2019-01

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

Noel, Melanie; Rosenbloom, Brittany N.; Pavlova, Maria; Campbell, Fiona; Isaac, Lisa A.; Pagé, M. Gabrielle; Stinson, Jennifer N.; Katz, Joel D.

International Association for the Study of Pain

Noel, M., Rosenbloom, B. N., Pavlova, M., Campbell, F., Isaac, L. A., Pagé, M. G., Stinson, J. N., & Katz, J. D. (2019). Remembering the pain of surgery 1 year later: a longitudinal examination of anxiety in children's pain memory development. "Pain". 2019. pp. 1-43.
http://dx.doi.org/10.1097/j.pain.0000000000001582

http://hdl.handle.net/1880/112073

journal article

PAIN Publish Ahead of Print
DOI: 10.1097/j.pain.0000000000001582

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

Melanie Noel, PhD, RPsych

Department of Psychology, University of Calgary and Alberta Children's Hospital Research Institute

Brittany Rosenbloom, MA

Department of Psychology, York University

Maria Pavlova, MSc

Department of Psychology, University of Calgary

Fiona Campbell, MD, FRCA

Department of Anesthesia, University of Toronto and The Hospital for Sick Children

Lisa Isaac, MD, FRCPC

Department of Anesthesia, University of Toronto and The Hospital for Sick Children

M. Gabrielle Pagé, PhD

Centre de recherche du Centre hospitalier de l'Université de Montréal (CRCHUM) and Department of anesthesiology and pain medicine, Faculty of Medicine, Université de Montréal

Jennifer Stinson, PhD, RN-EC, CPNP

Department of Anesthesia and Pain Medicine, Hospital for Sick Children, Toronto and Lawrence S Bloomberg Faculty of Nursing, University of Toronto

Joel Katz, PhD, CPsych

Department of Psychology, York University

Department of Psychology, Hospital for Sick Children

Corresponding author: Melanie Noel, PhD, RPsych, Department of Psychology, The University of Calgary and Alberta Children's Hospital Research Institute; 2500 University Dr. N.W. Calgary, AB, T2N 1N4, Canada; Telephone: 403-477-1162; Email: melanie.noel@ucalgary.ca

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 post-surgical pain memories after one 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, 48-72 hours post-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 one-year post surgery. Findings revealed that children who had higher levels of anxiety at baseline and 48-72 hours post-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

Introduction

Chronic pain in adolescence has been coined a "modern public health disaster" [9] 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 [21,26]. 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 [34] and higher pain and distress at subsequent pain experiences [8,21]. Pain memories have been implicated in the development of chronic pain [12]. A recent study of adolescents undergoing spinal fusion/pectus repair revealed that more negatively-biased memories of pain 2-4 months after surgery predicted higher reports of pain 2 months later, precisely when pain is at risk of becoming chronic [27]. Given the rising prevalence and debilitating impact of pediatric chronic pain [17], 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 [21,27]. Pain-specific (pain anxiety, pain catastrophizing) and general anxiety factors (anxiety sensitivity) have been posited as risk factors for pain memory biases. Theoretical models [3,23] 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 8-12 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 [22]. Similarly, higher levels of pain catastrophizing among adolescents prior to major surgery were linked to greater negatively-biased recall of pain 2-4 months later [28]. Nevertheless, the roles of other general and pain-specific anxiety factors on children's longer-term recall of post-surgical 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.

The present study aimed to fill these gaps. Youth undergoing major general and orthopaedic surgeries known to lead to a 15-20% one-year incidence of chronic pain [33,36,37,40] were prospectively followed for 1 year. Anxiety risk factors were assessed at multiple time points over the follow-up period and their relationship to pain memories was examined 1 year after surgery. We hypothesized that youth with higher levels of pain-related anxiety constructs (catastrophizing, pain anxiety, anxiety sensitivity) would develop greater negatively-biased recall of post-surgical 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 (i.e., sensory versus affective, pain at rest versus 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.

Method

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

Participants

Patients aged 8-17 years undergoing either orthopedic surgery (i.e., osteotomy, plate insertion tibial/femur, surgery for scoliosis) or general surgery (i.e., 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.

Measures

The Numerical Rating Scale (NRS). The NRS is an 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 7-17 years [46].

Childhood Anxiety Sensitivity Index (CASI). The CASI [41] is an 18-item scale that measures the extent to which the symptoms of anxiety (e.g., increased heart rate, shortness of breath, racing thoughts) are feared due to 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 (α = 0.87), satisfactory test-retest reliability (r = 0.76) and adequate construct validity [41]. Internal consistency for the present study was very good T0 (α = 0.864), T1 (α = 0.872), T2 (α = 0.850), and T3 (α = 0.856).

