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Attentional biases in pediatric chronic pain: An eye-tracking study assessing the nature of the bias and its relation to attentional control

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Abstract

Attentional biases are posited to play a key role in the development and maintenance of chronic pain in adults and youth. However, research to date has yielded mixed findings and few studies have examined attentional biases in pediatric samples. The present study used eye-gaze tracking to examine attentional biases to pain-related stimuli in a clinical sample of youth with chronic pain and pain-free controls. The moderating role of attentional control was also examined. Youth with chronic pain (*n* = 102) and pain-free controls *(n* = 53) viewed images of children depicting varying levels of pain expressiveness paired with neutral faces while their eye gaze was recorded. Attentional control was assessed using both a questionnaire and a behavioural task. Both groups were more likely to first fixate on high pain faces but showed no such orienting bias for moderate or low pain faces. Youth with chronic pain fixated longer on all pain faces than neutral faces, whereas youth in the control group exhibited a total fixation bias only for high and moderate pain faces. Attentional control did not moderate attentional biases between or within groups. The results lend support to theoretical models positing the presence of attentional biases

in youth with chronic pain. Further research is required to clarify the nature of attentional biases and their relationship to clinical outcomes.

Keywords: chronic pain; Pediatric; attentional bias; attentional control; eye-tracking

Pediatric chronic pain is highly prevalent, affecting 11-38% of youth [30]. It is associated with significant distress, functional impairment, and high psychiatric comorbidity [10; 53; 55]. Despite its prevalence and impact, a comprehensive understanding of the factors contributing to its development and maintenance remains elusive. Theoretical models of chronic pain posit that attentional biases contribute to its onset and maintenance [2; 11; 54], yet pain-related attentional biases remain poorly understood, particularly in youth. Given the significant increase in the onset of chronic pain in adolescence [28], and the fact that adolescent chronic pain often persists into adulthood [55], a better understanding of underlying mechanisms during this developmental period is critical for mitigating potentially lifelong impacts [31].

Attentional bias is defined as preferential attention to emotionally relevant or salient information [9; 12]. Few studies have examined pain-related attentional biases in youth [23; 52], and only a handful have examined clinical samples of youth with chronic pain [3; 5; 22]. To date, the literature on attentional biases in youth echoes findings with adult samples: results are equivocal, with some studies reporting the presence of an attentional bias toward pain-related stimuli [3; 23], and others reporting no evidence of attentional bias [22]. A recent systematic review found weak evidence in favour of attentional bias for pain-related information in youth with chronic pain as compared to youth without chronic pain [6]. Only one of the studies in this review assessed attentional bias using eye-tracking methodology [23]. Eye-tracking is especially advantageous for such research because it provides a direct measure of attention to stimuli over

an extended interval, unlike tasks that use response latencies to infer the focus of attention at a specific moment in time [44]. In this study, healthy youth showed an initial orienting bias toward pain images, and this preferential attending was maintained over a 3500 ms presentation time [23]. There was also evidence of a moderating effect of attentional control, such that for youth with lower attentional control, higher anxiety was associated with less dwell time on pain faces [23]. Similar research with clinical samples is necessary to determine whether and how attentional biases in youth with chronic pain differ from youth without chronic pain, as this remains unclear.

This is the first study to use eye-tracking to examine attentional biases to pain-related facial stimuli in a clinical sample of youth with chronic pain. The purpose of the investigation was to assess: 1) the nature of attentional bias (i.e., initial orienting bias; total fixation bias) in a clinical sample of youth with chronic pain as compared to a pain-free control group; and 2) the moderating effect of attentional control on attentional bias. We hypothesized that, consistent with fear-avoidance models, youth with chronic pain would exhibit an attentional bias for pain faces that would differ from the bias of controls. We hypothesized that attentional control would moderate attentional biases, such that lower attentional control would be associated with longer total fixation times for pain faces.

Methods

Participants

All study procedures were approved by the University of Calgary Conjoint Health Research Ethics Board. Consistent with the Canadian research ethics policy [41], youth who were at least 14 years of age provided their consent to participate and signed a consent form.

Youth who were below the age of 14 were asked to provide their assent and signed an assent form. In addition, one parent of each participant (regardless of age) attended the lab visit and provided their consent and, for youth below the age of 14, consent for their child to participate in the study. The participants were youth aged 10-18 years with chronic pain (N = 102, 71% girls, M_{age} = 14.20 years; SD = 2.29) and youth without chronic pain (the control group; N = 53, 50% girls, M_{age} = 13.49 years; SD = 2.71). As a token of appreciation for their participation, youth and their parents were told at the outset that they would each receive $20 gift cards.

Chronic pain group.

Youth were eligible if they were between 10 and 18 years of age and were referred to a chronic pain program for pain assessment and/or treatment. Youth who did not speak English or were diagnosed with a developmental disorder were not eligible for the study. Participants were recruited from three outpatient clinics (Headache, Abdominal Pain, Complex Pain) housed within the pain and rehabilitation center of a children's hospital in Western Canada. Recruiting a mixed sample of youth with various pain conditions is consistent with previous research on pediatric chronic pain [36; 38; 56]. To facilitate recruitment, clinical staff provided the study team with the contact information of new patients and patients who had received care in the program within the last year. Research staff also generated a list of participants who were participating in a clinical outcomes study and who had consented to be contacted about future studies. Research staff contacted prospective participants to provide information about the study, along with an option to decline participation. During recruitment, youth were confirmed to have experienced persistent or recurrent pain for at least 3 months, consistent with the current definition of chronic pain endorsed by the International Association for the Study of Pain (IASP)

[33]. These youth were recruited as part of a larger longitudinal study that examined mechanisms underlying chronic pain and mental health issues.

Control group of youth without chronic pain.

