

CHILDREN'S MEMORY FOR PAIN:
EXPERIMENTAL INVESTIGATIONS OF THE ROLE OF ANXIETY IN
CHILDREN'S PAIN MEMORIES AND THE INFLUENCE OF PAIN MEMORIES ON
SUBSEQUENT PAIN EXPERIENCE

by

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DALHOUSIE UNIVERSITY
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For my grandmother, Rita Noel, for lighting up my life with memories

&

Beverley Harnum, for inspiring one of my most important epiphanies.

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ABSTRACT

Children are often required to repeatedly undergo painful medical procedures (e.g. immunizations) and their memories for pain are predictive of their health behaviours across the lifespan. Although trait anxiety has been shown to influence pain memories, little is known about the impact of state anxiety, and the influence of stable anxiety-related variables (e.g., anxiety sensitivity), on children's memories for pain. Furthermore, although memory is often implicated in children's reactions to future pain, there is a dearth of research directly examining the relationship between the two. The current dissertation project involved two studies. The first study investigated the impact of experimentally manipulated state anxiety, and the influence of anxiety-related variables, on children's memories for a novel pain experience. The second study examined the influence of children's pain memories on a subsequent pain experience. In Study 1, one hundred ten children (60 boys; 50 girls) between the ages of 8 and 12 years ($M_{age} = 9.45$ years, $SD = 1.35$) were randomly assigned to complete either a state anxiety induction task or a control task. Then, children completed a laboratory pain task (the cold pressor task) and provided pain ratings. Children also completed measures of state anxiety and stable anxiety-related variables. Two weeks following the laboratory visit, children were contacted by telephone and provided pain ratings based on their memories of the initial pain experience, as well as their expectancies about future pain. Results showed that children in the state anxiety induction group did not have more negative pain memories (i.e., they did not recall higher levels of pain) than children in the control group. However, irrespective of group assignment, children who had higher levels of state anxiety had more negative memories of pain intensity and pain-related fear than children with lower levels of state anxiety. Furthermore, state anxiety was a unique predictor of children's pain memories over and above the influences of sex, stable anxiety-related variables, and experienced pain intensity and pain-related fear. Stable anxiety-related variables (anxiety sensitivity and trait anxiety) were also significant predictors of recalled pain-related fear. In Study 2, the same children once again completed the pain task and provided pain ratings one month following the initial laboratory visit. Results revealed that children's memory of pain intensity was a better predictor of subsequent pain reporting than their actual initial experience of pain intensity; in fact, children's pain memories mediated the relationship between reporting of pain intensity at Lab Session 1 and Lab Session 2. Children who had negatively estimated pain memories developed expectations of greater pain prior to a subsequent pain experience and showed greater increases in pain ratings over time than children who had accurate and positively estimated pain memories. Overall, these data highlight the importance of anxiety in the development of children's memories for pain and present a model of acute pain memories that add to the growing literature on pain memories across development. Results also highlight the powerful influence of pain memories on healthy children's pain expectancies and subsequent pain experiences, and extend predictive models of subsequent pain reporting to childhood.

LIST OF ABBREVIATIONS AND SYMBOLS USED

<i>cm</i>	Centimeters
<i>F</i>	F distribution Value of the F Test for Testing Equality of Variances
<i>M</i>	Mean
<i>N</i>	Population Size
<i>n</i>	Sample Size
<i>p</i>	P-value for Significance Testing
<i>t</i>	Student's t Value of the t Test for Testing Mean Differences
<i>r</i>	Correlation Coefficient
<i>R</i> ²	Multiple Correlation Coefficient
<i>SD</i>	Standard Deviation
Δ	Change
α	Cronbach's Alpha
β	Standardized Regression Coefficient
η_p^2	Partial Eta Squared (Estimate of Effect Size)

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CHAPTER 1: INTRODUCTION

Pediatric Pain

Forty years ago, it was widely believed that infants could not feel or remember pain (Swafford & Allan 1968), which led to inadequate treatment and needless suffering (Schechter, 1989). Since that time, there have been dramatic advances in the field of pediatric pain, which have, at least in part, dispelled these erroneous beliefs and misconceptions. Current conceptions of pain across the lifespan embrace the complex and multidimensional nature of the construct as involving physiological, developmental, cognitive, emotional, behavioural, and sociocultural aspects, which are all subjectively experienced by the individual (e.g., Hadjistavropoulos & Craig, 2004; Hadjistavropoulos et al., 2011). This complexity is captured in the widely accepted definition of pain put forth by the International Association for the Study of Pain (IASP) which defines pain as “an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage” (IASP Task Force on Taxonomy, 2004). Importantly, this definition was subsequently amended in order to capture the unique context of infancy and childhood wherein pain is not always verbally communicated yet nevertheless experienced and deserving of pain-relieving treatment (Craig & Hadjistavropoulos, 2004). Indeed, pediatric pain researchers continue to demonstrate that understanding pain during early developmental periods transcends downward extension of knowledge garnered in adulthood and necessitates appreciation of the unique context of childhood (McGrath, 2005).

Theoretical models have been proposed in attempts to disentangle and better understand the unique complexity inherent in pediatric pain (e.g., Integrative Framework

of Parent and Family Factors in Children's Pain, Palermo & Chambers, 2005; Pain Empathy Model, Goubert, Craig, & Vervoort, 2006; Pediatric Fear Avoidance Model of Chronic Pain, Asmundson, Noel, Petter, & Parkerson, in press; Social Communications Model of Pain, Craig, 2009). It is now well established that pain experienced early in development can have long-lasting consequences across the lifespan (Grunau & Tu, 2007). Enhanced understanding of acute pain, which occurs frequently throughout childhood and adolescence (Public Health Agency of Canada, 2006), has been derived from investigations with children in medical procedure contexts (e.g., needle-related medical procedures; Uman, Chambers, McGrath, & Kisely, 2008) as well as innovative laboratory-based settings involving experimental pain (e.g., the cold pressor task, Birnie, Petter, Boerner, Noel, & Chambers, under revision). There is now growing recognition of the complex and surprisingly prevalent problem of pediatric chronic pain in community samples (King et al., 2011) and researchers have begun to explore the factors that influence the transition of pain from its acute to chronic phase in childhood (Pagé, 2012). Unique to childhood, the field has demonstrated the powerful influence of parents in pediatric pain and the dynamic interplay between individual (e.g., child age, sex, psychological characteristics), dyadic (e.g., parent-child interactions), and contextual (e.g., family environment) factors in influencing child pain (Palermo & Chambers, 2005).

In the area of pediatric pain management, the importance of valid and reliable pain assessment as a precursor for effective treatment continues to be underscored and there are now numerous psychometrically sound self-report and observational tools for use across infancy and childhood (von Baeyer & Spagrud, 2007; Stinson, Kavanagh, Yamada, Gill, & Stevens, 2006). In addition to advancements in pediatric pain

assessment, there is a growing evidence-base for effective pharmacological and non-pharmacological interventions for pediatric chronic and acute pain across development (e.g., Palermo, Eccleston, Lewandowski, Williams, & Morley, 2010; Pillai Riddell et al., 2011; Taddio et al., 2007; Uman et al., 2008), which is continually updated as new emerging treatments are developed and investigated (e.g., Wicksell, Melin, Lekander, & Olsson, 2009). The field of pediatric pain has moved toward synthesizing evidence and translating knowledge into clinical practice to improve pediatric pain management. Nevertheless, important questions remain and further research is needed to improve our understanding of the complexity inherent in the child's pain experience.

Children's Memory for Pain: An Introduction

Prior to the 1980's, infants were erroneously believed to be incapable of encoding, storing, and retrieving memories of past autobiographical events (Bauer, Larkina, & Deocampo, 2010). Recognition of the importance of children's memories for pain was largely inspired by landmark studies that were published prior to the turn of the millennium. The seminal research by Taddio and colleagues (1997) provided evidence of the adverse impact of poorly managed pain in the first days of life on subsequent pain experienced at 4 and 6 months. In their study, infants who were circumcised without the use of topical local anesthetic (e.g., lidocaine-prilocaine cream), as compared to infants who were uncircumcised, displayed a greater pain response and cried longer at a subsequent routine immunization. Furthermore, the infants circumcised with placebo were observed to experience a greater increase in pain during the subsequent immunization than infants circumcised with topical local anesthetic. A subsequent investigation by the same research group demonstrated that infants of diabetic mothers

who were exposed to repeated heel lances in the first 2 to 3 days of life, as compared to normal infants who were not exposed to repeated painful procedures, exhibited a greater pain response prior to (i.e., during skin preparation and cleansing) and during a subsequent venipuncture (Taddio, Shah, Gilbert-MacLeod, & Katz, 2002). These studies dramatically demonstrated how inadequately managed pain in the first days of life could lead to later sensitization to pain. Furthermore, the findings suggest that infants who had received inadequate pain management in the first days of life learned to anticipate pain during a subsequent procedure and may have developed some form of implicit (i.e., non-conscious, nonverbal) memory of the previous painful experience that then influenced their distress during subsequent pain (von Baeyer, Marche, Rocha, & Salmon, 2004). Research also suggests that young children's memories for undertreated pain might reduce the effectiveness of subsequent pharmacological pain management (e.g., oral transmucosal fentanyl; Weisman, Bernstein, & Schechter, 1998). Taken together, these studies provide critical evidence for the powerful role of children's early pain memories in their subsequent pain experience and established the importance of this area in the field of pediatric pain.

Memory Development in Childhood

It is now well recognized that children are capable of remembering early pain experiences and that these memories are formed early in life. Pain memories refer to the type of memories that are encoded and stored in, and later retrieved from, one's central nervous system. These types of memories may be implicit (non-conscious, nonverbal) or explicit (conscious, typically verbal) and can influence subsequent responses and behaviours. There is evidence that these types of memories may be present from the time

of birth and even earlier (e.g., DeCasper & Spence, 1986; Howe, 2000); indeed, infants have been shown to be capable of differentiating between a novel story passage and one that was read to them by their mothers several weeks before birth (DeCasper & Spence, 1986).

The pain memories studied in this dissertation are a type of explicit memory referred to as autobiographical memories. Autobiographical memories are event memories that are relevant to the self and can be tied to a specific time and place from the past. These memories can be expressed verbally—although they can also be validly and reliably inferred through nonverbal behaviours (Howe, Courage, & Edison, 2003)—and the process of retrieval is thought to involve re-experiencing of the event. For example, when children are asked to indicate how painful a previous medical procedure was (e.g., a venipuncture), they are required to access a representation of that event that is situated in time and place (e.g., the blood draw lab in their local hospital 2 weeks prior to a memory interview) and verbally recount the level of pain that they remember experiencing. Importantly, these types of memories are thought to form our personal life histories, define the essence of who we are, influence our current behaviour, and guide our future behaviour (Bauer et al., 2010; Courage & Howe, 2010).

During the first 3 to 4 years of life, children's cognitive skills, including their mnemonic abilities, undergo rapid changes at both physiological (e.g., hippocampal volume and myelination, maturation of the prefrontal cortex) and psychological (e.g., completeness and descriptive richness of recall) levels (Bauer et al., 2010). Prior to 3 years of age, children are generally unable to reliably recount experiences from the

past: a phenomenon referred to as “infantile amnesia”¹. Similarly, it has been argued that the onset of autobiographical memory is marked by the emergence of the cognitive self (i.e., the objective aspect of the self, encompassing unique and recognizable characteristics, that comprises an individual’s self-concept), which occurs late into the second year of life (see Howe & Courage, 1997). Nevertheless, explicit memory has been inferred in nonverbal infants as young as 6 months of age (Collie & Hayne, 1999) through changes in behaviour or performance following exposure to a stimulus or event. This type of memory, evidenced from elicited and deferred imitation memory paradigms, involves consciously recollecting previous events and is considered to be the nonverbal analogue of verbal recall (see Bauer et al., 2010; von Baeyer et al., 2004).

With the advent of language and children’s increasing capabilities to express their knowledge and recollections, children’s autobiographical memory skills become more organized and complete. This is also facilitated by increased knowledge of their social environments, enhanced metamemory skills (i.e., a component of metacognition that refers to one’s knowledge about their own memory capabilities and associated memory strategies) and working memory, as well as increasingly sophisticated language abilities. Children’s autobiographical memories are also highly socialized in that they are largely influenced by verbal interactions with individuals in the social environment, who shape both the information that children deem to be important to remember as well as their expression of their memories (Bauer et al., 2010; Peterson, Sales, Rees, & Fivush, 2007), processes that become increasingly complex and entrenched over time. Although there is a wealth of literature on the development of children’s autobiographical memories in

¹ Research has also demonstrated that children as young as 1 and 2 years of age show long-term memory competence and some have called for the adoption of a more flexible definition of infantile amnesia that acknowledges individual differences (e.g., gender, culture) and is reflective of a process versus an all or none phenomenon (see Peterson, 2002).

general, far less is known about children's autobiographical memories specifically for pain. Nevertheless, the evidence that exists and is emerging indicates that these memories are critically important to our understanding of pediatric pain and its trajectories across development.

The Importance of Children's Memories for Pain

Children's memories for pain have several important implications for pain assessment, treatment, and health across the lifespan (for a discussion see Ornstein, Manning, & Pelphrey, 1999; von Baeyer et al., 2004; Noel, McMurtry, Chambers, & McGrath, 2010). First, many of the tools used to assess pain rely on children's retrospective accounts of their psychological and physical experience of pain. For example, self-report instruments often require children to remember their worst pain and provide ratings based on how their current pain compares to the remembered pain experience. Second, memory for pain is often used to infer the effectiveness of interventions (e.g., a child's perspective about the degree to which his/her pain has decreased relative to the level that he/she experienced in the past). Third, recalled pain is thought to influence one's perception of pain, although this relationship is likely bidirectional wherein a pain experience characterized by high intensity and fear leads to the development of negative pain memories (i.e., recall a higher degree of pain than was initially experienced), which in turn heightens one's tendency to experience elevated levels of anxiety prior to, and fear and pain during, subsequent pain experiences. Fourth, memories for pain are thought to play an important role in the transition of pain from an acute to chronic state; indeed, pain memories have been implicated in the development and maintenance of chronic pain over time (Flor & Birbaumer, 1994; Sun-Ok & Carr,

1999). Finally, early memories for pain can have important long-term consequences for subsequent health behaviours. Retrospective research suggests that early pain memories influence one's fear and avoidance of medical care in adulthood (Pate, Blount, Cohen, & Smith, 1996). Moreover, among children diagnosed with cancer, memories for pain arising from invasive medical procedures (e.g., lumbar punctures) have been shown to influence the level of distress that they exhibit during subsequent procedures. In particular, children who develop pain memories that are negatively exaggerated (i.e., recalled pain is higher than initial pain report) appear to be particularly at risk for experiencing increases in distress in response to pain over time (Chen, Zeltzer, Craske, & Katz, 2000). As such, children's memories for pain appear to be as important to their subsequent health behaviours and pain coping as their actual experience of pain itself.

Children's Memories for Pain: The State-of-the-Science

Pain memories are—not unlike the experience of pain itself (IASP Task Force on Taxonomy, 2004)—subjective and multidimensional, consisting of somatosensory (e.g., pain intensity), affective (e.g., fear, unpleasantness), and contextual (e.g., people, place, time) aspects (Ornstein et al., 1999). Children's memories for pain are constructive and reconstructive, which makes them susceptible to distortion over time. The manner in which memories are framed is influenced by a host of factors including, but not limited to: age (see Peterson & Warren, 2009); distress (Chen et al., 2000); pain intensity (Noel et al., 2010); trait anxiety (Rocha, Marche, & von Baeyer, 2009); negative affectivity (Gedney & Logan, 2006); parent-child discourse about the event following exposure (see review in Fivush, Haden & Reese, 2006); length of time between the pain experience and memory assessment (Everts, Karlson, Währborg, Abdon, Herlitz, &

Hedner, 1999; Gedney, Logan, & Baron, 2003); and state anxiety at the time of memory elicitation (Kent, 1989). As a result, empirical investigation in this area is methodologically complex, particularly in clinical and naturalistic settings wherein researchers have less control over variables of interest as well as the timing of assessments. Nevertheless, given the importance of children's pain memories in shaping their subsequent experiences of pain, understanding the processes involved in the development of these memories over time is of critical importance.

There is a substantial body of literature on the development of children's autobiographical memories for stressful and traumatic events (see reviews in Howe, 1997; Deffenbacher, Bornstein, Penrod, & McGorty, 2004); however, the research on children's memories for pain is much more limited. To date, two reviews on the topic of children's memories for pain have been conducted. The first, by Ornstein et al. (1999), provided an overview of the findings derived from 14 empirical investigations that were primarily conducted in medical procedure contexts (e.g., emergency room visits, voiding cystourethrograms, venipunctures, immunizations, dental procedures, lumbar punctures, daily pains in hospitalized patients) with children of varying ages (i.e., 3-18 years). This early work was heavily influenced by literature on the development of children's autobiographical memories. The authors provided an information-processing framework informed by this literature within which the acquisition, retention, and distortion of pain information could be understood. The review highlighted the significance of children's pain memories for assessment, treatment, and longitudinal health outcomes and emphasized the multidimensional nature of pain memories. Despite the importance of this initial review, the authors themselves emphasized the limitations of the framework and

research that had accumulated at that time. Given that the majority of reviewed studies assessed children's memory for contextual details as opposed to aspects of the pain itself, it was unclear whether the same principles underlying children's contextual memory also applied to memory for somatosensory and affective aspects of pain.

The second review, conducted by von Baeyer and colleagues (2004), provided an overview of developments in the field since the time of the 1999 review by Ornstein and colleagues, emphasized the consequences of children's pain memories for subsequent reactions to pain and acceptance of later medical interventions, and discussed individual differences (e.g., age, temperament, anxiety, previous experience, pain response) as well as situational and methodological influences in children's recall. Perhaps most importantly, this review highlighted the individual variability in children's pain memories and resulting health behaviours as well as potential intervention targets that could prevent the deleterious consequences of negatively exaggerated pain memories. Overall, these reviews contributed to the field of pediatric pain by advancing our understanding of children's memory for pain and establishing the importance of this area of inquiry for future research and clinical intervention. This work, in addition to the evidence that has accumulated since the publication of the 2004 review, serves as the focus of the brief review described herein.

Children's autobiographical memory has been described as both remarkably robust yet significantly fragile (Courage & Howe, 2010; for a discussion also see Bauer, 2007). Like memory for stressful events, children have generally been found to be capable of accurately recalling previous painful experiences; indeed, children as young as 3 years of age are fairly accurate at recalling contextual aspects of painful medical

procedures (i.e., no age differences in the number of errors made during free recall), especially in the absence of specific or leading questions (Sjöberg & Lindholm, 2005; Quas et al., 1999). Similar findings have also been generated from examinations of children's memories specifically for pain itself (Badali, Pillai, Craig, Geisbrecht, & Chambers, 2000; Lander, Hodgins, & Fowler-Kerry, 1992; Zonneveld, McGrath, Reid, & Sorbi, 1997). Badali and colleagues (2000) examined children between the ages of 5 and 12 years who completed a laboratory pain induction task (cold pressor task) and found that children's and parents' pain recall did not differ and was consistent after a year delay (i.e., the difference between recalled and experienced pain intensity was less than or equal to +/- one face on a 7-point faces scale). Similarly, research on children's memory for venipuncture pain revealed that children between the ages of 5 and 17 years had fairly accurate recall for sensory pain (i.e., the difference between recalled and experienced sensory pain was less than or equal to +/- 9 mm on a 100 mm visual analogue scale [VAS] for 43% of children) but showed superior recall for the affective as opposed to the sensory aspect of the pain (i.e., the difference between recalled and experienced affective pain was within +/- 1 face on a 9-point faces scale for 75% of children; Lander et al., 1992). High accuracy of children's recall of pain has also been demonstrated in a prospective examination of children's pain memories among an inpatient sample of children and adolescents (i.e., the difference between recalled and experienced pain intensity was within +/- 1 face on a 7-point faces scale; Zonneveld et al., 1997) as well as among children with chronic illness following lumbar punctures (i.e., the difference between recalled and experienced pain was < 1 point on a 10-point VAS; Chen et al., 2000).

Nevertheless, memory by its very nature is constructive and reconstructive (see von Baeyer et al., 2004) and can become distorted over time (e.g., Chen et al., 2000; Cohen, Blount, Cohen, Ball, McClellan, & Bernard, 2001; Noel et al., 2010; Rocha et al., 2009). The first and perhaps most compelling demonstration of the malleability and reconstructive nature of pain memories was in an investigation conducted by Bruck and colleagues (1995). They examined children's memories for both the contextual details of, and the level of pain and distress experienced during, an immunization. They also examined the effect of providing children with different types of verbal information following the procedure on their subsequent recall. Following immunization, children were randomly assigned to receive either pain affirming ("the shot hurt"), pain-denying ("the shot did not hurt"), or neutral ("the shot is over") feedback. One week later, children provided ratings of their levels of perceived pain and distress experienced during the immunization using a poker chip tool and a faces scale. Children's recall did not differ at this time. Approximately one year (*Range* = 4-18 months) following the immunization, the researchers conducted follow-up home visits on three separate occasions to provide children with additional positive (i.e., pain-denying) or neutral feedback and misleading or non-misleading information about the individuals involved in their care. At a fourth and final visit, children once again provided pain and distress ratings based on their memories of the procedure. Those children who received positive pain-denying feedback, as compared to those who received neutral feedback, recalled crying less and experiencing less pain during the immunization. Furthermore, children who received misleading information made more false allegations regarding the individuals involved in their care (e.g., reported that the research assistant gave them the

vaccination) than children who did not receive this misleading information. Interestingly, those children who exhibited greater distress during the immunization (e.g., longer time to calm down following the injection) were found to be more susceptible to suggestibility 4 to 18 months following the procedure. This study was and remains an important contribution to the field by highlighting the malleability of children's memories for pain and the impact that discourse surrounding the experience following the event can have on subsequent recall of pain as well as the context in which the pain was experienced.