Pain Catastrophizing Scale-Children (PCS-C). The 13-item PCS-C [10] is a child version of the PCS [42] 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) [43]. 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 three subscale scores assessing 1.) rumination, 2.) magnification, and 3.) helplessness. The PCS-C has excellent internal consistency (α = 0.90) and strongly correlates with pain intensity (*r*=0.49) and disability (*r*=0.50) [10]. Internal consistency for the present study was excellent at T0 (α = 0.935), T1 (α = 0.942), T2 (α = 0.926), and T3 (α = 0.932).

Child Pain Anxiety Symptoms Scale (CPASS). The CPASS [32] 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-20 [20] and can be administered to children as young as eight years old [20]. 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 (α = 0.89 to 0.903) and strong construct validity [13,31,32]. Internal consistency for the present study was excellent at T0 (α = 0.920), T1 (α = 0.941), T2 (α = 0.925), and T3 (α = 0.932).

Pain Memory Interview. Similar to previous research with adolescents undergoing spinal fusion and pectus repair [27,28], youth completed a memory interview that probed their recall of the post-surgical pain experience while in hospital. First, youth were asked to think back to their in-hospital experience (i.e., 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*).

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 pre-operative assessment clinic or by telephone if they did not attend the pre-operative clinic. Parents provided consent to participate and children provided assent for their participation. This prospective study involved four assessment time points over the course of a year: pre-operative (T0), in-hospital recovery (T1), and 6 (T2) and 12 (T3) months after surgery.

Pre-operative 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 pre-operative medication use (analgesics and others) was obtained from the parents and confirmed by the patient's hospital medical record.

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, systemic opioids (i.e., opioids given for the surgical procedure).

In-hospital Post-operative Assessment. Pain intensity scores (NRS-I), movement-evoke pain scores (NRS-M), and pain unpleasantness scores (NRS-U) were obtained daily by a research assistant. Daily NRS scores from the first three 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, 48-72 hours after surgery children completed the CPASS, PCS-C, and CASI.

Six and 12 Month Post-operative 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, NRS-M) and anxiety (CPASS, PCS-C, 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 pre-operatively when participants either took them home to complete and return on the day of surgery or in the pre-anaesthesia 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 (e.g., 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.

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 (i.e., 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 (e.g., questionnaires, 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.

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 two-tailed hypothesis testing.

Differences between key variables were examined using t-tests, chi-squared tests, and repeated measures ANOVAs. 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, unpleasantness) also were compared to their respective peak pain scores across the first 3 days after surgery. In line with previous research [21,28], biases in pain recall were assessed using partial correlations and hierarchical regressions. Specifically, the correlations between criteria (i.e., 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 48-72 hours post-surgery was controlled/used as a covariate. Peak pain scores were defined for each measure (rest, movement, 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. [28], 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 (e.g., memory for pain intensity at rest on the first day post-surgery controlled for initial pain intensity at rest rating obtained on the first day post-surgery). Hierarchical linear regression models were used to test the relationships between the various anxiety factors and children's memories for pain one 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 if age should be included as a covariate in the hierarchical regression models. To examine distinct contributions of individual predictors (anxiety sensitivity, pain catastrophizing, pain anxiety) to biases in children's recall of post-surgical pain, we conducted dominance analyses [5]. 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 (i.e., recall that was greater than the initial pain ratings) and chronic post-surgical 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.

Results

Recruitment

There were no significant differences on any of the measures at baseline between participants who completed the study at 12 months compared to those who did not. For the purposes of this paper, 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 48-72

hours post-surgical pain. Patients who were transferred to ICU had significantly longer surgical times ($p < .001$) and hospital stays ($p = .001$).

Descriptive Statistics

The final sample consisted of 237 children [M_{age} = 14.11 years (*SD* = 2.47), *Range* 8-18 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 prior to their current surgery. No patients were using gabapentinoids at any point during the study. The majority of 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, two (0.8%) had a thoracotomy, and fourteen (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 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 48-72 hours post-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.)

Further, 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 $p > .05$).

Associations between anxiety-related factors and memories for pain

All correlation analyses controlled for the initial pain rating that corresponded to each memory question (i.e., 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; when examining memory for pain during the hospital stay, an average of NRS-R or NRS-M on the first three 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, four 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 if 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, $r = -.001$, $p > .05$. Therefore, age was not included as a covariate in Model 1. After controlling for initial pain ratings, age was significantly associated with negatively biased recall for movement-evoked pain intensity in the first days after surgery, $r = .31$, $p < .01$. Therefore, age was included as a covariate in Models 2, 3, and 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, $\Delta R^2 = .039$, $F(2, 143) = 3.22$, $p < .05$. Collectively, the baseline predictor model accounted for 14.1% of the variance in recalled pain levels, $F(3, 143) = 7.81$, $p < .001$.

In Hospital Predictors of Memory Biases (Model 2)

After controlling for initial ratings of movement-evoked pain intensity in the first three days after surgery and age, anxiety sensitivity, pain catastrophizing, and pain-related anxiety accounted 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, $F(3, 92) = 3.17$, $p < .05$. Collectively, the predictors accounted for 18.2% of the variance in recalled pain levels, $F(5, 92) = 4.09$, $p < .05$.

