Attentional processing of other's facial display of pain: An eye tracking study

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ABSTRACT

The present study investigated the role of observer pain catastrophizing and personal pain experience as possible moderators of attention to varying levels of facial pain expression in others. Eye movements were recorded as a direct and continuous index of attention allocation in a sample of 35 undergraduate students while viewing slides presenting picture pairs consisting of a neutral face combined with either a low, moderate or high expressive pain face. Initial orienting of attention was measured as latency and duration of first fixation to one of two target images (i.e. neutral face versus pain face). Attentional maintenance was measured by gaze duration. With respect to *initial orienting to pain*, findings indicated that participants reporting low catastrophizing directed their attention more quickly to pain faces than to neutral faces, with fixation becoming increasingly faster with increasing levels of facial pain expression. In comparison, participants reporting high levels of catastrophizing showed decreased tendency to initially orient to pain faces, fixating equally quickly on neutral and pain faces. Duration of the first fixation revealed no significant effects. With respect to *attentional maintenance*, participants reporting high catastrophizing and pain intensity demonstrated significantly longer gaze duration for all face types (neutral and pain expression), relative to low catastrophizing counterparts. Finally, independent of catastrophizing, higher reported pain intensity contributed to decreased attentional maintenance to pain faces versus neutral faces. Theoretical implications and further research directions are discussed.

Keywords: pain catastrophizing, selective attention, facial pain expression, eye movement

1. INTRODUCTION

The intrinsic threat value of pain serves adaptive functions by drawing upon attentional resources and motivating action to escape, reduce, or avoid tissue damage [11,58]. The function of pain to demand attention and interrupt ongoing activity is well-documented in clinical and nonclinical populations [12;43;56;57]. Pain may likewise serve protective functions in the interpersonal context by impelling expressive pain behaviours that attract the attention of others, thereby initiating concern and care [9;18;21;34;64]. Despite the importance of attention for observer responses, few studies have investigated observers' attentional processing of others' pain [24;36;60;61].

In-line with the intrapersonal pain literature, studies of interpersonal attention to pain highlight the role of both bottom-up (e.g., pain expressiveness of the person in pain) and top-down variables (e.g., observer pain catastrophizing and pain experience) known to amplify the threat value of pain. Studies using the dot-probe paradigm show that high fear chronic pain patients [24;36] and their caregivers [36] selectively shift attention toward pain faces. Using dot-probe and visual search paradigms, Vervoort et al. [60;61] similarly found higher attentional allocation among parents with a strong tendency to catastrophize about pain toward higher child pain expression.

Existing studies of attentional bias towards personal and others' pain have significant limitations. First, existing paradigms examine attentional processing indirectly via registration of manual reaction times. Second, current methodology does not permit assessment of continuous attentional processing and thus does not allow distinction between initial attentional allocation and subsequent maintenance of attention to stimuli. This distinction is theoretically and clinically important as current intrapersonal literature supports that, particularly among individuals who catastrophize about pain [56;57] or report intense pain [12;31], attentional disruption by pain originates mainly from difficulties in attentional

disengagement rather than initial attentional allocation [31;44;56]. This literature thus points to the importance of attentional maintenance versus initial orienting to pain. In the context of *inter*personal pain experience, evidence of similar disengagement difficulty (reflecting attentional maintenance processes) would suggest excessive cognitive processing of threat as well as potential problems in attention and emotion regulation.

Eye-tracking technology provides an intuitive and ecologically-valid method to directly examine attentional processes over time, thus addressing the above issues [16;62;66]. The current study employed eye-tracking methodology to assess the impact of both observer characteristics and characteristics of the person observed upon attention to pain in others. Specifically, we examined the role of observers' pain catastrophizing and personal pain experience as possible moderators of attention to varying levels of facial pain expression. Initial orienting of attention was measured as latency to first fixation to one of two target images (i.e., neutral face versus pain face) and the duration of this first fixation. Subsequent attentional processing (i.e., attentional maintenance) was measured by gaze duration. We expected that higher levels of pain catastrophizing and personal pain experience would be associated with greater attention to pain faces, particularly in the case of greater facial pain expressiveness. Additionally, we explored whether observers' attentional processing of others' pain was characterized by initial orienting to pain and/or maintained attention.

2. METHOD

2.1 Participants

A total of 55 undergraduate psychology students from Ghent University participated for course credits or received financial compensation. Descriptive statistics of socio-demographic and pain-related variables of the participant sample are shown in Table 1. All participants provided informed consent and were free to terminate the experiment at any time. The study

was approved by the ethics committee of the Faculty of Psychology and Educational Sciences of Ghent University.

