospital stay were averaged to obtain mean in-hospital pain ratings. Postoperative analgesic use was recorded from the child’s medical record. In addition, 48 to 72 hours after surgery, children completed the CPASS, PCS-C, and CASI.

### 2.3.4. Six- and 12-month postoperative follow-ups

Six and 12 months after surgery, patients were contacted by telephone to complete a series of measures to assess pain experienced over the past week (NRS-I, NRS-U, and NRS-M) and anxiety (CPASS, PCS-C, and CASI). At the 12-month follow-up, a research assistant conducted the pain memory interview (described above) with children.

We did not record the percentage of questionnaires completed by the child alone; however, the only time point when the child/adolescent might not have completed them by themselves was preoperative when participants either took them home to complete and return on the day of surgery or in the preanaesthesia clinic (in which case a researcher was present and could see that the participants were completing the forms themselves and were there to help if help was needed). However, for the remaining time points, it was the child/adolescent alone who completed the questionnaires: For the in-hospital time point, questionnaires were completed by the child/adolescent, and, at times, the questionnaires were read to the participants who responded verbally (eg, when the surgery type made it difficult for the child to write). The 6- and 12-month questionnaires were completed over the phone with the research assistant reading the questions to the children. This was done to ensure that the child was the one completing the questionnaires and also to avoid missing data.

### 2.4. Recruitment

Recruitment took place between February 2011 and August 2015. See Figure 1 for recruitment details and participant flow through the study. Research records of children assessed for eligibility between February 2011 and August 2014 were lost; therefore, Figure 1 shows eligibility numbers between September 2014 and August 2015.

Of the 349 approached for consent, 270 children and their parents consented to participate. Three children withdrew consent before participating in any part of the study, one patient’s surgical procedure was changed and they no longer met study criteria, and 26 children were missed (ie, the research assistant was unable to locate or reach them) for their T0 assessment. One patient was diagnosed with cancer after consent and was withdrawn from the study. A total of 265 patients completed some part of the in-hospital (T1) assessment (eg, questionnaires and daily pain measures). Twenty-seven patients were admitted directly to the intensive care unit (ICU) from the operating room, and therefore, the research assistant was unable to obtain daily pain measures. The 6- and 12-month retention rates of participants in this study were 81.13% and 85.28%, respectively.

### 2.5. Statistical analyses

Data analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 24.0. Descriptive,
correlational, and regression analyses were conducted using 2-tailed hypothesis testing.

Differences between key variables were examined using t-tests, χ² tests, and repeated-measures analysis of variances. Paired tests were used to compare mean 12-month pain recall scores of initial pain intensity for rest pain, movement-evoked pain, pain unpleasantness, with their respective actual initial pain scores on day 1 and across the first 3 days after surgery. Mean 12-month pain recall scores for all measures (rest, movement, and unpleasantness) also were compared with their respective peak pain scores across the first 3 days after surgery. In line with previous research, biases in pain recall were assessed using partial correlations and hierarchical regressions. Specifically, the correlations between criteria (eg, children’s recalled levels of pain) and predictors all controlled for children’s initial reports of pain. For instance, when assessing biased recall of in-hospital pain at rest, children’s initial report of pain at rest within the first 48 to 72 hours after surgery was controlled/used as a covariate. Peak pain scores were defined for each measure (rest, movement, and unpleasantness) as the highest pain score reported across the first 3 days after surgery. Partial bivariate Pearson correlations were conducted between the child psychological variables and memories for pain to justify their inclusion in regression models. Similar to Noel et al. to be included in the regression models, anxiety sensitivity, child pain catastrophizing, and pain anxiety had to be significantly correlated with children’s memories for pain at rest, movement, or pain unpleasantness after controlling for initial pain ratings that corresponded to each memory question (eg, memory for pain intensity at rest on the first day after surgery controlled for initial pain intensity at rest rating obtained on the first day after surgery). Hierarchical linear regression models were used to test the relationships between the various anxiety factors and children’s memories for pain 1 year after surgery. All regression models controlled for the initial pain ratings that corresponded to each memory question/outcome. Additionally, we conducted partial correlational analyses to determine whether age should be included as a covariate in the hierarchical regression models. To examine distinct contributions of individual predictors (anxiety sensitivity, pain catastrophizing, and pain anxiety) to biases in children’s recall of postsurgical pain, we conducted dominance analyses. Dominance analysis computes an average increase in the amount of explained variance in the criterion variable with the inclusion of each predictor across all possible regression models.

Finally, to confirm the association between greater negatively-biased recall of pain (ie, recall that was greater than the initial pain ratings) and chronic postsurgical pain, a series of bivariate partial correlations were conducted between the pain memory measures and pain ratings at 6 and 12 months, while controlling for initial pain ratings that corresponded to each memory measure.