Once children's pain memories become distorted, they can have important implications for distress experienced during subsequent pain experiences. Chen and colleagues (2000) are the only researchers to have examined this among children diagnosed with leukemia who were required to undergo repeated lumbar punctures as part of their medical treatment. One week following lumbar puncture, children's memories for details about both the event and their emotional responses were elicited. Children then received a second lumbar puncture. At each time point, children's anticipatory pain and anxiety prior to the procedure, as well as their behavioural distress (assessed using both physiological and observational measures), pain, and anxiety during the procedure were measured. Although children's memories for pain experienced during the lumbar puncture one week prior to the memory interview were generally accurate, a subset of children who exhibited greater behavioural distress later developed exaggerated memories (i.e., pain recall was greater than initial report) of the negative details of the lumbar puncture. Furthermore, children who developed more negatively exaggerated memories of pain and anxiety (i.e., those who recalled more pain and anxiety than they reported during the first lumbar puncture) exhibited greater increases in behavioural

distress and reported more pain over time: a robust finding that persisted even after controlling for age, initial distress, and number of previous lumbar punctures. This research highlighted the importance of memory distortion for subsequent distress and identified children who are most at risk (i.e., those with negatively exaggerated memories) for developing maladaptive responses to pain versus those who may be buffered from such outcomes (i.e., those with accurate or positively exaggerated memories).

Given the potential malleability of children's pain memories and the importance of negative distortion for subsequent pain and distress, research has moved toward identifying children who are most at risk for developing negatively exaggerated pain memories. Although the relationship between stress and children's memories for autobiographical events is controversial and marked by inconsistencies across studies (see Peterson & Warren, 2009), in the context of pain there is a clear link between children's level of distress experienced during a painful event and the subsequent framing of their memories. Across a range of medical procedures and among both clinical and healthy samples (e.g., lumbar punctures for cancer treatment, venipunctures during routine blood draws), it has been demonstrated that children who exhibit greater behavioural distress and report higher levels of pain tend to develop negatively exaggerated pain memories (Chen et al., 2000; Noel et al., 2010).

Chen and colleagues (2000) examined pain memories of children aged 3 to 18 years who were diagnosed with cancer and who were required to repeatedly undergo highly invasive lumbar punctures. Higher distress at the initial lumbar puncture was associated with more negatively exaggerated memories, even when controlling for

number of previous lumbar punctures. To ensure the generalizability of these findings to the non-clinical population of children, Noel and colleagues (2010) examined the relationship between venipuncture pain experienced during routine blood draws and memories for the intensity and affective (i.e., anxiety) aspects of the pain experience. Similar to Chen and colleagues (2000), children who reported higher levels of pain intensity during venipuncture later developed negatively exaggerated memories of anxiety. Similarly, children undergoing hepatitis vaccinations who received standard care (i.e., those who did not receive pain management prior to the procedure) developed more negatively exaggerated memories of pain intensity as compared to children who received pharmacological (e.g., topical anesthetic) and non-pharmacological (e.g., distraction) interventions. These children also developed less accurate memories of anxiety than children who received pharmacological intervention (Cohen et al., 2001). Furthermore, children undergoing dental procedures who had higher levels of trait anxiety—a relatively stable aspect of one’s personality reflecting the tendency to perceive threat in the environment and experience anxiety states (Spielberger, 1973)—tended to recall more pain after a delay than children with lower levels of trait anxiety, suggesting that highly trait anxious children may have developed negatively exaggerated pain memories (Rocha et al., 2009). Although this research is limited due to its correlational nature, thereby precluding examination of the impact of distress on children’s pain memories, it highlights potentially important individual difference variables that may identify children who are most at risk for developing negatively exaggerated pain memories, which could then shape their responses to pain over time.

Fear, Anxiety, and Memory for Pain

Pain and memories for pain encompass more than the somatosensory experience and representation (IASP Task Force on Taxonomy, 2004; Ornstein et al., 1999); indeed, it is well recognized that the emotional, motivational and social context of pain can have a profound influence on one's experience of pain (Hadjistavropoulos & Craig, 2004). Furthermore, pain memories are multidimensional and include somatosensory, affective, and contextual aspects (Ornstein et al., 1999). Of particular importance to the development of children's memories for pain may be fear and anxiety, which are related but qualitatively different affective states (Barlow, 2002). Fear is an immediate response to perceived threat to one's safety that arises in the present moment and provokes arousal of the sympathetic nervous system as well as defensive behaviour (e.g., escape tendencies). Conversely, anxiety is a future-oriented response to the threat of danger to one's safety and is associated with hypervigilance toward threat, negative affect, bodily tension and sensitivity, as well as preventative behaviours (e.g., avoidance). Although the distinction between fear and anxiety is contentious, there is empirical (McCracken, Gross, Aikens, & Carnrike, 1996; Carleton & Asmundson, 2009) as well as potential theoretical and clinical (Asmundson et al., in press) support for this distinction as it relates to pain.

Fear and anxiety are central to one's experience of pain and have been shown to alter pain perception (Rhudy & Meagher, 2000). Whereas induction of anxiety (e.g., threat of shock/noxious stimulus) can increase pain reactivity, induction of fear (actual exposure to shock/noxious stimulus) can decrease pain reactivity, as indicated by both subjective and physiological measures. Importantly, these relationships have been

found even when the focus of fear and anxiety was irrelevant to the pain task. Moreover, the severity of the stressor appears to be an important determinant of pain reactivity (Rhudy & Meagher, 2003). Anxiety-induced hyperalgesia (i.e., increased sensitivity to pain) is expected when individuals are exposed to less severe stressors or diffuse threat and when arousal is of low to moderate intensity (e.g., verbal threat of shock without delivery, novelty). On the other hand, fear-induced hypoalgesia (i.e., decreased sensitivity to pain) is expected when individuals are exposed to severe stressors and when arousal is of high intensity (e.g., exposure to a predator, intense shock). Indeed, anxiety-induced hyperalgesia has been elicited by induction tasks that are both related and unrelated to pain; for example, following provision of threatening descriptions of a pain task and anticipation of a stressful interview (Cornwall & Donderi, 1988). This phenomenon is supported by attentional theories, which attribute this augmentation in perceived intensity found among anxious individuals to a heightened tendency for them to attend to salient information (e.g., pain) in the environment (e.g., Janssen & Arntz, 1996; Villemure & Bushnell, 2002). Given that induced anxiety is related to increased pain reactivity (Cornwall & Donderi, 1988; Rhudy & Meagher, 2000) and pain intensity and anxiety have been linked to memory biases among children undergoing clinical pain (Chen et al., 2000; Noel et al., 2010; Rocha et al., 2009), it is likely that state and trait anxiety influence the development of biases in children's memories for pain.

Both fear and anxiety are at the core of fear avoidance models used to account for the processes by which pain transitions from an acute to chronic state among adults (Asmundson, Norton, & Norton, 1999; Vlaeyen & Linton, 2000). In light of emerging and compelling evidence for the importance of fear-avoidance variables among children

and adolescents, this model has recently been extended to pediatric populations (Asmundson et al., in press). Although not explicitly outlined in the new model, pain memories were included in the foundational work on which these models were based (Philips, 1987) and have also been implicated in the development and maintenance of chronic pain (Flor and Birmaumer, 1994; Sun-ok and Carr, 1999). In both clinical and healthy samples, individuals who are anxious consistently show a memory bias for threatening information as compared to non-anxious individuals (Mitte, 2008); however, a significant limitation of this research is that it has only examined adults' memories for lists of words as opposed to children's memories for more ecologically valid stimuli, like pain. Only one study to date has examined the relationship between trait anxiety and pain memories among children, revealing that children with higher levels of trait anxiety had more negative pain memories (Rocha et al., 2009). This suggests that trait anxiety could be an individual vulnerability factor that may account for distortions in children's pain memories over time.

In addition to trait anxiety, state anxiety may also influence the development of children's memories for pain. State anxiety refers to subjective and consciously perceived feelings of anxiety that become elevated in situations perceived to be stressful and that can vary in intensity and fluctuate over time (Spielberger, 1973). Only two investigations have attempted to examine the relationship between state anxiety and children's memories for pain and both failed to find a relationship between the two, which could have been due to methodological issues. The first was an examination of children (aged 5-17 years) undergoing venipuncture who completed measures of state anxiety and expected pain before, and pain intensity and pain affect after, the procedure (Lander et

al., 1992). Two months later, children once again completed ratings based on their memories of the procedure. Results revealed that state anxiety was weakly correlated with experienced and recalled pain yet moderately correlated with expected pain. However, it is unclear whether state anxiety in this investigation was measured *immediately* prior to venipuncture and given that the study was conducted in a clinical setting, it is likely that the timing of measurement varied between children resulting in measurement error and/or heterogeneity among children. The second study examined pain and dental anxiety among children (aged 4-11 years) undergoing local anesthesia injections during dental procedures on two subsequent visits (Versloot, Veerkamp, & Hoogstraten, 2008). However, state anxiety in this study was inferred through parent report of general dental fears, based on perceptions of how the child would respond in hypothetical situations, which were not necessarily related to the procedure under investigation. Furthermore, parents were not present in the procedural room as the children received the injections; therefore, they were not able to provide proxy ratings of the child's anxiety as observed during the procedure. Finally, the majority of children in the study were referred due to behaviour management problems making generalizations based on these results to other populations difficult. Indeed, there is theoretical support for the role of state anxiety in the development of memory biases (discussed in more detail below; Beck & Clark, 1997) as well as empirical support for the relationship between anticipatory anxiety and negative pain memories among children undergoing invasive painful medical procedures (Chen et al., 2000). Furthermore, physiological evidence for this relationship has been generated from research demonstrating the relationship between cortisol and memory impairments, which is thought to be due to

cortisol's detrimental effect on the hippocampus (Newcomer, Craft, Hershey, & Askins, 1994). Given the methodological issues in previous research (Lander et al., 1992; Versloot et al., 2008) and theoretical and empirical support for the relationship between state anxiety and memory, further research in this area is warranted.

Another anxiety-related variable that may be particularly important in the development of children's memories for pain is anxiety sensitivity. Anxiety sensitivity is a relatively stable individual difference variable characterized by fear of anxiety-related sensations as signifying physiological, psychological, or social harm (Reiss, Peterson, Gursky & McNally, 1986; Taylor, 1999). For example, a child with high anxiety sensitivity upon noticing his/her heart racing might interpret that potentially benign sensation as signifying an imminent heart attack. He/she might also fear that other anxiety-related sensations, such as sweating and difficulties concentrating, would embarrass him/her in front of peers and be indicative of a mental illness. There is evidence that anxiety sensitivity is highly relevant to one's experience of pain; indeed, anxiety sensitivity is thought to heighten one's propensity to experience anxiety, which increases individuals' perception of pain (Schmidt & Cook, 1999; Stewart & Asmundson, 2006). Although there is a dearth of research examining anxiety sensitivity in the context of pediatric pain, it has been shown to be a robust predictor of healthy children's pain-related anticipatory anxiety prior to a laboratory pain induction task (Tsao, Lu, Kim, & Zeltzer, 2006). Moreover, anxiety sensitivity, anxiety symptoms, and anticipatory anxiety collectively accounted for 62% of the variance in laboratory pain intensity ratings among these children (Tsao et al., 2006), highlighting the importance of these various anxiety-related constructs in laboratory pain contexts. In addition to its effects on pain-related

anticipatory anxiety, anxiety sensitivity has been shown to promote catastrophic cognitions about pain as well as fear of pain (Norton & Asmundson, 2004) in adults, highlighting the reciprocal relationship between fear and anxiety among these highly anxiety sensitive individuals. Among children, anxiety sensitivity has been shown to be associated with pain catastrophizing (Muris, Meesters, van den Hout, Wessels, Franken, & Rassin, 2007; Tsao, Allen, Evans, Lu, Myers, & Zeltzer, 2009), pain anxiety (Pagé, Campbell, Issac, Stinson, Martin-Pichora, & Katz, 2011), and fear of pain (Huguet, McGrath, & Pardos, 2011; Martin, McGrath, Brown, & Katz, 2007). Although there is some evidence that high anxiety sensitivity is related to memory biases toward threat among both clinical and healthy samples of adults (Becker, Rinck, & Margraf, 1994; Cloitre & Leibowitz, 1991; Cloitre, Shear, Cancienne, & Zeitline, 1994; McCabe, 1999; McNally, Foa, & Donnell, 1989; Noel, Taylor, Quinlan, & Stewart, 2011)—which is thought to arise due to attentional biases favoring the processing of threatening information—the relationship between anxiety sensitivity and memory for pain among pediatric populations has not yet been investigated.

Theories of Anxiety and Memory Biases

Several cognitive theories have been proposed to account for memory biases among anxious individuals. Beck and colleagues (1985) developed a theory to explain the nature of information processing in anxiety. They posited that anxiety is characterized by danger-related schemata—defined as stable cognitive structures including representations of past events that organize how one processes information—that become activated and influence attention, interpretation, and memory for threat-related information. Among anxious individuals, these schemas are often related to danger and a perceived inability to

cope with threat. Upon confrontation with a perceived threat, the individual's threat-related schemas become activated and influence the processing of information in a manner that is congruent with these schemas. For example, prior to getting a needle, an anxious child's schemas related to threat, fear, and pain may become activated in the procedural context, which could cause the child to become hypervigilant to pain-related cues. Furthermore, this would facilitate interpretations of people and objects in their immediate environment as signifying threat and potential harm, as well as promote thoughts related to their perceived inability to cope with pain. The theory assumes that anxious individuals selectively remember threat-related information as a result of their activated threat-related schemas. Beck and Clark (1997) later amended this theory to account for various stages (e.g., automatic and strategic) involved in information processing. In the first stage (initial registration), individuals automatically detect and orient toward threat whereas in the second stage (immediate preparation) threat-related schemas become activated and individuals engage in preferred processing of information that is congruent with their danger-related schemata. Finally, in the third stage (secondary elaboration), more elaborative and reflective modes of thinking become activated. The theory posits that high anxious individuals differ from low anxious individuals at both automatic and strategic levels of information processing. Moreover, high anxious individuals are thought to engage in selective encoding and retrieval of threat-related information, congruent with their threat-related schemas, particularly when they experience high levels of state anxiety.

Similarly, other cognitive theories, such as Attentional Control Theory (Eysenck, Derakshan, Santos, & Calvo, 2007), have been used to explain memory biases among

non-clinically anxious individuals, including those who have high levels of trait and state anxiety (e.g., under situations in which anxiety is experimentally manipulated). The theory was a major extension of the former Processing Efficiency Theory (Eysenck & Calvo, 1992) and posits that in the presence of threat-related stimuli, anxiety exhausts one's cognitive resources, thereby decreasing the efficiency of the goal-directed attentional system and increasing the influence of the stimulus-driven attentional system. This therefore decreases attentional control, which is a critical function of the central executive of working memory (Baddeley, 1986), and impairs one's ability to inhibit and shift attention. Specifically, worry—the aspect of state anxiety thought to account for the effect of anxiety on cognitive processing—is thought to limit the processing and storage capacity of working memory and heightens one's motivation to reduce the associated aversive emotional state. Simply put, highly anxious individuals, upon perceiving danger in their environments, tend to allocate attentional resources toward the threat, whether by internally focusing on worrisome thoughts or externally focusing on threat-related stimuli in the environment, and divert attention away from task-relevant stimuli. Similar to Schema Theory (Beck et al., 1985) and the Information Processing Model of Anxiety (Beck & Clark, 1997), Attentional Control Theory posits that anxiety heightens one's attentional orientation toward threat-related stimuli. This is empirically supported; indeed, a meta-analysis of 172 studies revealed that attentional biases toward threat have been reliably found among high anxious individuals from both clinical and non-clinical populations across development (i.e., children and adults; Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007).

The Cognitive-Affective Model of the Interruptive Function of Pain (Eccleston & Crombez, 1999) holds that pain is an evolutionarily relevant threat that serves to capture and interrupt one's attention and motivate behaviour (e.g., escape). It is thought that this interruptive function is moderated by characteristics of the pain (e.g., the perceived inherent threat value, pain intensity, novelty, unpredictability, extent of catastrophic cognitions about pain, somatic awareness) as well as the environment (e.g., degree of emotional arousal). Therefore, the model predicts that pain would disrupt attention most among individuals who perceive pain as having a high degree of threat and who experience high levels of somatic awareness and emotional arousal (e.g., individuals high in state and trait anxiety and anxiety sensitivity). Although these models do not explicitly make predictions regarding the influence of anxiety on memory biases, similar attentional theories (e.g., Eysenck, 1982) have been used to explain the relationship between anxiety and memory biases among children with chronic illness in the context of invasive painful medical procedures (Chen et al., 2000). Despite the theoretical importance of state anxiety in memory, research has largely failed to examine the role of state anxiety in the development of memory biases (Mitte, 2008). In addition, not one study has examined the role of state anxiety, in the context of other stable anxiety-related variables, in children's memories for ecologically and evolutionarily valid stimuli, such as pain.

Memory and Subsequent Pain Experience

Arguably the strongest rationale for investigating children's memories for pain is the deleterious influence that pain memories can have on children's subsequent pain experience and health behaviours over time. Nevertheless, to date only one prospective study has demonstrated this among children (Chen et al., 2000). Children diagnosed with

cancer who developed more negatively exaggerated memories of pain and anxiety one week following lumbar puncture showed greater increases in self-reported and behavioural distress from an initial to a subsequent lumbar puncture. This provided evidence for the powerful influence of children's pain memories on their reactions during subsequent pain experiences, which the authors hypothesized may have been caused by contextual cues that triggered negatively exaggerated memories about the previous procedure and thereby led to subsequent increases in distress. However, as noted by the authors, a limitation of this research was its potential lack of generalizability to the general population of healthy children, given the negative cognitive and neuropsychological effects of cancer treatment (e.g., cranial radiation) and potential differences in memory abilities among children in their sample. Surprisingly, in the 12 years since this research was published, not one study has examined the influence of pain memories on subsequent pain experiences among healthy children, despite the frequency with which acute pain (e.g., immunizations) is experienced during childhood and adolescence (Public Health Agency of Canada, 2006). Among healthy adults repeatedly undergoing experimental pain, pain memories have been shown to be a strong predictor of subsequent pain experience; in fact, recalled pain was found to be a better predictor of subsequent pain reporting than was initial pain reporting (Gedney & Logan, 2006). Although this evidence highlights the influence of pain memories on subsequent pain experience among healthy adults, examination of this relationship among healthy children is warranted.

Outline of Dissertation Studies: Goals and Hypotheses

Based on the current state-of-the-science in the area of children's memories for

pain, the present dissertation project was designed to address important gaps in the literature and advance understanding of both the contributing roles of anxiety in healthy children's memories for pain as well as the long-term influence of pain memories on their subjective experience of pain over time. To accomplish this, two complementary research studies, encompassed within a larger dissertation project, were conducted. These studies are presented as two separate manuscripts (e.g., chapters) in this dissertation.

The first study was a laboratory-based experimental investigation of the role of state anxiety and stable anxiety-related variables in children's memories for a novel pain experience. Children were randomly assigned to complete either a state anxiety induction task or a control task prior to undergoing an experimental task that generates pain. Measures of state anxiety were administered prior to, and stable anxiety-related variables were assessed following, pain induction. Children's memories—assessed by the same self-report measures of pain intensity and pain-related fear that were administered following pain induction—were then elicited 2 weeks following the initial laboratory visit via telephone. It was hypothesized that children in the state anxiety induction group, as well as those participants with higher levels of general state anxiety, trait anxiety and anxiety sensitivity, would develop more negative pain memories than children in the control group and those with lower levels of general state anxiety, trait anxiety and anxiety sensitivity.

The second study examined the influence of children's memories for pain on their subsequent pain experience as well as the influence of children's style of remembering (e.g., negatively estimated vs. accurate/positively estimated memories) on expectations of future pain and changes in pain reporting over time. This research study utilized baseline

data obtained from the first study as well as data from an additional laboratory visit wherein the same children completed a second experimental pain induction task. In addition, measures of children's expectancies about subsequent pain, as assessed during the telephone interview, were used. It was hypothesized that, similar to adults (Gedney & Logan, 2006), children's memory for pain would be a unique and better predictor of subsequent pain reporting than their actual initial pain reporting. It was also hypothesized that children who developed pain memories that were negatively estimated, as compared to children whose memories were accurate or positively estimated, would have higher levels of anxiety, expect to experience more pain and fear during a subsequent pain experience, and would show greater increases in pain reporting over time.

Together, these studies were designed to refine our understanding of the influence of anxiety on children's memories for both the somatosensory (i.e., pain intensity) and affective (e.g., pain-related fear) aspects of pain, as well as to provide evidence for the influence of pain memories on subsequent pain reporting among healthy children who are repeatedly exposed to acute pain during childhood and adolescence.