Youth were eligible if they were between 10 and 18 years of age and did not endorse the presence of chronic pain (i.e., recurrent or persistent pain lasting 3 months or more). As with the chronic pain sample, youth who did not speak English or who were diagnosed with a developmental disorder were not eligible for the study. Youth who comprised the control group were recruited via a hospital-based registry of healthy families in Western Canada who were interested in participating in pediatric health-related research. Similar to the protocol used to recruit the chronic pain sample, research staff contacted prospective participants via email and telephone to provide information about the study.

Procedure

Either during or 1-4 weeks prior to their laboratory visit, youth and parents provided consent using an online consent form and completed questionnaires via REDCap, a secure online data collection tool [20]. Parents completed questionnaires that collected sociodemographic information. Youth completed self-report measures to assess pain characteristics and attentional control. Youth and parents then visited the hospital-based research laboratory, located within the clinical milieu of a tertiary-level chronic pain and rehabilitation center. During this lab visit, participants completed an eye-tracking task and a behavioural measure of attentional control (the flanker visual filtering task).

Self-report measures

Demographic characteristics.

Parents were asked to report sociodemographic information including youth age, sex, ethnicity, and annual household income.

Pain characteristics.

Youth in the chronic pain group completed the Pain Questionnaire [39]. Youth were asked to report their primary pain location using a body map [43]. Youth reported how long their pain problem had been present (in years and months) and its frequency over the past 7 days (rated on a 5-point Likert scale ranging from "not at all" to "daily"). The Pain Questionnaire was developed by Palermo and colleagues [39] to assess a variety of pain characteristics in youth with chronic pain. It is comprised of a series of single-item questions (e.g., "How much do aches or pains bother or upset you?"). This measure has documented reliability and validity in youth with chronic pain [39] and has been used in previous research to assess various pain characteristics in pediatric clinic samples, such as pain duration, location, unpleasantness, and interference [4; 35].

Pain outcomes: Pain intensity and interference.

The Patient-Reported Outcomes Measurement Information System (PROMIS-25) Pediatric Profile (version 1.0) was used to assess pain interference. PROMIS instruments are short forms developed by the National Institutes of Health to assess a variety of physical and mental health symptoms across the life span. The scales were created using item response theory, which produces more precise and informative measures [26] using fewer items, thereby reducing

respondent burden [29]. The 4 items of the Pain Interference subscale are rated using a five-point Likert scale ranging from 0 ("never") to 4 ("almost always"). Total scores range from 0 and 16, with higher scores indicating greater difficulty over the past 7 days. This scale is valid for use with youth with chronic pain [29]. Total scores were transformed into standardized T-scores. For the current sample, internal consistency of pain interference subscales was good (α = .82). Pain intensity was rated on an 11-point numerical rating scale (NRS) ranging from 0 ("no pain") to 10 ("worst pain you can think of"), with the rating reflecting average pain intensity in the past 7 days. The NRS has been shown to be a valid and reliable measure for assessing pain intensity in youth with chronic pain [7].

Attentional Control Scale (ACS).

The ACS is a 20-item measure that assesses an individual's self-reported level of attentional control [13]. Items are rated on a 4-point Likert scale, with higher total scores indicating greater self-reported attentional control. The measure consists of two subscales that assess attention focusing and attention shifting. The ACS has good reliability [13]. The ACS has been shown to have good construct validity and reliable factor structure in pediatric samples [49]. Exploratory and confirmatory factor analyses of the ACS have consistently supported a two-factor structure (attention focusing and attention shifting), with some variations as to which items can be excluded from the calculation of total and subscale scores [27; 37; 40; 49]. For the analyses reported below, the ACS total score and corresponding scales were calculated excluding item 9, as recommended to enhance factor structure fit and increase measure precision [27; 37; 40; 49]. For the current sample, internal consistency of the ACS was good (α = .85).

Eye tracking apparatus and task.

Eye movements were recorded using an EyeLink 1000 eye tracking system (SR Research Ltd.), which uses infrared video-based tracking technology. The system has a 1000 Hz sampling rate, allowing for a temporal resolution of 1 ms, with an average gaze error of less than 0.5 degrees of visual angle. Images were shown on a 21-inch BenQ XL2430T computer display positioned approximately 90 cm away from the participant. Images were 14 cm in height and 13 cm in width, and the centre of each image was located 8.5 cm from the fixation marker. Prior to the presentation of each pair of images a fixation marker was displayed in the centre of the display for 500 ms to standardize the starting position of participants' gaze for each trial. Participants were instructed to focus on the fixation marker during the 500 ms and then to view the images subsequently presented. The two images were arranged horizontally in the display, with an image placed on the left and the right of the fixation marker location. Participants' eye-gaze was measured continuously throughout the 3000 ms presentation time for each trial. The two images presented were defined as interest areas in the system programming, and fixations to these areas were automatically registered by the eye-tracking system. Fixation data were processed using the EyeLink Data Viewer software (SR Research) to filter for blinks, missing data, and other recording artifacts (using the default settings). To be included in analyses, a fixation had to be at least 100 ms in duration; sequential, adjacent fixations less than 100 ms in duration were merged into a single fixation.

Eye tracking stimuli.

Stimuli consisted of 40 grey-scaled images of 10 different children (5 boys and 5 girls, ranging in age from 9-16 years) depicting pain and neutral facial expressions. These images were

used in previous research investigating attentional biases for pain-related stimuli in healthy children [52]. The images were taken from video recordings of children experiencing an experimental pain task (the cold pressor task [51]), and levels of pain expression assigned to the images correspond to observer ratings of pain intensity [50]. Children and their parents provided permission for these images to be used for research purposes. For each of the 10 children in the images, 4 images represent 4 categories of facial expression: neutral face, low pain face, moderate pain face, and high pain face (see Figure 1). The stimulus set consisted of 30 pairs of images, each pair showing 2 images of the same child, one with a neutral face and the other one of the 3 pain expressions (low, moderate, high; see Figure 2). Each pair was duplicated, with the neutral and pain face switching locations, thereby resulting in a total of 60 pairs (20 neutral-low pain pairs, 20 neutral-moderate pain pairs, and 20 neutral-high pain pairs).