3. Results

3.1. Recruitment

There were no significant differences on any of the measures at baseline between participants who completed the study at 12 months compared with those who did not. For the purposes of this article, we included children who had a typical hospital trajectory, and therefore, the 27 children who were admitted to the ICU are excluded from the present analyses. This decision was made a priori. While we assume that pain was assessed routinely in the ICU as part of clinical assessment, research assistants were not permitted to enter the ICU based on hospital regulations, which precluded assessment of their 48- to 72-hour postsurgical pain. Patients who were transferred to ICU had significantly longer surgical times ($P < 0.001$) and hospital stays ($P = 0.001$).

3.2. Descriptive statistics

The final sample consisted of 237 children ($M_{age} = 14.11$ years [SD = 2.47], range 8 to 18 years, female $n = 140, 59.1\%$ and their parents or guardians. The majority of children identified as white (59.5%; Table 1). Sixty-one percent of patients ($n = 145, 61.2\%$) had had a previous surgery, and 62.2% ($n = 148$) had an ongoing pain problem prior to the current surgery; most frequent pain locations were back/spine ($n = 61, 25.7\%$) and legs/hips ($n = 44, 18.6\%$). Only 8.4% ($n = 20$) of patients were taking pain medications before their current surgery. No patients were using gabapentinoids at any point during the study. Most children underwent surgery for scoliosis ($n = 107, 45.14\%$) and 39.24% ($n = 93$) underwent an osteotomy. Nineteen children (8.0%) had a Nuss or Ravitch procedure, 2 (0.8%) had a thoracotomy, and 14 (5.9%) had another type of surgery. The mean duration of surgery was 4.39 hours (SD = 2.0 hours, range = 0.70-8.55 hours) and children stayed in hospital have an average of 4.74 days (SD = 2.93, range 1-36 days).

At baseline, children reported a mean rating of 2.00/10 (SD = 2.35) for pain at rest; average pain at rest 48 to 72 hours after surgery was 4.01/10 (SD = 2.29), 2.39/10 (SD = 2.31) at the 6-month follow-up, and 2.80/10 (SD = 2.54) at the 12-month follow-up. Children, who had pain at surgical site (pain intensity rating $>0, n = 132$), reported a mean rating of 3.94/10 (SD = 1.63) for pain at the 6-month follow-up and 4.33/10 (SD = 1.83) at the 12-month follow-up (n of children who reported pain $>0 = 144$). The incidence of CPSP (pain ratings 4-10/10) was 35.1% ($n = 68/194$) at the 6-month follow-up and 38.2% ($n = 78/204$) at the 12-month follow-up.

Furthermore, 12 months after surgery, participant recall of initial pain intensity for rest pain, movement-evoked pain, and pain unpleasantness was significantly higher than all respective initial pain ratings. Pain recall scores 12 months after surgery were also significantly higher than peak pain scores for all measures (Table 2). Table 2 provides additional characteristics of the participants’ pain. Descriptive statistics for anxiety sensitivity (CASI), pain-related anxiety (CPASS), and pain catastrophizing (PCS-C), at baseline, during the acute recovery period, and at 6- and 12-month follow-ups are summarized in Table 3.

Boys and girls did not differ on reported pain characteristics or memories for pain (all values of $P > 0.05$).

3.3. Associations between anxiety-related factors and memories for pain

All correlation analyses controlled for the initial pain rating that corresponded to each memory question (ie, when examining memory for pain at rest on the first day after surgery, the NRS-R on the first day after surgery was used; when examining memory for movement-evoked pain on the first day after surgery, the NRS-M on that was used; and when examining memory for pain during the hospital stay, an average of NRS-R or NRS-M on the first 3 days was used). The bivariate correlations between predictors are reported in Table 4.

Table 5 shows the partial correlation coefficients between the psychological measures (pain catastrophizing, anxiety sensitivity, and pain-related anxiety) at T0-T3 and pain recall at 12 months. T0 pain catastrophizing and anxiety sensitivity scores were
positively correlated with greater negatively-biased recall of pain at rest during the first day after surgery. T1 pain catastrophizing, anxiety sensitivity, and pain anxiety scores were positively correlated with greater negatively-biased recall of movement-evoked pain. The pattern of significant correlations for T2 and T3 was the same: Higher levels of pain catastrophizing, anxiety sensitivity, and pain anxiety at 6 and 12 months were significantly correlated with greater negatively-biased recall of movement-evoked pain.

Based on the results of the correlation analyses, 4 hierarchical regression models were tested (baseline [model 1], in-hospital recovery [model 2], and 6- and 12-month follow-ups [models 3 and 4]) to examine the predictive value of risk factors on pain memory biases. Initial pain ratings that corresponded to each memory question were entered in the first step of each model followed by the key variables. Results of the regression analyses are summarized in Table 6. Only significant findings are presented.

