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Negative Interpretation Bias and the Experience of Pain in Adolescents

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Abstract: **Negative interpretation bias, the tendency to appraise ambiguous situations in a negative or threatening way, has been suggested to be important for the development of adult chronic pain. To our knowledge, this is the first study to examine the role of a negative interpretation bias in adolescent pain. We first developed and piloted a novel task that measures the tendency for adolescents to interpret ambiguous situations as indicative of pain and bodily threat. Using this task in a separate community sample of adolescents (N = 115), we then found that adolescents who catastrophize about pain, as well as those who reported more pain issues in the preceding 3 months, were more likely to endorse negative interpretations, and less likely to endorse benign interpretations, of ambiguous situations. This interpretation pattern was not, however, specific for situations regarding pain and bodily threat, but generalized across social situations as well. We also found that a negative interpretation bias, specifically in ambiguous situations that could indicate pain and bodily threat, mediated the association between pain catastrophizing and recent pain experiences. Findings may support one potential cognitive mechanism explaining why adolescents who catastrophize about pain often report more pain.**

Perspective: ***This article presents a new adolescent measure of interpretation bias. We found that the tendency to interpret ambiguous situations as indicative of pain and bodily threat may be one potential cognitive mechanism explaining why adolescents who catastrophize about pain report more pain, thus indicating a potential novel intervention target.***

Key words: *Interpretation bias, adolescents, pain catastrophizing, cognitive bias, ambiguous situations.*

Pain is commonly experienced in youth, but for some can become chronic and debilitating.[32,46] Guided by theoretical models,[14,54,61] adult research suggests that cognitive factors, such as the tendency to process ambiguous information as indicative of pain and bodily threat, can maintain and even play a causal role in the development of chronic pain.[27,29,30,55-57] Indeed, a range of experimental tasks show that chronic pain patients

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interpret ambiguous information in more threatening ways compared with control subjects.[17,31,39,47,48] Moreover, studies suggest that this interpretation bias acts as a cognitive mechanism underlying pain-related vulnerability, mediating the association between emotional responses to pain and pain outcomes.[27,29,55]

In youth, research has also shown that cognitive factors contribute to the experience of pain. For example, studies suggest that youth with chronic pain are characterized by biases in the way they attend to[5,7,26,58] and remember[33] pain-related information. Moreover, recent research suggests that these attention and memory biases also characterize youth who catastrophize about the experience and potential consequences of pain,[3,25,42,60] suggesting that biases may be relevant for pain-related vulnerability in youth.[41] Further, current theoretical models indicate that biases in attention, memory, and interpretation interact with each other to affect pain chronicity.[15,41,54] However, unlike studies on attention and memory bias, to our knowledge, there are currently no studies measuring interpretation biases in child and adolescent pain, despite the potential importance of this mechanism for the maintenance/development of chronic pain.

In this study, we first aimed to develop a novel task that measures the tendency for adolescents to interpret ambiguous situations as indicative of pain and bodily threat. Although some previous adult studies have used words and facial expressions as ambiguous stimuli,[17,30,47,48] these often lack contextual information, raising questions about their ecological validity. In anxiety and depression,[40,51] and in a small number of innovative adult pain studies,[27,29,56,57] alternative paradigms use vignettes to describe real-world situations where it is unclear what is happening. The individual is asked to imagine herself in the situation, and asked what she thinks is happening. She is then asked whether particular interpretations come to mind (interpretation generation) and how strongly she believes the interpretations to be true (interpretation belief). These interpretations may be negative, benign, or positive. These tasks can also probe the content-specificity of biases, that is, whether biases exist only for information specifically relating to the individual's disorder (eg, chronic pain may be associated with biased interpretations of information only regarding pain and bodily threat) or extend to other domains of functioning (eg, social situations).

Using a new vignette-based task, we then aimed to examine associations between negative interpretation biases, pain catastrophizing, and recent pain experiences in a community sample of adolescents. We hypothesized that adolescents who catastrophize about pain would endorse more negative interpretations, and reject more benign interpretations of ambiguous situations. We also hypothesized that the same pattern of biased interpretations would be associated with reporting greater pain in the preceding 3 months, as indexed by a composite score of pain intensity, frequency, and interference. We explored whether these associations would be stronger for interpretation generation versus belief, and would be specific to situations regarding pain and bodily threat or would extend to social situations. Finally, we investigated whether a negative interpretation bias would mediate the relationship between pain catastrophizing and recent pain experiences (Fig 1). That is, we test the hypothesis that the tendency to negatively interpret ambiguous information as indicating pain and bodily threat is one potential cognitive mechanism by which adolescents with high pain catastrophizing report greater pain experiences.