- INSERT TABLE 1 ABOUT HERE -

2.2 Materials

The stimulus set consisted of 32 pictures of 8 adult faces (4 male and 4 female). All pictures were drawn from one-second video clips of simulated facial expressions of pain taken from a larger collection of such stimuli previously created and validated in the laboratory by Simon et al. [47] who provided permission for using these stimuli. For these stimuli eight actors were videotaped while producing neutral facial displays (NFE) and simulated facial expressions of pain at three different levels – low (LFE), moderate (MFE) and high (HFE) facial expression of pain. Using these 32 pictures, a series of three different pairs were generated, resulting in 24 study slides (See Figure 1). Each slide consisted of two pictures of the same adult presenting a neutral face (NFE) combined with either (1) a simulated low expressive pain face (LFE); (2) a moderate expressive pain face (MFE); or (3) a high expressive pain face (HFE). Pairs were compiled twice such that the neutral expression appeared equally often on the left and right side. Using the Facial Action Coding System [14], these video clips were previously reliably coded on occurrence and intensity of facial expression of pain [47].

- INSERT FIGURE 1 ABOUT HERE -

To further determine the validity of the pain expression categories (i.e., NFE, LFE, MFE, and HFE) twenty independent judges (10 male, 10 female; age range 22-66 years; $M = 35.8$ years, $SD = 13.53$) rated the 32 pictures on pain intensity using a 0-10 numerical rating scale (NRS). Analysis of Variance (ANOVA) indicated significant differences in picture ratings between different sets ($F(3,17) = 254.29$, p < .0001). Specifically, contrast analyses revealed that judges' pain ratings of high expressive pain faces ($M = 7.59$, $SD = 1.30$) were

significantly higher than ratings of moderate expressive pain faces (M = 5.83, SD = 1.69; $F(1,19)$ = 747.32, p < .0001). Moderate expressive pain faces were rated significantly higher in pain intensity than low expressive pain faces (M = 3.98, SD = 1.70; $F(1, 19)$ = 256.85, p < .0001) and low expressive pain faces were rated significantly higher in pain intensity than neutral faces (M =.75, SD = .76; $F(1, 19)$ = 97.92, p < .0001).

2.3 Eye movement measurement

Participants' eye movements were tracked with a 60 Hz Tobii (T60) table-mounted eye tracker (Tobii Technology AB − www.tobii.com, Falls Church, VA, USA). This system consists of a 17 inch computer screen with a camera and infrared LED optics embedded beneath it and records eye movements based on the corneal reflection caused by the infrared light source. Participants were seated comfortably 60cm away from the center of the screen using a chinrest to minimize head movements. Participants were shown an overview of one trial (on paper) in order to ensure familiarity with the experimental set up. Participants were instructed to first focus on a centrally-presented white fixation cross when it appeared on screen and then to simply view the faces that would subsequently appear on the screen. This information was again presented on the screen after calibration and prior to commencement of the free viewing task. As part of calibration, participants were asked to focus on 9 sequentially appearing red dots presented in random placement on the screen.

The viewing task commenced after valid calibration. Each trial within the viewing task began with a 500ms presentation of the white fixation cross. Then, a slide with the pair of facial stimuli against a black background was presented for 3000 ms and participants were free to visually explore the slide. A 3000ms presentation period allows investigation of both initial orienting to pain and/or maintained attention [37;43]. Following an inter trial interval of 200 ms (black screen), the next trial again began with the presentation of the fixation cross. In total, the experiment consisted of 48 trials: each of the 24 slides was presented twice, once

with the pain face on the left and once on the right side of the screen. Pictures were 16 cm high and 10 cm wide. Pictures were separated by 4.4 cm from their central points. Slides were presented to participants in two different (randomised) orders (i.e. order 1 and 2).

2.3 Measures

2.3.1 Picture pain ratings

Immediately after the viewing task, participants were seated in front of a computer screen and asked to rate each picture on pain intensity using a 0-10 Numerical Rating Scale (NRS). Pictures were presented using Microsoft Office PowerPoint in randomized but fixed order across participants. Participants were instructed to make written ratings of pain intensity and were encouraged to proceed as fast as possible. Picture ratings were averaged for each facial pain display category (NFE, LFE, MFE, HFE) resulting in 4 mean pain intensity ratings ranging from 0-10. This allowed us to again check whether participants' pain intensity ratings corresponded to the facial pain display category.