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, $\Delta R^2 = .078$, $F(3, 95) = 2.76$, $p < .05$. Collectively, the predictors accounted for 10.3% of the variance in recalled pain levels, $F(4, 95) = 2.71$, $p < .05$. However, after including age as a covariate, the set of predictors no longer accounted for a significant amount of variance. Specifically, in Model 3 (Six-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, $\Delta R^2 = .058$, $F(3, 93) = 2.19$, $p > .05$. Collectively, the predictors accounted for 18.2% of the variance in recalled pain levels, $F(5, 93) = 4.14$, $p < .05$.

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, $\Delta R^2 = .064$, $F(3, 100) = 2.33$, $p > .05$. Collectively, the predictors accounted for 8.6% of the variance in recalled pain levels, $F(4, 100) = 2.34$, $p > .05$. However, after including age as a covariate, the set of predictors no longer accounted for a significant amount of variance. Specifically, in Model 4 (Twelve-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, $\Delta R^2 = .044$, $F(3, 96) = 1.66$, $p > .05$. The overall model accounted for 15.9% of the variance in recalled pain levels, $F(5, 96) = 3.62$, $p < .05$.

Dominance analyses for Models 1 and 2.

To examine distinct contributions of individual predictors (anxiety sensitivity, pain catastrophizing, pain anxiety) to biases in children's recall of pain, we conducted dominance analyses [5].

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,

$F(2, 143) = 3.22$, $p < .05$. 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).

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, $F(3, 92) = 3.17$, $p < .05$. 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).

Association of memories for pain with CPSP

A series of bivariate partial correlations revealed significant associations between greater negatively biased recall of pain and post-surgical 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 ($r = .27$, $p = .008$). 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 ($r = .17$, $p = .032$, $r = .19$, $p = .020$, respectively).

Discussion

This study was the first to examine the relationship between anxiety-related risk factors for children's pain memory development one 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 48-72 hours post-surgery significantly predicted biases in recall for movement-evoked pain one 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 48-72 hours post-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 the present 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, pain anxiety) anxiety are linked to greater exaggerations in recall of pain. Previous research on post-surgical pain memories has exclusively focused on baseline predictors of memory biases 2-4 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 versus at movement, particularly in the acute recovery phase. Moreover, different relationships have been found between anxiety-related factors and memory for the sensory versus affective aspects of pain [26]. This further supports the importance of assessing memory for pain in a comprehensive way as initially argued Ornstein and colleagues [30]. Moreover, it was catastrophic thinking about pain that occurred while in the first 48-72 hours following 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 (i.e., post-surgical pain) [16].

Catastrophic thinking about pain before surgery may not adequately reflect catastrophic cognitions that youth develop *after* surgery [16]. Memory in the present study was assessed at one-year post-surgery, which is much later than previous research that used time frames of 2-4 months post-surgery [27,28]. It could be that catastrophic thinking immediately after (versus 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 48-72 hours post-surgery was significantly higher than pain catastrophizing at any other timepoint. 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 (versus 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 post-surgical pain experienced in the first several weeks after surgery (following hospital discharge [28]) whereas the present study probed memory for pain experienced both at rest and during movement in the first few days while in hospital (i.e., 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 post-surgical pain experience, are likely capturing different aspects of the broader post-surgical 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 thought to be intricately tied to the pain experience [29] and the development and maintenance of pain problems in children [1] and adults [2]. 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 [23]. Due to an excessive attentional focus on bodily sensations, anxiety sensitivity may lead to more post-event 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 two weeks after exposure to an experimental pain task[22]. Core differences in experimental and clinical pain contexts (e.g., uncontrollability, unpredictability) require extension of this work to clinical samples [19], 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 following surgery [11]. Differences across these studies could be due to several factors. First, the present study examined older children and adolescents undergoing major, invasive surgeries whereas the other study examined young (5-7-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 [25]. This may account for the primary influence of parental (versus child) anxiety on young (5-7-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) [27]. Beyond developmental stage and age, we also note that there are important differences in pain trajectories between these two surgical contexts. Tonsillectomy is a surgery that involves acute pain in the first week post-surgery that almost always resolves by the second week. This is not the case for more major surgeries like spinal fusion, pectus repair, and a variety of orthopedic surgeries which 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 [33]. Puberty is also a time when rates of pediatric chronic pain peak [17]; 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 [15,21,27,28]; therefore, these differences in pain trajectories are important for understanding different findings across pain and developmental contexts.