CHAPTER 2:
THE ROLE OF STATE ANXIETY IN CHILDREN'S MEMORIES FOR PAIN

The manuscript based on this study is presented below. Readers are advised that Melanie Noel, under the supervision of Dr. Christine Chambers, developed the research questions, methodology, and analytical approach for this research. She was responsible for developing the study protocol and proposal, applying for and obtaining funding to support this research, applying for and obtaining ethics approval, and overseeing all data collection. She conducted all of the background research and literature review for this manuscript and was responsible for all aspects of the writing process. Prior to submission, she received editorial feedback from the study's co-authors/co-investigators (i.e., dissertation committee members and Dr. Sherry Stewart). This manuscript underwent editorial and peer-review and was accepted for publication in the *Journal of Pediatric Psychology* following one revision on January 18, 2012. Prior to acceptance, Melanie Noel was responsible for preparing the response to reviewers' and editor's comments as well as all manuscript revisions. Once again, she received editorial feedback from the study's co-authors/co-investigators. The full reference for this manuscript is:

Noel, M., Chambers, C. T., McGrath, P. J., Klein, R. M., & Stewart, S. H. (2012). The role of state anxiety in children's memories for pain. *Journal of Pediatric Psychology*. DOI 10.1093/jpepsy/jss006

Abstract

Objective: To investigate the impact of experimentally manipulated state anxiety and the influence of anxiety-related variables on children's memories for pain. Methods: One hundred ten children (60 boys) between the ages of 8 and 12 years were randomly assigned to complete a state anxiety induction task or a control task. Following experimental manipulation, children completed a laboratory pain task, pain ratings, and questionnaire measures of anxiety-related variables. Two weeks later, children provided pain ratings based on their memories of the pain task. Results: The experimental manipulation effectively induced state anxiety; however, pain memories did not differ between groups. Irrespective of group assignment, children with higher state anxiety had more negative pain memories. State anxiety uniquely predicted children's pain memories over and above other well established factors. Anxiety sensitivity and trait anxiety were significant predictors of recalled pain-related fear. Conclusions: These data highlight the importance of anxiety in the development of children's memories for pain.

Keywords: anxiety sensitivity; children; fear, memory, pain; state anxiety, trait anxiety.

The Role of State Anxiety in Children's Memories for Pain

Medical procedures including immunizations and venipunctures are a common source of pain in childhood (Public Health Agency of Canada, 2006). In addition to experiencing pain during medical procedures, many children also experience fear before procedures even begin, which can heighten a child's pain perception (Rhudy & Meagher, 2003). The impact of pain and fear can persist long after medical procedures end; the manner in which children remember painful experiences can influence how they cope with and manage future painful procedures (Chen, Zeltzer, Craske, & Katz, 2000). Pain memories are rooted early in life (for reviews see: Ornstein, Manning, & Pelphrey, 1999; von Baeyer, Marche, Rocha, & Salmon, 2004). Children as young as 6 months of age can form memories of painful procedures that then influence their reactions to future painful procedures (Taddio, Katz, Ilersich, & Koren, 1997; Weisman, Bernstein, & Schechter, 1998)¹. Early pain memories can persist into adulthood and influence the level of fear and avoidance of medical care later in life (Pate, Blount, Cohen, & Smith, 1996). It has been suggested that memories for pain may initiate the development and maintenance of chronic pain syndromes over time (Flor & Birbaumer, 1994; Sun-ok & Carr, 1999). In fact, memories for pain are often a better predictor of future pain experiences than the initial experience of pain itself (Gedney & Logan, 2006).

Although young children's recall of previous painful experiences can be accurate (Badali, Pillai, Craig, Geisbrecht, & Chambers, 2000; Lander, Hodgins, & Fowler-Kerry, 1992), remembering is an interpretive process and memories are continually being reconstructed, which makes them susceptible to distortion over time (Bruck, Ceci, Francoeur, & Barr, 1995). Negatively distorted memories of painful medical procedures

have been linked to greater distress during subsequent procedures (Chen, Zeltzer, Craske, & Katz, 1999). Furthermore, the level of distress that children experience during painful procedures influences the manner in which pain memories are framed. Across a range of medical procedures, children who report higher levels of pain and distress (e.g., trait anxiety, pain intensity, behavioral distress) tend to develop negatively exaggerated pain memories (Chen, Zeltzer, Craske, & Katz, 2000; Noel, McMurtry, Chambers, & McGrath, 2010; Rocha, Marche, & von Baeyer, 2009); however, this research has primarily been correlational, which has precluded examination of the causal impact of distress on memory.

Theorists have posited that memory biases exist because highly trait anxious individuals selectively encode and/or retrieve threatening information (Eysenck, Derakshan, Santos, & Calvo, 2007), particularly when those individuals experience high levels of state anxiety (i.e., short-term anxiety that arises in threatening situations; Beck & Clarke, 1997). However, research has largely neglected investigating the role of state anxiety in children's memories for pain, perhaps due to previous assertions of a lack of relationship between the two (Lander et al., 1992; Versloot, Veerkamp, & Hoogstraten, 2008), which could have been due to methodological issues (e.g., timing of the measurement of state anxiety, reliance on parent- versus self- report measures). Moreover, no study to date has directly examined the impact of state anxiety prior to an acute pain experience on children's memories for pain.

In addition to trait and state anxiety, anxiety sensitivity (i.e., the fear of anxiety-related sensations) could also influence children's pain memories. Anxiety sensitivity is a trait-like variable that is thought to heighten one's propensity to experience anxiety which

then increases pain perception (Schmidt & Cook, 1999; Stewart & Asmundson, 2006). Indeed, there is evidence of a robust relationship between child anxiety sensitivity and pain-related anticipatory anxiety, which is a strong predictor of children's pain ratings during laboratory pain (Tsao, Lu, Kim, & Zeltzer, 2006). In addition, anxiety sensitivity in adults has been found to be related to memory biases toward threat-related information (McCabe, 1999). Nevertheless, no study has examined the influence of anxiety sensitivity on children's memories for pain, particularly in the context of other important anxiety-related variables.

The current laboratory-based study investigated the impact of experimentally manipulated state anxiety on children's memories for pain. The impetus for inducing state anxiety among children in the present study was to examine the impact of state anxiety on pain memories as well as to ensure sufficient variability in levels of state anxiety among children immediately prior to completing the pain task. Unlike medical procedures, children do not report being anxious prior to completing laboratory pain induction tasks like the cold pressor task (Tsao, Myers, Craske, Bursch, Kim, & Zeltzer, 2004; Wilby, Chambers, & Perrot-Sinal, 2010). As such, induction of state anxiety was also deemed necessary in order to establish a greater degree of ecological validity and to provide a more accurate analogue of a clinical medical procedure context. Therefore, in addition to investigating the impact of experimentally induced state anxiety on pain memories, it was also of conceptual interest to examine state anxiety as a continuous variable that varied among children and that might impact the framing of their pain memories. As such, this study also examined the influence of anxiety-related individual difference variables on children's recall of pain using a correlational design. It was

hypothesized that children in the state anxiety induction group would have more negative pain memories than children in the control group. Additionally, it was hypothesized that children with higher scores on a variety of anxiety-related questionnaires (state and trait anxiety, anxiety sensitivity) would also have more negative memories of pain.

Method

The data for this paper was collected as part of a larger study examining two distinct research questions that are presented in two empirical papers. The present paper examined the impact of state anxiety on children's memories for experimental pain, as well as the influence of anxiety-related individual difference variables on their recall. The other paper by Noel et al. (in press) examined the influence of children's pain memories on their expectations and experience of a subsequent painful experience, through investigation of changes in children's distress during multiple exposures to the same pain stimulus over time. This other paper utilized data obtained from an additional laboratory visit, which was not included in the present paper and is not relevant to the research questions or aims of the present investigation. As a result, the methods reported below contain only those details relevant to the present study and are an abbreviated version of the larger study protocol. All study materials and procedures were approved by the health center research ethics board (REB).

Participants

Participants were 110 healthy children (60 boys, 50 girls; $M_{age} = 9.45$ years, $SD = 1.35$) and one of their parents/guardians (99 mothers, 1 stepmother, 9 fathers, 1 stepfather; $M_{age} = 40.3$ years; $SD = 5.94$). By parent-report, the majority of participating children and parents were identified as "white" (86.4%; $n = 95$). The educational

breakdown of the parents was self-identified as follows: (a) graduate school/professional training ($n = 30$); (b) university graduate ($n = 39$); (c) partial university (i.e., at least 1 year) ($n = 5$); (d) trade school/community college ($n = 25$); (e) high school graduate ($n = 9$); or (f) some high school ($n = 2$). Children in the state anxiety induction group did not differ from children in the control group on any of the demographic variables (e.g., age, sex, ethnicity, parental education).

In order to participate in the study, children had to be between 8 and 12 years of age and accompanied by a parent/guardian. Participants were excluded from the study if they did not speak English as a first language or had developmental delays or significant hearing or vision impairments. Participants were also excluded if children had been diagnosed with an Anxiety Disorder or Attention Deficit Hyperactivity Disorder and/or had chronic illnesses or health-related medical conditions, including: circulation disorders; heart problems; injuries to their arms or hands. In order to ensure that memory for the experimental pain task was not affected by previous scripts of similar pain experiences, children who had previously completed the experimental pain task (the cold pressor task) were excluded. Finally, children were excluded from the study if they experienced pain (such as headaches, stomach aches, ear/throat pain, muscle or joint pain) on a regular basis (i.e., at least once a month for 3 consecutive months) that was typically of moderate or severe intensity, that interfered with school or social functioning, and/or for which they took medication. Following enrolment, no families withdrew from the study and no adverse events were reported.

Measures

Pain Intensity

Pain intensity was measured using the one-item Faces Pain Scale-Revised (FPS-R; Hicks, von Baeyer, Spafford, van Korlaar, & Goodenough, 2001). The FPS-R consists of six gender-neutral faces depicting “no pain” (neutral face) to “most pain possible” expressions. Children select a face that represents how much pain she/he feels and the faces are scored: 0, 2, 4, 6, 8, and 10. The FPS-R is the most psychometrically sound self-report measure of pain intensity in children between the ages of 4 and 12 years (Stinson, Kavanagh, Yamada, Gill, & Stevens, 2006).

Pain-related Fear

Pain-related fear was measured using the one-item Children’s Fear Scale (CFS; McMurtry, Noel, Chambers, & McGrath, 2011), which was adapted from the Faces Anxiety Scale (McKinley, Coote, & Stein-Parbury, 2003). The CFS consists of five faces representing varying degrees of anxiety/fear. Children are instructed to select a face that represents how scared she/he feels and the ordered faces are scored from 0 to 4. The CFS has shown good evidence of test-retest ($rs = .76, p < .001$) and inter-rater ($rs = .51, p < .001$) reliability as well as construct validity among children (McMurtry et al., 2011).

Anxiety

Visual Analogue Scale

Using a 10 cm visual analogue scale (VAS) with the anchors “not nervous/anxious” and “most nervous/anxious”, children provided self-report ratings (VAS-child) and parents provided proxy ratings (VAS-parent) of children’s state anxiety. Possible scores ranged from 0.00 cm to 10.00 cm. VASs have previously been used to

measure child anxiety among children (Chen, Craske, Katz, Schwartz, & Zeltzer, 2000) and parents (Smith, Shah, Goldman, & Taddio, 2007). There is evidence for the validity of a 10 cm VAS to assess perioperative anxiety among children aged 7-16 years of age (Bringuier et al., 2009).

State Trait Anxiety Inventory for Children (STAIC; Spielberger, 1973)

Children's state and trait anxiety was measured using the STAIC. The STAIC consists of both state and trait subscales containing 20 items each. The items on the state subscale of the STAIC (STAIC-s) ask children to rate how they feel at a particular moment in time. The tool was designed to measure transitory anxiety states (i.e., subjective and consciously perceived feelings of state anxiety that vary in intensity and that can fluctuate over time), which are typically elevated in stressful situations. The items on the trait subscale of the STAIC (STAIC-t) ask children to rate how they generally feel and measures relatively stable individual differences in the tendency to experience anxiety states and perceive situations as threatening. The STAIC-s has been found to have good internal consistency (Cronbach's alpha = .82-.87) and evidence of construct validity. Similarly, the STAIC-t shows evidence of good internal consistency (Cronbach's alpha = .78-.81) and concurrent validity (Spielberger, 1973). Given the strong psychometric properties of the STAIC-s, this measure was used as the operationalization of state anxiety in all primary analyses.

Anxiety Sensitivity

Anxiety sensitivity was measured using the Childhood Anxiety Sensitivity Index (CASI; Silverman, Fleisig, Rabian, & Peterson, 1991), which consists of 18 items that assess the tendency to interpret anxiety-related bodily sensations as threatening

(e.g., “It scares me when I have trouble getting my breath”). The CASI has been found to have adequate test-retest reliability (range = .62-.78 over 2 weeks) and high internal consistency ($\alpha = .87$; Silverman et al., 1991). Although the measure has a moderate correlation with trait anxiety ($r = .55-.69$), the construct explains variance in fear that is unaccounted for by trait anxiety (Weems, Hammond-Laurence, Silverman, & Ginsburg, 1998).

State Anxiety Induction Task

Children assigned to the state anxiety induction group completed a modified version of the Trier Social Stress Task for Children (TSST-C; Buske-Kirschbaum et al., 1997), in which they *anticipated* having to complete the task versus actually completing it. Like the unmodified task, the modified version used in the current study involved bringing children into a room containing 3 chairs, a table, three clipboards containing red pens and rating tools, a television, and a video camera on a tripod. Children completing the TSST-C were told that they would be asked to prepare and deliver a speech in front of 3 judges who were doctors and researchers in the hospital and who had experience judging public speaking competitions with children their age. They were told that the judges would be rating and evaluating their speeches for quality and that they would be videotaped during that time. Children were instructed that they would have 4 minutes to prepare the speech and 4 minutes to deliver the speech. Then, they were told that they would be asked to complete a difficult mental arithmetic task by subtracting specific numbers and that every time they provided an incorrect answer, they would be asked to complete the arithmetic task once again from the beginning. Finally, children were told that many children considered the task to be difficult and that the judges would be

arriving soon². The TSST-C involves elements (e.g., uncontrollability, unpredictability, threats to the social self) that have been identified as being strong psychological triggers of the HPA axis that regulates the release of cortisol (i.e., the stress hormone; see Dickerson & Kemeny, 2004; Gunnar, Talge, & Herrera, 2009). Several studies have shown that the TSST-C and modifications of the task are successful in provoking heightened self-perceptions of stress and anxiety among children (Buske-Kirschbaum et al., 1997; Buske-Kirschbaum et al., 2003; Gunnar, Frenn, Wewerka, & Van Ryzin, 2009; Stroud et al., 2009). Moreover, anticipation of completing the TSST versus actual completion of the task—which was the modified version of the TSST-C used in the present investigation—has been shown to be as effective in eliciting a stress/anxious response (e.g., increased subjective anxiety, perceived stress, heart rate, cortisol) as the actual completion of the task (Hermann, Vogl, & Maras, 2004).

Control Task

Children assigned to the control group were brought into the same room as children in the state anxiety induction group (described above) and were told that they would be asked to watch a nature video from the video series “Planet Earth” that showed different animals and wildlife. They were reassured that the video camera would not be used for them. Children were instructed that they would watch the video for 12 minutes and were told that many children thought that the videos were interesting.

Cold Pressor Task

The cold pressor task is an ethically acceptable pain induction technique for use with children (Birnie, Noel, Chambers, von Baeyer, & Fernandez, 2011). It involves children submersing their non-dominant hand up to their wrist fold into 10 degree Celsius

water for an informed ceiling of 4 minutes. Children were asked to leave their hand in the water even if it was uncomfortable; however, they were told that they could remove their hand at any time if it became too uncomfortable or painful to leave it in. The cold pressor device was a commercially manufactured plastic cooler filled with water with a temperature that was maintained at $10^{\circ}\text{C} \pm 1^{\circ}\text{C}$ (in keeping with published guidelines; von Baeyer, Piira, Chambers, Trapanotto, & Zeltzer, 2005). A plastic screen separated the cooler into two sections and ice cubes were placed in the first section to cool the water. The device measured 43.5 cm long, 23.5 cm wide, and 28.0 cm deep. Children lowered their hand into the water in the second section through a round opening (13 cm in diameter) in the lid of the cooler. A bilge pump circulated the water to prevent local warming around the child's hand.

Procedure

Participants were recruited using paper and online advertisements distributed in the community surrounding the health centre. Interested parents contacted the research centre by telephone and completed a series of screening questions to determine study eligibility. Following screening, participating families came to the research centre for an initial visit. Parents and children were separated from each other and remained separated for the entire testing session. Parents provided full and informed consent from a separate adjoining room and watched the entire experiment via video monitors. Children provided assent; however, they were not fully informed about the nature of the experimental or control conditions (i.e., that they would not actually be required to fully complete the tasks). They were also not aware about the memory component of the study in order to ensure that their experience and ratings would not be affected by knowledge that their

memories for the pain task would later be assessed. Following provision of assent, children completed the VAS-child to assess their baseline level of anxiety. Then, a different research assistant disclosed to the children to which group they had been randomly assigned. This research assistant assumed a serious demeanour whereas the research assistant who obtained assent from children assumed a friendly demeanour. Next, children were led into the experimental room and given instructions for their respective groups. Immediately following administration of the instructions and while anticipating having to complete the experimental or control tasks, children rated their level of state anxiety on the VAS-child and the STAIC-s. After watching their children receive the instructions via video, parents concurrently provided proxy ratings of children's levels of state anxiety on the VAS-parent. Immediately after measures of state anxiety were completed, children were taken into a separate testing room and completed the cold pressor task. Immediately after children removed their hands from the water, they completed measures of pain intensity and pain-related fear using the FPS-R and the CFS. The administration order of these scales was counterbalanced across children. Next, children were brought into a waiting room and the research assistant who obtained assent informed them that they did not have to complete the speech ("the judge could not make it") or watch the video ("the video equipment is not working"). Children then completed measures of trait anxiety and anxiety sensitivity using the STAIC-t and the CASI. The administration order of these scales was counterbalanced across children.

Prior to leaving the laboratory, parents were given a sealed envelope containing copies of the pain intensity and pain-related fear scales, which were individually contained in sealed and numbered envelopes. Parents were asked to refrain from opening

the sealed envelope until a researcher called them to conduct the memory interview. They were also asked to minimize discussion about the experiment in the interim between the laboratory visit and subsequent telephone interview. Children were aware that a research assistant would call them in approximately two weeks to ask them questions; however, they were not aware that they would be asked about their memories of the pain experience. Prior to leaving the laboratory, appointments to conduct the telephone interviews were scheduled with parents.

Approximately two weeks following the laboratory visit ($M = 14.00$ days, $SD = 1.24$ days, $Range = 9-19$ days), parents were contacted over the telephone to conduct the memory interviews. Telephone interviews for research on children's memory for cold pressor, venipuncture, and postoperative pain have been effectively conducted with children (Badali et al., 2000, Lander et al., 1992; Noel et al., 2010; Zonneveld, McGrath, Reid, & Sorbi, 1997). Previous memory research has used time frames ranging from one week to one year (e.g., Chen et al., 2000; Badali et al., 2000). The present study employed a 2-week time frame in an attempt to limit exclusions as a result of intervening pain experiences and attrition. This attempt was successful in that all participants (100%) who participated in the initial laboratory visit completed the telephone interviews. At the beginning of the interview, parents were asked to refrain from influencing their children's responses so as to not bias their recall. The memory assessment followed a similar protocol to that used with children aged 5 to 10 years in previous research examining children's memory for venipuncture and cold pressor pain (Badali et al., 2000; Noel et al., 2010). During the memory interview, children could not physically point to the faces in front of the researcher as they had done immediately following completion of the CPT.

Therefore, to facilitate ease of telephone communication and to avoid introducing a confounding numerical scale, letters of the alphabet were placed in random order under the faces on each of the scales used during the telephone interviews. Children were reinstructed in the use of each rating scale and oriented to the placement of letters under each face. The order of scale presentation was counterbalanced and randomly numbered from 1 to 2 for ease of telephone communication. Children were asked to recall when they completed the CPT and provided pain intensity and pain-related fear ratings based on their memories of the pain task.

Results

Data Analysis

To determine if the experimental manipulation was effective in inducing state anxiety among children, independent samples t-tests were conducted between children in the state anxiety induction group and the control group on all state anxiety measures obtained immediately after completion of the TSST-C. Next, a series of between subjects analyses of covariance (ANCOVA) were conducted between the groups on their recalled pain and pain-related fear scores while controlling for initial pain intensity and pain-related fear scores. In order to examine the relative influences of anxiety-related variables on children's recall, bivariate correlations were first conducted between key variables to justify their inclusion in predictive models. Similar to the approach taken by Gedney and Logan (2004), hierarchical linear regression modeling was used to test the ability of state anxiety (STAIC-s) to account for variance in 2-week recall of pain intensity and pain-related fear. Preliminary analyses revealed that girls had higher levels of baseline state anxiety [VAS-child; $M = 3.56$, $SD = 2.40$; $M = 2.63$, $SD = 2.28$, respectively;

$t(108) = 2.08, p < .05$], anxiety sensitivity [$M = 29.06, SD = 5.21$; $M = 26.47, SD = 5.03$, respectively; $t(108) = 2.65, p < .01$] and trait anxiety [$M = 34.44, SD = 6.32$; $M = 32.00, SD = 6.34$, respectively; $t(108) = 2.01, p < .05$] than boys. Therefore, sex was controlled in the first step of all regression models. Stable anxiety-related variables (trait anxiety and anxiety sensitivity) were entered in step 2³, followed by baseline pain intensity and pain-related fear ratings in step 3. Finally, state anxiety (STAIC-s) was entered in step 4 to predict recall scores. Descriptive data for all included measures obtained at baseline, immediately post-pain task, and during recall for the total sample and each experimental condition are shown in Table 2.1.