Methods

Participants

One hundred and nineteen participants from 8 classes in 2 secondary schools in the South of England were invited to take part. All agreed. Parents provided informed consent for their children. Participants aged ≥16 years provided informed consent for themselves and participants younger than 16 years provided informed assent. All participants were fluent in English. Four participants were excluded from analysis because they did not complete at least 25% of items on 1 or more questionnaires (n = 2) or because their participant numbers did not match across the different measures (n = 2). The final sample entered in the analysis thus comprised 115 adolescents (58 female; mean = 14.8 years; SD = 1.79, age range = 11–18 years). A power analysis on the basis of effect sizes from similar studies conducted in adults (ie, those that assessed correlations between pain catastrophizing measures and interpretation biases in community samples) reported that 102 participants would be required to detect a correlation of .27 at $P < .05$ with 80% power, 2-tailed. A correlation of .27 reflects the middle value of previously reported correlations that ranged from .17 to .45.[44,55,57] For task development purposes (described in the Measures section), data were first collected from 2 additional adolescent samples to generate items that were truly ambiguous (defined as those that elicited most variability among adolescents in terms of selection of negative vs benign interpretations). The study was approved by the Central University Research Ethics Committee at the University of Oxford.

Measures

Adolescent Interpretations of Bodily Threat Task

The Adolescent Interpretations of Bodily Threat (AIBT; Supplementary Table 1) task is a new, computerized

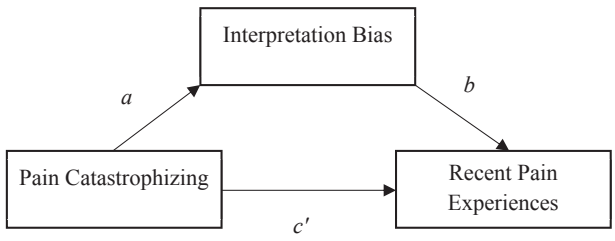

Figure 1. Proposed mediation model.

measure of interpretation bias for adolescents. The task consists of 8 vignettes describing ambiguous situations that may be interpreted as relating to bodily threat or pain, and 8 vignettes describing ambiguous social situations. The situations reflect events that may occur at school, at home, or during everyday adolescent life. The task structure is based on the self-report instruments developed by Clark and colleagues[10] for adult populations and by Miers and colleagues[40] for adolescents, and on the lexical decision task developed by Vancleef and colleagues.[56]

In the AIBT task, participants are first presented with one of the ambiguous situations in the center of the screen. For example, "Your dad jumps out of his chair and puts his hands to his face, making a loud noise. He is…." The situation is ambiguous because there are at least 2 different possible word endings, reflecting different interpretations. The participants are instructed to read the situation and to imagine themselves in the situation before pressing the spacebar. After pressing the spacebar, participants are offered one possible end word that resolves the situation in a negative or benign manner. For example, "Your dad jumps out of his chair and puts his hands to his face, making a loud noise. He is hurt." Participants then rate whether or not that interpretation was likely to pop into their mind on a scale of 1 to 5 (1 = did not pop into my mind, 3 = might pop into my mind, 5 = definitely pops into my mind). After rating the first word, they are presented with a second word that resolves the situation in a different way; for example, "Your dad jumps out of his chair and puts his hands to his face, making a loud noise. He is surprised," and are again asked to rate if that interpretation popped into their mind. Finally, participants are asked to select the interpretation that most easily popped into their mind. After the participants have responded to all 16 scenarios, they receive new instructions. Participants are informed that they will see the same situations again, however this time, they are asked to rate their belief that each interpretation would actually be happening in that situation—that is, whether the interpretation would be a true reflection of reality. The addition of this belief question has been used in a number of previous studies to measure interpretation bias in adults and children.[9,43,54] All items and interpretations are presented in a random order that was fixed across participants.