There were limitations to the present 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 to memories assessed at 2-4 months as has been done in previous research. Moreover, consistent with previous research [21,27,28], the present study assessed memories using single item pain scales. Future research should expand memory assessment to include free recall (e.g., 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 [25]. Furthermore, important anxiety-related constructs, such as fear of pain, that are closely associated with anxiety sensitivity and the pain experience [6] 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 [23]; however, there are other factors that were not assessed in the study that likely play an influential role. Indeed, post-event processing (i.e., 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 [24], and should be examined in future research in the surgical context. Additionally, we were unable to obtain in hospital pain ratings from youth who were admitted to the ICU due to hospital and REB protocols. There could be key differences in the experiences of youth who were versus 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. Additionally, 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 [23,26,30,45]) as well as empirical research with pediatric [18,23,38] and adult samples [14], 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 (e.g., pectus repair, spinal fusion) [28]. 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 48-72 hours post-surgery. This time frame could be considered a limitation.

Memories for pain are by their nature, susceptible to distortion and highly malleable [26]. Previous trials of brief memory reframing interventions to provide children with post-event information (e.g., emphasizing positive details, correcting negative exaggerations, promoting self-efficacy) following needle procedures were found

to lead to more accurate/positive pain memories [4,7,35]. 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, psycho-education, cognitive restructuring, and interoceptive exposure [47]. Adaptations in these brief interventions could be a fruitful area for pre- and post-operative 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 post-surgical pain trajectories [36] and pain memories [28], this line of research could inform how to prevent chronic post-surgical 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 post-surgical pain one year following surgery. Findings revealed that children who had higher levels of anxiety at baseline and 48-72 hours post-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 post-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 [26] and the development of chronic pain [12], this could inform how to foster more optimal pain trajectories in childhood and beyond.

Acknowledgements

The authors thank Shima Razavi, Kerime Arisan, Arly Sutton, Kelly Chin, and Meghan Rossi for their assistance with this study. Melanie Noel is supported by the Vi Riddell Pain Research Initiative and the Alberta Children's Hospital Research Institute. Joel Katz is supported by a Canadian Institutes of Health Research (CIHR) Canada Research Chair in Health Psychology at York University. Maria Pavlova is supported by an Alberta Strategy for Patient Oriented Research Graduate Studentship. Brittany Rosenbloom is supported by a CIHR CGS Doctoral Award in Honor of Nelson Mandala. Gabrielle Pagé was supported by a CIHR Frederick Banting and Charles Best CGS Doctoral Award. The research reported herein was supported by operating grant FRN-102700 from the CIHR Institute of Neurosciences, Mental Health and Addiction. The authors have no conflicts of interest.

References

[1] Asmundson GJ, Noel M, Petter M, Parkerson HA. Pediatric fear-avoidance model of chronic pain: foundation, application and future directions. Pain Res Manag 2012;17(6):397-405.

[2] Asmundson GJ, Norton PJ, Vlaeyen JW. Fear-avoidance models of chronic pain: An overview. In: GJ Asmundson, JW Vlaeyen, G Crombez, editors. Understanding and treating fear of pain. New York: Oxford University Press, 2004. pp. 3-24.

[3] Beck AT, Clark DA. An information processing model of anxiety: automatic and strategic processes. Behav Res Ther 1997;35(1):49-58.

[4] Bruck M, Ceci SJ, Francoeur E, Barr R. "I hardly cried when I got my shot!" Influencing children's reports about a visit to their pediatrician. Child Dev 1995;66(1):193-208.

[5] Budescu DV. Dominance analysis: A new approach to the problem of relative importance of predictors in multiple regression. Psychological bulletin 1993;114(3):542-551.

[6] Cappucci S, Simons LE. Anxiety sensitivity and fear of pain in paediatric headache patients. Eur J Pain 2015;19(2):246-252.

[7] Chen E, Zeltzer LK, Craske MG, Katz ER. Alteration of memory in the reduction of children's distress during repeated aversive medical procedures. J Consult Clin Psychol 1999;67(4):481-490.

[8] Chen E, Zeltzer LK, Craske MG, Katz ER. Children's memories for painful cancer treatment procedures: implications for distress. Child Dev 2000;71(4):933-947.

[9] Clinch J, Eccleston C. Chronic musculoskeletal pain in children: assessment and management. Rheumatology (Oxford) 2009;48(5):466-474.

[10] Crombez G, Bijttebier P, Eccleston C, Mascagni T, Mertens G, Goubert L, Verstraeten K. The child version of the pain catastrophizing scale (PCS-C): a preliminary validation. Pain 2003;104(3):639-646.

[11] Fischer S, Vinall J, Pavlova M, Graham S, Jordan A, Chorney J, Rasic N, Brookes JT, Hoy M, Yunker WK. The role of anxiety in young children's pain memory development following surgery. Pain 2018;In Press.

[12] Flor H. New developments in the understanding and management of persistent pain. Curr Opin Psychiatry 2012;25(2):109-113.

[13] Fuss S, Page G, Katz J. Persistent pain in a community-based sample of children and adolescents. Pain Res Manag 2011;16(5):303-309.

[14] Gedney JJ, Logan H. Memory for stress-associated acute pain. J Pain 2004;5(2):83-91.

[15] Gedney JJ, Logan H. Pain related recall predicts future pain report. Pain 2006;121(1-2):69-76.