Manipulation Check

Prior to being told which group they were in, children in the state anxiety induction group did not differ from children in the control group in their baseline levels of state anxiety [VAS-child; $t(108) = .61, p > .05, \eta_p^2 = .00$]. They also did not differ in levels of trait anxiety [$t(108) = -1.40, p > .05, \eta_p^2 = .02$] or anxiety sensitivity [$t(108) = -1.37, p > .05, \eta_p^2 = .02$]. However, following completion of the experimental and control tasks, children in the state anxiety induction group had significantly higher levels of state anxiety than children in the control group as measured by both the child [$t(108) = 4.88, p = .000, \eta_p^2 = .18$] and parent [$t(108) = 7.75, p = .000, \eta_p^2 = .36$] VAS and the STAIC-s [$t(82.32) = 4.10, p = .000, \eta_p^2 = .14$]⁴. Furthermore, a 2 (group) X 2 (time) repeated measures analysis of variance (ANOVA) conducted on the baseline and post-manipulation VAS-child scores revealed a significant interaction [$F(1, 108) = 22.12, p = .000, \eta_p^2 = .17$]. Subsequent paired samples t-tests revealed that child state anxiety as measured by the VAS-child significantly increased from baseline to post-

manipulation for the state anxiety induction group only [$t(108) = -5.88, p = .000$]. This suggests that state anxiety was successfully manipulated and was higher among children in the state anxiety induction group as compared to children in the control group.

Impact of Experimentally Manipulated State Anxiety on Pain Memories

To determine the impact of experimentally manipulated state anxiety on children's memories for pain, a series of between-subjects ANCOVAs were conducted between the state anxiety induction and control groups on remembered pain intensity and pain-related fear scores, while controlling for initial pain intensity and pain-related fear scores. Despite successful manipulation of state anxiety among children in the state anxiety induction group, there were no significant differences between children in the experimental and control groups on their memories for pain intensity [$F(1, 107) = 0.45, p > .05, \eta_p^2 = .004$] or pain-related fear [$F(1, 107) = 0.04, p > .05, \eta_p^2 = .00$].

Correlations between Key Variables

Overall, children who had higher levels of state anxiety (STAIC-s) immediately after exposure to the experimental and control task instructions recalled significantly higher levels of pain intensity ($r = .21, p < .05$) and pain-related fear ($r = .26, p < .01$) than children who had lower levels of state anxiety. Children with higher levels of trait anxiety and anxiety sensitivity recalled higher levels of pain-related fear ($r = .27, p < .01$; $r = .28, p < .01$, respectively). Trait anxiety and anxiety sensitivity were significantly positively correlated with each other ($r = .64, p < .001$). Experienced pain intensity was significantly positively correlated with experienced pain-related fear ($r = .27, p < .01$) and both experienced pain intensity and pain-related fear were significantly positively correlated with recalled pain intensity ($r = .70, p < .01$; $r = .32, p < .01$, respectively) and

pain-related fear ($r = .49, p < .001$; $r = .49, p < .01$, respectively). These significant correlations in addition to theoretical and empirical support (e.g., Beck & Clark, 1997; Gedney & Logan, 2004; McNally, 1995; 1999) justify the inclusion of these variables in the regression models.

Influence of Anxiety-Related Variables on Pain Memories

Table 2.2 presents results for all groups reporting the effect of sex, stable anxiety-related variables, experienced pain intensity, and state anxiety (STAIC-s) in predicting recalled pain intensity. After controlling for sex, stable anxiety-related variables (trait anxiety and anxiety sensitivity), and experienced pain intensity, state anxiety accounted for a significant portion of variance in recalled pain intensity. As expected, experienced pain intensity was also a unique predictor of recalled pain intensity. Collectively, this model accounted for 52% of the variance in recalled pain intensity.

Table 2.3 presents results for all groups reporting the effect of sex, stable anxiety-related variables, experienced pain-related fear and state anxiety (STAIC-s) in predicting recalled pain-related fear. After controlling for sex, stable anxiety-related variables (trait anxiety and anxiety sensitivity), and experienced pain-related fear, state anxiety accounted for a significant portion of variance in recalled pain-related fear. As expected, experienced pain-related fear was also a unique predictor of recalled pain intensity. Stable anxiety-related variables (trait anxiety and anxiety sensitivity) also accounted for a significant portion of the variance in recalled pain-related fear. Collectively, this model accounted for 35% of the variance in recalled pain-related fear.

Discussion

Children's memories for pain have implications for their health throughout life (Chen et al., 2000; Pate et al., 1996). Although the role of trait anxiety in pain memories has been previously investigated (Rocha et al., 2009), far less is known about the role of state anxiety in children's memories for pain. This study represents the first examination of the impact of state anxiety on children's memories for pain. It also extends research by examining the influence of general levels of state anxiety on children's pain memories over and above the contributions of other well established factors implicated in those memories (e.g., experienced pain intensity and pain-related fear, and stable anxiety-related variables). Although state anxiety was successfully manipulated among children who underwent the state anxiety induction task (TSST-C), children in the experimental group did not develop pain memories that were more negative than those of children in the control group. However, irrespective of group assignment, children who reported higher levels of state anxiety recalled higher levels of pain intensity and pain-related fear than children with lower levels of state anxiety. Furthermore, the influence of state anxiety on pain memories persisted over and above the contributions of sex, trait anxiety, anxiety sensitivity and the powerful influence of pain intensity and pain-related fear experienced at baseline. Collectively, these models accounted for a large portion of the variance in children's memories of pain intensity and pain-related fear (52%, 35%, respectively). This extends research on adult acute pain experiences (Gedney & Logan, 2004) to provide a similar model for earlier developmental periods.

There are several possible reasons why children in the state anxiety induction group did not have more negative memories than children in the control group; but, that

irrespective of group, state anxiety was a significant predictor of pain memories. First, by comparing experimental groups using ANOVA (i.e., analyzing state anxiety as a categorical variable), there was less power to detect effects as compared to analyzing state anxiety continuously (Aiken & West, 1991). Moreover, the individual variation in state anxiety among children within each experimental group following the manipulation (e.g., higher state anxiety among some children in the control group; lower state anxiety among some children in the state anxiety induction group) was treated as random/error variance in ANOVA. Conversely, in the regression models, the individual variability in state anxiety among children in each group (when treated as a continuous variable) was used to predict individual memory scores, thereby capturing individual variation among children and creating power to detect effects. Second, there were likely other trait variables that were not accounted for in the current study such as individual coping style/ attentional orientation (see Krohne 1993), which could have influenced whether or not individuals exhibited state anxiety in response to experimental instructions. Indeed, the relationship between anxiety and memory is thought to be mediated through attention, and high anxious individuals may differ in their attentional style (e.g., hypervigilant vs. avoidant of pain cues; see Krohne, 1993; Noel et al., 2011). This could have introduced additional variability within experimental groups that might have obscured the ability to detect effects using ANOVA. Future research should investigate the impact of individual attentional style among highly anxious children to determine its impact on the development of their pain memories. Finally, regression models, unlike ANOVA, allowed for examination of the *relative* contribution of varying degrees of state anxiety on pain memories that were contextualized among the contributions of other important

factors (e.g., sex, experienced pain and pain-related fear, stable anxiety-related variables). The relationship between state anxiety and children's pain memories is likely complex and therefore examination of other factors that impinge on this relationship may be necessary to fully understand it.

The limited research that has previously examined state/pre-procedural anxiety and children's pain memories concluded a lack of relationship when assessed in clinical contexts (e.g., venipuncture, dental treatment; Lander et al., 1992; Versloot et al., 2008). However, limitations inherent in these study designs might have precluded accurate assessment of this relationship. For example, among children undergoing dental treatment, pre-procedural pain was inferred by parent report of general dental fears that were not necessarily specific to the procedure that children later recalled. Moreover, these parents were not present during the dental treatments and therefore did not directly observe their children in the procedural context. Among children who underwent venipunctures (Lander et al., 1992), it is unclear whether or not state anxiety was measured immediately prior to the pain experience. Moreover, given the unpredictability inherent in clinical settings, it is unlikely that the duration between assessment of state anxiety and pain exposure was consistent across children, which could have introduced measurement error. The present laboratory-based study offers advantages over these previous investigations by enabling standardization of these variables across children. The fact that state anxiety was a significant predictor of more negative pain memories, even over and above the influences of stable anxiety-related variables and experienced pain, suggests that children who perceive themselves as being relatively more anxious immediately prior to a painful experience are at risk for developing negative pain

memories. Although children higher in trait anxiety and anxiety sensitivity are more likely to experience relatively higher levels of state anxiety, this is not a perfect relationship and fails to capture the range of children who might exhibit higher levels of state anxiety prior to a painful experience (Tsao, Lu, Kim, & Zeltzer, 2006; Dorn et al., 2003). Children who are relatively less high in trait anxiety or anxiety sensitivity yet who still exhibit higher levels of state anxiety in a procedural context may not be identified *a priori* as being at risk for having negative pain experiences that could later shape their pain memories. Nevertheless, the present research suggests that children who have higher levels of state anxiety are at risk for developing negative pain memories, which could negatively affect their subsequent pain experiences. This implies that identification of, and intervention with, children with relatively higher levels of state anxiety in the immediate pain context may also be important for preventing such longitudinal outcomes.

The relationship between trait anxiety and children's pain memories (Rocha et al., 2008) has been previously documented. Furthermore, there is a wealth of literature documenting the effect of trait anxiety (see review in Mitte, 2008) and anxiety sensitivity (for discussion see Noel et al., 2011) on memory for threatening information among adults. However, this is the first study to examine the relative contributions of stable anxiety-related variables, initial pain experience, and state anxiety to children's pain memories. In addition to state and trait anxiety, the present study demonstrated the importance of anxiety sensitivity in influencing children's memories of pain-related fear. To date, no study has examined the role of anxiety sensitivity (i.e., the fear of anxiety-related symptoms) in children's memories for pain. Anxiety sensitivity is thought to heighten one's susceptibility to experience anxiety which then increases pain perception

(Schmidt & Cook, 1999; Stewart & Asmundson, 2006). It is also thought that anxiety sensitivity promotes catastrophic cognitions about pain and the development of fear of pain (see Norton & Asmundson, 2004). Indeed, previous research revealed a robust relationship between child anxiety sensitivity and pain-related anticipatory anxiety, which is strongly predictive of children's ratings of laboratory pain intensity (Tsao et al., 2006). The present study suggests that higher levels of anxiety sensitivity in addition to trait anxiety are predictive of more negative memories of pain-related fear but not pain intensity. This also suggests that children's memories of pain-related fear, although related to their memories of pain intensity, encompass a unique aspect of children's remembered pain experience. Memories of pain are multidimensional and involve representations of sensory (i.e., pain intensity), affective (i.e., fear/anxiety), and contextual aspects of the pain experience (Ornstein et al., 1999). Despite this, the majority of research on children's memories for pain has primarily focused on recalled pain intensity as opposed to recalled pain-related fear (for an exception see Noel et al., 2010). Although memories for pain intensity and pain-related fear are related to one another, they reflect different aspects of the pain experience and have different relationships with established predictors of pain and pain memories (e.g., anxiety sensitivity and trait anxiety). Future research should further examine aspects of pain memories beyond the somatosensory representation in order to better capture the complexity inherent in children's memories for pain.

In addition to several strengths, the present research had some potential limitations that highlight avenues for future empirical investigation in this area. First, the children included in the present study were healthy and did not have clinically significant

levels of anxiety that warranted diagnosis of an anxiety disorder. As such, the generalizability of these findings to clinical samples of children with high levels of anxiety is currently unknown. Second, the research largely relied on self-report measures reflecting children's subjective perceptions of their own levels of anxiety, pain intensity, and pain-related fear. Future examinations should assess anxiety and pain using a variety of measurement tools, including physiological and behavioural measures, as well as self- and proxy-report completed by different informants (e.g., children, parents, experimenters), as this would likely refine our understanding of the nature of these relationships. Finally, the anxiety-related measures used in the current study assessed children's general levels of anxiety (i.e., their general tendency to perceive threat in their environments), as opposed to anxiety that is specific to pain-related threat. Indeed, similar to the present findings, previous research has shown that both anxiety sensitivity and trait anxiety are not consistently related to healthy children's initial pain ratings following cold pressor pain induction in laboratory settings (Tsao et al., 2004). Moreover, although anticipatory anxiety related to pain has been found to strongly predict children's initial pain reports (Tsao et al., 2004), the measure of state anxiety used in the current study did not assess state anxiety that was specific to pain; rather, children's general levels of anxiety following exposure to task instructions was assessed. The lack of relationship between general state anxiety and experienced pain is consistent with previous research (Arntz, van Eck & Heijmans, 1990; Lander et al., 1992). On the other hand, the relationships between these general anxiety-related variables and children's pain memories were expected and were likely found because higher scores on the anxiety-related measures reflected a tendency for children to develop more catastrophic

cognitions, characterized by amplified perceptions of threat. These types of cognitions and associated appraisals could have contributed to negative exaggerations in memory over time as children recalled the pain experience in the interim between the first laboratory visit and the telephone interview. It is also possible that although children were instructed to provide recall ratings based on how they specifically felt about the pain task, their recalled pain ratings could have also reflected their perceptions of the overall emotional context surrounding the pain experience (i.e., the general level of threat that they perceived in their environments before and during the pain task) and not solely the somatosensory or affective experience related to pain. Future investigations should increase the specificity of anxiety constructs for pain contexts through the use of recently developed measures of pain-specific anxiety and fear (e.g., Pediatric Pain Fear Scale, Huguet, McGrath, & Pardos, 2011; Child Pain Anxiety Symptoms Scale, Pagé, Fuss, Martin, Escobar, & Katz, 2010). Such examinations could potentially increase the explanatory power of the models presented herein.

The impact of pain and fear is not over when the painful stimulus is removed. The quality of children's pain experiences can influence the development of their pain memories over time. Although the relationship between children's initial pain experience (e.g., self-reported pain intensity, behavioral distress), trait anxiety, and pain memories has been previously established (Chen et al., 2000, Noel et al., 2010, Rocha et al., 2009), the present study extends this research by showing that state anxiety is also an important and unique predictor of children's memories for pain. This implies that children who report higher levels of state anxiety (irrespective of their natural tendencies to experience anxiety and fear and the quality of their initial pain experiences) will likely develop more

negative pain memories. Previous research also suggests that these children may be at risk for experiencing greater distress at subsequent painful experiences (Chen et al., 2000) and developing fear and avoidance of medical care into adulthood (Pate et al., 1996). The present study also extends previous research by showing that anxiety sensitivity in addition to trait anxiety is an important predictor of the development of children's memories for pain-related fear. There is evidence suggesting that a brief cognitive-behavioral intervention designed to reduce anxiety sensitivity among high anxiety sensitive individuals results in concomitant reductions in pain-related fear and anxiety in adults (Watt, Stewart, LeFaivre, & Uman, 2006). Although this has yet to be examined among children, it suggests potential avenues for intervention which could prevent the development of negative pain memories from forming.

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Conflicts of interest: None declared.

Footnotes

¹ These studies demonstrated that previous painful experiences could cause changes in infants' behavioral reactions to subsequent pain, suggesting that the infants were sensitized to pain. As noted in a review by von Baeyer et al. (2004), it is possible that these infants had learned to anticipate pain cues and formed some form of long-term memory of the pain experience. These types of long-term memories are implicit (unconscious, nonverbal) and differ from explicit memories (conscious, verbal).

² A copy of the experimental and control group scripts used in this study are available from the corresponding author upon request.

³ When trait anxiety and anxiety sensitivity were each entered alone in Step 2 of each regression model, the results did not change and state anxiety continued to be a unique and significant predictor of recalled pain intensity and pain-related fear.

⁴ The t-value with unequal variances assumed was used given that Levene's Test for Equality of Variances was significant.

Table 2.1

Descriptive data for measures obtained at baseline, immediately post-pain task, and during recall for the total sample and each experimental condition

Variables	Total Sample (<i>N</i> = 110)	State Anxiety Induction Group (<i>n</i> = 55)	Control Group (<i>n</i> = 55)
	<i>M</i> (<i>SD</i>) <i>Range</i>	<i>M</i> (<i>SD</i>) <i>Range</i>	<i>M</i> (<i>SD</i>) <i>Range</i>
Baseline state anxiety (VAS-child)	3.05 (2.37) .00-9.70	3.19 (2.26) 0.00-8.10	2.91 (2.49) 0.00-9.70
State anxiety post- manipulation (VAS- child)	3.46 (2.60) 0.00-10.00	4.56 (2.51) 0.00- 10.00	2.36 (2.22)*** 0.00-7.25
State anxiety post- manipulation (STAIC-s)	29.07 (4.98) 21.00-49.00	30.89 (5.81) 21.00-49.00	27.25 (3.09)*** 12.00-22.00
State anxiety post- manipulation (VAS-parent)	4.61 (2.83) 0.00-10.00	6.30 (2.23) .25-10.00	2.93 (2.33)*** 0.00-8.80
Experienced pain intensity (FPS-R)	3.22 (2.20) 0.00-10.00	2.91 (2.03) 0.00- 8.00	3.53 (2.34) 0.00-10.00
Experienced pain- related fear (CFS)	.45 (.71) 0.00-4.00	.38 (.65) 0.00-3.00	.51 (.77) 0.00-4.00
Trait anxiety (STAIC-t)	33.11 (6.42) 20.00-51.00	32.25 (6.55) 20.00-51.00	33.96 (6.23) 23.00-51.00
Anxiety sensitivity (CASI)	27.65 (5.25) 18.00-41.00	26.96 (5.01) 18.00-40.00	28.33 (5.44) 18.00-41.00
Recalled pain intensity (FPS-R)	3.09 (2.06) 0.00-8.00	2.98 (2.03) 0.00-8.00	3.2 (2.09) 0.00-8.00
Recalled pain-related fear (CFS)	.70 (.76) 0.00-4.00	.65 (.91) 0.00-4.00	.75 (.58) 0.00-2.00

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 2.2

Summary of hierarchical regression analyses for state anxiety predicting children's recalled pain intensity

N = 110 (Entire Sample)	Variable	β	ΔF	$p \leq$	ΔR^2	Cumulative R^2
Step 1	Sex	.031	.103	.75	.001	.001
Step 2	Trait anxiety, Anxiety sensitivity	.027, .151	1.47	.24	.027	.028
Step 3	Experienced pain intensity	.697	96.68	.001*	.466	.494
Step 4	State anxiety	.158	5.13	.05*	.024	.518

Note. The following measures were used: STAIC-t (trait anxiety), CASI (anxiety sensitivity), FPS-R (experienced pain intensity), STAIC-s (state anxiety) in the regression model. Collectively, this model accounted for 52% of the variance in recalled pain intensity. When the order of steps 3 and 4 were reversed, both variables continued to account for a significant portion of the variance in recalled pain intensity suggesting that state anxiety did not mediate the relationship between experienced pain intensity and recall. * $p < .05$.

Table 2.3

Summary of hierarchical regression analyses for state anxiety predicting children's recalled pain-related fear

N = 110 (Entire Sample)	Variable	β	ΔF	$p \leq$	ΔR^2	Cumulative R^2
Step 1	Sex	.145	2.31	.132	.021	.021
Step 2	Trait anxiety, Anxiety sensitivity	.149, .169	4.61	.012*	.078	.099
Step 3	Experienced pain-related fear	.459	30.20	.001*	.201	.300
Step 4	State anxiety	.222	7.51	.01*	.047	.348

Note. The following measures were used: STAIC-t (trait anxiety), CASI (anxiety sensitivity), CFS (experienced pain-related fear), STAIC-s (state anxiety) in the regression model. Collectively, this model accounted for 35% of the variance in recalled pain-related fear. When the order of steps 3 and 4 were reversed, both variables continued to account for a significant portion of the variance in recalled pain-related fear suggesting that state anxiety did not mediate the relationship between experienced pain-related fear and recall. * $p < .05$.

CHAPTER 3:
THE INFLUENCE OF CHILDREN'S PAIN MEMORIES ON SUBSEQUENT PAIN
EXPERIENCE

The manuscript based on this study is presented below. Readers are advised that Melanie Noel, under the supervision of Dr. Christine Chambers, developed the research questions, methodology, and analytical approach for this research. She was responsible for developing the study protocol and proposal, applying for and obtaining funding to support this research, applying for and obtaining ethics approval, and overseeing all data collection. She conducted all of the background research and literature review for this manuscript and was responsible for all aspects of the writing process. Prior to submission, she received editorial feedback from the study's co-authors/co-investigators (i.e., dissertation committee members and Dr. Sherry Stewart). This manuscript underwent editorial and peer-review and was accepted for publication in *Pain* following one revision on February 16, 2012. Prior to acceptance, Melanie Noel was responsible for preparing the response to reviewers' and editor's comments as well as all manuscript revisions. Once again, she received editorial feedback from the study's co-authors/co-investigators. The full reference for this manuscript is:

Noel, M., Chambers, C. T., McGrath, P. J., Klein, R. M., & Stewart, S. H. (in press). The influence of children's pain memories on subsequent pain experience. *Pain*.

Abstract

Healthy children are often required to repeatedly undergo painful medical procedures (e.g. immunizations). Although memory is often implicated in children's reactions to future pain, there is a dearth of research directly examining the relationship between the two. The current study investigated the influence of children's memories for a novel pain stimulus on their subsequent pain experience. One hundred and ten healthy children (60 boys) between the ages of 8 and 12 years completed a laboratory pain task and provided pain ratings. Two weeks later, children provided pain ratings based on their memories as well as their expectancies about future pain. One month following the initial laboratory visit, children again completed the pain task and provided pain ratings. Results showed that children's memory of pain intensity was a better predictor of subsequent pain reporting than their actual initial reporting of pain intensity and mediated the relationship between initial and subsequent pain reporting. Children who had negatively estimated pain memories developed expectations of greater pain prior to a subsequent pain experience and showed greater increases in pain ratings over time than children who had accurate or positively estimated pain memories. These findings highlight the influence of pain memories on healthy children's expectations of future pain and subsequent pain experiences and extend predictive models of subsequent pain reporting.

