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The relation between children's attention bias to pain and children's pain-related memory biases is moderated by parental narrative style

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A B S T R A C T

Children's heightened attention to pain and parental narrative style have been linked to the development of negatively-biased pain memories in children (i.e., recalling higher levels of pain and fear than initially reported, which robustly predicts maladaptive pain outcomes). However, the interplay between child attention bias and parental narrative style remains to be assessed. This study aims to fill this gap using enhanced paradigms assessing children's cognitive biases for cues signaling actual pain. Healthy school children (N = 63; 9–15 years old) received painful heat stimuli while performing a spatial cueing task measuring attention bias to cues signaling actual pain. Parent-child interaction upon completion of the painful task, was coded for parental narrative style (i.e., elaboration, repetition and evaluation). Children's pain-related memories were elicited two weeks later. Findings indicated that children showed an attention bias to cues signaling pain. Furthermore, children who were hypervigilant to pain cues benefitted from parents elaborating more about the pain experience, while children who avoided pain cues developed more negatively-biased pain memories if parents had a more elaborative style compared to a more evaluative parental style. In conclusion, this study suggests that optimal ways to talk about children's pain depend upon child characteristics (i.e., children's attention bias to pain).

1. Introduction

Children's pain memories are a robust predictor of future pain, anxiety and distress (Chen et al., 2000; Noel et al., 2017), even more so than children's initial reporting of pain (Noel et al., 2012b). They furthermore help shape future pain coping (Pate et al., 1996) and are thought to underlie the transition to chronic pain (Flor, 2012; Noel et al., 2017). Despite the clinical relevance of children's negatively-biased pain memories (i.e., recalling higher levels of pain and fear than initially reported) in paediatric pain management, processes underlying its development remain understudied (Noel, 2016; Pavlova et al., 2020). Children's heightened or selective attention to pain has been theorized as being critical in the development of children's negatively-biased pain memories (Cowan, 1998; Noel et al., 2012a; Noel, Rabbits, et al., 2015). Children who prioritize the processing of pain and show an attention bias to pain-related stimuli, might more easily spiral into a pain attending mindset, ultimately leading to the development of negatively-biased pain memories (Van Ryckeghem et al., 2019). Despite the theoretical connection and call for research on relations between children's attention bias to pain and memory bias for pain, research simultaneously investigating both cognitive biases is scarce and has not yet found a link between both (see Lau et al., 2018; Van Ryckeghem et al., 2019; Van Ryckeghem & Vervoort, 2016). This might have several causes. First, previous research primarily investigated attention bias to pain using symbolic representations of pain (e.g., pain words or pictorial stimuli depicting pain). Symbolic representations of pain may however lack relevance and be less capable to activate bodily threat than actual signs of pain (Crombez et al., 2015; Lau et al., 2018; Todd et al., 2018; Van Ryckeghem & Crombez, 2018; Van Ryckeghem et al., 2019; Van Ryckeghem & Vervoort, 2016). Second, earlier research has primarily focused on the isolated role of attention bias to pain in explaining pain memories. Yet, previous research has indicated that children's memory bias for pain is impacted by a dynamic interplay between intra-individual characteristics (e.g., children's attention bias to pain) and inter-individual contributors (Wauters et al., 2020). Specifically, the latter study's findings suggested that parental non-pain attending talk

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buffered the emergence of negatively-biased pain memories for children showing a high attention bias to pain. Parents have indeed been found to be powerful agents in the construction of children's pain memories (Noel et al., 2015a, 2019; Pavlova et al., 2020, 2021). In particular, parent-child interactions about a past adverse experience are critical in helping the child remember, label and emotionally interpret the event (Fivush et al., 2006; Salmon & Reese, 2015) and are thought to set the stage for how children cope with future adverse (e.g., painful) events. Parents who have a more elaborative narrative style (i.e., providing rich information thereby encouraging their children to co-construct a narrative about past distressing emotions; see Fivush et al., 2006), have children with more accurate/positively-biased pain memories, while a less elaborative style (i.e., repeating or merely evaluating what the child said) contributes to more negatively-biased pain memories (Noel et al., 2019; Pavlova et al., 2021). The current study aimed to examine the interplay between child attention bias and parental narrative style in the emergence of negatively-biased pain memories in children for experimentally induced heat pain. In doing so, the current study was the first to measure children's attention bias to cues signaling actual pain, allowing to investigate attention and memory bias for the same pain-relevant signals. We hypothesized that a more elaborative parental style might buffer the influence of children's heightened attention bias to pain on the emergence of negatively-biased pain-related memories, while a less elaborative parental style (i.e., using more repetitions and evaluations) would strengthen the relation between children's attention bias and memory biases for pain. Indeed, parents elaborating on the diverse aspects of the pain experience might help their children to interpret and frame the painful event, especially for children showing heightened attention to pain cues who might have a predominant focus on the sensory and fear-inducing aspects of the painful event. Providing a richer narrative might consequently hinder the spiraling into a pain attending mindset, resulting in more accurate recall of the pain event.

2. Method

2.1. Participants

Participants (i.e., parent-child dyads) were recruited through social media calls on Facebook and through flyers that were distributed at schools, sport clubs and youth clubs in the vicinity of Ghent University (Belgium). Parent-child dyads who showed interest in the study (N = 151), were contacted by phone to provide more information about the study. They were informed that they would participate in a study investigating how children and their parents think and feel when their child experiences pain, whereby the heat stimulation procedure was described. Eventually, 113 parent-child dyads participated in the study. If parent-child dyads did not meet the eligibility criteria, they were excluded from the study (N = 4). Parent-child dyads were not eligible to participate in the study if (1) the child experienced chronic pain (i.e., pain in ≥1 anatomic region that persists or recurs for longer than 3 months (Treede et al., 2015), (2) the child was diagnosed with a developmental disorder (e.g., attention deficit hyperactivity disorder (ADHD) or autism spectrum disorder (ASD)), (3) the child had a chronic illness (e.g., cancer, diabetes, asthma), (4) the child was not in the age range of 9–15 years, (5) the child or parent had insufficient knowledge of the Dutch language. Other parent-child dyads chose not to participate because they did not find the time to participate (N = 8) or because the child was too afraid or felt too uncomfortable to do the painful task with heat stimuli (N = 6). Other parent-child dyads agreed to participate but later cancelled their appointment or did not show up at the pre-arranged time for similar reasons (N = 20). This study was part of a broader research design investigating three distinct research questions: (1) the effect of child attention to pain upon pain-related memory biases (2) the role of parental attention to their child's pain; and (3) the impact of a brief Pain Neuroscience Evidence-based video (PNE) upon child pain-related outcomes. This manuscript reports on the combined effects of research questions (1) and (2) and therefore only includes data from the sample that did not receive the PNE intervention from research question (3), as they functioned as control group in the latter study (see Rheel et al., 2021). The description of measures is restricted to the tasks relevant to research question (1). For the current research aim, a priori sample calculations were performed with G*Power (version 3.1.9.2.; Franz Faul, Kiel, Germany) and indicated a sample size of 55 participants was needed to detect a medium effect with power .80 using $\alpha = 0.05$ (two-tailed). We did however over-recruit participants to anticipate the possibility of a drop-out of 20% and collected data of 69 parent-child dyads. Data of 6 participants was not included in the final data set as 2 children decided to stop while receiving the heat stimuli, 1 child did not receive the pain stimuli due to technical difficulties and data from 3 parent-child interactions were lacking because 1 parent-child dyad did not give consent to use the video material, 1 parent-child dyad interacted in another language and audio was not recorded for 1 parent-child dyad. The final sample used for analyses thus contained data of 63 parent-child dyads. The final sample included 37 boys and 26 girls with age ranging from 9 to 15 years ($M = 11.89$ years, $SD = 1.66$ years, $M_{boys} = 11.86$, $M_{girls} = 11.96$) and 55 mothers and 8 fathers with age ranging from 31 to 55 years ($N = 42.54$ years; $SD = 5.44$ years).