[16] Katz J. Establishment of a new pain catastrophizing baseline after pediatric major surgery? The journal of pain : official journal of the American Pain Society 2015;16(4):388.

[17] King S, Chambers CT, Huguet A, MacNevin RC, McGrath PJ, Parker L, MacDonald AJ. The epidemiology of chronic pain in children and adolescents revisited: a systematic review. Pain 2011;152(12):2729-2738.

[18] Lander J, Hodgins M, Fowler-Kerry S. Children's pain predictions and memories. Behav Res Ther 1992;30(2):117-124.

[19] Liossi C, Fitzgerald M. Remember, remember.... a child's pain experience. Pain 2012;153(8):1543-1544.

[20] McCracken LM, Dhingra L. A short version of the Pain Anxiety Symptoms Scale (PASS-20): Preliminary development and validity. Pain Research and Management 2002;7(1):45-50.

[21] Noel M, Chambers CT, McGrath PJ, Klein RM, Stewart SH. The influence of children's pain memories on subsequent pain experience. Pain 2012;153(8):1563-1572.

[22] Noel M, Chambers CT, McGrath PJ, Klein RM, Stewart SH. The role of state anxiety in children's memories for pain. J Pediatr Psychol 2012;37(5):567-579.

[23] Noel M, Chambers CT, Petter M, McGrath PJ, Klein RM, Stewart SH. Pain is not over when the needle ends: a review and preliminary model of acute pain memory development in childhood. Pain Manag 2012;2(5):487-497.

[24] Noel M, McMurtry CM, Pavlova M, Taddio A. Brief clinical report: A systematic review and meta-analysis of pain memory-reframing interventions for children's needle procedures. Pain Pract 2017.

[25] Noel M, Palermo TM, Chambers CT, Taddio A, Hermann C. Remembering the pain of childhood: applying a developmental perspective to the study of pain memories. Pain 2015;156(1):31-34.

[26] Noel M, Pavlova M, McCallum L, Vinall J. Remembering the hurt of childhood: A psychological review and call for future research. Can Psychol 2017;58(1):58-68.

[27] Noel M, Rabbitts JA, Fales J, Chorney J, Palermo TM. The influence of pain memories on children's and adolescents' post-surgical pain experience: A longitudinal dyadic analysis. Health Psychol 2017;36(10):987-995.

[28] Noel M, Rabbitts JA, Tai GG, Palermo TM. Remembering pain after surgery: a longitudinal examination of the role of pain catastrophizing in children's and parents' recall. Pain 2015;156(5):800-808.

[29] Ocanez KL, McHugh RK, Otto MW. A meta-analytic review of the association between anxiety sensitivity and pain. Depress Anxiety 2010;27(8):760-767.

[30] Ornstein PA, Manning EL, Pelphrey KA. Children's memory for pain. J Dev Behav Pediatr 1999;20(4):262-277.

[31] Page MG, Campbell F, Isaac L, Stinson J, Martin-Pichora AL, Katz J. Reliability and validity of the Child Pain Anxiety Symptoms Scale (CPASS) in a clinical sample of children and adolescents with acute postsurgical pain. Pain 2011;152(9):1958-1965.

[32] Page MG, Fuss S, Martin AL, Escobar EM, Katz J. Development and preliminary validation of the Child Pain Anxiety Symptoms Scale in a community sample. J Pediatr Psychol 2010;35(10):1071-1082.

[33] Page MG, Stinson J, Campbell F, Isaac L, Katz J. Identification of pain-related psychological risk factors for the development and maintenance of pediatric chronic postsurgical pain. Journal of pain research 2013;6:167-180.

[34] Pate JT, Blount RL, Cohen LL, Smith AJ. Childhood medical experience and temperament as predictors of adult functioning in medical situations. Child Health Care 1996;25(4):281-298.

[35] Pickrell JE, Heima M, Weinstein P, Coolidge T, Coldwell SE, Skaret E, Castillo J, Milgrom P. Using memory restructuring strategy to enhance dental behaviour. Int J Paediatr Dent 2007;17(6):439-448.

[36] Rabbitts JA, Fisher E, Rosenbloom BN, Palermo TM. Prevalence and predictors of chronic postsurgical pain in children: a systematic review and meta-analysis. J Pain 2017;18(6):605-614.

[37] Rabbitts JA, Zhou C, Groenewald CB, Durkin L, Palermo TM. Trajectories of postsurgical pain in children: risk factors and impact of late pain recovery on long-term health outcomes after major surgery. Pain 2015;156(11):2383-2389.

[38] Rocha EM, Marche TA, von Baeyer CL. Anxiety influences children's memory for procedural pain. Pain Res Manag 2009;14(3):233-237.

[39] Schneider S, Stone AA, Schwartz JE, Broderick JE. Peak and end effects in patients' daily recall of pain and fatigue: a within-subjects analysis. J Pain 2011;12(2):228-235.