The Influence of Children's Pain Memories on Subsequent Pain Experience

Healthy children undergo painful medical procedures repeatedly throughout early childhood, receiving over 20 immunizations before the age of 18 years (Public Health Agency of Canada, 2001). The impact of pain does not end when a painful stimulus is removed. Children's memories for pain relate to avoidance of medical care in adulthood (Pate, Blount, Cohen, & Smith, 1996) and may contribute to the development and maintenance of later chronic pain (Flor & Birbaumer, 1994). The manner in which children remember painful experiences influences how they react to subsequent painful experiences. For example, children with cancer who developed negatively estimated memories following lumbar punctures showed heightened distress during subsequent lumbar punctures (Chen, Zeltzer, Craske, & Katz, 2000). However, research has not examined the influence of healthy children's memories for less invasive pain experiences on subsequent pain experiences. Given the frequency with which healthy children experience acute pain (e.g., needles), it is important to examine how their pain memories shape their experience of pain over time.

Insight into this issue may be gleaned from investigations of adult pain. Gedney and Logan (2006) examined healthy adults who underwent a forehead cold pressor task and then an identical task 9 months later. Memories for the pain task were elicited 6 months after the initial session. The researchers developed a predictive model of subsequent pain reporting with recalled pain intensity emerging as a unique and better predictor than initial pain reporting. However, it is unclear whether similar predictive models apply to earlier developmental periods. Furthermore, although pain memories are multidimensional including sensory and affective components (Ornstein, Manning, &

Pelphrey, 1999), and memory for affective aspects of pain have been previously assessed (Lander, Hodgins, Fowler-Kerry, 1992; Noel, McMurtry, Chambers, & McGrath, 2010), research has largely neglected examining the relationship between children's memories for affective aspects of pain (e.g., fear) and subsequent pain reporting.

Children are capable of accurately remembering pain; however, recall is susceptible to distortion over time (Ornstein et al., 1999; von Baeyer, Marche, Rocha, & Salmon, 2004). Previous research has identified groups of children who differ in their style of remembering pain. Whereas some children develop pain memories that are negatively estimated, other children develop memories that are accurate or positively estimated. Children who develop negative pain memories are more likely to have experienced greater pain intensity (Noel et al., 2010) and state anxiety (Noel, Chambers, McGrath, Klein, & Stewart, 2012) during previous painful experiences. They also have higher levels of trait anxiety (Rocha, Marche, & von Baeyer, 2009) and anxiety sensitivity (i.e., fear of anxiety-related sensations, Noel et al., 2012). Importantly, children who develop negatively estimated pain memories may experience more distress during subsequent pain experiences than children who have accurate or positively estimated memories (Chen et al., 2000); however, this has yet to be investigated among healthy children undergoing experimental pain of mild to moderate intensity. The current study examined the influence of children's memories for a novel pain stimulus on their subsequent pain experience. We hypothesized that children's memories for pain would be a unique and better predictor of subsequent pain reporting than their actual initial pain reporting. We also hypothesized that children who developed negatively estimated pain memories would develop expectations of greater pain prior to a subsequent pain

experience, report greater increases in pain over time, and have higher levels of state and trait anxiety and anxiety sensitivity than children who developed accurate or positively estimated pain memories.

Methods

The data for this paper was collected as part of a larger study examining two distinct research questions that are presented in two empirical papers. The present paper examines the influence of children's pain memories on their expectations and experience of subsequent pain. The other paper by Noel et al. (2012) examined the impact of state anxiety, and the contributions of stable anxiety-related variables, on children's memories for pain. As a result, the methods reported below contain only those details relevant to the present study and are an abbreviated version of the larger study protocol. Ethical approval for this study was obtained from the health centre research ethics board (REB).

Participants

Participants were 110 healthy children (60 boys; 50 girls) aged 8 to 12 years ($M_{age} = 9.45$ years, $SD = 1.35$) who were accompanied by a parent/guardian (99 mothers, 1 stepmother, 9 fathers, 1 stepfather; $M_{age} = 40.3$ years; $SD = 5.94$). Participants were recruited from the community through advertisements in local papers, doctors' offices and community centers, as well as the local children's hospital intranet, parenting websites, science camps, online classified advertisement sites, etc. The majority of parents identified themselves and their children as being "white" (86.4%; $n = 95$). The remaining 13.6% of participants self-identified as "asian" ($n = 1$), "arab" ($n = 1$), "black" ($n = 7$) and "other" ($n = 6$). By parent-report, parents' educational background was as follows: (a) graduate school/professional training ($n = 30$); (b) university graduate

($n = 39$); (c) partial university (i.e., at least 1 year) ($n = 5$); trade school/community college ($n = 25$); (d) high school graduate ($n = 9$); and (e) high school ($n = 2$).

The following exclusion criteria were used in the study: Participants who did not speak English as a first language and/or who had developmental delays or significant hearing or vision impairments; children diagnosed with an Anxiety Disorder or Attention Deficit Hyperactivity Disorder; children who had chronic illnesses or health-related medical conditions (e.g., circulation disorders; heart problems; injuries to their arms or hands); children who had previously completed the laboratory pain task; children who experienced pain (e.g., headaches, stomach aches, ear/throat pain, muscle or joint pain) on a regular basis (i.e., at least once a month for 3 consecutive months), which was typically of moderate or severe intensity and interfered with school or social functioning, or for which they took medication. Prior to enrolment in the study, exclusion criteria were assessed during a telephone screening with parents. At this time, psychiatric diagnoses and recurrent pain status were verified through parent report. No families withdrew following enrolment in the study; no adverse events were reported following enrolment.

Measures

Pain Intensity

The one-item Faces Pain Scale-Revised (FPS-R; Hicks, von Baeyer, Spafford, von Korlaar, Goodenough, 2001) was used to measure pain intensity among children. Among six gender-neutral faces depicting “no pain” (neutral face) to “most pain possible” expressions, children select a face that represents how much pain they feel and the faces are scored: 0, 2, 4, 6, 8, and 10. The psychometric properties of the FPS-R are

well established among children aged 4 to 12 years (Stinson, Kavanagh, Yamada, Gill, & Stevens, 2006).

Pain-related Fear

The one-item Children's Fear Scale (CFS; McMurtry, Noel, Chambers, & McGrath, 2011), which was adapted from the Faces Anxiety Scale (McKinley, Coote, & Stein-Parbury, 2003) was used to measure pain-related fear among children. Among five faces representing varying degrees of fear, children select a face that represents how "scared" they feel. The faces are scored from 0 to 4. Among children, the CFS has been shown to have good test-retest ($r_s = .76, p < .001$) and inter-rater ($r_s = .51, p < .001$) reliability as well as construct validity (McMurtry et al., 2011). Consistent with previous literature on children's memories for pain (Noel et al., 2010), pain-related fear was assessed in the current study, as opposed to other affective aspects of the pain experience, in order to reduce the number of self-report measures used and the number of analyses conducted, which could have resulted in an inflated type 1 error rate.

Anxiety

Children's levels of state and trait anxiety were measured using the 20-item state and trait subscales of the State Trait Anxiety Inventory for Children (STAIC; Spielberger, 1973). The state subscale of the STAIC (STAIC-s) measures subjective feelings of anxiety that are typically elevated in stressful situations and that can fluctuate and vary in intensity over time. Conversely, the trait subscale of the STAIC (STAIC-t) measures more stable individual differences in an individual's tendency to perceive situations as threatening and to experience states of anxiety. The STAIC-s has been shown to have good internal consistency (Cronbach's alpha = .82-.87) and construct validity. Similarly,

the STAIC-t has been shown to have good internal consistency (Cronbach's alpha = .78-.81) and concurrent validity (Spielberger, 1973).

Anxiety Sensitivity

The 18-item Childhood Anxiety Sensitivity Index (CASI; Silverman, Fleisig, Rabian, & Peterson, 1991) measures the tendency to interpret anxiety-related bodily sensations as threatening (e.g., "It scares me when my heart beats fast"). Anxiety sensitivity as measured by the CASI has been found to be moderately correlated with trait anxiety ($r = .55-.69$); however, the construct accounts for variance in fear that is not accounted for by trait anxiety (Weems, Hammond-Laurence, Silverman, & Ginsburg, 1998). The CASI has been shown to have adequate test-retest reliability (.62-.78 over 2 weeks) and high internal consistency ($\alpha = .87$; Silverman et al., 1991). Furthermore, anxiety sensitivity is highly relevant to one's experience of pain. For example, a recent meta-analysis revealed that anxiety sensitivity is strongly associated with fearful appraisals of pain (Ocañez, McHugh, & Otto, 2010). Anxiety sensitivity has also been shown to amplify one's tendency to experience anxiety, thereby heightening pain perception (Schmidt & Cook, 1999; Stewart & Asmundson, 2006). In addition, child anxiety sensitivity has a robust relationship with pain-related anticipatory anxiety, which strongly predicts laboratory pain ratings (Tsao, Lu, Kim, & Zeltzer, 2006).

Cold Pressor Task

Children completed the cold pressor task (CPT) by submerging their non-dominant hand up to the wrist fold in 10 degree Celsius water for an informed ceiling (i.e., maximum immersion time) of 4 minutes. Children were instructed to leave their hands in the water for as long as they could tolerate for a maximum of 4 minutes. They

were informed that they could remove their hand at any time if it became too uncomfortable or painful to leave it in. This task has been deemed to be an ethically acceptable pain induction technique for use with children (Birnie, Noel, Chambers, von Baeyer, & Fernandez, 2011). The cold pressor device was a commercially manufactured plastic cooler filled with water and measured 43.5 cm long, 23.5 cm wide, and 28.0 cm deep. Consistent with published guidelines, the water temperature was maintained at $10^{\circ}\text{C} \pm 1^{\circ}\text{C}$ (von Baeyer, Piira, Chambers, Trapanotto, & Zeltzer, 2005). The cooler was separated into two sections by a plastic screen and ice cubes were placed in the first section to cool the water. Children lowered their hand into the water in the second section through a round opening (13 cm in diameter) in the lid of the cooler. To prevent local warming around children's hands, a bilge pump was located within the device, which circulated the water.

Procedure

Participant recruitment was achieved using paper and online advertisements distributed in the community. Parents contacted the research centre by telephone and were screened to determine study eligibility. The study involved three phases: An initial laboratory visit (Lab Session 1), a telephone interview 2 weeks later, and a second laboratory visit 1 month following the initial visit (Lab Session 2). During Lab Session 1, parents provided full and informed consent in a room that was separate from their child. From this room, parents watched the entire experiment via video monitors. Children provided assent; however, they were not aware that their memories would later be assessed. Immediately prior to undergoing the pain task, children's level of state anxiety was measured by child self-report (STAIC-s). Next, children completed the CPT

in a separate testing room after which they completed measures of pain intensity (FPS-R) and pain-related fear (CFS). The administration order of these scales was counterbalanced across children (i.e., half of the participants received the FPS-R followed by the CFS and the other half received these measures in the reverse order, which was determined at random). Then, children were brought into a waiting room and completed measures of trait anxiety (STAIC-t) and anxiety sensitivity (CASI). The administration order of these measures was counterbalanced across children. Trait anxiety and anxiety sensitivity were measured after the CPT and not beforehand when state anxiety was first measured in order to limit the duration of time between administration of the state anxiety measures and completion of the experimental pain task. In doing so, it was ensured that the measures of state anxiety captured the level of state anxiety experienced immediately prior to pain induction. Furthermore, measuring trait anxiety and anxiety sensitivity after pain induction (i.e., when children were in a resting state) was intended to capture children's baseline levels of these stable anxiety-related variables, which were less influenced by elevated state anxiety experienced during anticipation of experimental pain. Appointments to conduct the follow-up telephone interviews were scheduled with parents prior to leaving the laboratory. All parents were given a sealed envelope containing copies of the pain intensity and pain-related fear scales, which were individually contained in sealed and numbered envelopes. Parents were asked to refrain from opening the sealed envelope until a researcher called them to conduct the memory interview. In addition, they were asked not to talk about the laboratory visit with children in the interim between Lab Session 1 and the telephone interview. During Lab Session 1, children were informed that a research assistant would contact them over the telephone;

however, they were unaware that their memories for the pain task would later be elicited. Prior to leaving the laboratory, parents and children were each given a \$20 honorarium.

The telephone interviews were conducted approximately two weeks following the laboratory visit ($M = 14.00$ days, $SD = 1.24$ days, $Range = 9-19$ days). All participants (100%) who participated in Lab Visit 1 completed the telephone interviews. Telephone interviews have previously been conducted with children in research examining memory for cold pressor, venipuncture, and postoperative pain (Badali, Pillai, Craig, Giesbrecht, & Chambers, 2000; Lander et al., 1992; Noel et al., 2010; Zonneveld, McGrath, Reid, & Sorbi, 1997). Previous research examining children's memories for pain has employed time frames ranging from 1 week to 1 year (Badali et al., 2000; Chen et al., 2000). In order to minimize participant attrition due to intervening pain experiences, the present study used a 2-week time frame, which is consistent with previous research (Noel et al., 2010). None of the participants experienced medically-induced acute pain in the interim between Lab Session 1 and the telephone interview, as verified by parental report.

During the telephone interview, parents were asked to refrain from influencing their children's responses, so as to not bias their recall. The memory assessment protocol was based on protocols used in previous research examining children's memory for cold pressor and venipuncture pain (Badali et al., 2000; Noel et al., 2010). Given that children could not physically point to the faces in front of the researcher during the telephone interview, letters of the alphabet were placed in random order under the faces on the scales. This was done to facilitate ease of telephone communication and avoid introducing a confounding numerical scale. Children were provided with instructions for each scale and oriented to the placement of the letters under each face. The order of scale

presentation was counterbalanced. Children were asked to think back to when they completed the CPT during Lab Session 1 and to rate the pain intensity and pain-related fear they remembered having experienced. They also rated how much pain intensity and pain-related fear that they expected to experience during the next CPT on scales ranging from 0 (“no hurt or pain/not worried or scared”) to 10 (“most hurt or pain/most worried or scared”). Different measures were used to measure expected versus observed/remembered pain intensity and pain-related fear in order to limit the likelihood that children would once again provide ratings based on their memories of the initial pain experience as opposed to their expectations of subsequent pain on the second pain task.

Lab Session 2 took place approximately one month following Lab Session 1 ($M = 28.62$ days, $SD = 2.86$ days, $Range = 21-43$ days). All but one participant (99.09%) who participated in Lab Session 1 and the telephone interview completed Lab Session 2. Once again, parents and children were separated and parents watched the entire experiment via video monitors from an adjoining room. Children completed the CPT after which they completed measures of pain intensity (FPS-R) and pain-related fear (CFS). The administration order of these scales was counterbalanced across children. Parents and children were joined in the waiting room at which time children were fully debriefed about the nature of the study. Parents and children were given a handout outlining strategies for positively reframing pain memories (based on the work of Chen et al., 1999), which has been shown to lead to reductions in children’s pain and distress during repeated medical procedures (Chen et al., 1999). A research assistant reviewed these strategies with participants. Parents and children were each given another

honorarium in the amount of \$20; children were given a certificate in acknowledgement of their contribution to the research.

Results

Data Analysis

In order to examine the relative influences of anxiety-related variables, Lab Session 1 experienced pain, and pain memories on subsequent pain experience, bivariate correlations were first conducted between key variables to justify their inclusion in the predictive models. Regression models for the prediction of Lab Session 2 pain reporting were based on the analytic approach used by Gedney and Logan (2006) in a study investigating the relationship between adults' memories of pain intensity and subsequent pain reporting. Age and sex were not included in the regression models to be consistent with models established with adults (Gedney & Logan, 2006); however, when age and sex were entered in the first step of all regression models, the pattern of results did not change. Based on findings yielded from the regression models, mediation models based on the steps outlined by Baron and Kenny (1986) were tested as appropriate. Next, in order to determine the influence of memory style on expectations of future pain and subsequent pain reporting, children were categorized into one of two memory style subgroups separately for recalled pain intensity and recalled pain-related fear (Noel et al., 2010). Thus, two separate classifications were created for each participant. "Negative Estimators (pain intensity)" and "Negative Estimators (pain-related fear)" were defined as children who recalled more pain intensity and pain-related fear than they reported immediately after completing the pain task in Lab Session 1 (i.e., the difference between recalled pain intensity/pain-related fear and Lab Session 1 pain intensity/pain-related fear

was ≥ 1 face). “Positive/Accurate Estimators (pain intensity)” and “Positive/Accurate Estimators (pain-related fear)” were defined as children who recalled less or the same level of pain intensity and pain-related fear than they reported immediately after completing the pain task in Lab Session 1 (i.e., the difference between recalled pain intensity/pain-related fear and Lab Session 1 pain intensity/pain-related fear was ≤ 1 face or = 0). Children were categorized into 2 memory style subgroups (“Negative Estimators” vs. “Positive/Accurate Estimators”); children who developed positively estimated memories were combined with those who had accurate recall. This method of classification was chosen, as opposed to separating “Positive Estimators” and “Accurate Estimators”, based on previously used methods of classification (Noel et al., 2010) and research indicating that this classification meaningfully categorizes children as being at risk (“Negative Estimators”) versus not being at risk (“Positive/Accurate Estimators”) for exhibiting heightened distress at subsequent painful experiences (Chen et al., 2000). Similar to the analytic approach used by Chen et al. (2000), we computed pain intensity and pain-related fear change scores (Lab Session 2 pain intensity/pain-related fear – Lab Session 1 pain intensity/pain-related fear) such that more positive scores reflected greater increases in reported pain intensity and pain-related fear from Lab Session 1 to Lab Session 2.

We examined differences in expectations and changes in pain intensity and pain-related fear scores between memory style subgroups for each type of pain memory separately (pain intensity, pain-related fear) with independent samples t-tests. Given that it was hypothesized *a priori* that “Negative Estimators” would show greater increases in pain intensity and pain-related fear from Lab Session 1 to Lab Session 2 as well as

expectations of greater pain intensity and pain-related fear prior to Lab Session 2 than “Positive/Accurate Estimators”, we conducted directional one-tailed independent samples t-tests on expectations of pain intensity/pain related fear and pain intensity and pain-related fear change scores between memory style subgroups. Given that it was also hypothesized *a priori* that “Negative Estimators” would have higher levels of anxiety (state/trait anxiety and anxiety sensitivity) than “Positive/Accurate Estimators”, directional one-tailed independent samples t-tests were conducted on anxiety levels between memory style subgroups.

Correlations between Key Variables

Table 3.1 reports correlations among key variables measured in the present study across children. Children’s memory for pain intensity was positively related to their level of state anxiety at Lab Session 1, Lab Session 1 pain intensity and pain-related fear ratings, memories of pain-related fear, expectations of subsequent pain intensity and pain-related fear prior to Lab Session 2, and Lab Session 2 pain intensity and pain-related fear ratings. Likewise, children’s memory of pain-related fear was positively related to all anxiety-related variables (state and trait anxiety, anxiety sensitivity), Lab Session 1 pain intensity and pain-related fear ratings, memories of pain intensity, expectations of subsequent pain intensity and pain-related fear prior to Lab Session 2, and Lab Session 2 pain intensity and pain-related fear ratings. Therefore, children’s pain memories were related to their level of anxiety at Lab Session 1, their expectations of subsequent pain intensity and pain-related fear prior to Lab Session 2, and their subjective experiences of pain intensity and pain-related fear over time (Lab Session 1 and 2).

Regression Models

Prediction of Lab Session 2 Pain Intensity

The results of regression models predicting Lab Session 2 pain intensity are shown in Table 3.2. State anxiety and stable anxiety-related variables (trait anxiety and anxiety sensitivity) were entered in steps 1 and 2 of each model ($\Delta R^2 = .012, p = \text{ns}$; $\Delta R^2 = .039, p = \text{ns}$). In Model 1, recalled pain intensity was entered in step 3 and was a significant predictor of Lab Session 2 pain intensity ($\Delta R^2 = .374, p < .001$); however Lab Session 1 pain intensity, when entered in step 4, was not a significant predictor of Lab Session 2 pain intensity ($\Delta R^2 = .007, p = \text{ns}$). The order of the loading of recalled pain intensity and Lab Session 1 pain intensity was reversed in Model 2. When Lab Session 1 pain intensity was entered in step 3, it was a significant predictor of Lab Session 2 pain intensity ($\Delta R^2 = .232, p < .001$). Likewise, recalled pain intensity when entered in step 4 remained a significant predictor of Lab Session 2 pain intensity ($\Delta R^2 = .15, p < .001$). Together, the models accounted for 43.2% of the total variance in Lab Session 2 pain intensity.

Similar to Gedney and Logan (2006), the loadings of the variables between the two models were compared in order to understand the shared variance between Lab Session 1 pain intensity and recalled pain intensity. The variance accounted for by anxiety-related variables was controlled in steps 1 and 2 of each model. In step 3, either recalled pain intensity (Model 1) or Lab Session 1 pain intensity (Model 2) was controlled. The remaining unique variance after controlling for variables entered in steps 1-3 is reported in step 4 of each model. Shared variance was calculated as the *difference* between the total variance of each model ($R^2 = .432$) and the sum of the variances of step

1 ($\Delta R^2 = .012$), step 2 ($\Delta R^2 = .039$), and step 4 of Model 1 ($\Delta R^2 = .007$) and Model 2 ($\Delta R^2 = .150$). The shared variance of recalled pain intensity and Lab Session 1 pain intensity was 22.4%. This is depicted in Figure 3.1.

Prediction of Lab Session 2 Pain-related Fear

The results of regression models predicting Lab Session 2 pain-related fear are shown in Table 3.3. Similar to the regression models for the prediction of Lab Session 2 pain intensity, state anxiety and stable anxiety-related variables (trait anxiety and anxiety sensitivity) were entered in steps 1 and 2 of each model ($\Delta R^2 = .000$, $p = ns$; $\Delta R^2 = .040$, $p = ns$). In Model 1, recalled pain-related fear was entered in step 3 and was a significant predictor of Lab Session 2 pain-related fear ($\Delta R^2 = .044$, $p < .05$). Similarly, Lab Session 1 pain-related fear, entered in step 4, was also a significant predictor of Lab Session 2 pain-related fear ($\Delta R^2 = .059$, $p < .01$). The order of the loading of recalled pain-related fear and Lab Session 1 pain-related fear was reversed in Model 2. When Lab Session 1 pain-related fear was entered in step 3, it was a significant predictor of Lab Session 2 pain-related fear ($\Delta R^2 = .099$, $p < .001$). However, recalled pain-related fear, when entered in step 4, did not remain a significant predictor of Lab Session 2 pain-related fear ($\Delta R^2 = .004$, $p = ns$). Collectively, the models accounted for 14.3% of the total variance in Lab Session 2 pain-related fear.