2.2. Study overview

A schematic representation of the study design is provided in Fig. 1.

2.3. Stimulus materials

2.3.1. Visual stimuli

Target stimuli of the spatial cueing task consisted of black squares (1.1 × 1.1 cm), presented on a white background. Two coloured squares (pink and orange; 4.8 cm high x 6.5 cm wide) were used as spatial cues for the location of the targets.

2.3.2. Pain-inducing heat stimuli

Short-lived heat stimuli were delivered using the Contact Heat Evoked Potentials Stimulator (CHEPS) of the Medoc Neuro Sensory Analyzer, Model TSA-II (Medoc Ltd. Advanced Medical Systems, Ramat, Yishai, Israel). Children were told the experimenter would first determine which heat stimulus was painful for them. Parents were not present during this task and could not watch the child from the adjacent room. The thermode, with a contact area of 572.5 mm^2, was placed in contact with the inside of child's wrist (i.e. the wrist of their non-dominant hand) and was secured with a Velcro strap. The thermode delivered pain stimuli, for a time period of 300 ms (plateau phase), with an accelerated velocity of 70 °C/s and a cooling rate of 40 °C/s. This technology allowed for eliciting pain under highly controlled conditions. For the entire experiment, the baseline temperature of the thermode was 32 °C. A heat pain stimulus that was evaluated by children as "moderate pain" was determined individually by the method of limits before the start of the spatial cueing task. To determine a heat pain stimulus of moderate pain, two series of heat pain stimuli with increasing temperature were presented to the child until the stimulus was judged to be of moderate pain. Specifically, the series of heat stimuli started with a heat stimulus of 42 °C and following stimuli increased each time with 1 °C. At the end of each stimulus, the thermode returned back to the baseline temperature of 32 °C and participants were asked to rate the experienced stimulus as either 'no pain', 'mild pain', 'moderate pain' or 'severe pain'. If the child indicated no pain or mild pain, the calibration phase continued with the subsequent target temperature (i.e., 1 °C increase). Children performed this calibration phase twice. The first calibration phase was ended at the heat stimulus where the child for the first time reported to feel at least moderate pain or at the maximum target temperature of 54 °C (for safety purposes). This was followed by the second series of heat pain stimuli, which was identical to the first one. The final heat pain stimulus used for the spatial cueing task (see

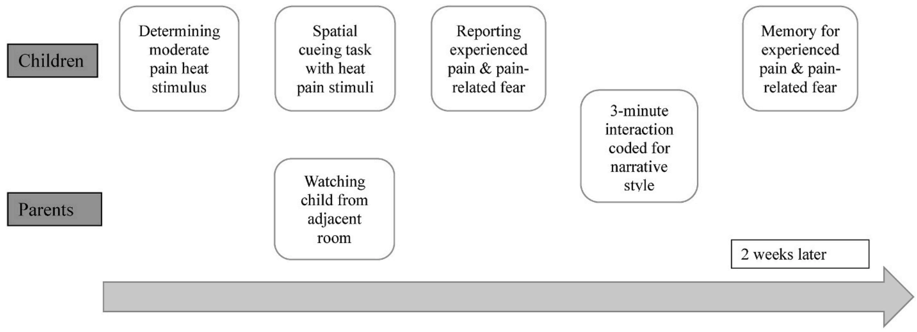

Fig. 1. Schematic representation of the study design.

2.2.) was the stimulus of the highest temperature that children received during both calibration sessions and had indicated as moderately painful. Moderate heat pain stimuli were chosen over severe heat pain stimuli as this allows for the impact of top-down factors (i.e., cognitive processes), which may be compromised when using high intense pain stimuli (see Van Ryckeghem et al., 2018). The mean moderate pain heat stimulus in the current sample was 46.70° ($SD = 3.18$). This procedure was ethically approved and used successfully in previous laboratory-based studies with children (Caes et al., 2012; Hermann et al., 2006; Vervoort et al., 2012; Zohsel et al., 2008).

2.4. Measures

2.4.1. Spatial cueing task

To investigate attention bias towards pain-related information (i.e., cues predictive of pain), a spatial cueing task was adapted from previous research (see Van Damme et al., 2004; Van Ryckeghem et al., 2012; Van Ryckeghem et al., 2013). Children were told they had to perform a computer task while they would receive painful heat stimuli. Their parent was able to watch the child via livestream on a television screen in the adjacent room. In the current task, participants were asked to focus on a fixation cross, which was followed by a coloured cue, which in turn was followed by the presentation of the target. Targets were presented at the same (i.e., validly cued trials) or opposite (i.e., invalidly cued trials) spatial location of the cues. Participants were asked to indicate the location of the target as quickly as possible. Crucially, using a conditioning approach, one cue signaled the potential presence of an actual pain stimulus (i.e., the moderate heat pain stimulus), whereas the other cue was never linked with the heat pain stimulus (see Fig. 2 for a schematic representation of the spatial cueing paradigm). Specifically, each trial began with a black fixation cross in the middle of the screen that was presented for 1000 ms. This was followed by one cue for a duration of 200 ms (see stimulus materials). Based on principles of classical conditioning, cues were differentially conditioned upon their colour. In one third of the trials, the conditioned cue (CS+) was followed by a painful stimulus (i.e., the moderate heat pain stimulus; UCS) presented 400 ms after cue onset, whereas the other cue (CS-) was never followed by the UCS. The colours of the CS+ and CS- were counterbalanced across participants. The CS+ and CS- trials were presented equally often in a random order. Children were not informed that one