The ambiguous situations used in the AIBT task were chosen from 2 pilot studies. Participants for these pilot studies (aged 16–18 years) were also recruited from secondary schools in the South of England, and gave informed consent to participate. In pilot study 1, 100 adolescents were presented with 45 ambiguous situations that could be interpreted benignly or as relating to pain or bodily threat. In pilot study 2, 45 adolescents were presented with 32 social situations that could be interpreted benignly or negatively. Some of the pain/bodily situations were adapted from an interpretation bias task developed for Dutch adults by Vancleef et al[56] and some of the social items were adapted from a cognitive bias modification task for adolescents.[6] All remaining situations were generated by the authors and assessed for age relevance by a group of adolescents taking part in work experience or research at the University of Oxford. Participants were presented with threatening and benign words for each ambiguous situation, and were asked to assign a likelihood percentage between 0 and 100 to each word, and to select the word that they thought was most likely to end the sentence. After both pilot studies, the experimenters selected the most ambiguous items on the basis of 4 stages. First, we selected items for which, on average, 30 to 70% of participants had chosen the benign word to end the sentence. This removed items for which participants were very likely to choose the negative word (ie, <30% benign choice) or the benign word (ie, >70% benign choice). Second, we removed any items for which one of the words was given a likelihood percentage, on average, <30%. This removed items that contained any words that participants considered were very unlikely to end the sentence. Third, we removed any items that correlated with the other items below the .1 level (ie, corrected item total correlation in reliability analysis) on the ratings of benign words, ratings of negative words, or on forced choice. One final bodily threat item was removed on the basis that one of the possible end words might not be understood by younger participants, leaving 8 social and 8 bodily threat items. These 16 items were included in the final AIBT task (Supplementary Table 1). The validity of the social items were investigated by assessing interpretations of these items and their correlation with social anxiety scores (see the section on "Validity of social items in the AIBT" in the Supplementary Material).

Pain Catastrophizing Scale for Children

This assessed adolescents' catastrophic thinking about pain[13] and was adapted from the adult Pain Catastrophizing Scale.[53] It consists of 13 items that yield a total score from 0 to 52. Higher scores indicate more pain catastrophizing. Subscale scores for rumination, magnification, and helplessness can be derived. The Pain Catastrophizing Scale for children has good reliability and validity for children older than 9 years.[13] Cronbach α in this study was .90 for the total score.

Recent Pain Experiences

Four items from the Brief Pain Inventory[11] assessed subjective experiences of pain in the preceding 3 months. The Brief Pain Inventory has been widely used to measure pain experiences in nonclinical and clinical populations. Participants rated their average pain intensity and worst pain intensity in the past 3 months (0 = no pain; 10 = worst pain possible), the amount that pain had interfered with daily activities over the past 3 months (0 = I don't miss out on any activities; 10 = I miss out on all activities), and the frequency of their pain over the past 3 months (1 = on less than 1 day each month; 6 = every day). As in previous studies,[38,59] the pain ratings were highly correlated (all r between .38 and .65). To avoid performing multiple analyses, a summed score was created across the 4 scales (total score ranged from 1 to 36). Similar composite scores have been usefully

applied in previous studies to measure pain experiences in healthy children and adolescents,[59] adolescents with chronic pain,[28] adolescent cancer patients,[2] adult cancer patients,[62] and aged populations.[45]

Revised Child Anxiety and Depression Scale

To assess whether biases in interpretations were linked specifically to pain variables rather than to co-occurring generalized anxious or depressive symptomatology, we administered the Revised Child Anxiety and Depression Scale (RCADS[9]). The RCADS consists of 47 items, scored on a 4-point Likert scale from never to always. Higher scores indicate more anxiety or depression. The RCADS is comprised of 6 subscales but in this study, we only calculated scores for generalized anxiety disorder and major depressive disorder. The RCADS has yielded good reliability and validity for children and adolescents.[8,18,37] Cronbach α in this study was .85 for the generalized anxiety disorder subscale and .88 for the major depressive disorder subscale.

Social Anxiety Scale, Adolescent Version

To establish the validity of our social items within the AIBT task (see the section on "Validity of social items in the AIBT" in the Supplementary Material), we investigated biases in relation to adolescent social anxiety symptoms assessed using the 22-item Social Anxiety Scale—Adolescent version.[22] Each item is scored on a 5-point Likert scale from 1 (not at all), to 5 (all the time). Because 4 items are filler items, total scores range from 18 to 90. The Social Anxiety Scale—Adolescent version has yielded good reliability and validity for adolescents.[21,22,52] Cronbach α in this study was .92 for the total score.