Additionally, we conducted partial correlational analyses to determine whether age should be included as a covariate in the hierarchical regression models. After controlling for initial pain ratings, the association between age and biases in children’s recall of pain intensity at rest during the first day after surgery was not significant, \( r = -0.001, P > 0.05 \). Therefore, age was not included as a covariate in model 1. After controlling for initial pain

### Table 1
Sociodemographic characteristics of the sample.

| Demographic characteristic | N = 237 |
|----------------------------|---------|
| Age, M ± SD                | 14.11 (2.47) |
| Sex, %                     | Female 59.1 |
| Ethnicity, %               | White 59.5 |
|                           | Other 11.0 |
|                           | African Canadian 5.5 |
|                           | South Asian 5.1 |
|                           | East Asian 4.6 |
|                           | African Caribbean 1.7 |
|                           | Hispanic 1.7 |
|                           | Aboriginal 1.3 |
|                           | Middle Eastern 0.4 |
| Grade, %                   | 3 2.1 |
|                           | 4 3.0 |
|                           | 5 3.8 |
|                           | 6 8.4 |
|                           | 7 8.4 |
|                           | 8 7.6 |
|                           | 9 13.5 |
|                           | 10 13.1 |
|                           | 11 13.1 |
|                           | 12 12.2 |
| Participating parent sex, %| Female 73.8 |
| Parent education, %        | Elementary 2.5 |
|                           | High school 22.4 |
|                           | Undergraduate/college degree 43.0 |
|                           | Graduate/university degree 17.7 |
|                           | Other 3.8 |

### Table 2
Pain characteristics of the sample.

| Pain characteristic                           | N = 237 |
|-----------------------------------------------|---------|
| Ongoing pain problem at baseline, %          | Yes 62.2 (148) |
| Pain at rest                                  | 2.00 (2.36) |
| Pain at movement†                            | 5.86 (2.26) |
| Pain unpleasantness‡                         | 4.84 (2.56) |
| Pain on the first day while in hospital, M (SD)| Pain at rest 3.72 (2.18) |
| Pain at movement†                            | 5.59 (1.92) |
| Pain unpleasantness‡                         | 4.68 (1.98) |
| Pain on the first 3 days while in hospital, M (SD) | Pain at rest 3.55 (1.81) |
| Pain at movement†                            | 5.59 (1.92) |
| Pain unpleasantness‡                         | 4.68 (1.98) |
| Peak pain across the first 3 days while in hospital, M (SD) | Pain at rest 4.52 (2.18) |
| Pain at movement**                           | 6.42 (2.28) |
| Pain unpleasantness††                        | 5.76 (2.50) |
| Pain at 6-month follow-up, M (SD)            | Pain at rest 2.39 (2.31) |
| Pain unpleasantness                          | 2.73 (2.56) |
| Pain at rest in the last week                | 4.08 (1.82) |
| Pain unpleasantness in the last week         | 4.14 (2.16) |
| Pain at 12-month follow-up, M (SD)           | Pain at rest 2.80 (2.54) |
| Pain unpleasantness                          | 2.81 (2.66) |
| Pain at rest in the last week                | 4.22 (2.15) |
| Pain unpleasantness in the last week         | 4.17 (2.21) |
| Memory for day 1 postsurgical pain at 12-month follow-up, M (SD) | Pain at rest 6.48 (2.69) |
| Pain at movement§                            | 7.71 (2.23) |
| Pain unpleasantness§                         | 7.34 (2.18) |
| Memory for average postsurgical pain during acute recovery (days 1–3) at 12-month follow-up, M (SD) | Pain at rest 5.81 (2.08) |
| Pain at movement§                            | 6.98 (1.95) |
| Pain unpleasantness§                         | 6.82 (1.99) |

*The following reported pain intensity score was significantly different from the corresponding recalled pain intensity level \( t(158) = -12.03 \).
† The following reported pain intensity score was significantly different from the corresponding recalled pain intensity level \( t(157) = -7.69 \).
‡ The following reported pain intensity score was significantly different from the corresponding recalled pain intensity level \( t(158) = -10.42 \).
§ The following reported pain intensity score was significantly different from the corresponding recalled pain intensity level \( t(106) = -11.49 \).
‖ The following reported pain intensity score was significantly different from the corresponding recalled pain intensity level \( t(108) = -5.75 \).
¶ The following reported pain intensity score was significantly different from the corresponding recalled pain intensity level \( t(107) = -9.62 \).
# The following reported pain intensity score was significantly different from the corresponding recalled pain intensity level \( t(171) = -6.99 \).
†† The following reported pain intensity score was significantly different from the corresponding recalled pain intensity level \( t(171) = -2.47 (P = 0.014) \).
### Table 3

| Psychological characteristic       | M (SD)     | N   |
|-----------------------------------|------------|-----|
| T0 baseline                       | 19.56 (12.04) | 201 |
| PCS-C*                            | 29.44 (6.75)  | 212 |
| CASI                              | 32.48 (18.51) | 211 |
| T1 in-hospital recovery            | 22.27 (12.04) | 202 |
| PCS-C                             | 30.57 (6.93)  | 201 |
| CASI                              | 46.50 (21.33) | 200 |
| T2 6-month follow-up              | 17.67 (11.39) | 194 |
| PCS-C†                            | 29.89 (6.92)  | 194 |
| CASI                              | 32.65 (18.73) | 194 |
| T3 12-month follow-up             | 17.88 (11.27) | 202 |
| PCS-C‡                            | 29.79 (6.55)  | 202 |
| CASI                              | 33.90 (19.24) | 201 |

* Pain catastrophizing score during in-hospital recovery was significantly higher than pain catastrophizing scores at other time point, \(R^2 = 3.0, P = 0.003\).
† Pain catastrophizing score during in-hospital recovery was significantly higher than pain catastrophizing scores at other time point, \(R^2 = 5.76, P < 0.001\).
‡ Pain catastrophizing score during in-hospital recovery was significantly higher than pain catastrophizing scores at other time point, \(R^2 = 5.8, P < 0.001\).

ratings, age was significantly associated with negatively-biased recall for movement-evoked pain intensity in the first days after surgery, \(r = 0.31, P < 0.01\). Therefore, age was included as a covariate in models 2, 3, and 4.