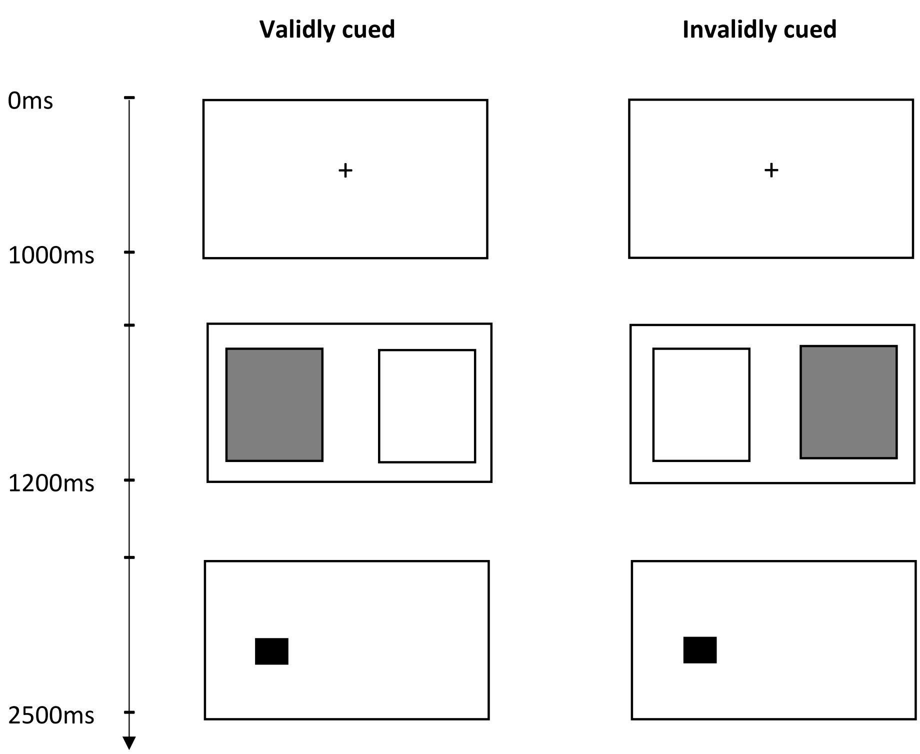

Fig. 2. Schematic representation of the exogenous cueing paradigm. First, a fixation cross was presented for 1000 ms, which was then followed by a coloured cue (either pink or orange; 200 ms duration). Immediately after cue offset, targets were presented at the same (i.e., validly cued trials) or opposite (i.e., invalidly cued trials) spatial location of the cues. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

colour signaled pain or safety. Target onset followed immediately after cue offset. Participants were instructed to respond to this target as quickly as possible without sacrificing accuracy by pressing "4" when the target appeared on the left and "6" when the target appeared on the right with their dominant index finger on an AZERTY computer keyboard. Trials ended when the participant responded or 2500 ms had passed after onset of presenting the target. To discourage anticipatory responses (i.e., responding to cues instead of targets), a number of catch trials were presented, in which the cue was not followed by a target. Furthermore, a number of digit trials were presented during the task, to encourage participants to maintain gaze on the fixation cross in the middle of the screen. During these trials, a randomly selected digit between 1 and 9 followed the fixation cross for a duration of 100 ms. Participants were instructed to type this digit on the computer keyboard. Inter-trial-intervals were 3000 ms after heat pain trials and digit trials and 1000 ms after all other test trials. The task started with a first practice phase during which no pain stimuli were administered. Participants were aware that no UCS would be presented. This was followed by an acquisition phase of 2 reinforced CS + trials (1 valid, 1 invalid), which were immediately followed by the test phase. The test phase consisted of 188 trials (96 validly cued trials, 48 invalidly cued trials, 32 catch trials and 12 digit trials). In total, 26 moderate heat pain stimuli were administered (2 during the acquisition phase and 24 during the test phase). Participants were presented trials for which the cue was either valid (i.e., if the target was presented at the same spatial location of the cue) or invalid (i.e., if the target was presented at the opposite spatial location of the cue) and either threatening (i.e., the coloured cue was sometimes followed by a painful heat stimulus) or neutral (i.e., the coloured cue was never followed by a painful heat stimulus). This resulted into four trial categories: valid-threatening trials, valid-neutral trials, invalid-threatening trials and invalid-neutral trials. Overall, it is expected that participants should be faster on valid than on invalid trials, a phenomenon called the cue validity effect. It is assumed that when participants' attention is biased towards pain-related cues, the cue validity-effect should be larger on CS + trials than on CS- trials.

2.4.2. Experienced pain intensity and pain-related fear

In line with previous research (Noel et al., 2012a, 2012b, 2015b, 2019; Wauters et al., 2020), we assessed both children's memory for sensory (i.e., pain intensity) and affective (i.e., pain-related fear) aspects of the painful event. Experienced *pain intensity* was assessed with the Faces Pain Scale-Revised (Hicks et al., 2001), a self-report measure specifically developed to measure pain intensity in children. The scale includes one item that comprises six neutral faces depicting an increasing degree of pain intensity, ranging from "no pain (0)" to "worst pain possible (10)". After the pain task, children circled the face that best indicated the pain they experienced during the heat stimuli task (experienced pain). The FPS-R is considered the most suited method for measuring acute pain intensity in children aged 4 years and up (Hicks et al., 2001; Stinson et al., 2006) and has previously been used in Dutch paediatric samples (Brands et al., 2011; Wauters et al., 2020). Experienced *pain-related fear* was assessed with the Children's Fear Scale (CFS; McMurtry et al., 2011), a single item self-report scale that measures pain-related fear among children. The questionnaire was adapted from the adult Faces Anxiety Scale (McKinley et al., 2003). The CFS comprises five neutral faces depicting a varying degree of pain-related fear, ranging from "not scared at all (0)" to "most scared possible (4)". Right after the pain task, children circled the face that best indicated the amount of fear they experienced during the heat stimuli task (experienced fear). The CFS has shown good test-retest reliability and construct validity among children (McMurtry et al., 2011) and has previously been used in Dutch paediatric samples (Wauters et al., 2020). Both the FPS-R and CFS are suitable for universal use as the faces display no racial features and are sex and age neutral. Instructions for both the FPS-R and CFS were read aloud by the researcher. Both scales have previously been used to assess pain and fear experiences and subsequent recall of those pain experiences in children (Noel et al., 2010, 2012b, 2019; Wauters et al., 2020).