2.3.2 Pain intensity and pain catastrophizing

Finally, participants also reported on their pain intensity and catastrophic thoughts about pain. Pain intensity was assessed by means of two 0-10 NRS. Participants were asked to indicate the average level of pain that they had experienced during the past 3 months, and their current level of pain intensity using the endpoints labeled 'no pain' and 'worst possible pain'. Catastrophic thinking about pain was assessed with the Dutch version of the *Pain Catastrophizing Scale* (PCS [48;55]). This scale contains 13 items describing thoughts and feelings that participants may experience during painful experiences (e.g., 'I become afraid that the pain may get worse'). Participants indicate on a five-point scale, ranging from 0 (not at all) to 4 (always), how frequently they experience each thought or feeling when in pain. The Dutch version of the PCS has good reliability and validity in both clinical and non-clinical samples [55]. In our sample, Cronbach's α was .89.

2.4 Procedure

Upon arrival, participants first completed the informed consent form. They were informed that we were interested in eye movements in response to visual information. They were also told that various pictures would be shown on the screen while their eye movements would be tracked and that, after completion of the viewing task, they would be asked to fill out some questionnaires. No additional task instructions were provided in order to ensure a free viewing context. Participants were then comfortably seated in a chair in front of the monitor. After the calibration procedure, participants were shown an overview of one trial and were instructed to follow the instructions presented on the screen. The experimenter was seated behind an opaque screen during the entire experimental task. After completion of the viewing task, participants were asked to provide the picture pain ratings and to complete the measures of pain catastrophizing and personally experienced pain intensity.

2.5 Data analysis and eye movement parameters

Gaze behaviour was analyzed off-line using the Tobii software analysis package with the Clearview Fixation Filter [42]. The Clearview fixation filter defines the maximum pixel-distance between two points for them to be considered belonging to the same fixation and the minimum time for which gaze needs to be within the radius to be considered a fixation. Within the present study, the two target pictures were defined as areas of interest (AOIs) within which eye movements would be monitored. Gaze that remained stable within a 35 pixel radius and that lasted at least 100 ms on a defined AOI was classified as fixation to that position [see e.g., 63; 66]. Using these criteria to define fixation, three parameters were calculated for each picture. Indices of initial or early attention allocation included (1) time to first fixation and (2) first fixation duration. Attentional maintenance was indexed by (3) gaze duration. None of the eye tracking measures showed any differences between slide order presentation 1 and 2 (all $t(33) \leq |1.92|$, ns).

Time to First Fixation was defined as the time it took (in ms) following the onset of a picture pair to first fixate on a specific AOI (i.e., neutral face or painful face). The mean time that it took before the first fixation was made was calculated for each type/level of facial expression (NFE, LFE, MFE, HFE). Time to first fixation gauged early or initial allocation/orienting of attention. Initial attention bias to pain faces was inferred when, following the onset of a picture pair, the first fixation made on the pain face (e.g., 500 ms after picture pair onset) occurred significantly earlier in comparison to the first fixation made on the neutral face (e.g, 630 ms after picture pair onset).

First Fixation Duration was defined as the duration (in ms) of the first fixation that a participant made for each type/level of facial expression (NFE, LFE, MFE, HFE). First fixation duration also indexed initial attentional processing -- the time a participant's gaze remained fixated upon a particular AOI during the first fixation that was made on that AOI.

Gaze Duration was defined as the total duration of time that a participant's gaze remained fixated within the boundaries of a particular facial expression category (NFE, LFE, MFE, HFE), taking into account the amount of attentional shifts. The mean gaze duration for each facial expression category was calculated by dividing the mean total fixation time for each facial expression category by mean fixation frequency for each facial expression category. Total fixation time was the total duration (in ms) a participant fixated on a particular facial expression. The total mean fixation time for each facial expression was generated by averaging total fixation duration for each facial pain expression category. Fixation frequency was the participants' absolute number of visual fixations on a particular facial expression. The mean fixation frequency for each facial expression was generated by averaging the number of visual fixations for each face type over the respective study slides. Gaze duration thus indicated *maintenance of attention* [13;37].

Repeated measures ANCOVA with facial expressiveness (NFE, LFE, MFE, HFE) as a within subject factor and pain catastrophizing/pain intensity entered as covariates were conducted for each dependent variable (i.e., time to first fixation, first fixation duration, gaze duration). Gaze behaviour to neutral faces was collapsed across the three different pairings. This approach was preferred since the same neutral face of a particular actor was paired with either the corresponding low, moderate, or high pain expression of the same actor. Furthermore, analyses indicated that gaze pattern for neutral faces (i.e. Time to First Fixation, First Fixation Duration and Gaze duration) did not differ across the different pairings (all $F(2,32) \leq 2.77$, ns). Continuous predictor variables (pain catastrophizing / pain intensity) were centered prior to entering the analyses. Centering reduces the multicollinearity between predictors and any interaction terms among them and facilitates post-hoc probing of significant interaction effects [23].