Once again, the loadings of the variables between the two models were compared in order to understand the shared variance between Lab Session 1 pain-related fear and recalled pain related fear. Shared variance was calculated as the *difference* between the total variance of each model ($R^2 = .143$) and the sum of the variances of step 1 ($\Delta R^2 = .000$), step 2 ($\Delta R^2 = .040$), and step 4 of model 1 ($\Delta R^2 = .059$) and model 2

($\Delta R^2 = .004$). The shared variance of recalled pain-related fear and Lab Session 1 pain-related fear was .04%. This is depicted in Figure 3.2.

Mediation Analysis

Given that recalled pain intensity was a significant predictor of both Lab Session 1 pain intensity and Lab Session 2 pain intensity, a mediation model was tested to examine whether memories of pain intensity mediated the relationship between reporting of pain intensity at Lab Session 1 and Lab Session 2. Covariates, state and trait anxiety and anxiety sensitivity, were included in the first step of each regression. The relationship between reporting of pain intensity at Lab Session 1 and reporting of pain intensity at Lab Session 2 was mediated by the effect of children's recalled pain intensity. As illustrated in Figure 1, the standardized regression coefficient between Lab Session 1 pain intensity and Lab Session 2 pain intensity decreased substantially (from .50 to .12) and became non-significant when controlling for recalled pain intensity. All other conditions of mediation were met: Lab Session 1 reporting of pain intensity was a significant predictor of Lab Session 2 reporting of pain intensity, and recalled pain intensity was a significant predictor of Lab Session 2 reporting of pain intensity, while controlling for Lab Session 1 reporting of pain intensity. A Sobel test confirmed that the mediation path was significantly different from zero ($z = 6.28, p < .001$). This mediation model is depicted in Figure 3.3.

Memory Style Subgroups

Mean (SD) expected pain intensity and pain-related fear, pain intensity and pain-related fear change, and anxiety scores across memory style subgroups are shown in Table 3.4. "Negative Estimators (pain intensity)" had significantly higher levels of state

anxiety at Lab Session ($t(108) = 1.79, p < 0.05, \eta_p^2 = .03$) and greater increases in pain intensity from Lab Session 1 to Lab Session 2 ($t(107) = 2.96, p < 0.01, \eta_p^2 = .08$) than “Positive/Accurate Estimators (pain intensity)”. “Negative Estimators (pain-related fear)” had significantly higher levels of state anxiety ($t(108) = 1.81, p < 0.05, \eta_p^2 = .03$), trait anxiety ($t(108) = 2.32, p < 0.05, \eta_p^2 = .05$), and anxiety sensitivity ($t(108) = 2.58, p < 0.01, \eta_p^2 = .06$) at Lab Session 1 than “Positive/Accurate Estimators (pain-related fear)”. During the memory interview, “Negative Estimators (pain-related fear)” expected that they would experience higher levels of pain intensity at Lab Session 2 ($t(108) = 2.88, p < 0.01, \eta_p^2 = .07$). They also showed greater increases in pain-related fear from Lab Session 1 to Lab Session 2 ($t(107) = 1.88, p < 0.05, \eta_p^2 = .03$) than “Positive/Accurate Estimators (pain-related fear)”.

Discussion

This is the first examination of the influence of healthy children’s pain memories on subsequent pain reporting during an acute pain experience. Similar to adults (Gedney & Logan, 2006), children’s memory for pain intensity was a unique predictor of their subsequent experience of pain intensity, over and above state and trait anxiety, anxiety sensitivity, and their initial pain experience. Children’s recalled pain intensity was a better predictor of subsequent pain reporting than was their initial actual experience of pain intensity. Recalled pain intensity uniquely accounted for 15% of the variance in later reporting of pain intensity, whereas experienced pain intensity during Lab Session 1 only uniquely accounted for 0.7% of the variance. Collectively this model explained a large portion of the variance in children’s subsequent reporting of pain intensity (43.2%). This extends research with adults by applying a similar predictive model with substantial

explanatory power to earlier developmental periods. Moreover, the relationship between reporting of initial and subsequent pain intensity was mediated by children's memories of pain intensity, which further highlights the powerful role of memory in subsequent pain experience.

Conversely, children's memories of pain-related fear were less important to their subsequent experience of pain-related fear than was their initial experience. This predictive model had less explanatory power than the predictive model for subsequent reporting of pain intensity, accounting for 14.3% of the total variance in subsequent reporting of pain-related fear. These differential relationships might in part be due to methodological issues. For the majority of children, fear may not have been sufficiently induced by the cold pressor task. Pain-related fear might have more relevance for the majority of children when evoked in a clinical setting involving an invasive stimulus (e.g., needles, which are among children's most feared experiences; Broome & Hellier, 1987; Hart & Bossert, 1994) as opposed to voluntary immersion of the hand in 10 degree Celsius water, which children can control. This is supported by research showing that most children reported having very positive experiences taking part in CPT studies, were willing to take part in second exposures, and rated their overall experiences taking part in second exposures as more positive than the first (Birnie et al., 2011). It is possible that the effect of fear was attenuated at Lab Session 2 because the CPT was no longer novel. Fear avoidance models predict that fear of pain leads to avoidance (Asmundson, Norton, & Vlaeyen, 2004); however, avoidance of pain was not observed among children in the present study (e.g., all but one child willingly came back to the laboratory to complete a second pain task), suggesting that the level of fear among most children might have

lacked sufficient variability and generalizability to clinical pain experiences. Furthermore, the temperature of the water (10°C) is thought to be potentially too limiting (Birnie et al., 2011) and could have reduced variability in fear responses among children. Researchers have started to lower water temperatures for the CPT (e.g., 5°C) in order to reduce ceiling effects (Dahlquist et al., 2010)—observed in over half of the current sample—which could result in lower tolerance, increased pain intensity, and induction of greater fear and/or anxiety. It is possible that pain-related fear was most relevant for the subset of children who negatively estimated their memories in this particular experimental paradigm. Nevertheless, these findings extend predictive models established in adulthood to earlier developmental periods.

The degree of accuracy of children's pain memories appears to have important implications for expectancies about future pain and subsequent pain reporting. Children who developed negatively estimated pain memories reported greater increases in pain intensity and pain-related fear over time than children who developed accurate or positively estimated memories. This extends research on children with cancer undergoing highly invasive lumbar punctures (Chen et al., 2000) to healthy children repeatedly undergoing acute pain of mild-to-moderate intensity. Children who had negatively estimated pain memories also had higher levels of state anxiety prior to the initial pain experience than children who had accurate and positively estimated pain memories. This indicates that children with high levels of state anxiety not only recall higher levels of pain (Noel et al., 2012) but their recall of pain is likely to be higher than their actual level of experienced pain.

Prior to a subsequent pain experience, children who had negatively estimated memories of pain-related fear developed expectations that they would experience greater pain intensity in the future. They also had higher levels of trait anxiety and anxiety sensitivity than children who had accurate and positively estimated memories. Given that memory biases for pain-related fear, but not pain intensity, exist among this highly anxious group of children, this suggests that the fearful aspect of their pain experience is susceptible to distortion over time. This finding is consistent with research showing that individuals who are anxious consistently show a memory bias for threatening information as compared to non-anxious individuals (Mitte, 2008), and individuals who are highly trait anxious are more likely to develop negatively estimated pain memories (Rocha et al., 2009). Cognitive and attentional theories posit that memory biases exist because anxious individuals selectively encode and retrieve threatening information (Eysenck, Derakshan, Santos, & Calvo, 2007), particularly when they experience high levels of state anxiety (Beck & Clark, 1997). Indeed, individuals with high levels of anxiety sensitivity and trait anxiety have been shown to have attentional biases favouring the processing of threatening information (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Hunt, Keogh, & French, 2006; Keogh, Dillon, Georgiou, & Hunt, 2001; Koven, Heller, Banich, & Miller, 2003; Stewart, Conrod, Gignac, & Pihl, 1998). This implies that children with higher levels of state and trait anxiety as well as anxiety sensitivity could have attentional biases toward threat, which contribute to the development of negatively estimated pain memories. Moreover, the present findings suggest that once these memory biases develop, they can adversely impact children's subsequent reactions to pain.

The present study offers advantages over previous research by investigating healthy children's memories for a novel acute pain experience. This enabled examination of the development of pain memories from their inception and was therefore not impacted by previous memory scripts developed from earlier exposure to the same painful stimulus. The experimental nature of the investigation afforded a high degree of control over key variables that could not be achieved in a clinical setting. Nevertheless, the study had limitations that require consideration and highlight avenues for future research. First, although the CPT is thought to provide an analogue for real-world acute pain experiences (von Baeyer et al., 2005), it is unclear whether the task induces variability in fear responses comparable to those evoked during painful medical procedures. Future research should examine the ecological validity of the CPT for inducing pain-related fear among children of this age range to determine whether the fearful aspect of pain memories is relevant for most children within this experimental paradigm. Second, the measure of pain-related fear used in the study (CFS) was validated among a sample of children (aged 5-10 years) undergoing venipunctures and instructs children to rate how "scared" they were when they experienced pain (McMurtry et al., 2011); as such, it might be less relevant in this experimental setting and/or with children of this age range. Future research examining the validity of this measure in different pain contexts and with older children is needed. Third, it is possible that other affective aspects of the pain experience might be more appropriate to assess than pain-related fear in this pain context. Negative affectivity, which encompasses several negative mood states, might be an important variable to assess with children, since it has been shown to be related to exaggerated recall and subsequent pain reporting in adults (Gedney &

Logan, 2006; Watson, 2000). Furthermore, future research should assess state anxiety prior to each pain exposure to examine whether negatively estimated pain memories are related to increases in anticipatory state anxiety over time. In addition, the present study assessed memory after a two-week delay. Previous research with adults suggests that recall becomes more exaggerated after a longer delay (6-18 months; Everts et al., 1999; Gedney, Logan, & Baron, 2003); therefore, the current findings might underestimate the degree of exaggeration in children's pain memories and the impact of recall on subsequent pain experience. Although the frequency with which pain is assessed has not been shown to influence recalled pain ratings (Zonneveld et al., 1997), providing pain ratings during the telephone interview could have altered subsequent pain reporting. Finally, the type 1 error rate could have been inflated for analyses pertaining to memory style subgroup differences; therefore, these findings should be replicated.

In conclusion, children's memory of pain intensity was a powerful predictor of their subsequent pain reporting and a better predictor than their initial pain reporting; in fact, the relationship between initial and subsequent reporting of pain intensity was mediated by children's pain memories. Conversely, children's initial reporting of pain-related fear was a more important predictor of subsequent reporting of pain-related fear than their memory of pain-related fear. The degree of accuracy of pain memories appears to have important implications for children's expectations and subsequent experience of pain. Children who developed negatively estimated pain memories had higher levels of anxiety (state/trait anxiety and anxiety sensitivity), expected to experience more pain in the future, and experienced greater increases in pain reporting over time than children who developed accurate or positively estimated memories. This research provides

evidence for the influence of pain memories on subsequent pain experiences among healthy children undergoing pain of mild to moderate intensity and extends predictive models of subsequent pain reporting to childhood.

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Table 3.1

Correlations among the key variables of anxiety-related variables and experienced and recalled pain

N = 110	Trait Anxiety	Anxiety Sensitivity	Lab Session 1 Pain Intensity	Lab Session 1 Pain-related Fear	Recalled Pain Intensity	Recalled Pain-related Fear	Expected Lab Session 2 Pain Intensity	Expected Lab Session 2 Pain-related Fear	Lab Session 2 Pain Intensity	Lab Session 2 Pain-related Fear
State Anxiety	.16	-.01	.10	.07	.21*	.26**	.08	.14	.11	-.01
Trait Anxiety		.64**	.18	.14	.12	.27**	.09	.27**	.14	.19
Anxiety Sensitivity			.18	.08	.17	.28**	.16	.26**	.20*	.08
Lab Session 1 Pain Intensity				.27*	.70**	.49**	.50**	.42**	.52**	.27**
Lab Session 1 Pain-related Fear					.32**	.49**	.24*	.34**	.15	.33**
Recalled Pain Intensity						.49**	.60**	.30**	.65**	.32**
Recalled Pain-related Fear							.43**	.43**	.28**	.23*
Expected Lab Session 2 Pain Intensity								.40**	.39**	.20*
Expected Lab Session 2 Pain-related Fear									.17	.42**
Lab Session 2 Pain Intensity										.22*

Note. The following measures were used: STAIC-s (state anxiety), STAIC-t (trait anxiety), CASI (anxiety sensitivity), FPS-R (Lab Session 1, recalled, and Lab Session 2 pain intensity), CFS (Lab Session 1, recalled, and Lab Session 2 pain-related fear).

* $p < .05$, ** $p < .01$.

Table 3.2

Regression models predicting Lab Session 2 pain intensity

<i>N</i> = 109	β	ΔF	$p \leq$	ΔR^2	Cumulative R^2
Model 1					
Step 1: State Anxiety	.110	1.321	.253	.012	.012
Step 2: Trait Anxiety, Anxiety Sensitivity	-.013, .205	2.137	.123	.039	.051
Step 3: Recalled Pain Intensity	.640	67.720	.001*	.374	.425
Step 4: Lab Session 1 Pain Intensity	.120	1.296	.258	.007	.432
Model 2					
Step 1: State Anxiety	.110	1.321	.253	.012	.012
Step 2: Trait Anxiety, Anxiety Sensitivity	-.013, .205	2.137	.123	.039	.051
Step 3: Lab Session 1 Pain Intensity	.496	33.551	.001*	.232	.282
Step 4: Recalled Pain Intensity	.557	27.203	.001*	.150	.432
Shared Variance					.224 ^a

Note. The following measures were used: STAIC-t (trait anxiety), CASI (anxiety sensitivity), FPS-R (pain intensity), STAIC-s (state anxiety) in the regression model. The order of loadings of steps 3 and 4 were reversed between the 2 models, thus allowing calculation of shared variance. Beta weights (β) for each step are reported along with their measures of significance (change in the F statistic and associated p-value). The change in variance at each step in the models is reported as ΔR^2 , and the cumulative variance for each model is reported as Cumulative ΔR^2 .

^a Total – (Step 1 + Step 2 + Step 4_{Model 1} + Step 4_{Model 2})

Table 3.3

Regression models predicting Lab Session 2 pain-related fear

<i>N</i> = 109	β	ΔF	$p \leq$	ΔR^2	Cumulative R^2
Model 1					
Step 1: State Anxiety	-.008	.006	.936	.000	.000
Step 2: Trait Anxiety, Anxiety Sensitivity	.247, -.078	2.192	.117	.040	.040
Step 3: Recalled Pain-related Fear	.226	5.005	.05*	.044	.084
Step 4: Lab Session 1 Pain-related Fear	.282	7.077	.01*	.059	.143
Model 2					
Step 1: State Anxiety	-.008	.006	.936	.000	.000
Step 2: Trait Anxiety, Anxiety Sensitivity	.247, -.078	2.192	.117	.040	.040
Step 3: Lab Session 1 Pain-related Fear	.318	11.962	.001*	.099	.139
Step 4: Recalled Pain-related Fear	.078	.473	.493	.004	.143
Shared Variance					.04 ^a

Note. The following measures were used: STAIC-t (trait anxiety), CASI (anxiety sensitivity), CFS (pain-related fear), STAIC-s (state anxiety) in the regression model. The order of loadings of steps 3 and 4 were reversed between the two models thus allowing calculation of shared variance. Beta weights (β) for each step are reported along with their measures of significance (change in the F statistic and associated p-value). The change in variance at each step in the models is reported as ΔR^2 and the cumulative variance for each model is reported as Cumulative ΔR^2 .

^a Total – (Step 1 + Step 2 + Step 4_{Model 1} + Step 4_{Model 2})

Table 3.4

Mean (SD) expected pain intensity and pain-related fear, pain intensity and pain-related fear change, and anxiety scores across memory groups

Variable	Negative Estimators (pain intensity) (<i>n</i> = 24)	Positive/Accurate Estimators (pain intensity) (<i>n</i> = 86)	Negative Estimators (pain-related fear) (<i>n</i> = 35)	Positive/Accurate Estimators (pain-related fear) (<i>n</i> = 75)
State Anxiety	30.67 (5.31)	28.63 (4.82)*	30.31 (5.09)	28.49 (4.86)*
Trait Anxiety	31.96 (6.89)	33.43 (6.28)	35.14 (5.80)	32.16 (6.51)*
Anxiety Sensitivity	27.13 (5.35)	27.79 (5.24)	29.49 (4.99)	26.79 (5.18)**
Lab Session 1 Pain Intensity	2.17 (1.95)	3.51 (2.19)**	4.00 (2.38)	2.85 (2.03)*
Lab Session 1 Pain-related Fear	.54 (.83)	.42 (.68)	.17 (.38)	.57 (.79)**
Recalled Pain Intensity	4.33 (1.93)	2.74 (1.97)**	3.89 (2.00)	2.72 (1.99)**
Recalled Pain-related Fear	.71 (.86)	.70 (.74)	1.29 (.62)	.43 (.66)***
Expected Pain Intensity	3.77 (2.24)	3.49 (2.27)	4.43 (1.93)	3.14 (2.29)**
Expected Pain-Related Fear	1.71 (2.11)	1.55 (1.58)	1.87 (1.84)	1.45 (1.63)
Pain Intensity Change Score	1.30 (1.96)	-.21 (2.23)**	-.18 (2.33)	.24 (2.23)
Pain-related Fear Change Score	.09 (1.00)	.01 (.73)	.24 (.65)	-.07 (.83)*

Note. The following measures were used: STAIC-s (state anxiety), STAIC-t (trait anxiety), CASI (anxiety sensitivity), FPS-R (pain intensity), CFS (pain-related fear).

* $p < .05$, ** $p < .01$, *** $p < .001$.

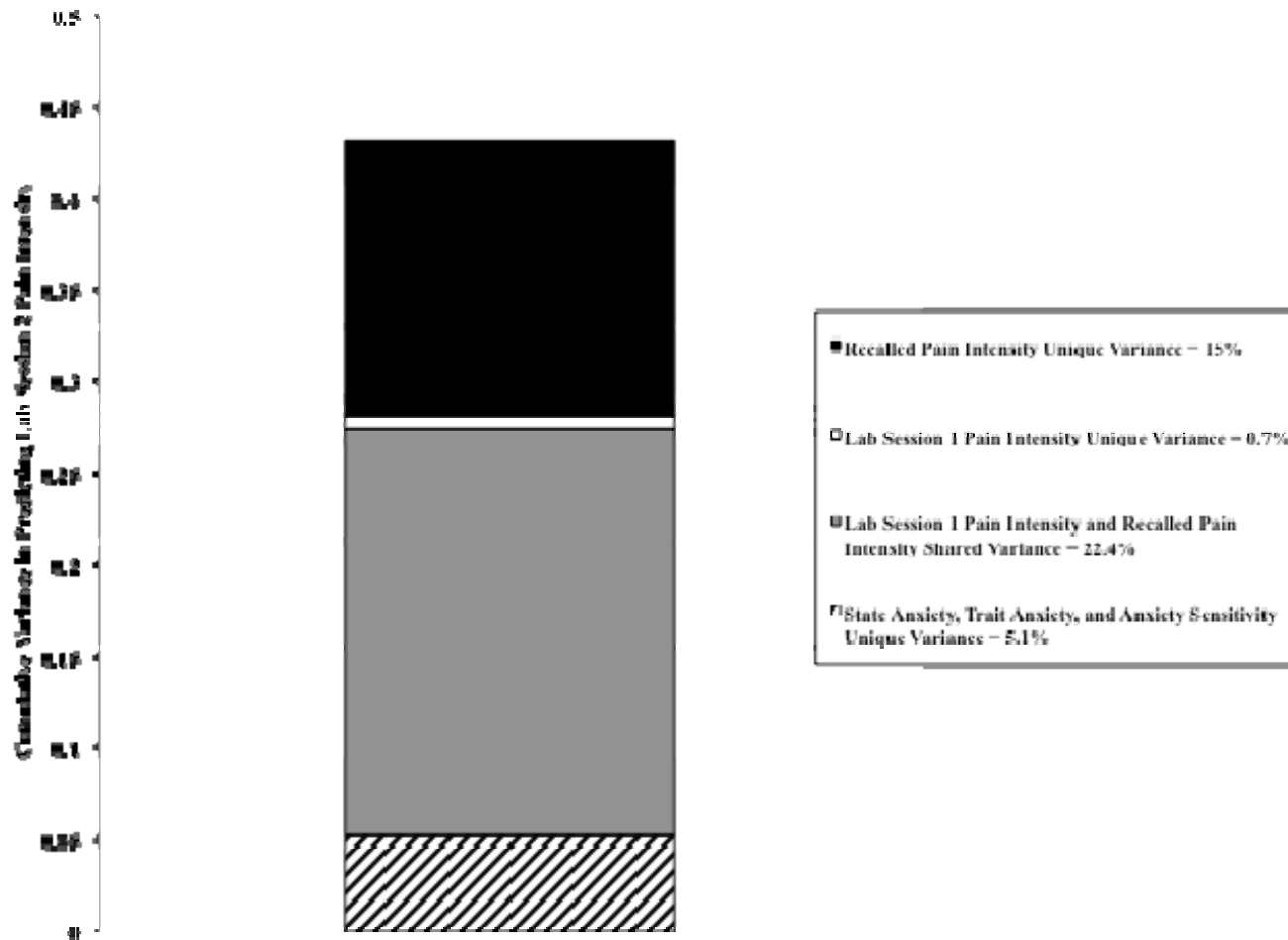


Figure 3.1. Chart depicting unique and shared variance between variables predicting Lab Session 2 pain intensity. Recalled pain intensity (black shade) and anxiety-related variables (striped) were better predictors of Lab Session 2 pain intensity than was Lab Session 1 pain intensity (unshaded).