[40] Sieberg CB, Simons LE, Edelstein MR, DeAngelis MR, Pielech M, Sethna N, Hresko MT. Pain prevalence and trajectories following pediatric spinal fusion surgery. J Pain 2013;14(12):1694-1702.

[41] Silverman WK, Fleisig W, Rabian B, Peterson RA. Childhood anxiety sensitivity index. Journal of Clinical Child and Adolescent Psychology, 20(2), 162-168. Journal of Clinical Child and Adolescent Psychology 1991;20(2):162-168.

[42] Sullivan MJ, Bishop SR, Pivik J. The pain catastrophizing scale: development and validation. . Psychological assessment 1995;7(4):524.

[43] Sullivan MJ, Thorn B, Haythornthwaite JA, Keefe F, Martin M, Bradley LA, Lefebvre JC. Theoretical perspectives on the relation between catastrophizing and pain. Clin J Pain 2001;17(1):52-64.

[44] Taylor S. Anxiety sensitivity: Theory, research, and treatment of the fear of anxiety. New York, NY: Routledge, 1999.

[45] von Baeyer CL, Marche TA, Rocha EM, Salmon K. Children's memory for pain: overview and implications for practice. J Pain 2004;5(5):241-249.

[46] von Baeyer CL, Spagrud LJ, McCormick JC, Choo E, Neville K, Connelly MA. Three new datasets supporting use of the Numerical Rating Scale (NRS-11) for children's self-reports of pain intensity. Pain 2009;143(3):223-227.

[47] Watt MC, Stewart SH, Lefaivre MJ, Uman LS. A brief cognitive-behavioral approach to reducing anxiety sensitivity decreases pain-related anxiety. Cogn Behav Ther 2006;35(4):248-256.

Table 1. Socio-demographic characteristics of the sample.

Demographic Characteristic	*N* = 237
Age, $M \pm SD$	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)
Ongoing pain location at baseline	
Back/spine	25.6
Foot/leg/hip	20.6
Chest/ribs/shoulder	6.3
Two or more locations	3.4
Other	3.4
Abdomen	2.1
Pain at baseline before surgery, *M(SD)*	
Pain at rest	2.00 (2.36)
Pain at movement	2.66 (2.76)
Pain unpleasantness	2.52 (2.98)
Pain on the first day while in hospital, *M(SD)*	
Pain at rest [a]	3.72 (2.18)
Pain at movement [b]	5.86 (2.36)
Pain unpleasantness [c]	4.84 (2.56)
Pain on the first three days while in hospital, *M(SD)*	
Pain at rest [d]	3.55 (1.81)
Pain at movement [e]	5.59 (1.92)
Pain unpleasantness [f]	4.68 (1.98)
Peak pain across the first three days while in hospital, *M(SD)*	
Pain at rest [g]	4.52 (2.18)
Pain at movement [h]	6.42 (2.28)
	5.76 (2.50)

Pain unpleasantness [i]	
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 post-surgical 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 post-surgical 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)

Note. The following reported pain intensity scores were significantly different from the corresponding recalled pain intensity levels: [a]$t(158) = -12.03$, [b]$t(157) = -7.69$, [c]$t(158) = -10.42$, [d]$t(108) = -11.49$, [e]$t(106) = -5.75$, [f]$t(107) = -9.62$, [g]$t(171) = -6.99$, [h]$t(171) = -2.47$ ($p = .014$), [i]$t(170) = -5.46$, $ps < .001$.

Table 3. Participant pain catastrophizing (PCS-C), anxiety sensitivity (CASI), and pain-related anxiety (CPASS) scores at baseline, in-hospital recovery phase, and 6-month and 12-month follow-ups.

Psychological Characteristic	*M(SD)*	*N*
T0 Baseline		
PCS-C [a]	19.56 (12.04)	210
CASI	29.44 (6.75)	212
CPASS	32.48 (18.51)	211
T1 In-hospital recovery		
PCS-C	22.27 (12.04)	202
CASI	30.57 (6.93)	201
CPASS	46.50 (21.33)	200
T2 6- month follow-up		
PCS-C [b]	17.67 (11.39)	194
CASI	29.89 (6.92)	194
CPASS	32.65 (18.73)	194
T3 12-month follow-up		
PCS-C [c]	17.88 (11.27)	202
CASI	29.79 (6.55)	202
CPASS	33.90 (19.24)	201

Note. Pain catastrophizing scores during in-hospital recovery were significantly higher than pain catastrophizing scores at other time points: [a]$t(182) = 3.01$, $p = .003$; [b]$t(174) = 5.76$, $p < .001$; [c]$t(180) = 5.85$, $p < .001$.

Table 4. Bivariate correlations between baseline, in hospital, and six- and twelve-month follow-up predictors of recall biases.