Flanker visual filtering task.

Participants completed a flanker visual filtering task [18] to provide a behavioural measure of attentional control. This task measures an individual's ability to ignore irrelevant or distracting stimuli while processing target stimuli [8]. The flanker visual filtering task is the most frequently used task for assessing this aspect of executive inhibition. The present study used the same version of the task used in previous studies [8; 22], which is a simplified version of the visual filtering task with child-friendly stimuli. In this version of the task, a central target (an image of a fish facing either left or right) is presented on a computer display and is flanked by congruent (facing the same way) or incongruent (facing the opposite way) fish placed on either side of the target.

Participants were seated in front of a computer monitor and were shown a series of trials depicting a horizontal row of five fish. For each trial, participants were asked to respond as quickly as possible and indicate whether the middle fish was facing either left or right by selecting the left or right keyboard key. There were two types of trials: congruent and incongruent. Congruent trials were trials where all five fish pointed in the same direction (> > > > > or < < < < <). On incongruent trials the four fish pointed in the opposite direction of the target fish (> > < > > or < < > < <). For each trial, stimuli were presented until participants selected a response or more than 3000 ms elapsed. If a response was not made within 3000 ms an audio tone and the message "too slow" were presented. If a participant responded incorrectly, a tone and the message "wrong response" were presented. The intertrial interval was 1500 ms. Participants completed two practice blocks of 20 trials each to familiarize them with the task. After the practice trials, participants completed 120 randomly presented experimental trials (60 congruent and 60 incongruent trials). Three 30-second breaks were provided during the task (at 40-trial intervals).

Statistical Analyses

Probability of first fixation (used to calculate first fixation bias) and mean total fixation time (used to calculate total fixation bias) were calculated as attention parameters to assess the initial orientation of attention and sustained attention, respectively [23]. Probability of first fixation refers to whether a participant first fixated on the pain face or the neutral face when the pair of images was presented. A first fixation bias to pain is thus characterized as a higher probability that a participant first fixates on the pain face relative to the neutral face. The first fixation bias was calculated as the proportion of trials in which the pain face was first fixated

divided by the total number of trials where the first fixation was made to either face. Proportion scores were calculated for each level of pain face expressiveness (high, moderate, low) separately. The resulting proportion scores are interpreted as follows: a first fixation bias greater than 0.5 reflects an initial orienting bias toward pain faces; a first fixation bias equal to 0.5 indicates no bias; a first fixation bias less than 0.5 reflects an initial orienting bias toward neutral faces and hence an initial attentional avoidance of pain faces.

Total fixation time was calculated by averaging the total time spent fixating on each face (pain face and neutral face) for each level of pain expressiveness separately (i.e., high pain, moderate pain, low pain). To quantify the bias, three total fixation bias scores (one for each level of pain face expressiveness) were calculated by subtracting the average of the total fixation time for the neutral faces from the averages of the total fixation time for the pain faces (high pain, moderate pain, low pain). Positive values indicate that total fixation times for pain faces were longer than for the paired neutral faces, indicative of a total fixation bias (i.e., greater attention) to pain faces. Negative values indicate that total fixation times for neutral faces were longer than for the paired pain faces, indicative of attentional avoidance of pain faces.

Statistical analyses were conducted using SPSS version 25 (IBM Corp, Armonk, NY). Statistical power was determined on the basis of previously published research [23; 52]. A power analysis for the planned mixed-model analysis of variance (ANOVA) with a medium effect size (f^2 = .25, α = .05, groups = 2; repeated measurements = 3) indicated that a total sample size of 82 participants (41 in each group) would provide 80% power to detect a two-way interaction. Thus, the current sample of 155 participants (102 chronic pain and 53 healthy control) provided more than adequate statistical power. An additional statistical power analysis was conducted to assess the power of the regression analyses with attentional control as a moderator. The results

indicated that the sample size of 155 participants would provide 81% power to detect a 5% increase in variance accounted for (i.e., increase in *R*-square) in the outcome variable by the interaction effect (a small effect size; $f^2 = .05$). Effect sizes for statistically significant *t*-tests (Cohen's *d*) are reported for key comparisons (where *d* values of .20, .50, and .80 correspond to small, medium, and large effects, respectively).

Data were examined before prorating and determined to be missing completely at random (MCAR) using Little's MCAR test, an essential assumption before proceeding with various techniques for the imputation of missing data [32]. For participants with missing data constituting < 20% of responses within a scale, a prorated score was calculated for that scale [17]. Descriptive, correlational, and ANOVA analyses were conducted using two-tailed hypothesis testing. Independent samples *t*-tests and chi-square tests were used to test for group differences in key variables (i.e., age, sex, attentional control).

T-tests were used to determine if the first fixation bias score for each pain face, for each group, differed significantly from chance (0.50), which would reflect an orienting bias toward or away from pain faces. Paired t-tests were used to determine if the total fixation time for each pain face, for each group, differed significantly from the total fixation time for each of the corresponding neutral faces. To test for group differences in attentional biases, the first fixation bias and total fixation bias scores were analyzed using mixed-model ANOVA, with group (chronic pain, control) as the between-subjects factor and pain expressiveness (low pain face, moderate pain face, high pain face) as the within-subjects factor. Significant interactions were probed using *t*-tests. Pearson correlations were used to test for associations between attentional bias measures and measures of attentional control (i.e., scores on the ACS and flanker task performance). Moderation models, testing whether attentional control moderated the magnitude

of attentional bias within each group, were carried out using the Hayes' PROCESS macro for SPSS (Hayes, 2018).