### 3.4. Baseline predictors of memory biases (model 1)

After controlling for the initial ratings of pain intensity at rest, child anxiety sensitivity at baseline and pain catastrophizing, accounted for a significant amount of variance in children’s memory for pain intensity, \(\Delta R^2 = 0.039, F(2, 143) = 3.22, P < 0.05\). Collectively, the baseline predictor model accounted for 14.1% of the variance in recalled pain levels, \(F(3, 143) = 7.81, P < 0.001\).

### 3.5. In hospital predictors of memory biases (model 2)

After controlling for initial ratings of movement-evoked pain intensity in the first 3 days after surgery and age, anxiety sensitivity, pain catastrophizing, and pain-related anxiety accounted for a significant amount of variance in children’s pain recall of pain intensity during the first day after surgery. Together, the predictors accounted for 8.4% of the variance above and beyond the initial pain ratings and age, \(F(3, 92) = 3.17, P < 0.05\). Collectively, the predictors accounted for 18.2% of the variance in recalled pain levels, \(F(5, 92) = 4.09, P < 0.05\).

### 3.5.1. Six-month follow-up predictors of memory biases (model 3)

After controlling for initial ratings of pain intensity during movement, anxiety sensitivity, pain catastrophizing, and pain anxiety accounted for a significant amount of variance in children’s recall of pain intensity, \(\Delta R^2 = 0.078, F(3, 95) = 2.76, P < 0.05\). Collectively, the predictors accounted for 10.3% of the variance in recalled pain levels, \(F(4, 95) = 2.71, P < 0.05\). However, after including age as a covariate, the set of predictors no longer accounted for a significant amount of variance. Specifically, in model 3 (6-month follow-up predictors of memory biases), the set of predictors accounted for 5.8% of variance in children’s recall of pain intensity during the first days after surgery, above and beyond initial pain ratings and age, \(\Delta R^2 = 0.058, F(3, 93) = 2.19, P > 0.05\). Collectively, the predictors accounted for 18.2% of the variance in recalled pain levels, \(F(5, 93) = 4.14, P < 0.05\).

### 3.5.2. Twelve-month follow-up predictors of memory biases (model 4)

Finally, after controlling for initial ratings of pain intensity during movement, anxiety sensitivity, pain catastrophizing, and pain anxiety did not account for a significant amount of variance in children’s recall of pain intensity, \(\Delta R^2 = 0.064, F(3, 100) = 2.33, P > 0.05\).

### Table 4

| Predictors | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|------------|---|---|---|---|---|---|---|---|---|----|----|----|
| T0 anxiety sensitivity | 0.45† | 0.56† | 0.67† | 0.37‡ | 0.48‡ | 0.58‡ | 0.62‡ | 0.36‡ | 0.48‡ | 0.22‡ | 0.30‡ |
| T0 pain catastrophizing | 0.44‡ | 0.45‡ | 0.39‡ | 0.43‡ | 0.50‡ | 0.51‡ | 0.42‡ | 0.38‡ | 0.41‡ | 0.40‡ |
| T0 pain anxiety | 0.49‡ | 0.44‡ | 0.49‡ | 0.48‡ | 0.45‡ | 0.53‡ | 0.43‡ | 0.30‡ | 0.40‡ |
| T1 anxiety sensitivity | 0.54‡ | 0.65‡ | 0.63‡ | 0.42‡ | 0.46‡ | 0.57‡ | 0.32‡ | 0.40‡ |
| T1 pain catastrophizing | 0.71‡ | 0.45‡ | 0.50‡ | 0.50‡ | 0.43‡ | 0.43‡ | 0.34‡ |
| T1 pain anxiety | 0.47‡ | 0.45‡ | 0.54‡ | 0.46‡ | 0.31‡ | 0.36‡ |
| T2 anxiety sensitivity | 0.49‡ | 0.61‡ | 0.71‡ | 0.37‡ | 0.47‡ |
| T2 pain catastrophizing | 0.81‡ | 0.51‡ | 0.64‡ | 0.57‡ |
| T2 pain anxiety | 0.60‡ | 0.56‡ | 0.61‡ |
| T3 anxiety sensitivity | 0.52‡ | 0.63‡ |
| T3 pain catastrophizing | 0.76‡ |
| T3 pain anxiety | — |

* Significant at 0.05.
† Significant at 0.01.
‡ Significant at 0.001.
The correlation coefficients between variables included in the same regression models (e.g., T0 anxiety sensitivity, T0 pain catastrophizing, and T0 anxiety sensitivity) are bolded.