	Predictors	1	2	3	4	5	6	7	8	9	10	11	12
1	T0 Anxiety Sensitivity	-	**.45 †**	**.56 †**	.67 †	.37 †	.48 †	.58 †	.27 †	.36 †	.48 †	.22 **	.30 †
2	T0 Pain catastrophizing		-	**.78 †**	.44 †	.45 †	.39 †	.43 †	.50 †	.51 †	.42 †	.38 †	.44 †
3	T0 Pain anxiety			-	.49 †	.44 †	.49 †	.48 †	.45 †	.53 †	.43 †	.30 †	.40 †
4	T1 Anxiety Sensitivity				-	**.54 †**	**.65 †**	.63 †	.42 †	.46 †	.57 †	.32 †	.40 †
5	T1 Pain catastrophizing					-	**.71 †**	.45 †	.50 †	.50 †	.43 †	.43 †	.34 †
6	T1 Pain anxiety						-	.47 †	.45 †	.54 †	.46 †	.31 †	.36 †
7	T2 Anxiety Sensitivity							-	**.49 †**	**.61 †**	.71 †	.37 †	.47 †
8	T2 Pain catastrophizing								-	**.81 †**	.51 †	.64 †	.57 †
9	T2 Pain anxiety									-	.60 †	.56 †	.61 †
10	T3 Anxiety Sensitivity										-	**.52 †**	**.63 †**
11	T3 Pain catastrophizing											-	**.76 †**
12	T3 Pain anxiety												-

* significant at .05; ** significant at .01; † significant at .001. The correlation coefficients between variables included in the same regression models (e.g., T0 anxiety sensitivity, T0 pain catastrophizing, T0 anxiety sensitivity) are bolded.

Table 5. Partial correlations coefficients between the psychological measures at T0-T3 and pain recall at 12 months.

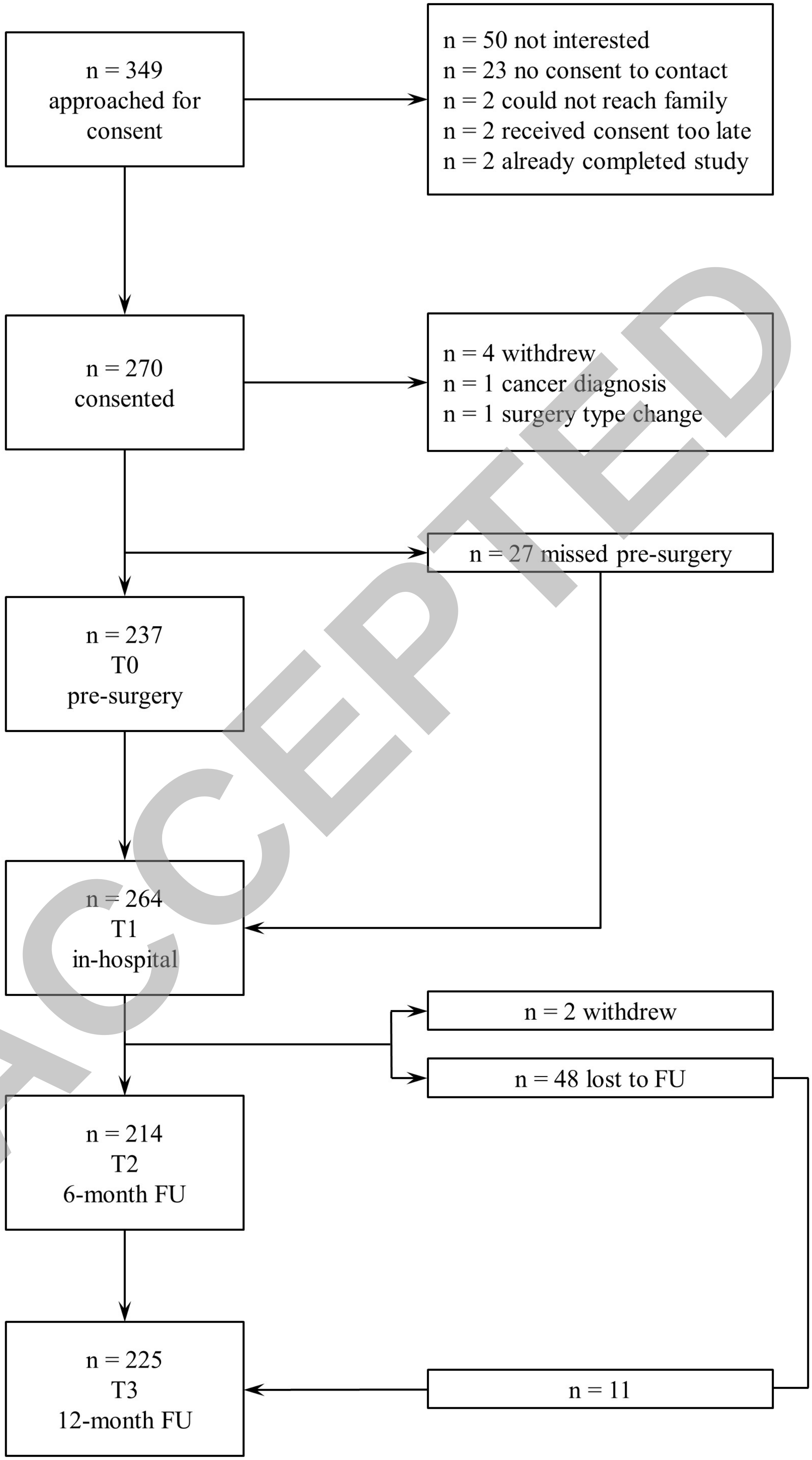
Psychological Characteristic	**Recall of pain at rest during day 1** ***r(df), p values***	**Recall of movement-evoked pain during day 1** ***r(df), p values***	**Recall of pain at rest during days 1-3** ***r(df), p values***	**Recall of movement-evoked pain during days 1-3** ***r(df), p values***
T0 Baseline				
PCS-C	.17*(144), *p* = .037	.15(143), *p* =.082	.13(99), *p* = .205	.24*(97), *p* = .015
CASI	.19*(146), *p* = .022	.16*(145), *p* =.049	.11(101), *p* = .281	.09(99), *p* = .368
CPASS	.15(146), *p* = .060	.09(145), *p* = .297	.11(101), *p* = .274	.13(99), *p* = .185
T1 In-hospital recovery				
PCS-C	.12(141), *p* = .123	.13(140), *p* = .138	.08(99), *p* = .441	.30**(97), *p* = .002
CASI	.13(141), *p* = .124	.16(140), *p* = .051	.08(99), *p* = .419	.22*(97), *p* = 029
CPASS	.14 (141), *p* = .094	.14(140), *p* = .101	.21*(99), *p* = .035	.26**(97), *p* = .010
T2 6- month follow-up				
PCS-C	.07(138), *p* = .426	.17(137), *p* = .052	.04(99), *p* = .687	.27**(97), *p* = .008
CASI	.09(138), *p* = .278	.11(137), *p* = .183	.17(99), *p* = .088	.21*(97), *p* = .042
CPASS	.01(138), *p* = .927	.10(137), *p* = .236	.05(99), *p* = .658	.20*(97), *p* = .047
T3 12-month follow-up				
PCS-C	.05(155), *p* = .544	.12(154), *p* = .135	.05(105), *p* = .584	.21*(104), *p* = .032
CASI	.02(156), *p* = .809	.14(155), *p* = .091	.03(106), *p* = .749	.20*(104), *p* = .044
CPASS	.03(154), *p* = .687	.14(153), *p* = .080	.09(104), *p* = .346	.23*(102), *p* = .017