Results

Processing of Eye-Tracking Data

A total of 168 youth completed the eye tracking task. The raw eye tracking data was examined prior to analyses to screen for sub-optimal data recording and potential outliers. Individual trials wherein no data was recorded (i.e., total fixation time for the trial equal to 0 ms) were interpreted as reflecting a lack of attending or recording errors and were coded as missing (3.9% of all trials). No eye-tracking data was available for seven participants due to inadequate calibration. The data from four participants were excluded from all analyses due to sub-optimal eye-tracking data (i.e., mean total trial fixation time less than 2000 ms). Finally, two participants were identified as statistical outliers on one or more of the attentional bias measures (using the SPSS Explore function) and were excluded from all analyses. The final sample consisted of 155 youth (102 in the chronic pain group and 53 in the control group).

Processing of Flanker Visual-Filtering Task Data

Consistent with previous research [8; 22], trials with errors and trials with response times shorter than 200 ms or longer than 3000 ms were excluded from all analyses (2.7% of trials). In addition, response times 3.0 standard deviations above or below the mean were considered outliers and were excluded (0.61% of response times on congruent trials and 0.91% of response times on the incongruent trials). For each participant, mean response times for congruent trials

were subtracted from mean response times for incongruent trials to produce a conflict score, with higher scores indicating greater interference in the presence of distracting information [42].

Sociodemographic Characteristics and Descriptive Statistics

Sociodemographic information (i.e., sex, age, ethnicity, household annual income) is listed in Table 1. For the youth in the chronic pain group, 61% were originally referred to a headache program and 39% were referred to a complex pain program. There were more females in the chronic pain group (70.6%) than in the control group (50.0%), $X^2(2) = 7.11$, $p = .029$. This outcome is consistent with the sociodemographic characteristics of chronic pain samples in previous research [35; 38], as well as the epidemiology of the condition in pediatric populations, which finds that a higher proportion of girls are affected by chronic pain as compared to boys [30]. Over half of the youth in the chronic pain group (54%) reported pain in one location and just under half (43%) reported pain in multiple locations. Sixty-eight percent of youth reported headache, 26% reported musculoskeletal pain, 18% reported abdominal pain, 14% reported leg pain, 11% reported chest pain, and 25% reported pain in the "other" category. The average pain intensity level in the past week was 5.60 out of 10 ($SD = 1.78$). On average, youth reported a pain duration of 3.38 years ($SD = 3.25$). When asked about pain frequency over the past 7 days, 52.0% of youth in the chronic pain group endorsed daily pain, 15.7% endorsed pain "4 to 6 times per week", 22.5% endorsed pain "2 to 3 times per week", 6.9% endorsed pain "1 time per week", and 2.9% endorsed no pain in the preceding week.

Descriptive statistics for the key variables of interest are shown in Table 2. Youth in the chronic pain group had lower scores on the ACS ($M = 49.45$; $SD = 8.61$) than youth in the control group ($M = 54.15$; $SD = 9.03$), $t(152) = 3.17$, $p < .01$. Given the impact of chronic pain

on attention and cognitive processing posited by theoretical models [16], and as evidenced in previous research with adults [14; 15; 34], this difference in ACS scores was expected. The two groups did not differ with respect to age, $t(148) = 1.58$, $p = .118$.

The flanker response times were analyzed using a 2 (Group: Chronic Pain, Control) by 2 (Trial Type: Congruent, Incongruent) mixed-model ANOVA. As expected, there was a significant main effect of Trial Type, $F(1, 146) = 306.49$, $p < .001$, partial $\eta^2 = 0.68$ such that response times for incongruent trials ($M = 525.65$, $SD = 112.94$) were slower than response times for congruent trials ($M = 490.16$, $SD = 107.33$), indicative of attentional interference due to distracting stimuli. The main effect of Group was not significant, $F(1, 146) = 0.02$, $p = .883$, partial $\eta^2 < 0.01$ nor was the interaction between Group and Trial Type , $F(1, 146) = 0.31$, $p = .580$, partial $\eta^2 < 0.01$. For both groups, response times for incongruent trials ($M_{pain} = 524.26$, $SD = 107.02$; $M_{control} = 528.16$, $SD = 123.88$) were slower than response times for congruent trials ($M_{pain} = 489.58$, $SD = 103.15$; $M_{control} = 491.21$, $SD = 115.44$), and there was no indication of a group difference in the interference effect ($M_{pain} = 34.68$ ms; $M_{control} = 36.95$ ms).

First Fixation Bias

The data were analysed using a 2 (Group: Chronic Pain, Control) by 3 (Pain Expressiveness: Low, Moderate, High) mixed-model ANOVA. There was a significant main effect of Pain Expressiveness, $F(2, 152) = 18.50$, $p < .001$, partial $\eta^2 = 0.11$ (see Figure 3), indicating that initial orienting bias differed as a function on pain expressiveness ($M_{low\ pain} = 0.50$ $SD = 0.10$; $M_{moderate\ pain} = 0.51$, $SD = 0.09$; $M_{high\ pain} = 0.56$, $SD = 0.10$). The main effect of Group was not significant, $F(1, 153) = 3.05$, $p = .083$, partial $\eta^2 = 0.02$, nor was there an interaction between Group and Pain Expressiveness, $F(2, 152) = 0.65$, $p = .562$. Follow up one-sample *t*-

tests indicated that for youth in the chronic pain group and the control group there was a first fixation bias for high pain faces (M_{pain} = 0.56; $M_{control}$ = 0.55) that was significantly greater than chance (0.50), $t(101) = 5.93$, $p < .001$, $d = 0.59$, and $t(52) = 4.21$, $p < .001$, $d = 0.58$, respectively. First fixation biases for low pain faces (M_{pain} = 0.51; $M_{control}$ = 0.47) did not significantly differ from chance for youth in the chronic pain group, $t(101) = 0.71$, $p = .480$, $d = 0.07$, or for youth in the control group, $t(52) = 1.91$, $p = .062$, $d = 0.26$. The same was true for first fixation biases for moderate pain faces (M_{pain} = 0.52; $M_{control}$ = 0.50), $t(101) = 1.79$, $p = .076$, $d = .18$, and $t(52) = 0.34$, $p = .737$, $d = 0.05$, respectively.