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**Table 5**

Partial correlations coefficients between the psychological measures at T0-T3 and pain recall at 12 months.

| Psychological characteristic | Recall of pain at rest during day 1, r(df), P | Recall of movement-evoked pain during day 1, r(df), P | Recall of pain at rest during days 1-3, r(df), P | Recall of movement-evoked pain during days 1-3, r(df), P |
|------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| **T0 baseline**              |                                               |                                               |                                               |                                               |
| PCS-C                        | 0.17* (144), P = 0.037                        | 0.15 (143), P = 0.082                        | 0.13 (99), P = 0.205                        | 0.24* (97), P = 0.015                        |
| CASI                         | 0.19* (146), P = 0.022                        | 0.16* (145), P = 0.049                        | 0.11 (101), P = 0.281                        | 0.09 (99), P = 0.368                        |
| CPASS                        | 0.15 (146), P = 0.060                        | 0.09 (145), P = 0.297                        | 0.11 (101), P = 0.274                        | 0.13 (99), P = 0.185                        |
| **T1 in-hospital recovery**  |                                               |                                               |                                               |                                               |
| PCS-C                        | 0.12 (141), P = 0.123                        | 0.13 (140), P = 0.138                        | 0.08 (99), P = 0.441                        | 0.30* (97), P = 0.002                        |
| CASI                         | 0.13 (141), P = 0.124                        | 0.16 (140), P = 0.051                        | 0.08 (99), P = 0.419                        | 0.22* (97), P = 0.029                        |
| CPASS                        | 0.14 (141), P = 0.094                        | 0.14 (140), P = 0.101                        | 0.21* (99), P = 0.035                        | 0.26* (97), P = 0.010                        |
| **T2 6-month follow-up**     |                                               |                                               |                                               |                                               |
| PCS-C                        | 0.07 (138), P = 0.426                        | 0.17 (137), P = 0.052                        | 0.04 (99), P = 0.687                        | 0.27* (97), P = 0.008                        |
| CASI                         | 0.09 (138), P = 0.278                        | 0.11 (137), P = 0.183                        | 0.17 (99), P = 0.088                        | 0.21* (97), P = 0.042                        |
| CPASS                        | 0.01 (138), P = 0.927                        | 0.10 (137), P = 0.236                        | 0.05 (99), P = 0.658                        | 0.20* (97), P = 0.047                        |
| **T3 12-month follow-up**    |                                               |                                               |                                               |                                               |
| PCS-C                        | 0.05 (155), P = 0.544                        | 0.12 (154), P = 0.135                        | 0.05 (105), P = 0.584                        | 0.21* (104), P = 0.032                        |
| CASI                         | 0.02 (156), P = 0.809                        | 0.14 (155), P = 0.091                        | 0.03 (106), P = 0.749                        | 0.20* (104), P = 0.044                        |
| CPASS                        | 0.03 (154), P = 0.687                        | 0.14 (153), P = 0.080                        | 0.09 (104), P = 0.346                        | 0.23* (102), P = 0.017                        |

The correlations are controlled for the corresponding initial pain ratings.

* Significant at 0.05.
† Significant at 0.01.
‡ Significant at 0.001.

PCS-C, Pain Catastrophizing Scale—Children; CASI, Childhood Anxiety Sensitivity Index; CPASS, Child Pain Anxiety Symptoms Scale.

$P > 0.05$. Collectively, the predictors accounted for 8.6% of the variance in recalled pain levels, $F(4, 100) = 2.34, P > 0.05$. However, after including age as a covariate, the set of predictors no longer accounted for a significant amount of variance. Specifically, in model 4 (12-month follow-up predictors of memory biases), the set of predictors accounted for 4.4% of variance in children’s recall of pain intensity during the first days after surgery, above and beyond initial pain ratings and age, $\Delta R^2 = 0.044, F(3, 96) = 1.66, P > 0.05$. The overall model accounted for 15.9% of the variance in recalled pain levels, $F(5, 96) = 3.62, P < 0.05$.

### 3.6. Dominance analyses for models 1 and 2

To examine distinct contributions of individual predictors (anxiety sensitivity, pain catastrophizing, and pain anxiety) to biases in children’s recall of pain, we conducted dominance analyses.\(^5\)

**Table 6**

Regression analyses explaining children’s recall of pain.