Procedure

All testing sessions took place during school hours. After completing the consent/assent forms participants were seated in front of a computer at a distance of approximately 60 cm from the screen, to complete the AIBT task. Participants completed 2 practice trials and the experimenter gave additional verbal instructions for any participants who were unclear (please contact the lead author for a full script). After finishing the interpretation bias task, participants completed the online questionnaires before being debriefed. The whole procedure took approximately 1 hour.

Data Analysis Plan

The AIBT task provides ratings of interpretations (ie, participants' ratings of the different interpretations on a scale of 1–5) and forced choice of interpretation (ie, participants' choice of one interpretation for each situation). Because these different response formats were highly correlated within each condition (all r between .63 and .83), and yielded similar results, only analysis on the ratings data is presented here. However, analysis and results for the forced choice data are shown in the "Forced choice data" section of the Supplementary Material.

To examine the effects of pain catastrophizing on negative and benign interpretations in bodily threat and social situations we used a $2 \times 2 \times 2$ multivariate repeated measures analysis of covariance (ANCOVA) design with valence (negative/benign), context (bodily threat/social), and block (interpretation generation/belief), as within-subject factors, and pain catastrophizing score entered as a covariate. This approach was chosen because we were interested in whether the effects of pain catastrophizing on negative and benign interpretations depended on whether participants reported on interpretations coming to mind (interpretation generation) or their belief in those interpretations being true (interpretation belief; ie, block), and whether interpretations varied across context (bodily threat/social situations). Performing a single analysis to investigate these questions afforded the most stringent approach to reduce error from multiple comparisons. Pain catastrophizing was entered as a covariate to retain the full range of scores on this continuous measure. To examine the effect of recent pain experiences on negative and benign interpretations in bodily threat and social situations, we used a similar multivariate repeated measures ANCOVA but with the pain composite score included as the covariate. If an association between a pain variable and an interpretation index became apparent, we examined whether this association was due to anxious or depressive symptomatology through partial correlations.

To examine whether interpretation bias mediated the association between pain catastrophizing and recent pain experiences (Fig 1), we used the PROCESS tool from Hayes.[24] The method first establishes whether or not the direct path (ie, path *c* in Fig 1) is significant, then, examines whether the indirect effect (combined effects of path *a* and *b* in Fig 1) is significantly different from 0 by producing a confidence interval for the indirect effect of the predictor variable (pain catastrophizing) on the outcome variable (recent pain experiences), through the mediating variable (interpretation bias), and which may not include 0. The Hayes[24] method moves beyond the causal steps approach popularized by Baron and Kenny[4] by minimizing the number of tests needed to examine mediation, increasing power to detect a possible effect, and enabling quantification of the indirect (mediating) effect.[24]

For all analyses, $P < .05$ was the cutoff for statistical significance. For the ANCOVA analyses, partial η^2 effect sizes were reported (small effect size = .01; medium effect size = .06; large effect size = .14[12,43]). For t-test analyses, Cohen's D (*d*) effect sizes were reported (small effect size = .2; medium effect size = .5; large effect size = .8[12]). For mediation analyses, κ^2 effect sizes were reported (small effect size = .01; medium effect size = .09; large effect size = .25[49]).

Results

Five participants reported experiencing no pain in the preceding 3 months, and were therefore told that they did not have to complete the remaining questions about their recent pain experiences. This was because an

indication of 'no pain' meant that participants could only report the lowest possible options for all following questions about pain intensity, frequency, and interference. These participants were therefore assigned the lowest possible scores by the experimenter, so as to keep testing time to a minimum. That is, they were assigned scores of 0 for pain intensity and interference, and a score of 1 for frequency.