Total Fixation Bias

Paired *t*-tests were used to determine if the mean total fixation time for each pain facial expression, for each group, was significantly greater than the mean total fixation time for neutral faces. For youth in the chronic pain group, total fixation time for high pain faces (1220.34 ms), moderate pain faces (1146.36 ms), and low pain faces (1115.36 ms) was significantly longer than total fixation time for the paired neutral faces, $t(101) = 7.19$, $p < .001$, $d = 0.71$, $t(101) = 2.83$, $p = .006$, $d = 0.28$, and $t(101) = 2.09$, $p = .039$, $d = 0.21$, respectively. For youth in the control group, total fixation time for high pain faces (977.62 ms) and moderate pain faces (1054.30 ms) was significantly longer than for paired neutral faces, $t(52) = 3.86$, $p < .001$, $d = 0.53$, $t(52) = 4.34$, $p < .001$, $d = 0.60$, respectively, whereas the bias for low pain faces (1064.79 ms) was not $t(52) = 0.91$, $p = .368$, $d = 0.12$. Thus, for youth in the chronic pain group there was an attentional bias for all of the pain faces, in contrast to youth in the control group who exhibited an attentional bias only for high pain and moderate pain faces. This result suggests that youth in the chronic pain group were more perceptive to pain stimuli than youth in the control group, as they

attended to low pain faces more than neutral faces, which was not the case for youth in the control group.

The total fixation bias data were then analysed using a 2 (Group: Chronic Pain, Control) by 3 (Pain Expressiveness: Low, Moderate, High) mixed-model ANOVA to determine if there were within- and between-group differences in the magnitude of the biases. Figure 4 shows the total fixation bias data for each group for each level of pain expressiveness (low, moderate, and high). There was a significant main effect of Pain Level, $F(2, 152) = 23.06$, $p < .001$, partial $\eta^2 = 0.23$. For the entire sample, total fixation bias for pain faces increased with each level of pain expressiveness (i.e., $M_{\text{low pain}} = 46.63$, $SD = 268.59$; $M_{\text{moderate pain}} = 115.65$, $SD = 310.95$; $M_{\text{high pain}} = 218.10$, $SD = 335.33$). There was no main effect of Group, $F(1, 153) = 0.01$, $p = .909$, partial $\eta^2 < 0.01$. There was a significant interaction between Group and Pain Expressiveness, $F(2, 152) = 3.39$, $p = .036$, partial $\eta^2 = 0.04$. This interaction was followed up using t-tests to examine within-group differences in total fixation bias between pain expressiveness. For the chronic pain group, total fixation bias for high pain faces ($M = 242.72$, $SD = 340.84$) was significantly greater than total fixation bias for low pain faces ($M = 50.58$, $SD = 243.99$), $t(101) = 6.91$, $p < .001$, $d = 0.68$, and moderate pain faces ($M = 92.06$, $SD = 328.90$), $t(101) = 4.78$, $p < .001$, $d = 0.47$. Total fixation bias for low and moderate pain faces did not differ, $t(101) = 1.36$, $p = .177$, $d = 0.13$. For the control group there was a different pattern of biases. Specifically, like the chronic pain group, total fixation bias for high pain faces ($M = 170.72$, $SD = 322.35$) was significantly greater than total fixation bias for low pain faces ($M = 39.04$, $SD = 312.94$), $t(52) = 3.41$, $p = .001$, $d = 0.47$. Unlike the chronic pain group, however, total fixation bias for high and moderate pain faces ($M = 161.06$, $SD = 270.27$) did not differ, $t(52) = 0.22$, $p = .826$, $d = 0.03$, and total fixation bias for moderate and low pain faces were significantly different, $t(52) = 2.88$, $p = .005$, $d = 0.39$. These

results indicate that youth with chronic pain attended to moderate and high pain faces differently, whereas youth without chronic pain did not, and that youth without chronic pain attended to low and moderate pain faces differently, whereas youth with chronic pain did not.

Correlations between Attentional Bias Scores and Attentional Control

Bivariate Pearson's correlations between the attentional bias measures (i.e., the first fixation biases and the three total fixation biases), the ACS total score, and the flanker task conflict score are listed in Table 3 for the chronic pain group and in Table 4 for the control group. For the chronic pain group, there were no statistically significant correlations between the attentional bias measures and the two measures of attentional control (the ACS total score and the flanker task conflict score; all *p*s > .05). Interestingly, there was no correlation between the ACS total scores and the flanker task conflict scores (r = -.03, p = .750).

For the control group, total fixation bias for low pain faces was negatively correlated with total score on the ACS (r = -.30, p = .030). First fixation bias for moderate pain faces was positively correlated with the flanker task conflict score (r = .32, p = .020). There were no other significant correlations between the attentional bias measures and the attentional control measures (all *p*s > .05). As was the case for the chronic pain group, there was no correlation between the ACS total scores and the flanker task conflict scores (r = .06, p = .677).