| Criterion variable | Step | Predictor | Beta | $\Delta R^2$ | Cumulative $R^2$ |
|--------------------|------|-----------|------|--------------|-----------------|
| **T0 baseline predictors** | 1 | Day 1 pain ratings | 0.319 | 0.102* | 0.102* |
|                     | 2 | T0 anxiety sensitivity | 0.126 0.104 | 0.039† | 0.133† |
|                     | 2 | T0 pain catastrophizing | - | - | - |
| **T1 in-hospital recovery predictors** | 1 | Days 1-3 pain ratings | 0.127 | 0.097† | 0.097† |
|                     | 2 | T1 anxiety sensitivity | 0.032 | 0.084† | 0.182‡ |
|                     | 2 | T1 pain catastrophizing | 0.291 | 0.141‡ | 0.141‡ |
|                     | 2 | T1 pain anxiety | -0.020 | -0.020 | -0.020 |
| **T2 6-month follow-up predictors** | 1 | Days 1-3 pain ratings | 0.135 | 0.124‡ | 0.124‡ |
|                     | 2 | T2 anxiety sensitivity | 0.111 | 0.058 | 0.058 |
|                     | 2 | T2 pain catastrophizing | 0.335 | 0.182‡ | 0.182‡ |
|                     | 2 | T2 pain anxiety | -0.217 | -0.217 | -0.217 |
| **T3 12-month follow-up predictors** | 1 | Days 1-3 pain ratings | 0.134 | 0.115‡ | 0.115‡ |
|                     | 2 | T3 anxiety sensitivity | 0.059 | 0.044 | 0.044 |
|                     | 2 | T3 pain catastrophizing | 0.162 | 0.159‡ | 0.159‡ |
|                     | 2 | T3 pain anxiety | 0.026 | 0.026 | 0.026 |

Regression analyses reported here only include variables that showed a significant univariate effect in correlational analyses.

* Significant at 0.001.
† Significant at 0.05.
‡ Significant at 0.01.
3.6.1. Baseline predictors of memory biases (model 1)
In total, anxiety sensitivity and pain catastrophizing accounted for 3.9% of variance in children’s memory for pain intensity, above and beyond initial pain ratings, \(F(2, 143) = 3.22, P < 0.05\). Of the 3.9%, anxiety sensitivity accounted for 55.7% (2.2% of total variance) and pain catastrophizing accounted for 44.3% (1.7% of total variance).

3.6.2. In hospital predictors of memory biases (model 2)
In total, anxiety sensitivity, pain catastrophizing, and pain anxiety accounted for 8.5% in children’s recall of pain intensity during the first days after surgery, above and beyond initial pain ratings and age, \(F(3, 92) = 3.17, P < 0.05\). Of the 8.5%, pain catastrophizing accounted for 70.1% (5.9% of total variance), pain anxiety accounted for 16.1% (1.4% of total variance), and anxiety sensitivity accounted for 13.9% (1.2% of total variance).

3.7. Association of memories for pain with CPSP
A series of bivariate partial correlations revealed significant associations between greater negatively-biased recall of pain and postsurgical pain at 6 and 12 months. Specifically, at the 6-month follow-up, youth who at the 12-month follow-up were to report greater negatively-biased recall of in-hospital movement-evoked pain had higher levels of pain at rest at the surgical site over the past week (\(r = 0.27, P = 0.008\)). At 12 months after surgery, adolescents’ report of higher pain levels at the surgical site over the past week were significantly related to greater negatively-biased recall of first day in-hospital movement-evoked pain and pain at-rest (\(r = 0.17, P = 0.032, r = 0.19, P = 0.020\), respectively).

4. Discussion
This study was the first to examine the relationship between anxiety-related risk factors for children’s pain memory development 1 year after major surgery. It also examined anxiety-related risk factors for long-term pain memory biases at multiple time points before and after the inciting painful event. Findings revealed that baseline anxiety sensitivity, pain anxiety, and pain catastrophizing predicted negative biases in children’s recall of pain intensity at rest. Moreover, these anxiety constructs assessed in-hospital at 48 to 72 hours after surgery significantly predicted biases in recall for movement-evoked pain 1 year later. Dominance analyses to determine the relative strength/superiority of predictors revealed that at baseline, anxiety sensitivity and pain catastrophizing were equally predictive of children’s recall. However, at 48 to 72 hours after surgery, pain catastrophizing was the strongest predictor of pain memory biases. Children who developed greater negatively-biased recall of pain reported higher pain scores at 6 and 12 months post-surgery. Thus, the results of this study also show that postsurgical pain intensity at 6 months is a risk factor for later pain memory distortion.

This study provides empirical support for the model of acute pain memory development that posits general (anxiety sensitivity) and pain-specific (pain catastrophizing and pain anxiety) anxiety are linked to greater exaggerations in recall of pain. Previous research on postsurgical pain memories has exclusively focused on baseline predictors of memory biases 2 to 4 months later.28 Contrary to this past research, pain catastrophizing (in addition to pain anxiety and anxiety sensitivity) was predictive of children’s recall of the sensory but not the affective dimension of pain. To date, research on children’s memories for pain in the context of surgery has not differentiated between movement-evoked pain and pain at rest nor assessed recall at 1 year. These findings support differentiated assessment of experienced and recalled pain at rest vs at movement, particularly in the acute recovery phase. Moreover, different relationships have been found between anxiety-related factors and memory for the sensory vs affective aspects of pain.30 This further supports the importance of assessing memory for pain in a comprehensive way as initially argued Ornstein et al.30 Moreover, it was catastrophic thinking about pain that occurred while in the first 48 to 72 hours after surgery that was the most powerful predictor of negative biases in children’s memory, and specifically their recall of movement-evoked pain. It has been argued that a new baseline for pain intensity may develop in the first few days after the surgery due to a new experience of intense pain sensation (ie, postsurgical pain).16