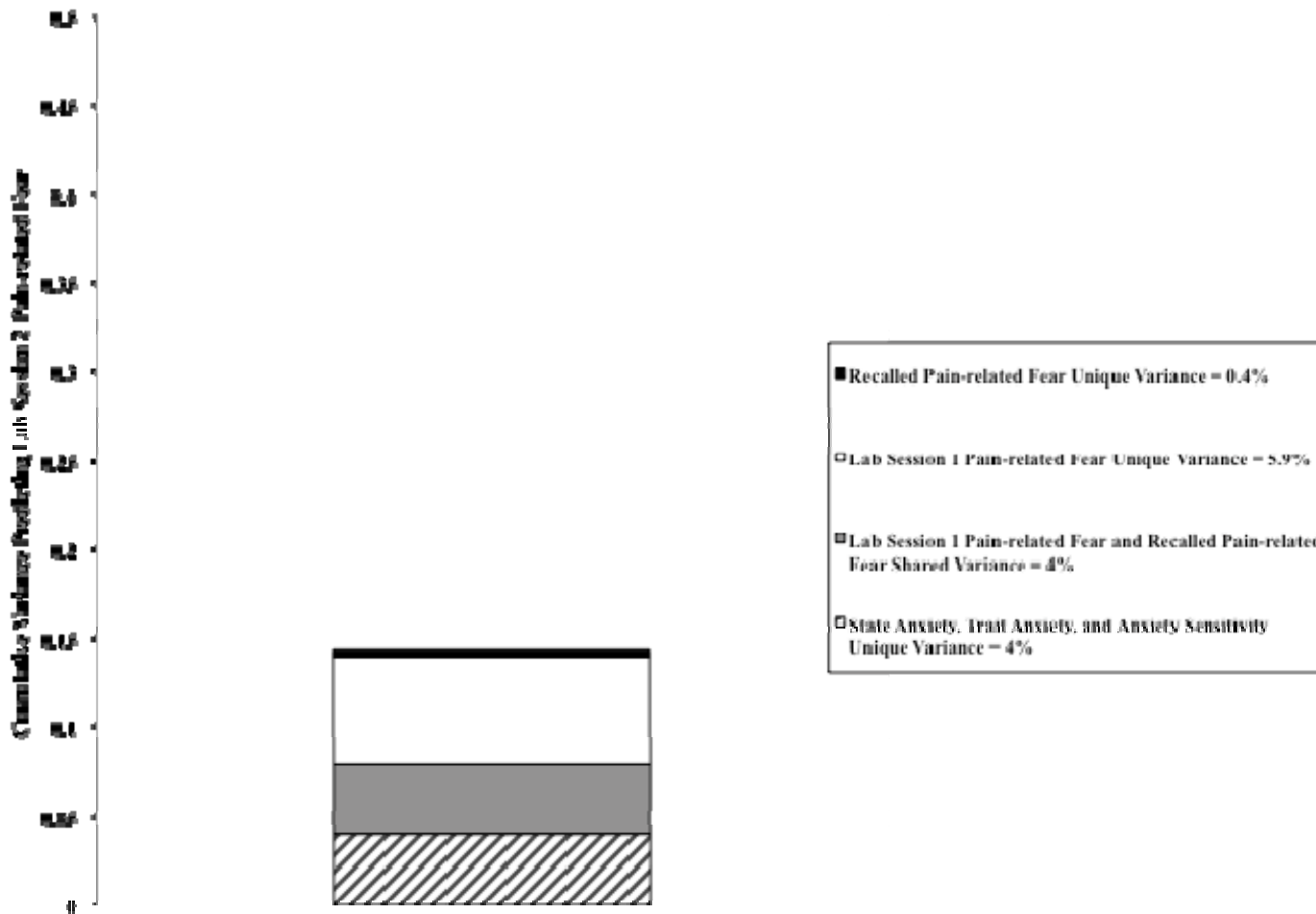


Figure 3.2. Chart depicting unique and shared variance between variables predicting Lab Session 2 pain-related fear. Lab Session 1 pain-related fear (unshaded) and anxiety-related variables (striped) were better predictors of Lab Session 2 pain-related fear than was recalled pain-related fear (black shade).

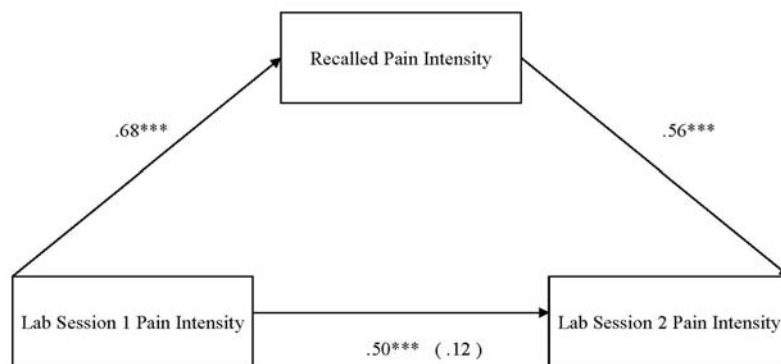


Figure 3.3. The mediation model depicting the standardized regression coefficients for the relationship between Lab Session 1 pain intensity and Lab Session 2 pain intensity as mediated by recalled pain intensity. The standardized regression coefficient between Lab Session 1 pain intensity and Lab Session 2 pain intensity, while controlling for recalled pain intensity, is indicated in parentheses. State and trait anxiety and anxiety sensitivity were entered as covariates in the first step of all regression analyses.
* $p < .05$; ** $p < .01$; *** $p < .001$.

CHAPTER 4: DISCUSSION

This dissertation examined the role of anxiety in the development of children's memories for pain as well as the influence of pain memories on subsequent pain reporting among healthy children undergoing pain of mild to moderate intensity. Specifically, the first research study experimentally investigated the impact of state anxiety, and the influence of anxiety-related variables, on children's memories for the somatosensory (e.g., intensity) and affective (e.g., pain-related fear) aspects of a novel pain experience. Following random assignment, children completed either a state anxiety induction task or a control task and subsequently completed measures of state anxiety. Immediately following this, children completed a laboratory pain induction task (the cold pressor task), pain ratings, and measures assessing stable anxiety-related variables (anxiety sensitivity, trait anxiety). Children's memories for the pain task and expectations about future pain were elicited 2 weeks later via telephone. Findings revealed that despite the effectiveness of the experimental state anxiety induction task in inducing levels of state anxiety among children undergoing it, state anxiety did not impact children's memories for pain. Nevertheless, irrespective of group assignment, children who had higher levels of state anxiety developed more negative memories (i.e., recalled higher levels) of pain intensity and pain-related fear, even over and above the influences of sex, stable anxiety-related variables, and experienced pain intensity and pain-related fear. These predictive models had substantial explanatory power, accounting for 52% and 35% of the variance in recalled pain intensity and pain-related fear, respectively. Moreover, stable anxiety-related variables (anxiety sensitivity and trait anxiety) emerged as significant and unique predictors of children's memories for the fearful aspect of the pain experience.

The second research study extended the first by investigating the influence of children's pain memories on their pain reporting during a second laboratory pain induction task, which they completed 1 month following the first exposure. The study also examined the influence of children's style of remembering (e.g., negatively estimated vs. accurate/positively estimated memories) on expectations of future pain as well as changes in pain reporting over time. Children who completed the first laboratory visit and telephone interview came back to the laboratory to complete the pain induction task once again, as well as measures of pain intensity and pain-related fear. Results revealed that, similar to adults (Gedney & Logan, 2006), children's memories of pain intensity were a unique and better predictor of subsequent pain reporting than was their actual initial experience of pain intensity; in fact, children's memories of pain intensity mediated the relationship between initial and subsequent reporting of pain intensity. Conversely, children's memories of pain-related fear were a less important predictor of subsequent fear reporting than was their initial experience of pain-related fear. Children who developed negatively estimated pain memories, as compared to those who developed accurate or positively estimated memories, tended to have higher levels of anxiety (state/trait anxiety, anxiety sensitivity), develop expectations of greater future pain, and show greater increases in pain reporting over time.

The following discussion integrates findings of both studies with existing literature, highlights study strengths and limitations/considerations, and describes clinical implications associated with this research that can guide intervention efforts. Directions for future empirical investigation in this area are highlighted throughout.

Integration of Findings with Existing Research

Anxiety and Children's Memories for Pain

Despite theoretical support for the role of state anxiety in the development of memory biases (Beck & Clark, 1997), to date only two studies have attempted to examine the influence of state anxiety on children's memories for pain, and both concluded a lack of relationship between the two (Lander et al., 1992; Versloot et al., 2008); however, these findings could have been due to methodological issues. For example, in the examination of children undergoing local anesthesia injections prior to dental treatments (Versloot et al., 2008), anxiety was inferred through parental proxy report of children's general dental fears (versus fears about the dental procedure under investigation) and parents were not present in the procedural room, thereby precluding parents' use of important behavioural cues (e.g., verbal utterances, facial expression) to guide their judgments and associated ratings. Furthermore, the generalizability of these findings to healthy children is unclear given that the sample was primarily comprised of children who were referred due to behaviour management problems. Finally, memory was inferred through history of previous dental treatment as opposed to formal assessment of recall, thereby precluding accurate assessment of individual differences in recall. Similarly, in the investigation of children undergoing venipuncture (Lander et al., 1992), it is unclear whether state anxiety in this study was assessed *immediately* prior to the procedure, which is unlikely given the variability and unpredictability inherent in clinical settings. Nevertheless, despite these methodological issues, the conclusions from both of these studies have deterred researchers from examining state anxiety as a contributing factor in the development of biases in children's pain memories (e.g., Rocha et al., 2009).

The results from our first study suggest that, similar to adults (Arntz, van Eck & Heijmans, 1990), state anxiety is a unique and important predictor of children's memories for both the somatosensory and affective aspects of pain. Moreover, children who are most at risk for developing increasingly negative responses to pain over time (e.g., those with negatively estimated pain memories) are more likely to have experienced higher levels of state anxiety during initial pain experiences.

There are several explanations to account for the finding that significant differences in memories were not found between children in the state anxiety induction group and those in the control group—despite evidence for the effectiveness of the experimental manipulation in increasing levels of state anxiety—yet irrespective of group assignment, state anxiety was a unique and significant predictor of children's recall. As described in the first manuscript, this could, in part, have been a function of differences between ANOVA and regression analyses in harnessing/modeling individual variability in levels of state anxiety among children within each group, as well as in the degree of power that is afforded by each analytic approach to detect effects (Aiken & West, 1991). Variability among children in each experimental group could have also been introduced as a result of individual difference variables that were not assessed in the present investigation. For example, inconsistencies in the adult literature on anxiety and memory biases among both healthy and clinical samples have been explained in terms of individual differences in attentional style. Indeed, memory differences have been found between high anxiety sensitive adults who are avoidant versus hypervigilant toward threat-related information (Noel et al., 2011) and this is supported by theoretical accounts of individual coping and attentional orientation in anxiety (Krohne, 1993), as well as

accumulating empirical evidence suggesting the presence of heterogeneity within high anxious groups of individuals who have traditionally been treated as a homogenous group (Mitte, 2008). Given the critical role of attention in several theories used to account for memory biases in anxiety (Beck & Clark, 1997; Eysenck et al., 2007), further examination of individual attentional subgroup differences in this context is warranted and could increase the precision with which we are able to identify children who are most at risk for memory biases and heightened pain responding over time.

In order to examine the impact of state anxiety as well as to introduce sufficient variability in state anxiety among children in the laboratory setting, a state anxiety induction technique was employed—a modified version of the Trier Social Stress Task for Children (TSST-C)—which has been shown to lead to concomitant increases in both autonomic and subjective measures of anxiety (Hermann et al., 2004). The task itself involves elements (uncontrollability, unpredictability, and threats to the social self) that have been identified as being strong psychological triggers of the HPA axis, which regulates the release of cortisol (i.e., the stress hormone; see Dickerson & Kemeny, 2004; Gunnar, Talge, & Herrera, 2009). Several studies have shown that the TSST-C and modifications of the task are successful in provoking a cortisol response as well as heightened self-perceptions of stress and anxiety among children (Buske-Kirschbaum et al., 1997; Buske-Kirschbaum et al., 2003; Gunnar, Frenn, Wewerka, & Van Ryzin, 2009; Jones et al., 2006). Given the performance nature of the task, it is possible that completion of this induction technique would be most distressing to children who are prone to experiencing anxiety related to social situations as opposed to physical or bodily threat, although this has yet to be empirically examined. Indeed, many validated

measures used to assess anxiety symptoms among children and adolescents are comprised of distinct factors relating to social threat and physical danger/bodily harm. For example, among both healthy and clinical samples, the widely used Multidimensional Anxiety Scale for Children (MASC) has been shown to assess four empirically derived and distinct dimensions of anxiety: social anxiety; harm avoidance; separation anxiety/panic; physical symptoms of anxiety (Baldwin & Dadds, 2007; March, 1997; Olason, Sighvatsson, & Smári, 2004; Rynn et al., 2006). Moreover, these distinct factors have been found to predict qualitatively different categorizations of anxiety disorders (Grills-Taquechel, Ollendick, & Fisak, 2008). Similarly, other more recently developed anxiety measures have taken a more multidimensional approach to the classification of anxiety, based on the distinct diagnostic categories outlined in the Diagnostic Statistical Manual of Mental Disorders, separating fears related to social threat from fears related to physical harm (e.g., Screen for Anxiety Related Emotional Disorders, Birmaher et al., 1997; Children's Anxiety Scale, Spence, 1997).

In assessing state and trait anxiety using the widely used State Trait Anxiety Inventory for Children (Spielberger, 1973), children were classified according to their general tendencies to perceive threat in their environments versus specific tendencies to respond to particular threat stimuli with negative arousal; as such, anxiety in this dissertation was conceived of in a global and unidimensional way. Although there is support for the multidimensionality of both state (e.g., cognitive-worry, autonomic-emotional) and trait (e.g., social evaluation, physical danger, ambiguous, daily routine) anxiety, and a multidimensional self-report measure has been developed to assess both, in addition to one's subjective perception of the anxiety-provoking situation (e.g., physical

danger versus social evaluation; Endler Multidimensional Anxiety Scales-State, Endler, Parker, Bagby, & Cox, 1991), this measure has not yet been validated for use with children before the onset of adolescence. Given the somatic nature of pain, it is possible that the use of state anxiety induction tasks designed to more specifically target physical or bodily threat/danger, as opposed to social threat as targeted by the TSST-C, could have led to significant between group differences that were not found in the first study; however, to date no such induction tasks have been validated for use with children. Moreover, as previously mentioned, no multidimensional self-report measure of anxiety for use with children currently enables one to separately assess state versus trait aspects of anxiety, which was critical to the aims of the current research. Future research should attempt to establish the psychometric properties of such multidimensional self-report measures of state and trait anxiety, given their potential utility in laboratory contexts. Assessment of the specific focus of the child's anxiety (e.g., social vs. physical threat) could reveal differential relationships with children's subjective experience of pain over time, as well as their pain memories.

In contrast to state and trait anxiety, which reflect tendencies to perceive threat in one's environment, anxiety sensitivity may offer a more precise measure of anxiety in pediatric pain contexts. In the present investigation, anxiety sensitivity emerged as an important predictor of children's memories for pain-related fear and children who were more anxiety sensitive subsequently developed more negatively estimated memories of pain-related fear. Although well researched among adult populations as a factor that predisposes individuals to develop catastrophic cognitions about pain (Norton & Asmundson, 2004), far less attention has been given to the role of anxiety sensitivity and

pain during earlier developmental periods. This is the first study to examine the role of anxiety sensitivity in children's memories for pain. At the core of the anxiety sensitivity construct is the notion that the individual's fear of anxiety-related symptoms stems from beliefs that these symptoms have harmful physical, psychological, and social consequences (Reiss et al., 1986; Taylor, 1999). The limited research that has been conducted with children suggests that the construct behaves in a similar way across development; indeed, anxiety sensitivity has emerged as a unique predictor of pain catastrophizing (encompassing subdimensions of rumination, magnification, and helplessness; Muris et al., 2007; Tsao et al., 2009), pain-related anxiety (i.e., cognitive, emotional, physiological, and behavioural reactions to the anticipation and experience of pain; Pagé et al., 2011), and fear of pain (i.e., fearful thoughts and fearful physical feelings and behaviours; Huguet et al., 2011; Martin et al., 2007) among children. This evidence suggests that like adults, anxiety sensitivity reflects a child's tendency to develop catastrophic cognitions and fear specifically about pain. It is likely that the cognitive amplification of pain-related threat, characteristic of children who are more anxiety sensitive, also reflects a tendency for the fearful representation of their previous pain experiences to become negatively exaggerated over time, a prediction that is supported by the present results. Similarly, healthy children's level of trait anxiety has been shown to predict the development of catastrophic cognitions about pain 6 months later (Vervoort, Eccleston, Goubert, Buysse, & Crombez, 2010). In this way, anxiety and resulting catastrophic cognitions and fear, like negative affect among adults (Gedney & Logan, 2006), may provide the experiential context through which the pain experience is later recalled. If the memory of the pain experience is retrieved and catastrophic

appraisals are applied to it, increasingly negative exaggerations in memory would be expected, as was demonstrated in the present research. In addition to memory, future research should examine pain catastrophizing among children at various time points during and following a painful event to test this hypothesis.

Memories and Subsequent Pain Reporting

The results of the second study extended models of memory and subsequent pain reporting developed with healthy adults undergoing experimental pain (Gedney & Logan, 2006) to earlier developmental periods. This research provides evidence that pain memories are a powerful and better predictor of subsequent pain experience than initial pain reporting across development and demonstrates that the relationship between initial and subsequent pain reporting is mediated by children's pain memories. Similar to findings derived from examinations of children with chronic illnesses undergoing highly invasive lumbar punctures (Chen et al., 2000), children who developed memories that were negatively estimated were characterized by higher levels of anxiety, developed expectations of greater future pain, and reported greater increases in pain intensity and pain-related fear during subsequent pain exposures. Consistent with previous research (e.g., Chen et al., 2000), these findings indicate that this categorization of children's memory style is important in that it distinguishes between children who are and who are not at risk for exhibiting and reporting higher levels of pain and distress over time. Similar to the adult literature (Gedney & Logan, 2006), these findings provide evidence of post-exposure modulation, which resulted in exaggerations in memory among a subset of children. This post-exposure modulation was influenced by a host of factors beyond the initial pain experience. Among children who are relatively highly anxiety sensitive

and trait anxious, the subsequent development of catastrophic cognitions and appraisals (Vervoort et al., 2010) likely attributed to exaggerations in memories seen among this subset of children. Additionally, this could have influenced the development of negative expectancies about future pain. It is thought that subsequent interpretations of the painful experience elicited through “self-talk narratives” (e.g., “the water was colder and hurt more than I thought it would”) can change expectations about future pain as well as pain memories (see Gedney & Logan, 2006). The relationship between expectancies and memory is likely bidirectional wherein negative exaggerations in recall influence expectations about greater pain, which in turn bias the reconstruction of the existing memory trace (McDonald & Hirt, 1997). Indeed, it has been shown that individuals with higher levels of anxiety show enhanced memory for their negative expectations as opposed to the direct experience of pain itself (Arntz et al., 1990).

The fact that children who developed negatively exaggerated memories and expectations of greater future pain later reported greater increases in pain and fear at subsequent pain exposures is consistent with previous research (Chen et al., 2000; Gedney & Logan, 2006). However, given that these results were derived from examination of healthy children undergoing pain of mild-to-moderate intensity in a laboratory setting, this suggests that the relationship between memory and subsequent pain reporting is robust. Unlike clinical medical procedures (e.g., venipunctures, lumbar punctures), children do not report being anxious prior to completion of laboratory pain induction tasks, such as the cold pressor task (Tsao et al., 2004; Wilby et al., 2010). Moreover, children typically report that they enjoy taking part in CPT research, are willing to take part in second exposures, and rate their overall experiences taking part in

research involving two exposures as more positive than research involving only one exposure (Birnie et al., 2011). Indeed, the level of state anxiety (VAS-child) reported by children in the study immediately prior to completion of the CPT was significantly reduced from Lab Session 1 to Lab Session 2 ($M = 3.41$, $SD = 2.57$; $M = 1.36$, $SD = 1.67$; $t(109) = 8.032$, $p < .001$), a finding that persisted for children who negatively estimated and accurately/positively estimated their pain memories. Yet, despite experiencing less state anxiety at the second laboratory visit, children who developed negatively estimated pain memories reported greater increases in pain intensity and pain-related fear from Lab Session 1 to Lab Session 2. Among children repeatedly undergoing invasive lumbar punctures, negative exaggerations in memory were related to increases in subjective pain reporting and observed behavioural distress but decreases in physiological measures of distress over time (Chen et al., 2000). This suggests that although children may habituate to repeated pain exposures, as indicated by dampening of their physiological reactivity, their subjective perceptions of pain can still become increasingly negative and amplified over time, which could be due to the fact that their negatively estimated memories were triggered by pain-related cues present in the room in which they experienced pain (Chen et al., 2000). Although the present studies did not examine more than two pain exposures, future longitudinal research should investigate the influence of children's pain memories on pain reporting during several pain exposures over time. Similarly, given that adults' pain memories become more exaggerated after longer delays (6-18 months; Everts et al., 1999; Gedney et al., 2003), and children's memories in the current study were elicited only 2 weeks following the initial pain exposure, research should examine the influence of duration of time between assessments on the development of children's memories for

pain. It is possible that longer delays between pain exposure and memory elicitation could result in greater exaggerations in recall and subsequently, greater increases in subsequent pain reporting. Furthermore, objective assessment of fear avoidance behaviours, in addition to subjective pain reporting, could provide important insights into the development of behavioural manifestations of exaggerated pain memories over time.