Participant Characteristics

As shown in Table 1, adolescents reported low to moderate levels of pain catastrophizing. These levels are consistent with those reported previously in similar samples.[25] In addition, adolescents reported low levels of generalized anxiety and depressive symptomatology, and moderate levels of social anxiety, which is again expected of an unselected sample, and in line with figures from similar samples.[1,20] Adolescents also reported low to moderate levels of pain in the preceding 3 months, which is again expected of an unselected sample. Girls reported more symptoms of generalized anxiety ($t_{113} = -2.54$, $P < .05$) and depression ($t_{113} = -2.78$, $P < .01$) than boys. There were no significant sex differences in social anxiety ($t_{113} = -1.71$, not significant [*ns*]), pain catastrophizing ($t_{113} = -.52$, *ns*), or recent pain experiences ($t_{113} = 1.16$, *ns*).

Pain Catastrophizing and Interpretation Bias

To examine the association between pain catastrophizing and interpretations, a 2 (valence) × 2 (block) × 2 (context) ANCOVA was conducted with pain catastrophizing score entered as a covariate (Table 2 shows the means and SDs of this analysis). The multivariate test yielded significant effects for Valence, $F_{1,113} = 31.61$, $P < .001$, partial $\eta^2 = .22$; Context, $F_{1,113} = 42.45$, $P < .001$, partial $\eta^2 = .27$; and Block, $F_{1,113} = 4.83$, $P < .05$, partial $\eta^2 = .04$. There was also a significant 2-way interaction for Valence × Block, $F_{1,113} = 11.94$, $P = .001$, partial $\eta^2 = .10$, and a significant 3-way interaction for Valence × Block × Context, $F_{1,113} = 10.87$, $P = .001$, partial $\eta^2 = .09$. There was also a significant Valence × Pain catastrophizing interaction, $F_{1,113} = 14.86$, $P < .001$, partial $\eta^2 = .12$. Pain catastrophizing did not interact with Context or Block to form any 3- or 4-way interactions.

Descriptive statistics for all main effects are presented in Table 3. To explore the Valence × Block × Context interaction (which subsumed the Valence × Block interaction), we performed 2 (Valence) × 2 (Context) repeated measures analyses of variance separately for each block. This revealed a significant Valence × Context 2-way interaction in both blocks (interpretation generation: $F_{1,114} = 7.36$, $P < .01$, partial $\eta^2 = .06$; interpretation belief: $F_{1,113} = 7.812$, $P < .01$, partial $\eta^2 = .06$). To further decompose these interactions, we performed t-tests comparing negative and benign interpretations in bodily threat versus social situations for each block. These revealed that negative interpretations received significantly lower ratings than benign interpretations when participants considered their belief in those interpretations (bodily threat: $t_{114} = -8.73$, $P < .001$, $d = .815$; social: $t_{114} = -4.56$, $P < .001$, $d = .43$) but not when considering how easily interpretations came to mind (bodily threat: $t_{114} = 1.66$, *ns*, $d = .16$; social: $t_{114} = -1.58$, *ns*, $d = .15$).

To further examine the Valence × Pain catastrophizing interaction, we conducted Pearson correlation analyses separately for adolescents' ratings of negative and benign interpretations, collapsed across Block and Context. These analyses revealed that adolescents with higher levels of pain catastrophizing were significantly more likely to endorse negative interpretations ($r = .22$, $P < .05$), and significantly more likely to reject benign interpretations ($r = .33$, $P < .001$), than adolescents with low levels of pain catastrophizing. After controlling for anxiety and depressive symptoms, the effect for benign ratings was still significant ($r = .22$, $P < .05$). However, the effect for negative ratings was no longer significant ($r = .02$, *ns*).

Table 1. Means, SDs, and Ranges for Pain Indices and Emotional Symptomatology

Questionnaire Indices	Mean (SD)	Possible Range (Actual Range)
Generalized anxiety	8.01 (3.79)	0–18 (1–18)
Depression	10.00 (5.60)	0–30 (0–30)
Social anxiety	50.61 (13.80)	18–90 (20–87)
Pain catastrophizing	18.09 (8.97)	0–52 (1–42)
Pain frequency (last 3 mo)	3.61 (1.41)	1–6 (1–6)
Average pain intensity (last 3 mo)	3.02 (1.94)	0–10 (0–8)
Worst pain intensity (last 3 mo)	5.63 (2.33)	0–10 (0–10)
Pain interference (last 3 mo)	1.66 (2.11)	0–10 (0–9)
Recent pain experiences (composite)	13.92 (6.17)	1–36 (1–27)

Table 2. AIBT Ratings Data*

AIBT Task Indices	Mean (SD)
Interpretation generation (block 1)	
Bodily threat negative word	3.38 (.59)
Bodily threat benign word	3.25 (.56)
Social negative word	2.93 (.73)
Social benign word	3.11 (.65)
Interpretation belief (block 2)	
Bodily threat negative word	3.15 (.57)
Bodily threat benign word	3.87 (.53)
Social negative word	2.93 (.62)
Social benign word	3.37 (.59)

*Rating scale possible range = 1 to 5.