Attentional Control as a Moderator of Attentional Biases

To test for a moderating effect of attentional control on attentional biases, regression analyses were conducted using the PROCESS macro for SPSS [21]. Bias-corrected and accelerated bootstrapping using 2000 samples was performed for all moderation models to

maximize the robustness of hypothesis testing and to address any potential issues of non-normality. The ACS total score and the flanker task conflict score were used as moderators (in separate analyses), with group membership (i.e., chronic pain or control) predicting total fixation bias to low, moderate, and high pain faces. The results of the moderation analyses are shown in Table 5. The interaction effect of ACS total score by group membership on total fixation bias to low pain faces was statistically significant, b = -10.25, p = .047; however, the overall model was not statistically significant, $F(3, 150) = 2.16$, p = .096, and thus was not interpreted further. For the other analyses, none of the models or interaction effects were statistically significant (all ps > .05). Although we had no reason to hypothesize or expect that first fixation biases would be moderated by attentional control, these moderation analyses were also carried out and none were found to be significant (all ps > .05).

Discussion

This study used eye-gaze tracking to assess attentional bias for pain-related stimuli in a clinical sample of youth with chronic pain and a control sample of youth without chronic pain. In what follows, we review the major findings of our study and their implications for our understanding of attentional biases in youth with chronic pain.

Initial Orienting Bias

For both groups, youth exhibited a first fixation bias for high pain faces. This result is consistent with Heathcote et al. [23], who found a first fixation bias for pain faces in a sample of healthy youth. Taken together, findings to date indicate that an initial orientating bias to pain faces is present in *both* youth with chronic pain and their pain-free peers. Consequently, we view

this orienting bias to pain stimuli as reflecting a common underlying information processing bias, as opposed to a consequence of chronic pain. This interpretation is consistent with the notion of an evolutionary predisposition for pain stimuli to capture attention [16]. However, given the cross-sectional nature of our data, this conclusion is necessarily speculative at this time.

Total Fixation Bias

For both groups, total fixation bias increased with each level of pain expressiveness, with the strongest biases exhibited for high pain faces. This finding is consistent with the results of Heathcote et al. [23]. In the present study, youth with chronic pain exhibited an attentional bias for pain faces at all expression levels. As compared to neutral faces, youth in the control group exhibited an attentional bias for moderate and high pain faces, but not for low pain faces. Youth with chronic pain appear to be more vigilant toward all levels of pain expressiveness as compared to youth without chronic pain, who did not appear to differentiate between low pain and neutral facial expressions.

For total fixation biases, there was an interaction between group and pain expressiveness. For the chronic pain group, total fixation bias for low and moderate pain faces did not differ, whereas the bias for high pain faces was significantly greater than the biases for low and moderate pain faces. Conversely, in the control group, total fixation bias for high and moderate pain faces did not differ, but both were greater than the bias for low pain faces. One explanation for this result is that youth with chronic pain may be habituated to moderate levels of pain imagery, given the regular presence of pain in their lives, resulting in low and moderate pain images being attended to similarly. Although there were group differences in the magnitude of the attentional biases to the different levels of pain imagery, it is important to keep in mind that,

overall, youth with chronic pain group did not attend to pain faces significantly more than youth in the control group. Instead, youth with chronic pain were distinguished from youth without chronic pain by their attentional bias for low pain faces, and by their heightened attention to high pain faces relative to moderate pain faces. Thus, it is not the presence of an attentional bias to pain stimuli that differentiates youth with chronic pain, but rather the degree to which they attend to different levels of pain expressions. Overall, our results are consistent with theoretical models that posit that attentional bias to pain stimuli is characterized by preferential attending to pain-related information, or hypervigilance [1; 2; 25; 45; 54].

The Role of Attentional Control

An unexpected finding was that both self-report and behavioural measures of attentional control were largely unrelated to attentional bias measures. Moreover, attentional control did not moderate attentional biases for any of the pain faces in either group. These results suggest that attentional control, in and of itself, may not play an important role in moderating attentional biases in youth with chronic pain, nor in youth without chronic pain. On the other hand, a limitation of our study is that we focused solely on the association between attentional bias and attentional control without factoring in other potential interacting mechanisms [23; 24]. Previous studies that have found a moderating role of attentional control in youth [23; 24] have typically examined it as a moderator of the link between cognitive-affective variables and attentional bias. It may be that, on its own, attentional control does not play as influential a role in moderating attentional biases to pain when other threat-related factors are not considered. For this reason future research should examine attentional control within the context of goal-directed behaviour and other contextual factors.

Interestingly, youth with chronic pain had lower scores on the ACS than youth in the control group, yet performance on the flanker task did not differ. Moreover, across both groups, there were no statistically significant associations between attentional control and performance on the flanker task. This finding aligns with recent research suggesting that, although widely used to measure attentional control, the ACS may not necessarily correlate with behavioural indicators of attentional control, and, may in fact, more accurately assess *perceived ability*, rather than actual ability [40]. This may, in part, explain why attentional control did not moderate attentional biases in our study. Future research examining the validity of the ACS as a measure of attentional control in behavioral tasks, particularly in pediatric samples, will help clarify whether the ACS can be used as a proxy for behavioral tasks.

Limitations and Directions for Future Research

This study had limitations that highlight important avenues for future research. First, like many studies on pediatric chronic pain, the sample was fairly homogeneous, comprised primarily of middle-class Caucasian youth. While this is representative of samples from tertiary-level pediatric chronic pain clinics [19; 38; 46], it limits the generalizability of the findings and underscores the importance of conducting similar research with more diverse samples. Second, although the inclusion of a control group allowed us to compare attentional biases of youth with chronic pain and pain-free peers, youth in the control group were not age- or sex-matched to the clinical sample. Further, the face stimuli used in the current investigation depicted neutral faces and three levels of pain expressiveness. While this allowed us to assess for possible differences in attentional bias as a function of pain expressiveness, it did not allow for a comparison with other negative facial expressions (e.g., anger, sadness, fear). Future studies should seek to

differentiate attentional biases to pain from those to other negative expressions such as anger, sadness, and fear. It is also important to keep in mind that the faces used in this study were evaluated and validated as indicative of acute pain. Given the unique experience of chronic pain, these stimuli may not necessarily generalize in the same way to a clinical sample.