Strengths and Limitations

Internal Validity versus Ecological Validity

The experimental nature of the present research afforded a high degree of control over the setting and variables of interest and decreased the potential impact of confounding variables, thereby maximizing internal validity. It allowed for examination of the development of pain memories from their inception, given that children selected for inclusion in the study had never before been exposed to the pain stimulus under investigation. Children were randomly assigned to experimental conditions, thereby enabling investigation of the impact of state anxiety on children's memories for pain. As such, the laboratory setting and experimental design facilitated examination of important research questions that could not be adequately addressed in a clinical setting. Moreover, the findings derived from this experimental investigation with healthy children undergoing pain of mild-to-moderate intensity are largely consistent with research conducted with healthy adults undergoing laboratory pain (Gedney & Logan, 2006) and children with chronic illnesses undergoing invasive lumbar punctures (Chen et al., 2000), thereby supporting the generalizability of these results beyond the laboratory setting. Nevertheless, a potential limitation of any experimental investigation is the extent to which findings can generalize beyond the laboratory setting, particularly when

convenience samples are used (Shadish, Cook & Campbell, 2002); indeed, the individuals in the present research were generally highly educated and Caucasian. Similarly, the degree of ecological validity of the state anxiety and pain induction tasks employed in this laboratory-based research is unclear. To date, only one study has investigated the ecological validity of the cold pressor task, demonstrating a relationship between CPT pain ratings and non-pain real world outcomes (e.g., school absences; Tsao, Glover, Bursch, Ifekwunigwe, & Zeltzer, 2002). However, research has not explored the relationships between responses evoked by the CPT and children's pain responses outside of the laboratory. Similarly, this research was the first to use the Trier Social Stress Task for Children to induce state anxiety (versus a cortisol response) among healthy children within the context of pediatric pain, and the relationship between anxiety responses induced by this task and those induced in real world pain contexts is currently unknown. Such future investigations will provide important insights into whether the current findings extend to real world pain experienced by healthy children.

Self-Report Measures

The present studies examined anxiety and pain-related constructs through the use of psychometrically sound self-report measures. This approach to measurement was deemed important given the subjective nature of pain (IASP Task Force on Taxonomy, 2004), as well as the internalizing nature of anxiety, which makes children themselves critical sources of information on their own behaviours and feelings (Edelbrock, Costello, Duncan, Kalas, & Conover, 1985; Wachtel, Rodrigue, Geffken, Graham-Pole, & Turner, 1994). Moreover, it has long been established that there is a lack of concordance between different informants (e.g., parents, children, teachers, clinicians) in assessing anxiety

(Brunshaw & Szatmari, 1988; Stavrakaki, Vargo, Roberts & Boodoosingh, 1987) and pain (Chambers, Reid, Craig, McGrath, & Finley, 1998), further highlighting the importance of self-report measures. Although there are several well-validated behavioural (for a review see von Baeyer & Spagrud, 2007) and self-report (for a review see Stinson et al., 2006) measures to validly and reliably assess pain among children, the measurement of state anxiety is far less developed; in fact, only one observational measure of state anxiety has been developed to date and is specific to preoperative contexts as opposed to laboratory settings (e.g., The Yale Preoperative Anxiety Scale; Kain, Mayes, Cicchetti, Bagnall, Finley, & Hofstadter, 1997). Nevertheless, despite acknowledgement of the primary importance of reliance on child self-report about subjective experiences of anxiety (Silverman, 1994) and pain (Craig & Badali, 2004; von Baeyer & Spagrud, 2007), as well as the lack of measures available to assess state anxiety, overreliance on self-report measures in the present studies could have limited the comprehensiveness of our understanding of the revealed relationships. Furthermore, it is also possible that the results from both studies could in part be attributable to a negative response bias among some children (i.e., a tendency/willingness for individuals to report negative states) on the self-report measures. Ideally, self-report measures should be considered in concert with behavioural observations (e.g., facial expression, verbal utterances), parent and observer report, and information pertaining to the child's social environment. Although these varying sources of information will likely differ, they represent different aspects of, and perspectives on, the child's pain experience (Manne, Jacobsen, & Redd, 1992) and therefore provide a richer understanding of the complexity inherent within it.

It is widely acknowledged, and described in the very definition of pain (IASP Task Force on Taxonomy, 2004), that pain is a multidimensional experience comprised of sensory and affective aspects. Similarly, children's memories for pain are also multidimensional (Ornstein et al., 1999); however, very few studies have examined children's memories for pain beyond the somatosensory representation (for exceptions see Noel et al., 2010; Lander et al., 1992; Chen et al., 2000). Some have argued that "describing pain only in terms of its intensity is like describing music only in terms of its loudness" (von Baeyer, 2006, pp. 157), an analogy that could also apply to the assessment of children's pain memories. The present studies offer advantages over previous research by examining both the somatosensory and affective aspects of the underlying representation of the pain experience. Moreover, the results of the present studies suggest that these aspects of children's memories for pain may indeed be qualitatively different given the differential influences that each type of memory had on subsequent pain reporting, as well as the differences in the percentage of variance accounted for in the respective explanatory models. Future research should continue to adopt a multidimensional assessment approach in order to capture the complexity in both children's pain experiences and their pain memories.

The Role of Parents

The present studies focused solely on the subjective experience of children and did not examine the broader social context in which pain, fear, and anxiety are experienced and pain memories develop. It is well established that particularly early in development, marked by increased dependence on caregivers, social interactions are critical in determining the child's experience and expression of pain (Craig, 2009;

Hadjistavropoulos et al., 2011). Children's beliefs and cognitions about the inherent threat value of pain develop within the familial context and information is conveyed to children early in development. Children as young as 15 months have been found to be capable of acquiring fear and avoidance behaviours through parent modeling (Gerull & Rapee, 2002), particularly among children of anxious mothers who more frequently exhibit these behaviours (Muris, Steerneman, Merckelbach & Meesters, 1996). Through early vicarious (i.e., pain and fear modeling by caregivers) and instrumental (i.e., reinforcement for pain and fear behaviours) learning, children develop beliefs and cognitions about the dangerousness of pain and the appropriateness of associated behaviours (e.g., approach versus avoidance). Indeed, certain parent behaviours have been conceived of as communicative cues of fear and anxiety, which can subsequently exacerbate child pain behaviours and associated distress (Chambers, Craig, & Bennett, 2002; McMurtry, Chambers, McGrath, & Asp, 2010). These behaviours are thought to function to amplify children's cognitions about the inherent threat value of pain and reinforce pain behaviours (e.g., escape/avoidance; see Wilson, Lewandowski & Palermo, 2011). These early social learning processes related to somatic symptoms (including pain) in childhood are predictive of high levels of anxiety sensitivity and pain-related anxiety in adulthood (Watt & Stewart, 2000; Stewart et al., 2001; Watt, O'Connor, Stewart, Moon, & Terry, 2008; Watt, Stewart, Moon, & Terry, 2010). Similarly, children's autobiographical memories develop within this familial context and are highly influenced by the quality and content of their verbal interactions with individuals in their social environments, particularly parents (Bauer et al., 2010; Peterson et al., 2007). As such, the inclusion of parents in future investigations of anxiety and children's memories

for pain is warranted. Specifically, examination of cognitive affective parent factors shown to increase child pain behaviours and anxiety, such as parental catastrophizing about child pain (Goubert, Eccleston, Vervoort, Jordan, & Crombez, 2006; Caes, Vervoort, Eccleston, Vandenhende, & Goubert, 2011) and anxiety sensitivity (Tsao et al., 2006), are likely to refine our understanding of the complex interrelationships between parent and child factors in influencing the development of pain memories and subsequent pain responding.

Theoretical Implications

The results of the current research studies have important theoretical implications and enhance our understanding of the factors that influence the development of children's pain memories from their inception, their reconstruction over time, and the manner in which these memories shape subsequent pain experience. Consistent with predictions of theories of anxiety and memory biases (Beck et al., 1985; Beck & Clark, 1997), children with higher levels of anxiety and danger-related schemata pertaining to their general environments and somatic sensations developed pain memories that were characterized by amplified estimations of somatosensory and affective threat over time. Several theories also predict that these memories likely developed as a result of highly anxious children's attentional biases toward threatening aspects of the painful experience (Beck & Clark, 1997; Eysenck et al., 2007); however, it is also possible that there are subtypes of highly anxious children who differ in their individual attentional style (e.g., hypervigilant versus avoidant of threat cues) and who may also differ in the degree to which their memories become negatively exaggerated over time (see Noel et al., 2011). It is likely that in addition to general anxiety-related constructs (e.g., state/trait anxiety, anxiety

sensitivity), fear and anxiety variables that are specific to pain itself (e.g., fear of pain, pain anxiety, pain catastrophizing) are strongly related to memory biases, given their close relationships with anxiety sensitivity among children (Huguet et al., 2011; Martin et al., 2007; Pagé et al., 2011; Tsao et al., 2009) and the degree to which they capture the tendency for children to magnify the threat value of pain over time. These highly anxious children are also likely to be characterized by a perceived inability to cope with pain (Beck et al., 1985), which could influence the construction and reconstruction of pain memories at encoding and retrieval, as well as the development of negative expectancies about future pain. Indeed, negative memory biases, like the anxiety constructs described herein, are characterized by amplified estimations of threat; that is, children recall their experience as *more* painful and fear inducing than they initially reported it to be. Once these negative memory biases develop, they become powerful predictors of children's subsequent pain experience. It is likely that the negative memory biases and pain expectancies seen among these highly anxious and fearful children become activated upon reentry into the pain context and then further exaggerated as a result of increased arousal (see Chen et al., 2000). As a result, these negatively exaggerated memories and expectancies likely become the experiential context through which subsequent pain is experienced. Not surprisingly then, these children's reactions to pain, like their pain memories themselves, become even more distressing over time. Furthermore, this process likely exacerbates and perpetuates the vicious cycle of increased anxiety and catastrophizing, additional reconstruction of negatively exaggerated pain memories and expectancies, and heightened subjective reactivity to pain over time.

Children do not live and experience pain in isolation; indeed, parents exert a powerful influence on the socialization of children's fear, anxiety, memory, and pain behaviours (Gerull & Rapee, 2002; Bauer et al., 2010; Peterson et al., 2007; Chambers et al., 2002; McMurtry et al., 2010). Moreover, the relationships between the psychological characteristics and behaviours of the parent and those of the child are likely reciprocal (Palermo & Chambers, 2005; Asmundson et al., in press); as such, parents can exert influence at every stage in the cycle. Accordingly, they have the potential to be critical agents in intervention efforts aimed at reducing children's anxiety before, and fear and pain during, painful experiences. Furthermore, they have the potential to strongly influence the reframing of children's pain memories and modification of expectancies through parent-child discourse following painful experiences.

Clinical Implications

There are numerous factors that have been shown to contribute to the manifestation of anxiety in clinical settings, including children's anticipation of pain, the experience of pain itself, fear of the unknown, uncontrollability, perceptions of stress in the environment, sex, separation from caregivers, parenting style and/or behaviours, and parent psychological responses (e.g., Crandall, Miaskowski, Kools, & Savedra, 2002; LaMontagne, Hepworth, & Salisbury, 2001; Logan & Rose, 2004; Kleiber, Schutte, McCarthy, Floria-Santos, Murray, & Hanrahan, 2007; McMurtry et al., 2010). In addition, many of these factors (e.g., anticipation of pain, separation from caregivers, uncontrollability, perceptions of stress) applied to the laboratory context in which this research took place, lending further support for the generalizability of these findings to clinical medical procedure contexts. The results of this dissertation research suggest that

children's anxiety—even if it is not specific to the anticipation of pain itself—may place children at risk for developing pain memories that are negatively exaggerated. Once these memories are formed and reconstructed, they can influence children's expectations about future pain as well as changes in their subjective pain experience over time. The results of this research, in the context of previous investigations with chronically ill children and healthy adults, offer important insights into potential avenues for clinical intervention.

First, this research highlights the importance of reducing children's anxiety prior to painful experiences in order to reduce the influence of high anxiety on subsequent memory development and pain experiences. This could involve interventions aimed at modifying children's schemas related to danger and their perceptions of their ability to cope, by lowering the threat value that children assign to stimuli in their environments and increasing their self-efficacy about their coping abilities. Given the theoretical support for the role of attentional biases toward threat and schema activation in mediating the relationship between anxiety and memory biases (Beck & Clark, 1997), use of cognitive behavioural strategies aimed at targeting attentional tendencies and cognitions are particularly promising. Cognitive behavioural strategies for pain management involve targeting maladaptive and catastrophic cognitions about pain and equipping children with coping skills to manage their pain and distress; as such, they directly target children's pain-related schemas and perceptions related to their coping abilities. Indeed, there is empirical support for the use of non-pharmacological interventions, such as distraction and hypnosis, for managing pain and associated distress (Uman et al., 2008). Given the strong influence of experienced pain and distress during acute pain experiences on subsequent memory development (e.g., Noel et al., 2010; Chen et al., 2000), and the

potential buffering influences of distraction and topical analgesics (e.g., EMLA™) against the development of negative pain memories (Cohen et al., 2001), the use of these pain management strategies is recommended. In addition to pharmacological agents such as topical analgesics, sedation and/or anxiolytics are sometimes used with children who are highly anxious and distressed (Finley, 2001). However, commonly used benzodiazapines (e.g., midazolam), although generally helpful in reducing pre-procedural anxiety in preoperative contexts, can have several negative side effects (Watson & Visram, 2003). Moreover, there is evidence that the use of such anxiolytics can impair explicit, but not implicit, memories (Pringle, Dahlquist & Eskenazi, 2003; Stewart, Buffett-Jerrott, Finley, Wright, & Valois Gomez, 2006), which might make subsequent procedures appear novel and evoke heightened distress (see Wright, Stewart, Finley, & Buffett-Jerrott, 2007) as well as preclude the ability to effectively use memory-reframing interventions. Furthermore, there is evidence that non-pharmacological interventions (i.e., hypnosis) are more effective in reducing preoperative anxiety than pharmacological interventions (i.e., midazolam; Calipel, Lucas-Polomeni, Wodey, & Ecoffey, 2005). By equipping children with coping strategies that can be used across settings and time, their underlying cognitions, self-efficacy, attentional control, and subsequent memories could be effectively targeted. The results of the present research suggest that the use of similar cognitive behavioural strategies aimed at reducing children's general perceptions of threat *prior* to painful procedures (i.e., before entering the procedural context) to reduce levels of state and trait anxiety is of particular importance.

Furthermore, given that anxiety sensitivity influences the development of children's affective pain memories, promotes catastrophic cognitions about pain and fear

of pain (Norton & Asmundson, 2004), and influences children's pain-related anticipatory anxiety (Tsao et al., 2006), interventions aimed at targeting anxiety sensitivity are also promising. There is evidence that a brief cognitive behavioural intervention (including interoceptive exposure) aimed at reducing anxiety sensitivity can reduce pain-related anxiety and fear in adult women (Watt, Stewart, Lefaiivre & Uman, 2006). Similarly, there is preliminary support for the effectiveness of interoceptive exposure (in addition to bilateral tactile stimulation and imagined use of coping strategies) in combination with standard multimodal treatment for reducing pain intensity and pain-related disability among adolescents with chronic pain (Hechler et al., 2010). Moreover, the mechanism thought to account for these reductions in pain and disability is change in memories (Hechler et al., 2010). Similar interventions involving the use of interoceptive exposure for the treatment of pre-procedural anxiety have not yet been investigated among children; however, in light of the importance of exposure in the treatment of anxiety and fear (Rapee, Schniering, & Hudson, 2009), investigation of similar, yet developmentally appropriate (e.g., with the involvement of parents), approaches for children in pain contexts is warranted. Given that stable anxiety-related variables were predictive of children's memories for the affective as opposed to the sensory aspects of the pain experience, these strategies might be most helpful in targeting the fearful aspect of children's pain memories.

The results of the present research highlight the importance of extending intervention efforts beyond the immediate pain context. Indeed, children's memory for pain intensity was a better predictor of subsequent pain reporting than their actual initial experience of pain, and mediated the relationship between initial and subsequent pain

reporting, which indicates that pain memories are an important mechanism through which intervention could have particularly beneficial effects over time. To date, very few studies have examined the effectiveness of memory reframing interventions on children's subsequent distress during medical procedures. Chen and colleagues (1999) examined the influence of a brief memory reframing intervention on subsequent distress during repeated lumbar punctures among children diagnosed with leukemia. The impetus for the intervention was to modify negatively exaggerated memories of painful procedures developed among anxious children through exposure to post-event information aimed at deflating the perceived aversiveness of the experience. To accomplish this, the memories of children in the treatment group were elicited through a memory interview designed to assess biases in children's recall of the threatening aspects of the lumbar puncture. Subsequently, a therapist who observed the procedure used cognitive behavioural strategies to reframe the memory based on objective information obtained during the procedure. Specifically, therapists assisted children in reevaluating their reactions by reinforcing their beliefs about their abilities to use coping strategies (e.g., increasing their perceived self-efficacy), appraising their responses to the procedure in a more realistic manner, and increasing the accuracy of their recall. In this way, the intervention directly targeted and aimed to reduce the catastrophic and negatively exaggerated aspects of children's recall and increase children's perceptions of the effectiveness of their coping abilities. Compared to children in the control group, those receiving the memory reframing intervention showed reductions in distress at a subsequent lumbar puncture one week later, as assessed by both physiological and self-report measures.

Similarly, Pickrell and colleagues (2007) examined the effectiveness of a memory reframing intervention among children (aged 6-9 years) undergoing repeated restorative dental treatments involving local anesthesia injections. Two weeks following the initial dental treatment, children were randomized to receive either a memory reframing intervention, which was designed to positively reframe their memories of the previous procedure, or an interactive neutral discussion (i.e., control condition). Both conditions involved interacting with the same individual, a female interventionist. Immediately following the intervention or control procedure, children once again underwent a similar dental treatment. Children's self-reported pain and fear was assessed at each time point. Findings revealed that children receiving the memory reframing intervention, as compared to children in the control group, remembered experiencing less pain and fear than they actually reported at the initial procedure, reported less fear following injections over time, and showed improvements in their behaviour (i.e., degree of cooperativeness) from the first to the second dental treatment. Given these findings, it is surprising that more research has not examined the effectiveness of similar memory reframing interventions for use with other pediatric populations (e.g., healthy children, children with anxiety disorders). Given the powerful role of parents in shaping children's pain experience/expression (Chambers et al., 2002; Craig, 2009; McMurtry et al., 2010), as well as their autobiographical memories (Bauer et al., 2010; Peterson et al., 2007), parent-led memory reframing interventions may be particularly promising and cost-effective. Moreover, given the frequency with which parent-child interactions take place in children's naturalistic environments, there would be a wealth of opportunities for

verbal interactions between parents and children aimed at positively reconstructing pain memories.

Additional Areas for Future Research

Researching children's memories for pain is not without its methodological challenges; however, the importance of understanding the development of pain memories and their influence on children's experience of pain over time cannot be overstated. The recent development of child and parent report measures of pain-related fear and anxiety (e.g., Child Pain Anxiety Symptoms Scale, Pagé et al., 2010; Fear of Pain Questionnaire Child and Parent Proxy Report, Simons, Sieberg, Carpino, Logan, & Berde, 2011; Pediatric Pain Fear Scale, Huguet, et al., 2011) will enable more refined examinations of the role of anxiety and fear in the development of children's pain memories. The development of the pediatric fear avoidance model of chronic pain (Asmundson et al., in press)—an adaptation of Vlaeyen and Linton's (2000) fear avoidance model to explain the processes by which pain transitions from an acute to chronic state—provides intriguing opportunities to examine the role of cognitive and affective fear avoidance factors in both the child's pain experience and the development of their pain memories over time. Furthermore, given that the mediating role of attention is at the core of several theories put forth to account for the relationship between anxiety and cognitive biases (Beck & Clark, 1997), inclusion of measures of attention in future investigations is warranted. Finally, multi-method investigations of the reciprocal influences of parent and child psychological and behavioural factors in the development of pain memories and coping over time will offer critical insights that will facilitate the ultimate goal of improved pain management for children.

Concluding Remarks

In summary, the two empirical studies presented herein provide evidence for the influence of state anxiety and stable anxiety-related variables on healthy children's memories for the somatosensory and affective aspects of a novel pain experience. Evidence is also provided for the powerful influence of pain memories on children's subsequent pain experience over time. This research offers important contributions to the field of pediatric pain. It is the first study to examine the relative contributions of state anxiety, stable anxiety-related variables, and initial pain to children's pain memories. It also extends predictive models of pain memories and subsequent pain reporting that were established with adults to earlier developmental periods, as well as findings derived from investigations of children with chronic illnesses undergoing highly invasive lumbar punctures to healthy children undergoing pain of mild to moderate intensity. Together, these findings provide a framework within which we can begin to identify children who are most at risk of developing negatively estimated pain memories that can adversely affect the way in which they experience pain over time. This research also offers insight into the factors that influence the different trajectories that a pain experience and memories of that experience can have in childhood. Although many intriguing questions about the nature of pain memory development in childhood exist and research is needed to further disentangle its inherent complexity, this research offers promise for improved identification, assessment, and treatment of children at risk of developing pain memories that can have critical implications for their health across the lifespan.

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