2.4.3. Parent-child interaction

After the spatial cueing task, children and parents were reunited in the child test room and left alone for a fixed time interval of 3 min. The researchers told them they went to get the documents needed for the debriefing. The parent-child interaction was recorded on video. In line with previous research (e.g., Caes et al., 2012; Vervoort et al., 2011; Wauters et al., 2020), parents and children were not informed of being videotaped during this interaction, in order to capture spontaneous behaviours. Upon study completion, parents and children were debriefed and told their interaction had been videotaped. They were asked to sign an additional consent/assent form for the use of the video data. Parents and children were explicitly told that they could choose to not sign this additional consent form and that they would still get the monetary reward. They were furthermore assured that the videos would not be distributed in any way and only viewed by the research team. Videos were transcribed verbatim and divided into independent child and parental utterances (i.e., sentences) by 2 trained coders (AW and ER). Utterances coded as parental pain attending (and thus discussing the child's pain experience) were further coded for narrative structure. To this end, the first author of the manuscript (AW) checked all transcriptions and then first coded all transcriptions for parental (non-)pain attending talk, based upon the coding procedure developed by Walker et al. (2006) and used in previous research (see Vervoort et al., 2011; Wauters et al., 2020). Parental and child utterances were ascribed to one of the following three categories; (a) pain attending utterances, (b) non-pain attending utterances and (c) other. Pain attending utterances were defined as parental or child utterances that focus upon the heat stimuli task (i.e., the painful heat stimuli itself) and all aspects related to the child's pain experience (e.g., "Did it hurt a lot?"; "It felt like a needle prick"). Non-pain attending utterances were defined as parental or child utterances that did not focus upon the child's pain experience or the heat stimuli task (e.g., "What are we going to eat tonight?"; "I really liked those cookies I got"). Parental and child utterances were coded as "other" if they were inaudible or if they were related to technical aspects of the experiment that were not pain-related (e.g., "I had to push 4 or 6 on the computer"; "Were you in the room next door?"). A second researcher (ER) recoded 20% of randomly selected transcriptions to calculate inter-rater reliability. In line with Walker et al. (2006), intra-class correlations were used to determine inter-rater reliability for each of the six coding categories. In this study, only parental pain attending utterances were used for further coding. Intra-class correlations for parental pain attending utterances were 0.87, indicating good reliability. Utterances coded as parental-pain attending (and thus discussing the child's pain experience) were then further coded for narrative structure (i.e., elaboration, repetition and evaluation), following the coding scheme used by Noel et al. (2019), which was drawn from research of Sales et al. (2003). Parental pain attending utterances could be coded as questions, statements or evaluations (i.e., utterances evaluating what was previously said). Questions were coded as open-ended (i.e., memory questions) or close-ended (i.e. yes-no questions). Both statements and questions were also coded as elaborative (i.e., containing or eliciting new pieces of information from the child) or as repetitive (i.e., containing/repeating old information from the conversation). Evaluations were mostly one-word utterances or short sentences (e.g., "Yes", "I know"). This resulted in 7 different coding categories; Memory Question Elaboration (MQE), Memory Question Repetition (MQR), Yes-No Question Elaboration (YNE), Yes-No Question Repetition (YNR), Statement Elaboration (SE), Statement Repetition (SR) and Evaluation (EVAL). Proportion scores for each category were used for further analyses, wherein the absolute number of utterances in each category was divided by the total amount of parental pain attending utterances, resulting in 7 proportion scores. In line with Noel et al. (2019), total proportion scores for overall parental use of elaboration elements (i.e., narrative structure codes containing novel information: MQE, YNE and SE) and total proportion scores for overall parental use of repetition elements (i.e., narrative structure codes repeating old information from the conversation: MQR, YNR and SR) were also calculated. As a result, three variables were used for further analyses; parental elaboration, parental repetition and parental evaluation. A trained coder (EVO) recoded 20% of randomly selected transcriptions to calculate inter-rater reliability. Intra-class correlations for parental elaboration, repetition and evaluation were 0.99, 0.83 and 0.87 respectively, indicating good to excellent reliability.

2.4.4. Memory interview

Approximately two weeks ($M = 15.24$ days; $SD = 3.07$ days, *range* = 12–24 days) after the initial laboratory session, children were phoned by a researcher of the study (ER) and a memory interview was conducted. Children were instructed to open the sealed envelope they had been given at the end of the laboratory session and rated by means of the FPS-R and CFS how much pain and pain-related fear they remembered to have had during the heat stimuli task. Parents were specifically asked to not prompt their child, so children's memory was assessed independent from parental influence. Directly below each face of the FPS-R and CFS was a random number of the alphabet, which children had to mention aloud to indicate the face of their choice. This method allowed for unambiguous communication via telephone and avoiding the use of a possible confounding numeric scale. This procedure has been used in previous research conducting memory interviews (Badali et al., 2000; Noel et al., 2010, 2012b, 2015b; Wauters et al., 2020).

2.5. Procedure

Children and the accompanying parent were invited to the research labs of the Faculty of Psychology and Educational Sciences of Ghent University. For the first phase of the study, participants were told they would participate in a study aiming to investigate how children and their parents think and feel when the child experiences pain. The heat stimuli procedure was described and they were shown how the thermal heat stimulation device worked. They were informed that the parent would be able to watch their child during the pain task from an adjacent room via video recordings that were live streamed on a television screen. Children were asked to provide their assent, while a parent of each participant also provided consent for their child to participate in the study. The child then stayed in the first room with one of the researchers, while the other researcher accompanied the parent to the adjacent room. First, children were presented a series of heat stimuli to determine a heat stimulus of moderate pain (i.e., moderate pain stimulus) by using the method of limits (i.e., determining the child's moderate pain stimulus by gradually increasing the heat of the stimulus in discrete steps of 1 °C). This heat pain stimulus was then used during a spatial cueing task, wherein children's attention bias to cues signaling pain was investigated. During the acquisition and test phase of the spatial cueing task, wherein children sometimes received a painful heat stimulus, parents were able to watch their child via livestream on a television screen in the adjacent room. After the spatial cueing task with the pain-inducing heat stimuli, children reported how much pain intensity and pain-related fear they experienced during the task by completing the FPS-R and CFS. Children and parents were then reunited in the child test room and were left alone for a fixed time interval of 3 min. In line with previous research (e.g., Caes et al., 2012; Vervoort et al., 2011; Wauters et al., 2020), parents and children were not informed of being videotaped during this interaction, in order to capture spontaneous behaviours. Upon study completion, parents and children were debriefed and told their interaction had been videotaped. They were asked to sign an additional consent/assent form for the use of the video data. Each parent-child dyad was also given a sealed envelope with questionnaires and was asked if they could be phoned again two weeks later to ask some additional questions. Participants were told not to open the envelope until the phone interview. They thus did not know that their memories about the pain task would be elicited. Approximately two weeks later, children were phoned by a researcher and recalled their levels of pain intensity and pain-related fear using the FPS-R and CFS, respectively. Each participant was compensated €25 for participating in the study and one iPad was raffled among all participants. All study procedures were approved by the Ethics Committee of the Faculty of Psychology and Educational Sciences of Ghent University, Belgium.

2.6. Data reduction

2.6.1. Attention bias index

Data from the spatial cueing task measuring attention bias to cues signaling pain was considered valid if participants got at least 80% of the trials correct. Within the current sample, all participants had at least 80% of the trials correct. Additionally, errors and outliers (i.e., responses faster than 150 ms or responses for which the reaction time deviated with more than 3 SD's from the mean) were excluded from the analyses (Van Damme et al., 2004; Van Ryckeghem et al., 2013). Furthermore, trials during which a painful heat stimulus was applied, were removed from further analyses in line with previous research (e.g., Van Damme et al., 2004; Van Ryckeghem et al., 2013) as response times in these trials could be affected by both the CS + and the UCS. Next, a cue validity effect (i.e., reaction times of invalid trials minus reaction times of valid trials) for CS + trials and CS- trials was calculated. As an index of attention bias, the difference between the cue validity effect for CS + trials and the cue validity effect for CS- trials was calculated (i.e., CS + minus CS-), whereby a positive value was considered a bias towards cues signaling pain.