Table 3. Main Effects on AIBT Task Parameters*

Variable	Mean (SD)
Benign interpretations	3.40 (.43)
Negative interpretations	3.10 (.43)
Bodily threat interpretations	3.41 (.29)
Social interpretations	3.09 (.30)
Interpretation generation	3.17 (.32)
Interpretation belief	3.33 (.28)

*Rating scale possible range = 1 to 5.

Pain Experiences and Interpretation Bias

To examine the association between recent pain experiences and interpretations, a 2 (Valence) × 2 (Block) × 2 (Context) ANCOVA was conducted with the recent pain experiences score entered as a covariate. The multivariate test yielded significant effects for Valence, $F_{1,113} = 29.71$, $P < .001$, partial $\eta^2 = .21$; Context, $F_{1,113} = 22.67$, $P < .001$, partial $\eta^2 = .17$; and Block, $F_{1,113} = 17.24$, $P < .05$, partial $\eta^2 = .13$. There was also a significant 2-way interaction for Valence × Block, $F_{1,113} = 14.69$, $P = .001$, partial $\eta^2 = .12$, and a significant 3-way interaction for Valence × Block × Context, $F_{1,113} = 10.15$, $P = .01$, partial $\eta^2 = .08$. There was also a significant Valence × Recent pain experiences interaction, $F_{1,113} = 14.46$, $P < .001$, partial $\eta^2 = .11$ and a significant Block × Recent pain experiences interaction, $F_{1,113} = 3.94$, $P < .05$, partial $\eta^2 = .03$. Because the main effects and interaction effects not including pain experiences were explored earlier, these were not explored again.

To further examine the Valence × Recent pain experiences interaction, we conducted Pearson correlations separately for adolescents' ratings of negative and benign interpretations, collapsed across Block and Context. These analyses revealed that adolescents who recently experienced more pain were significantly more likely to endorse negative interpretations (r = .33, $P < .001$), and significantly more likely to reject benign interpretations (r = −.21, $P < .05$), than adolescents who experienced less pain. To further examine the Block × Recent pain experiences interaction, we conducted Pearson correlations separately for adolescents' ratings of interpretations coming to mind and their belief in those interpretations being true, collapsed across Valence and Context. Although there was a significant interaction effect, neither correlation when performed separately was significant (interpretation generation: r = .17, *ns*; interpretation belief: r = .0, *ns*).

Testing for Mediator Effects

The analysis reported previously confirmed that a negative interpretation bias was associated with higher levels of pain catastrophizing and higher levels of experiences of recent pain. Analyses were therefore performed to determine whether a negative interpretation bias mediated the association between pain catastrophizing and recent pain experiences. To perform this analysis, we created an Interpretation Bias Score (IBS) by subtracting ratings for benign interpretations from ratings of negative interpretations. This score provides a single measure of interpretation bias, with higher scores indicating more negative interpretations. Because Context (bodily threat/social) and Block (interpretation generation/belief) did not interact with Valence and Pain catastrophizing or Recent pain experiences, we first performed the mediation analysis using an IBS that was collapsed across Context and Block. However, because we may expect a more specific role of bodily threat interpretations to act as a mediator between 2 pain-related variables, we also performed the mediation analysis separately for the bodily threat items and the social items.