Note. PCS-C – pain catastrophizing, CASI – anxiety sensitivity, CPASS – pain-related anxiety. The correlations are controlled for the corresponding initial pain ratings. * significant at .05; ** significant at .01; † significant at .001.

Table 6. Regression analyses explaining children's recall of pain.

Criterion Variable	Step	Predictor	Beta	ΔR^2	Cumulative R^2
T0 Baseline predictors					
Children's memory of pain at rest during the first day post-surgery	1	Day 1 pain ratings	.319	.102†	.102†
	2	T0 Anxiety sensitivity	.126	.039*	.133*
		T0 Pain catastrophizing	.104		
T1 In-hospital recovery predictors					
Children's memory of pain during movement during the first three days post-surgery	1	Days 1-3 pain ratings	.127	.097**	.097**
		Age	.276		
	2	T1 Anxiety sensitivity	.032	.084*	.182**
		T1 Pain catastrophizing	.291		
		T1 Pain anxiety	-.020		
T2 6-month follow-up predictors					
Children's memory of pain during movement during the first three days post-surgery	1	Days 1-3 pain ratings	.135	.124**	.124**
		Age	.313		
	2	T2 Anxiety sensitivity	.111	.058	.182**
		T2 Pain catastrophizing	.335		
		T2 Pain anxiety	-.217		
T3 12-month follow-up predictors					
Children's memory of pain during movement during the first three days post-surgery	1	Days 1-3 pain ratings	.134	.115**	.115**
		Age	.302		
	2	T3 Anxiety sensitivity	.059	.044	.159**
		T3 Pain catastrophizing	.162		
		T3 Pain anxiety	.026		

Note. * significant at .05; ** significant at .01; † significant at .001. Regression analyses reported here only include variables that showed a significant univariate effect in correlational analyses.


n = 349
approached for
consent
n = 50 not interested
n = 23 no consent to contact
n = 2 could not reach family
n = 2 received consent too late
n = 2 already completed study
n = 270
consented
n = 4 withdrew
n = 1 cancer diagnosis
n = 1 surgery type change
n = 27 missed pre-surgery
n = 237
T0
pre-surgery
n = 264
T1
in-hospital
n = 2 withdrew
n = 48 lost to FU
n = 214
T2
6-month FU
n = 225
T3
12-month FU
n = 11