2.6.2. Memory bias indices

In line with previous research (Wauters et al., 2020, 2021), *pain memory bias* was calculated as the difference between recalled pain intensity (as reported approximately two weeks after the pain-inducing heat stimuli) and experienced pain intensity (as reported by the child directly after the pain-inducing heat stimuli), both measured by the FPS-R. *Fear memory bias* was calculated as the difference between recalled pain-related fear (measured approximately two weeks after the heat stimuli task) and experienced pain-related fear (as reported by the child directly after the heat stimuli task), both measured by the CFS. Overestimation of pain or pain-related fear was defined as recalling the levels of pain intensity or pain-related fear two weeks after the lab session as being worse (i.e., higher) than initially reported (i.e., a positive value). In this manuscript, pain or fear memory bias is defined as an overestimation of pain intensity or pain-related fear, respectively.

2.7. Statistical analyses

Correlational and regression analyses were performed with the statistical software SPSS version 26 (SPSS IBM, New York City, NY). Significance levels were set at 0.05. Pearson correlations examined the relations between pain memory bias, fear memory bias, attention bias, parental elaboration, parental repetition and parental evaluation. Next, hierarchical linear regressions were conducted to investigate the moderating role of parental elaboration, parental repetition and parental evaluation in the relationship between children's attention bias to pain and pain-related memory biases. Hereto, a series of hierarchical linear regressions were performed for all interactions between each moderator variable (i.e., parental elaboration, parental repetition and parental evaluation) and the predictor variable (i.e., attention bias) on each outcome variable (i.e., pain memory bias and fear memory bias). Moderation analyses were based on the procedure by Holmbeck (1997), wherein continuous variables are first centred and significant interactions are then further investigated by plotting and testing the significance of the regression lines for high (i.e., +1SD above the mean) and low (i.e., -1SD below the mean) values of the continuous moderator variable (i.e., parental elaboration, parental repetition or parental evaluation). Child's age and sex was controlled for in the first block of each regression analysis. The centred values of child attention bias and parental narrative style were entered in a second block of the hierarchical regression analysis, whereas the cross-products of these variables were entered in a third block (Baron & Kenny, 1986). Variance-inflation factors of all regression analyses reported below were acceptable (range 1.00–1.39), suggesting that there was no problem of multicollinearity (Myers, 1990).

3. Results

3.1. Spatial cueing task and attention bias

For the spatial cueing task, cue expectancy ratings indicated that the differential conditioning of cues was successful. Participants were asked right after the spatial cueing task what colour they thought predicted a painful heat stimulus, with 71% of participants indicating the correct colour. Participants expected to experience a painful heat stimulus after the CS + cue ($M = 4.22$, $SD = 3.03$) more often than after the CS- cue ($M = 2.24$, $SD = 2.28$; $t(62) = 4.09$, $p < .001$). Next, a 2 (Cue validity: valid vs. invalid) x 2 (Signal: CS- vs. CS+) repeated measures ANOVA was performed. Results showed a main effect of both cue validity [$F(1,62) = 396.80$, $p < .001$] and signal [$F(1,62) = 56.73$, $p < .001$)], indicating that participants were significantly faster on valid trials than on invalid trials and on CS + trials than on CS- trials. Most importantly, a significant cue validity × signal interaction effect was found [$F(1,62) = 88.67$, $p < .001$; $\eta_p^2 = 0.59$] indicating an effect of differential conditioning upon attentional engagement. More specifically, the cue validity effect (i.e., detecting targets preceded by valid cues faster than when preceded by invalid cues) was larger for CS + signals than for CS- signals. Furthermore, a one sample *t*-test (null hypothesis value = 0) with the attention bias index was conducted to investigate whether there was an absolute child attention bias towards the painful heat stimuli. Results showed that children generally showed an attention bias towards cues signaling pain [$M = 17.15$, $SD = 38.77$; $t(62) = 3.51$, $p < .001$; $d = 0.44$].

3.2. Memory bias

To investigate whether there were memory biases for pain and fear, one sample t-tests were conducted with the memory bias indices (null hypothesis value = 0). No absolute memory biases were found for pain [$M = -0.19$, $SD = 1.59$; $t(62) = -0.95$, ns; $d = -0.12$] or fear [$M = 0.10$, $SD = 0.84$; $t(62) = 0.90$, ns; $d = 0.11$], indicating that children generally recalled their experienced levels of pain and pain-related fear accurately.

3.3. Narrative codes

Mean values and SD's of all narrative codes used by the parent and child during their interaction can be found in Table 1 (proportion scores). On average, parents produced 20.0 (pain attending) utterances (SD = 9.63) and children 21.8 (pain attending) utterances (SD = 10.4). In line with findings of Noel et al. (2019), further analyses were conducted with codes for overall parental elaboration (i.e., MQE, YNE and SE) and overall parental repetition (i.e., MQR, YNR and SR). Parental evaluation comprised only one code (i.e., EVAL).

Table 1
Mean values and SD's for proportions of parent and child narrative codes.

Utterance Code Type	M	SD
Parental utterances		
Memory question elaboration (MQE)	.07	.08
Yes-no question elaboration (YNE)	.20	.14
Statement elaboration (SE)	.45	.17
Memory question repetition (MQR)	.01	.02
Yes-no question repetition (YNR)	.07	.07
Statement repetition (SR)	.07	.08
Evaluation (EVAL)	.12	.10
Child utterances		
Memory elaboration (ME)	.74	.15
Memory placeholder (MP)	.26	.15

3.4. Correlation analyses

Mean scores, standard deviations and Pearson correlation coefficients for all variables of interest are presented in Table 2. Results showed that attention bias was not significantly associated with any of the memory biases (all $|r| \leq 0.08$, ns). Also, pain and fear memory bias were not significantly correlated with each other ($r = 0.06$, ns). Results furthermore showed that parental narrative style was not significantly associated with attention bias or any of the memory biases (all $|r| \leq 0.21$, ns). Parental elaboration was significantly negatively associated with parental repetition ($r = -0.68$, $p < .001$) and parental evaluation ($r = -0.67$, $p < .001$). Parental repetition and parental evaluation were not significantly associated with each other ($r = -0.09$, ns).