First, the analyses confirmed that pain catastrophizing is significantly associated with recent pain experiences (path *c* in Fig 1), $F_{1,113} = 25.02$, $P < .001$. Next, when using the IBS collapsed across Context and Block, there was a significant indirect effect of pain catastrophizing on recently experienced pain through interpretation bias, $b = .05$, bias-corrected (BCa) confidence interval (CI) = .015 to .115. This represents a small to medium effect, $\kappa^2 = .077$, 95% BCa CI = .026 to .161. Next, when using the IBS for bodily threat items only (collapsed across Block), there was again a significant indirect effect of pain catastrophizing on recently experienced pain through interpretation bias, $b = .04$, BCa CI = .009 to .111. This represents a small to medium effect, $\kappa^2 = .066$, 95% BCa CI = .014 to .157. Finally, when using the IBS for social items only (collapsed across Block), the indirect effect was not significant, $b = .02$, BCa CI = −.010 to .076. This indicates that, when considered separately, only a negative interpretation bias for ambiguous information regarding pain and bodily threat mediated the association between pain catastrophizing and recent pain experiences. A negative social interpretation bias did not play a mediating role.

Discussion

In this study we developed a novel, computerized task (the AIBT task) that measures the tendency for adolescents to interpret ambiguous situations as indicative of pain and bodily threat. On the basis of 2 pilot samples, we developed the final AIBT task. In a third and independent sample of adolescents, we then investigated whether negative bodily threat interpretations were associated with pain catastrophizing and recent pain experiences. Critically, we also examined whether a negative interpretation bias mediated the association between pain catastrophizing and recent pain experiences. We found that adolescents who catastrophize about pain, and those who reported more recent pain issues, endorsed more negative interpretations, and rejected more benign interpretations, of ambiguous situations, with a medium to large effect. This interpretation pattern was not, however, specific for situations regarding pain and bodily threat, but generalized across social situations as well. We also found that a negative interpretation bias, specifically in situations regarding pain and bodily threat, mediated the association between pain catastrophizing and recent pain experiences. This finding may explain why adolescents who catastrophize about pain also report more pain.

This study extends current findings. Although previous studies on adolescent pain and cognitive bias have focused on biased attending to pain cues,[5,7,25,26,60] to our knowledge, this is the first study to consider biased interpretations of ambiguity in youth. In this study, we present a novel tool for investigating pain-related interpretation bias using ecologically valid information. This tool allows us to measure whether adolescents endorse or reject negative and benign interpretations of the

same situations, as well as to differentiate interpretation generation (ie, whether an interpretation comes to mind) from interpretation belief (ie, belief that the interpretation is true). Investigating the nature of these interpretational processes in developmental samples is important for advancing theory. Current cognitive-affective models of pain indicate that biases in interpretation, attention, and memory do not exist in isolation, but instead, interact with each other to affect pain chronicity.[15,54] Moreover, recent models posit that negative interpretations may in fact drive biased attending to pain.[15,16,54,61] Thus, the current study provides a platform for examining the reciprocal relationships between different cognitive biases across an important developmental period, when pain often first becomes chronic.[46]

Our findings are in line with previous adult studies showing an association between negative interpretations of ambiguous information and individual differences in pain-related vulnerability constructs.[30,56,57] Our findings are also in line with adult studies showing that the tendency to interpret ambiguous information as indicative of bodily threat plays a mediating role in the association between emotional response to pain and pain outcomes.[27,29,55] In particular, our findings suggest that interpretation bias may be one reason why individuals who have a high emotional response to pain are also more likely to experience and report more pain. Of note, however, because mediation analysis on cross-sectional data cannot establish the direction of relationships, our findings and previous findings from adult samples could also be interpreted in the opposite direction. For example, recent experiences of pain could lead to a negative interpretation bias as well as greater catastrophizing in response to pain, and causality remains to be established in future studies. Nonetheless, we also extend findings from adult samples. For example, our findings indicate that pain-related vulnerability may be associated with the tendency to endorse negative interpretations as well as to reject benign interpretations of ambiguous situations. Also, when controlling for symptoms of generalized anxiety and depression, only the association with benign interpretations remained significant. This effect certainly remains to be replicated in adults, in other healthy child and adolescent samples, and in adolescent chronic pain samples. However, if we see a similar pattern in clinical and prospective studies, this could suggest that biased interpretations are a target for treatment, and moreover, rather than necessarily reducing negative interpretations, interventions that encourage more benign interpretations could be more potent at specifically reducing pain-related vulnerability.