While eye tracking paradigms overcome certain limitations of the dot-probe task, this methodology is not without its own limitations. As with other attention tasks, eye tracking data is typically collected in laboratory settings [48]. Recently, researchers have begun to question the ecological validity of assessing attention in this way [31; 47; 48]. Indeed, the integrated functional-contextual framework [48] posits that cognitive biases (including attentional biases) are context-dependent, dynamic, and interrelated. If true, assessing attentional biases in a laboratory setting may not accurately capture the bias as it manifests outside the laboratory and in relation to the individual's own pain experience, motivations, context, and goals. This recognition has fueled a call for new paradigms and technology such as ecological momentary assessment (EMA) and augmented reality to increase ecological validity and as a way to account for personally salient, contextual factors, such as motivation and goal-driven behaviour [31; 48]. Another goal for future research is to examine relationships between attentional bias and theoretical antecedents of chronic pain (e.g., anxiety sensitivity, pain catastrophizing) to better elucidate how attentional biases may factor into existing and future models of chronic pain [22]. Ultimately, to better understand the clinical utility of attentional biases to pain, prospective research is necessary to examine how such mechanisms relate to or influence pain-related outcomes and commonly co-occurring mental health symptoms.

Conclusion

Attentional biases are hallmark factors in theoretical models of chronic pain development and maintenance in both adult and pediatric populations [2; 11; 54]. Yet, experimental research to date has yielded mixed findings, with a paucity of research in youth as compared to adult populations. In the present study, youth with and without chronic pain showed an initial orienting bias and a sustained attention bias to pain faces. Group differences emerged when comparing sustained attention to low pain faces. Attentional control, assessed through self-report and a behavioural task, did not moderate attentional biases between or within groups. While research in this area is nascent, these findings underscore the utility of assessing attentional bias using eye tracking, as differences between the groups in their patterns of attending emerged only when attention was measured over the entire 3-second presentation time. With advances in paradigms and conceptualizations of attentional biases as being dynamic and contextually influenced, future research will further elucidate the role and clinical relevance of attentional biases in pediatric chronic pain.

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Supplemental audio content

An audio abstract associated with this article can be found at http://links.lww.com/PAIN/B28.

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Figure Legends

Figure 1.

Fig. 1. Example set of face images graded according to their pain expressiveness (i.e., neutral, low pain, moderate, high pain)

Figure 2

Fig. 2. Example trial for the eye-tracking task, depicting a neutral face paired with a pain face. Each pair of faces was presented for 3000 ms.

Figure 3

Fig. 3. First fixation bias for the chronic pain group and the control group. **Indicates statistically significant first fixation bias for high pain faces, as compared to the low and moderate pain faces ($p < .001$). Error bars depict one standard error.

Figure 4

Fig. 4. Total fixation bias for the chronic pain group and the control group. *Indicates statistically significant difference, $p < .01$; **Indicates statistically significant difference, $p < .001$; Error bars depict one standard error.

Table 1.

Sociodemographic and Pain Characteristics of the Sample (by Group)

Chronic Pain Group (*N* = 102)		Control Group (*N* = 53)	
Mean age in years	14.20 (2.29)	Mean age in years	13.49 (2.71)
Sex (% female)	70.6*	Sex (% female)	50.0*
Ethnicity (%)		Ethnicity (%)	
White (Caucasian)	86.3	White (Caucasian)	79.2
Aboriginal	4.9	Aboriginal	9.4
Black	2.0	Black	3.8
Latin American	2.0	Latin American	3.8
Arab/West Asian	2.0	Chinese	3.8
South Asian	1.0	Other	0.0
Other	4.9	Declined to answer	0.0
Declined to answer	1.0		
Household income (%)		Household income (%)	
<$10,000 to $29,999	5.3	< $10,000 to $29,999	0.0
$30,000 to $59,999	12.8	$30,000 to $59,999	7.0
$60,000 to $89,999	10.6	$60,000 to $89,999	9.3
More than $90,000	63.8	More than $90,000	76.7
Declined to answer	7.4	Declined to answer	7.0
Pain characteristics			
Intensity out of 10	5.60 (1.78)		
Interference T-score	55.27 (9.35)		
Duration in years	3.38 (3.25)		
Pain location (%)			
One location	54.1		
Multiple locations	43.1		
Headache	67.9		
Musculoskeletal	25.7		
Abdominal	18.3		
Leg	13.8		
Chest	11.0		
Other	25.7		

Note. *Indicates statistically significant group difference ($p < .05$) based on independent groups t-tests or Chi-square test. Standard deviations in parentheses.

Table 2.

Descriptive Statistics (mean, SD) of Key Variables

Variable	Overall Sample (N = 155) M (SD)	Chronic Pain Group (N = 102) M (SD)	Control Group (N = 53) M (SD)
First fixation bias (low pain face)	0.50 (0.10)	0.51 (0.10)	0.47 (0.10)
First fixation bias (moderate pain face)	0.51 (0.09)	0.52 (0.09)	0.50 (0.09)
First fixation bias (high pain face)	0.56 (0.10)	0.56 (0.10)	0.55 (0.09)
Total fixation bias (low pain face)	46.63 (268.59)	50.58 (243.99)*	39.04 (312.94)*
Total fixation bias (moderate pain face)	115.65 (310.95)	92.06 (328.90)	161.06 (270.26)
Total fixation bias (high pain face)	218.10 (335.33)	242.72 (340.84)	170.72 (322.35)
ACS total score	51.06 (9.01)	49.45 (8.61)*	54.15 (9.03)*
Flanker task (congruent trials)	490.16 (107.33)	489.58 (103.15)	491.21 (115.44)
Flanker task (incongruent trials)	525.65 (112.94)	524.26 (107.02)	528.16 (123.88)

Note. ACS = Attentional Control Scale; M = mean; SD = standard deviation. *Indicates statistically significant difference between the chronic pain group and the control group (p <.05).