3.5. The moderating role of parental narrative style in the relationship between children's attention bias to pain and pain-related memory biases

A set of hierarchical linear regressions (see Table 3) was conducted to investigate the moderating role of parental narrative style (i.e., parental elaboration, repetition and evaluation) in the relation between children's attention bias to pain and children's pain-related memory biases (i.e., pain memory bias and fear memory bias). **Parental elaboration.** Analyses investigating the moderating role of parental elaboration revealed a significant main effect of parental elaboration on pain memory bias ($\beta = -.38$, $p < .05$; $f^2 = 0.11$) indicating that if parents elaborated more on the child's pain experience, children were less likely to develop a pain memory bias. Furthermore, findings showed that parental elaboration moderated the relation between children's attention bias to pain and pain memory bias ($\beta = -.32$, $p < .05$; $f^2 = 0.08$). To further interpret this interaction, we plotted regression lines for low (-1SD below the mean) and high (+1SD above the mean) values of parental elaboration (Holmbeck, 1997). The analysis with pain memory bias as an outcome variable and inspection of regression lines and corresponding coefficients (see Fig. 3), indicated a cross-over interaction such that higher levels of attention bias were associated with less pain memory bias, for children whose parents showed high levels of parental elaboration ($\beta = -0.31$, ns). The opposite pattern (i.e., higher levels of attention bias associated with more pain memory bias) was observed for children whose parents showed low levels of elaboration ($\beta = 0.31$, ns). While both regression lines failed to reach absolute significance, effects were significantly opposite from each other, suggesting that parental elaboration served a buffering role in the relation between children's heightened attention bias to pain and the emergence of pain memory bias. Indeed, further inspection of the regression lines indicated that it is primarily when children showed high levels of attention bias to pain, that parental elaboration seemed to differentially impact the development of pain memory bias ($\beta = -0.68$, $p < .01$). Specifically, if children's attention was more focused on their pain experience, this led to the development of larger negatively-biased pain memories, but only if the parent did not elaborate on the child's pain experience. However, if the parent elaborated more on the child's pain experience, this led to less negatively-biased pain memories in the child. Regression lines in Fig. 3 showed that parental elaboration did not significantly impact the development of children's pain memory biases when children showed low levels of attention bias to pain ($\beta = -0.06$, ns.). Furthermore, parental elaboration also moderated the relation between children's attention bias to pain and fear memory bias ($\beta = -0.45$, $p < .01$; $f^2 = 0.17$). The interaction analysis with fear memory bias as outcome variable (see Fig. 4) revealed a comparable cross-over interaction as with

Table 2
Number of valid cases (N), Means (M), Standard Deviations (SD) and Pearson intercorrelations of all measures.

	N	M (SD)	2	3	4	5	6
1. Pain Memory Bias	63	−.19(1.59)	.06	.04	−.21	.21	.07
2. Fear Memory Bias	63	.10(.84)	–	−.08	.03	.08	−.12
3. Attention Bias	63	.00(38.77)		–	.05	−.05	−.02
4. Parental Elaboration	63	.72(.13)			–	−.68***	−.67***
5. Parental Repetition	63	.15(.10)				–	−.09
6. Parental Evaluation	63	.12(.10)					–

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

Table 3
Results of hierarchical linear regression analyses investigating the moderating role of **parental elaboration, parental repetition and parental evaluation** in the relationship between children's attention bias to pain and pain-related memory biases.

Criterion variable	Step	Predictor	B	ΔR²	Adjusted R²	f²
Pain Memory Bias	1	Child Age	−.05	.01	−.03	.01
		Child Sex	−.01			.01
	2	Child Attention Bias	.01	.05	−.02	.01
		Parental Elaboration	−.38*			.11
	3	Child Attention Bias x Parental Elaboration	−.32*	.07*	.04	.08
Fear Memory Bias	1	Child Age	−.06	.01	−.02	.01
		Child Sex	−.12			.01
	2	Child Attention Bias	−.15	.01	−.05	.02
		Parental Elaboration	−.19			.03
	3	Child Attention Bias x Parental Elaboration	−.45**	.14**	.09	.17
Pain Memory Bias	1	Child Age	.04	.01	−.03	.01
		Child Sex	.01			.01
	2	Child Attention Bias	.02	.05	−.02	.01
		Parental Repetition	.30*			.07
	3	Child Attention Bias x Parental Repetition	.18	.03	−.01	.03
Fear Memory Bias	1	Child Age	−.01	.01	−.02	.00
		Child Sex	−.10			.01
	2	Child Attention Bias	−.11	.01	−.05	.01
		Parental Repetition	.16			.02
	3	Child Attention Bias x Parental Repetition	.24	.04	−.02	.05
Pain Memory Bias	1	Child Age	−.05	.01	−.03	.01
		Child Sex	−.03			.01
	2	Child Attention Bias	.02	.01	−.06	.01
		Parental Evaluation	.13			.01
	3	Child Attention Bias x Parental Evaluation	.18	.03	−.05	.03
Fear Memory Bias	1	Child Age	−.05	.01	−.02	.01
		Child Sex	−.10			.01
	2	Child Attention Bias	−.12	.02	−.04	.01
		Parental Evaluation	−.02			.01
	3	Child Attention Bias x Parental Evaluation	.37**	.12**	.08	.14

*p < .05; **p < .01, ***p < .001.
Note: Standardized regression coefficients (β) from the last step of the analysis are displayed.

pain memory bias, indicating that the impact of attention bias to pain on fear memory bias was opposite for low vs. high levels of parental elaboration. Specifically, analyses revealed that higher levels of attention bias were associated with less fear memory bias for parents showing high levels of elaboration ($\beta = -0.57, p < .01$). The opposite pattern (i.e., higher attention bias associated with a larger fear memory bias) was observed if parents showed low levels of elaboration ($\beta = 0.28$, ns). Findings again suggest that it is primarily for children showing high levels of attention bias to pain that the amount of parental elaboration had an effect on the development of fear memory bias in children ($\beta = -0.61, p < .05$) and less for children showing low levels of attention bias to pain ($\beta = 0.25$, ns). If children showed more attention to their own pain experience, more parental elaboration on that pain experience buffered the development of fear memory bias, whereas less parental elaboration lead to the development of more fear memory bias. **Parental repetition.** Analyses investigating the moderating role of parental repetition revealed a significant main effect of parental repetition on pain memory bias ($\beta = 0.30, p < .05$; $f^2 = 0.07$). Although main effects in an interaction model should be interpreted with caution, this suggests that talking in a more repetitive way to the child about the child's pain experience, might lead to the development of a pain memory bias in children. No interaction effects were observed (all $|\beta| \leq 0.24$, ns). **Parental evaluation.** Analyses investigating the moderating role of parental evaluation indicated no significant main effects of parental evaluation (all $|\beta| \leq 0.13$, ns), but revealed a significant interaction between parental evaluation and children's attention bias to pain on children's fear memory bias ($\beta = 0.37, p < .01$; $f^2 = 0.14$). Further analysis of this interaction showed a cross-over interaction (see Fig. 5) indicating that the impact of attention bias to pain on fear memory bias was opposite for low vs. high levels of parental evaluation. Specifically and in line with our hypotheses, analyses revealed that higher levels of attention bias were associated with more fear memory bias, yet only for parents showing high levels of evaluation ($\beta = 0.29$, ns), while the opposite pattern (i.e., high attention bias associated with less fear memory bias) was observed for parents showing low levels of evaluation ($\beta = -0.53, p < .01$). Further inspection of regression lines however