It is interesting that we did not always find evidence for a specific effect of bodily threat interpretations as separate from negative social interpretations. Although adult data have not directly addressed this issue, the data do largely support a more general bias.[27] In our sample of adolescents, those who catastrophized about pain, and those who experienced more recent pain issues showed a more general bias that extended across both bodily threat as well as social situations. This may be because pain catastrophizing and acute pain are indeed associated with a more general tendency to interpret all ambiguous situations in a negative way, and thus with an information processing system that is broadly biased in favor of negative material.[27] However, our effects may be specific to bodily threat and social situations, but may not extend beyond these two domains. Indeed, adolescence is a time of increased independence from parents, increased focus on peer interactions, and thus increased salience of social situations. It may be important for future studies measuring individual differences in cognitions associated with pain experiences or chronic pain to consider situations outside of the social and bodily threat domains, for example, situations relating to academic performance or attainments. Despite this, we did find (in post hoc analysis) that negative interpretations specifically regarding bodily threat, but not social threat, mediated the association between pain catastrophizing and recent pain experiences. This indicates some degree of specificity in the association between biased interpretations and pain-specific measures, and warrants continued investigation of these relationships, rather than moving to a model of shared vulnerability across pain and psychopathology. It will also be interesting to examine whether there is more specificity in adolescent chronic pain samples, when the young person has been in pain for many months or years, and when issues regarding pain and bodily threat are more relevant for their concerns. Of further note, the valence-specific effects reported previously also did not differ for interpretation generation compared with interpretation belief. We did find that, independent of valence, pain experiences interacted with block, but with a very small effect size. Indeed, when performing separate analyses, neither correlation reached significance, suggesting that there is not a large difference in the associations between pain experiences and interpretation generation versus interpretation belief. However, we may expect that interpretation generation and interpretation belief would play different roles in prospective or clinical populations, and we therefore suggest retaining both blocks in the AIBT task for future studies.

This study has limitations, some that we can address in future research. First, all measures were self-reported, and shared method variance could inflate the chance of finding significant effects. Incorporating measures of more automatic, reflexive processing (eg, lexical decision tasks,[56] incidental learning tasks,[30] or word priming tasks[55]) within the context of ambiguous situations, particularly within youth samples, would be useful and revealing. Second, not all adolescents who catastrophize about pain develop chronic pain. Relatedly, we measured previous pain experiences rather than prospective pain-related outcomes. The presence and clinical relevance of a negative interpretation bias within an adolescent patient sample remains to be established. In addition, longitudinal studies will be necessary for assessing whether a negative interpretation bias predicts the transition from acute to chronic pain or whether,

as noted previously, a negative interpretation bias is merely the outcome of increased acute pain. Training studies can also be useful for illuminating causality. There already exist novel cognitive training tools that use simple learning mechanisms to encourage more negative or benign interpretations of ambiguous situations.[34,36,50] If training a more negative interpretation bias can increase pain catastrophizing and acute pain, and likewise, if training a more benign bias can reduce these, this could provide evidence that a negative interpretation bias plays a causal role in the pain experience. In addition, it will be important to consider why and how an adolescent might develop a negative interpretation bias. Recent findings from the psychopathology literature provide some suggestions, showing that biased interpretations of ambiguous information can be transferred from parents to children.[23,35] Future studies investigating family influence on young people's interpretations of ambiguous situations within the context of pain will be highly informative. Furthermore, it will be important to examine whether our findings extend to younger child samples. Recent findings from the psychopathology literature suggest that interpretation biases are acquired in later childhood, only when certain cognitive and social building blocks are in place.[19] These findings are relevant not only for guiding future studies of interpretation bias in child pain, but also for adapting the AIBT task. In particular, there may be developmental differences in younger and older children's ability to understand the difference between interpretation generation and belief. It will therefore be important to examine the utility of our task for investigating biases in younger samples.

Conclusions

The current findings extend our understanding of the role and nature of cognition in adolescent pain. Using a novel computerized task, we showed that cognitive biases toward threat, particularly in the interpretation of ambiguous information, might play an important role in adolescent pain experiences. Critically, we provided preliminary evidence that a tendency to interpret ambiguous situations as indicative of pain and bodily threat may be a cognitive mechanism that connects pain catastrophizing with actual pain experiences. The AIBT task can now be used in clinical and longitudinal samples to understand how interpretation bias, in reciprocal relations with other cognitive biases and emotional responses to pain, contribute to acute and chronic pain in adolescents.

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Supplementary Data

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