Table 3.

Correlations between Attentional Bias and Attentional Control Variables (Chronic Pain Group)

	Variable	1	2	3	4	5	6	7	8
1.	First fixation bias (low pain)	–							
2.	First fixation bias (moderate pain)	-.03	–						
3.	First fixation bias (high pain)	.12	.20*	–					
4.	Total fixation bias (low pain)	-.09	.11	.07	–				
5.	Total fixation bias (moderate pain)	.05	.22*	.05	.44**	–			
6.	Total fixation bias (high pain)	-.18	.14	.14	.61**	.56**	–		
7.	ACS total score	-.16	-.04	-.12	-.00	-.01	-.04	–	
8.	Flanker conflict score	.06	-.09	.05	-.03	.14	-.01	-.03	–

Note. $^{*}p < .05$, $^{**}p < .01$, two-tailed test. ACS = Attention Control Scale.

Table 4.

Correlations between Attentional Bias and Attentional Control Variables (Control Group)

	Variable	1	2	3	4	5	6	7	8
1.	First fixation bias (low pain face)	–							
2.	First fixation bias (moderate pain face)	.17	–						
3.	First fixation bias (high pain face)	.31*	.20	–					
4.	Total fixation bias (low pain)	.33*	-.00	.44**	–				
5.	Total fixation bias (moderate pain)	.10	.29*	.25	.47**	–			
6.	Total fixation bias (high pain)	.04	.18	.36**	.57**	.40**	–		
7.	ACS total score	-.09	.12	-.20	-.30*	-.11	-.19	–	
8.	Flanker conflict score	-.02	.32*	.07	-.14	.16	-.02	.06	-

Note. $^{*}p < .05$, $^{**}p < .01$, two-tailed test. ACS = Attention Control Scale.

Table 5.

Moderation Analyses with Attentional Control Variables

Outcome: Total fixation bias (Low Pain faces) *F(3, 150) = 2.16, p = .096, R^2 = .04*	*b (95% CI)*	*SE*	*t*	*p*
Constant	58.58 (14.86, 102.30)	22.13	2.65	*p* = .009
ACS total score	-3.60 (-8.47, 1.28)	2.47	1.46	*p* = .147
Group	18.77 (-74.36, 111.91)	47.14	0.40	*p* = .691
ACS total score x Group	-10.25 (-20.38, -0.13)	5.12	2.00	*p* = .047
Outcome: Total fixation bias (Moderate Pain faces) *F(3, 150) = 0.729, p = .536, R^2 = .014*	*b (95% CI)*	*SE*	*t*	*p*
Constant	118.74 (67.36, 170.12)	26.00	4.57	*p* < .001
ACS total score	-1.32 (-7.05, 4.41)	2.90	0.45	*p* = .650
Group	80.02 (-29.44, 189.49)	55.40	1.45	*p* = .151
ACS total score x Group	-3.01 (-14.91, 8.89)	6.02	0.50	*p* = .618
Outcome: Total fixation bias (High Pain faces) *F(3, 150) = 1.13, p* = .338, R^2 = .02	*b (95% CI)*	*SE*	*t*	*p*
Constant	221.93 (166.85, 277.01)	27.88	7.96	*p* < .001
ACS total score	-3.35 (-9.50, 2.79)	3.11	1.08	*p* = .238
Group	-46.14 (-163.48, 71.19)	59.38	0.78	*p* = .438
ACS total score x Group	-5.24 (-17.99, 7.52)	6.46	0.81	*p* = .418
Outcome: Total fixation bias (Low Pain faces) *F(3, 144) = 0.02, p = .997,* R^2 < .001	*b (95% CI)*	*SE*	*t*	*p*
Constant	42.61 (-2.13, 87.36)	22.64	1.88	*p* = .062
Flanker Conflict	-0.01 (-1.91, 1.90)	0.96	0.01	*p* = .994
Group	-6.06 (-99.41, 87.29)	47.23	0.13	*p* = .898
Flanker Conflict x Group	0.35 (-3.46, 4.15)	1.93	0.18	*p* = .858
Outcome: Total fixation bias (Moderate Pain faces)	*b (95% CI)*	*SE*	*t*	*p*

F(3, 144) = 1.72, p = .166, R^2 = .03				
Constant	107.72 (57.80, 157.64)	25.26	4.27	$p < .001$
Flanker Conflict	1.73 (-0.40, 3.86)	1.08	1.61	$p = .110$
Group	79.01 (-25.14, 183.17)	52.69	1.50	$p = .136$
Flanker Conflict x Group	0.11 (-34.14, 4.36)	2.15	0.05	$p = .960$
Outcome: Total fixation bias (High Pain faces) *F(3, 144) = 0.64, p = .591,* R^2 = .01	*b (95% CI)*	*SE*	*t*	*p*
Constant	216.67 (160.75, 272.58)	28.29	7.66	$p < .001$
Flanker Conflict	0.80 (-1.59, 3.18)	1.21	0.66	$p = .659$
Group	-72.45 (-189.10, 44.19)	59.01	1.23	$p = .222$
Flanker Conflict x Group	-0.64 (-5.40, 4.11)	2.41	0.27	$p = .790$

Note: *b* = regression coefficient (unstandardized). 95% confidence intervals (CI) in parentheses.

Neutral Pain Expression | Low Pain Expression | Moderate Pain Expression | High Pain Expression