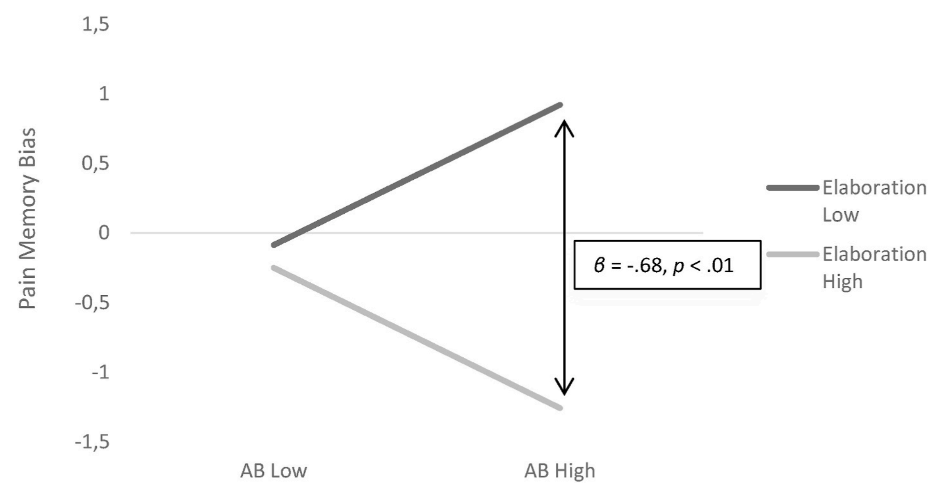

Fig. 3. Children's pain memory bias as a function of low (i.e., -1SD below the mean) and high (i.e., +1SD above the mean) levels of children's attention bias to pain and parental elaboration. Only values of the slopes that reached significance (i.e. $p < .05$) are shown.

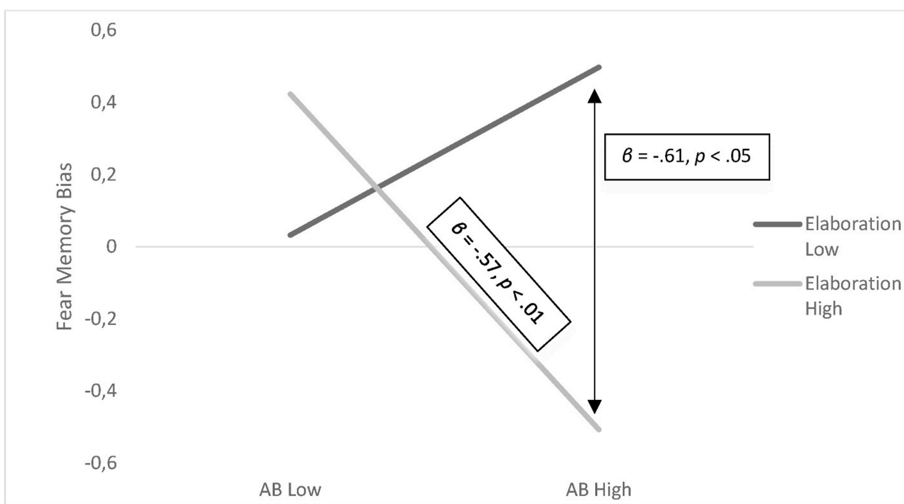

Fig. 4. Children's fear memory bias as a function of low (i.e., -1SD below the mean) and high (i.e., +1SD above the mean) levels of children's attention bias to pain and parental elaboration. Only values of the slopes that reached significance (i.e. $p < .05$) are shown.

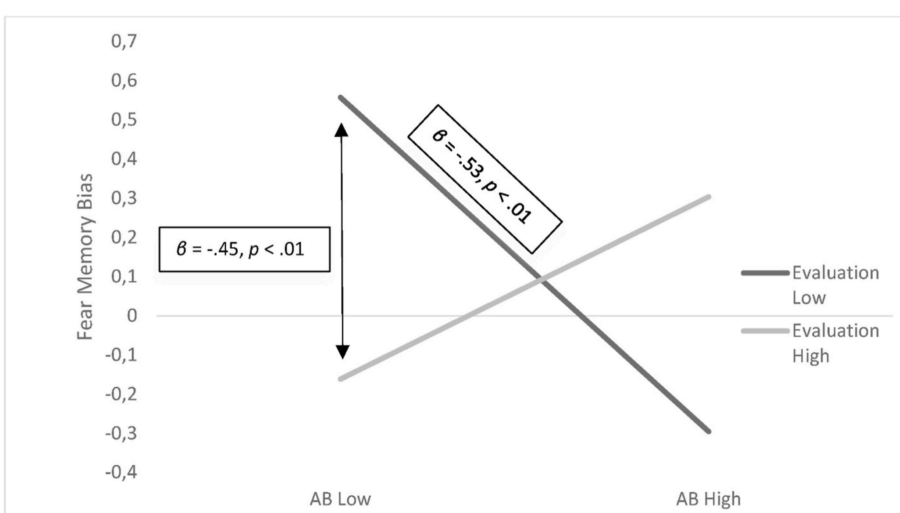

Fig. 5. Children's fear memory bias as a function of low (i.e., -1SD below the mean) and high (i.e., +1SD above the mean) levels of children's attention bias to pain and parental evaluation. Only values of the slopes that reached significance (i.e. $p < .05$) are shown.

indicated that the effect is now primarily situated in children showing low levels of attention bias to pain ($\beta = -0.45$, $p < .01$) and less in children showing high levels of attention bias to pain ($\beta = 0.37$, ns). Specifically, if children focused less on their own pain experience, more parental evaluation of the child's pain-related talk would lead to less fear memory bias, while less parental evaluation would lead to more fear memory bias in the child.