Catastrophic thinking about pain before surgery may not adequately reflect catastrophic cognitions that youth develop after surgery.16 Memory in this study was assessed at 1 year after surgery, which is much later than previous research that used time frames of 2 to 4 months after surgery.27,28 It could be that catastrophic thinking immediately after (vs before) surgery has a particularly lasting impact on memory for pain because the new pain catastrophizing baseline represents a salient negative cognitive and emotional experience that contributes to memory distortion and bias. Indeed, pain catastrophizing assessed within 48 to 72 hours after surgery was significantly higher than pain catastrophizing at any other time point. Moreover, the pain catastrophizing scale does not specify a pain incident to focus on, and the surgery type was novel for the vast majority of children. Thus, it is likely that assessment of pain catastrophizing that occurred immediately after (vs before) surgery reflected children’s catastrophic thoughts specifically about this surgery, just as the memory questions tapped pain associated with surgery, which could explain this finding.

Past research probed memories for postsurgical pain experienced in the first several weeks after surgery (after hospital discharge29), whereas the present study probed memory for pain experienced both at rest and during movement in the first few days while in hospital (ie, when pain is arguably most severe, particularly when moving). Indeed, peak effects have been shown to create biases in recalled pain.39 The pain memories assessed, while both specific to the postsurgical pain experience, are likely capturing different aspects of the broader postsurgical pain experience, thus explaining differences in their relationship to individual risk factors.

At baseline, anxiety sensitivity and pain catastrophizing were equally predictive of children’s recall of pain intensity at 1-year follow-up. Anxiety sensitivity is a transdiagnostic risk factor that reflects the tendency to fear the symptoms of anxiety because of beliefs they have harmful cognitive, social, and physical consequences.44 Although the construct does not pertain specifically to the experience of pain itself, it is believed to be intrinsically tied to the pain experience29 and the development and maintenance of pain problems in children1 and adults.3 As a shared vulnerability risk factor for both anxiety disorders and pain problems, anxiety sensitivity is posited to heighten internal awareness to physical sensations to both threat and pain, which can fuel catastrophic thinking, attentional biases favouring threat, and avoidance.2 In youth with chronic headaches, higher anxiety sensitivity is linked to greater somatization and fear of pain, which drives avoidance.6 The cognitive interruption caused by the
experience of pain and being highly anxiety sensitive may impede memory encoding, storage, and retrieval. Because of an excessive attentional focus on bodily sensations, anxiety sensitivity may lead to more postevent cognitive processing and rumination that may interfere with memory consolidation and introduce biases in recall. Only one study revealed that higher anxiety sensitivity led to children developing greater negatively-biased recall of pain 2 weeks after exposure to an experimental pain task. Core differences in experimental and clinical pain contexts (eg, uncontrollability and unpredictability) require extension of this work to clinical samples, which this study achieved. This study adopted an intrapersonal focus on the influence of child anxiety-related factors on the development of biased pain memories. Recent research with younger children undergoing tonsillectomies revealed that it was parents’ and not children’s baseline anxiety that predicted biases in children’s recall of pain-related fear 1 month after surgery. Differences across these studies could be due to several factors. First, this study examined older children and adolescents undergoing major, invasive surgeries, whereas the other study examined young (5- to 7-year-old) children undergoing tonsillectomies. These age and developmental differences are important given that children’s pain memory development is under the influence of different cognitive and social influences across child and adolescent development. Specifically, the developmental model of children’s pain memory development specifically isolates the period of early childhood as being a time when parental influences are greatest on children’s pain memory development. This may account for the primary influence of parental (vs child) anxiety on young (5- to 7-year-old) children’s pain memory development in the context of tonsillectomies. When shifting to the later developmental period of adolescence, parental influences become less predictive of longer term pain outcomes (beyond the acute recovery phase). Beyond developmental stage and age, we also note that there are important differences in pain trajectories between these 2 surgical contexts. Tonsillectomy is a surgery that involves acute pain in the first week after surgery that almost always resolves by the second week. This is not the case for more major surgeries such as spinal fusion, pectus repair, and a variety of orthopedic surgeries that are characterized by high levels of moderate-to-severe pain that often last for months and unfortunately, for approximately 22% of youth, leads to the development of persistent pain. Puberty is also a time when rates of pediatric chronic pain peak, therefore, examining these types of surgeries in adolescence is an important context to understand the development of pain problems. These problems are not observed among young children undergoing tonsillectomies. Pain is a key predictor of memory for pain, therefore, these differences in pain trajectories are important for understanding different findings across pain and developmental contexts.

There were limitations to this study. Pain memories were assessed at a single time point 1 year after surgery. Thus, it is unknown whether memories for pain became more or less biased for some children and how memories at 1 year compared with memories assessed at 2 to 4 months as has been performed in previous research. Moreover, consistent with previous research, this study assessed memories using single-item pain scales. Future research should expand memory assessment to include free recall (eg, open-ended questions that pull for a spontaneous account of the past) and probed recall (single-item pain items) to provide a richer account of children’s memories. Furthermore, important anxiety-related constructs, such as fear of pain, that are closely associated with anxiety sensitivity and the pain experience were not assessed in the present study. Finally, it could be argued that the negatively-biased recall of pain observed in the present study is not really a bias at all and instead is an accurate representation of the initial, in-hospital pain experience. It is well-established that postsurgical pain intensity fluctuates within and across days. Since pain was assessed only once per day, it is possible that the participants’ recalled pain was significantly higher than the specific measure of pain assessed, not because of a bias but because participants were accurately recalling the pain intensity from a different time of day. This is a difficult argument to refute empirically without a continuous record of in-hospital pain, which clearly is not possible to obtain. To address this argument, pain recall was compared with a variety of pain scores for each pain measure (intensity, movement-evoked, and unpleasantness), including pain on day 1 as well as average and peak pain scores across the first 3 days in-hospital. Recalled pain was significantly higher than all in-hospital pain scores obtained, including peak pain, arguing in favour of the interpretation that pain recall scores reflect a memory bias and not an accurate representation of the initial pain experience.

This study exclusively focused on anxiety-related constructs based on conceptual models of acute pain memory development, however, there are other factors that were not assessed in the study that likely play an influential role. Indeed, postevent processing (ie, language-based interactions about the past pain painful event after the fact) have been shown to be critically important in shaping children’s memories of needle pain and should be examined in future research in the surgical context. In addition, we were unable to obtain in-hospital pain ratings from youth who were admitted to the ICU because of hospital and REB protocols. There could be key differences in the experiences of youth who were vs who were not admitted to the ICU, which could influence children’s pain memory development. One key factor could be medical trauma, experienced by both parents and youth (which could affect memory encoding and retrieval), as well as consciousness of youth (which could affect memory encoding). This is an interesting area for future research. In addition, there was considerable heterogeneity in the sample in terms of the types of surgeries performed, and this could be conceived of as a limitation. On the other hand, based on the past several decades of research on memory for pain (see reviews in Refs. 23, 26, 30, 45) as well as empirical research with pediatric and adult samples, the relationship between negative affect/anxiety and biased recall of pain is robust and found across ages, healthy and illness populations, and clinical and experimental pain contexts. Past research linking catastrophic thinking about pain to biased recall included different types of surgery (eg, pectus repair and spinal fusion). Thus, extending these findings to a much larger, heterogeneous sample of youth undergoing a variety of surgeries is important as it speaks to the robustness of this relationship. Finally, in-hospital pain ratings were collected between 48 and 72 hours after surgery. This time frame could be considered a limitation.

Memories for pain are by their nature, susceptible to distortion, and highly malleable. Previous trials of brief memory reframing interventions to provide children with postevent information (eg, emphasizing positive details, correcting negative exaggerations, and promoting self-efficacy) following needle procedures were found to lead to more accurate/positive pain memories. Modification of risk factors for distortions in pain memories is another avenue for intervention. The present findings suggest that interventions that reduce levels of anxiety, and particularly anxiety sensitivity and pain catastrophizing at baseline and pain catastrophizing during the in-hospital acute recovery phase, may buffer children against the development of negatively-biased pain memories 1 year later. From a treatment perspective, the general approach of reducing anxiety sensitivity, pain anxiety, and
catastrophic thinking about pain could involve a similar cognitive-behavioral approach. Interventions to reduce anxiety sensitivity and anxiety related to pain sensations have been developed, albeit for use with adults, and involve cognitive behavioral therapy, psychoeducation, cognitive restructuring, and interoceptive exposure. Adaptations in these brief interventions could be a fruitful area for preoperative and postoperative interventions for youth. Similar cognitive-behavioral interventions aimed reducing catastrophic thinking about pain in the immediate acute recovery phase while in hospital could also be protective. With accumulating evidence for the maladaptive effects of anxiety on postsurgical pain trajectories and pain memories, this line of research could inform how to prevent chronic postsurgical pain.

In summary, this prospective study examined the role of anxiety-related factors, assessed at multiple time points over the course of a year, in children’s memories of postsurgical pain 1 year after surgery. Findings revealed that children who had higher levels of anxiety at baseline and 48 to 72 hours after surgery developed greater negatively-biased recall of pain intensity 12 months after surgery. Specifically, higher anxiety sensitivity at baseline and greater tendencies to catastrophize about pain at baseline and in the immediate acute recovery phase in hospital were most strongly linked to greater negatively-biased recall of pain. Greater negatively-biased recall of pain was related to higher pain at 6 and 12 months after surgery. These findings provide empirical support for conceptual models of anxiety and pain memory biases and can inform intervention efforts to reduce anxiety in the pre- and post-op periods to foster more accurate and positive pain memories. Given the robust role of pain memories in subsequent pain experiences and the development of chronic pain, this could inform how to foster more optimal pain trajectories in childhood and beyond.

Conflict of interest statement
The authors have no conflict of interest to declare.

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