4. Discussion

This study examined the association between children's attention bias to pain and pain-related memory biases and the moderating role of parental narrative style in this relationship, while optimizing the assessment of attention and memory biases. **Children's attention bias to cues signaling actual pain.** The current study is the first to measure attention bias in children for cues signaling actual pain, thereby investigating attention bias and memory bias for the same experimental stimuli, as called upon by research on cognitive biases in pain contexts (e.g., Lau et al., 2018; Van Ryckeghem et al., 2019; Van Ryckeghem & Vervoort, 2016) and thereby overcoming limitations concerning the relevance and difference in meaning of various stimuli (Van Ryckeghem et al., 2019; Van Ryckeghem & Vervoort, 2016). Until now, children's attention bias to pain had been measured by symbolic representations of pain (e.g., pain words or pictorial stimuli used in a dot-probe or eye-tracking task), which might not be personally relevant to the pain the participant fears or experiences and might not automatically activate relevant pain schemata (Crombez et al., 2013; Todd et al., 2018; Van Ryckeghem & Crombez, 2018). The omnipresence of studies using attention bias measures including stimuli only indirectly related to pain (i.e., symbolic stimuli), has been proposed as a possible explanation for the relatively poor evidence of attention biases to pain (Crombez et al., 2013; Lau et al., 2018; Todd et al., 2018). In the current study, children showed an overall attention bias to cues signaling pain, thereby substantiating the research avenue to use somatosensory cues predicting personal pain in investigating attention bias to pain. **Children's pain and fear memory bias.** No absolute memory biases were found. This is in line with earlier research showing that children generally recall pain accurately or even more positively over time, while only a minority of children develop negatively-biased pain memories (e.g., Noel et al., 2012b; Wauters et al., 2020; Wauters et al., 2021). Furthermore, pain and fear memory bias were not significantly associated with each other, attesting to earlier theoretical assumptions and empirical findings that children's memory for pain is a multidimensional construct, including both sensory (e.g., pain intensity) and affective (e.g., pain-related fear) components of pain (Jaaniste et al., 2019; Noel, Rabbits, et al., 2015; Ornstein et al., 1999; Pope et al., 2015; Wauters et al., 2020, 2021). As such, the current findings emphasize the need for comprehensive and multidimensional memory assessment. **The moderating role of parental narrative style.** The current study assessed the dynamic interplay between child (i.e., attention bias to pain) and parent (i.e., parental narrative style) antecedents of pain-related memory biases in children. Results confirmed the buffering role of parental elaboration in the emergence of negatively-biased pain memories, but only for children with high levels of attention bias to pain. For children with low levels of attention bias to pain, more parental elaboration generated no such effect (i.e., on the emergence of pain memory bias) or even an opposite effect (i.e., on the emergence of fear memory bias). Also in line with hypotheses, parental evaluation enhanced the effect of children's heightened attention bias to pain on the emergence of negatively-biased pain memories, but only in children with high levels of attention bias to pain, while parental evaluation even served a buffering role in children showing low levels of attention bias. Results thus indicate that different types of parental narrative style differentially moderated the relation between children's attention bias to pain and their pain-related memory biases. Specifically, results show that children who are hypervigilant to pain (i.e., show high levels of attention bias to pain) benefit from parents who elaborate more on the pain experience, but develop more pain and fear memory bias if parents do not. It might be that children who experience the pain event as threatening will predominantly keep their focus on the fearful aspects of the event and might increasingly need their parents to provide a richer narrative, helping them to co-construct their memories by elaborating on more diverse aspects of the pain experience (Salmon & Reese, 2015). If the parent however does not aid in interpreting and evaluating this threatening pain experience, children attentive for pain cues might spiral into a pain attending mindset, which might explain the development of more pain and fear memory biases two weeks later. However, for children with low levels of attention bias to pain, who thus focus less on the (threatening value) of the pain experience themselves, higher levels of parental elaboration are no longer beneficial. Possibly, if the child itself does not tend to focus on the pain experience, a parent drawing the child's attention to it by elaborating more on the past pain event, would in this case thus install a more fearful memory of the painful experience. For children with reduced attention for cues signaling pain, results suggest more beneficial effects if parents simply evaluate what the child says about the pain experience, without further elaborating on the painful topic. These results are in line with earlier findings from Wauters et al. (2020), which indicated that characteristics of the social context as well as factors related to the intra-individual experience of pain, should be studied jointly as they interact in their effect on the emergence of negatively-biased memories of painful events. Results in Wauters et al. (2020) suggested that for children with a high attention bias to pain, having a parent who focused more on the pain experience, was a risk factor for developing more negatively-biased pain memories. The current study corroborates findings of Wauters et al. (2020), but also extends findings by using more fine-grained methods for measuring parental verbalizations, by tapping into the diversity of parental pain attending verbalizations. Specifically, the current study assessed the narrative style (i.e., elaboration, repetition and evaluation) parents use when talking to their child about its pain experience, as recent studies (Noel et al., 2019; Pavlova et al., 2021) have shown that parental narrative style contributes to the development of negatively-biased pain memories in young children of 4–7 years old. Results in the current study replicated findings of Noel et al. (2019) as parental elaboration and parental repetition showed to directly lead to less and more negatively-biased pain memories in children, respectively. Results furthermore suggest that parental reminiscing is still a powerful contributor in the development of pain memories within older children (9–15 years old). **Clinical significance, limitations and areas for future research.** Study findings are of clinical significance as they suggest that future interventions aiming to alter children's negatively-biased pain memories should not proceed in a one-size-fits-all manner. A recent memory reframing intervention by Pavlova et al. (2021) showed promising results as parents who were instructed to reminisce with their child about its past surgery in a certain way (e.g., elaborating more on positive aspects of the child's pain experience) had children who showed less negatively-biased pain memories. Our study findings can contribute to future interventions aiming to alter children's negatively-biased pain memories by emphasizing the need to match how parents talk with child pain-related characteristics. Limitations of the current study also highlight avenues for future research. While the importance of parental narrative style for child pain-related memory outcomes is also backed by a vast amount of literature indicating that a more elaborative parental narrative style robustly predicts a wide range of more adapted child cognitive (e.g., memory skills, literacy, narrative skills and executive functioning skills) but also emotional and social outcomes (e.g., understanding of self and emotion, emotion regulation and social competence; see Fivush et al., 2006; Salmon & Reese, 2015; Salmon & Reese, 2016 for an overview and Lund et al., 2021), it must be noted that it likely only constitutes a fraction of parental (narrative) factors that affect the development of pain memories in children. Previous research suggests that also non-verbal features of the parent-child interaction might be of influence, such as vocal tone or pitch (McMurtry et al., 2007) or parental facial expression (Goodman & McGrath, 2003; Horton & Pilai Ridell, 2010). Indeed, earlier findings indicate that children might positively or negatively interpret what parents say based upon parents' vocal tone (pitch; rising and falling) and the facial expression (e.g., happy and fearful) parents display (McMurtry et al., 2010). Future research should ideally integrate both verbal and nonverbal information into a broader assessment of parental behaviours. Analyses of more extensive parent-child reminiscing about the child's past pain experience could provide more insight into what elaborative content (e.g., talking about the sensory aspects, emotional aspects or coping of the pain experience) would be especially beneficial for children (see Noel et al., 2019). Sequential dyadic analyses could provide more insight into the proportion of time parent and children elaborate and who initiates more elaborative style elements. Furthermore, the current study was performed in healthy children. Study findings have yet to be replicated in children experiencing chronic pain and for repeated clinical pain events, especially since memory for repeated events (e.g., vaccinations) has shown to be more susceptible to distortion than memory for single autobiographical events (Powell & Thomson, 1996). Finally, the current study did not discriminate between narrative style of mothers and fathers, although research suggests differences in how they talk and reminisce with their children (Fivush et al., 2000; Noel et al., 2019). Future research might furthermore investigate if other child variables, such as children's anxiety levels in general or in a pain-related context, also interact with parental narrative style in the development of negatively-biased pain memories. In conclusion, this study demonstrated that children showed an attention bias to cues predictive of pain and that parental narrative style affected how children's attention bias to pain influenced children's pain-related memory bias. Results further inform the development of parent-led interventions to reframe children's memories for pain, by highlighting the importance of child characteristics such as child pain-related attention bias in the interplay with parental narrative style.

CRediT authorship contribution statement

Aline Wauters: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Supervision, Visualization. **Tine Vervoort:** Conceptualization, Methodology, Resources, Writing – review & editing, Supervision, Project administration. **Melanie Noel:** Conceptualization, Methodology, Writing – review & editing. **Emma Rheel:** Investigation, Data curation, Writing – review & editing. **Dimitri M.L. Van Ryckeghem:** Conceptualization, Methodology, Software, Formal analysis, Resources, Data curation, Writing – review & editing.

Declaration of competing interest

There are no conflicts of interest that may arise as a result of the research presented in this article.

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Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2022.104202.

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