In case of significant interactions between facial expressiveness and catastrophizing and/or pain intensity, bias indices were calculated to further aid interpretation of direction of effects. Separate bias scores were calculated for each level of facial pain expressiveness (HFE, MFE, LFE) for each dependent variable. Positive values on the *initial gaze direction bias* (i.e., mean time to first fixation on pain faces subtracted from mean time to first fixation on neutral faces) indicated that attention was first directed to pain faces, whereas negative values indicated the reverse: attention was first directed to neutral faces suggesting initial avoidance of pain faces. Accordingly, the initial gaze direction bias indicates both which face is first looked at and whether one is significantly faster in first looking at one face type compared to another Positive values on the first fixation duration bias (i.e., first fixation duration on neutral faces subtracted from first fixation duration on pain faces) indicated that the first fixation to pain faces was longer than the first fixation to neutral faces. Positive values on the *gaze maintenance bias* (i.e.*,* gaze duration on neutral faces subtracted from gaze

duration on pain faces) indicated that attention maintenance to pain faces was higher than maintained attention to neutral faces, whereas a negative score indicated the reverse: higher maintained attention to neutral faces. ANCOVA was performed on these bias indices.

In case of significant interaction, additional moderation analyses were performed to interpret the interaction effect (i.e., whether the association between the predictor variable and the outcome was significant only for high levels of the moderator variable, low levels of the moderator variable, or both). All moderation analyses followed the procedure outlined by Holmbeck et al. [23]. This procedure does not categorize participants into two groups but allows, by manipulating the 0 point of the moderator, to examine conditional effects of the continuous moderator variable upon the outcome. To this end, two steps were performed. First, two new conditional continuous moderator variables were computed by (1) subtracting 1 SD from the centered moderator variable (i.e., high pain catastrophizing / pain intensity) and (2) adding 1 SD to the centered moderator variable (i.e., low pain catastrophizing / pain intensity). Next, two additional ANCOVAs were performed - incorporating each of these new conditional continuous moderator variables- to test the significance for high (+1 $\underline{SD}$ above the mean) and low (-1 $\underline{SD}$ below the mean) values of the conditional centered moderator variable (i.e., pain catastrophizing or pain intensity). Whenever the sphericity assumption was violated (Mauchly's test of sphericity was $p < .05$), Greenhouse-Geisser corrections (with adjusted degrees of freedom, or NDf) were performed.

3. RESULTS

3.1 Participant characteristics

Eight participants were discarded from analyses due to sub-optimal overall gaze track status (i.e., eye movements tracked less than 75% of total task viewing time). Further, for Gaze Duration, trials were considered invalid and hence coded as missing values, when eye movements were tracked less than 75% of the 3000ms trial. For Time to First Fixation and

First Fixation Duration, trials were coded as missing values when eye movements were tracked less than 75% during the first second of the 3000ms trial. Invalid composite scores (i.e., more than 75% of trials of a given category – i.e., NFE, LFE, MFE, HFE missing) were coded as missing values. Missing value analysis indicated that 12 participants had invalid data for at least one of the eye movement parameters. The final sample (for whom complete data were available) consisted of 35 participants (30 female).

Participants from the final sample reported levels of pain catastrophizing ($M = 20.97$, $SD = 7.73$; range 4-36) comparable to those obtained in other student samples [2]. More than two thirds of the final sample ($n = 23$) reported to have experienced pain during the past three months. The mean number of days having had pain during the past three months for participants in the final sample was 12.6 (SD = 9.8) though mean pain intensity during the past 3 months ($M = 2.43$, $SD = 2.49$; range 0-8) and current pain intensity ($M = 1.80$, $SD = 2.21$; range 0-7) were low. There were no differences on self-reported pain catastrophizing and pain intensity ratings between those who were discarded from the final analyses and those who were not (both $t(53) \leq |1.58|$, ns). Pearson correlation analyses indicated that pain catastrophizing was not significantly correlated with reported mean/current pain intensity ($r = -.04/-.32$, ns). Mean pain intensity during the past three months was highly correlated with current pain intensity level ($r = .71$, p $< .0001$)[1]. Furthermore, student age was not significantly correlated with pain catastrophizing ($r = -.06$, ns), or mean/current pain intensity ($r = .17/.20$, ns). Participant sex did not impact levels of catastrophizing ($t(33) = -1.06$, ns) or mean/current pain intensity ($t(33) = -1.41/-.65$, ns).

3.2 Picture ratings

To test whether participants rated the presented facial expressions in correspondence with the original selection of the pictures, mean ratings of pain intensity were examined using

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[1] Since all other pain-related characteristics concerned the past 3 months, mean pain intensity during the past 3 months was entered as covariate in the repeated measures analyses reported below. Analyses with the mean of both pain intensity ratings (i.e., current and 3 months), however, revealed similar findings.

repeated measures ANOVA. Results indicated significant differences between picture ratings of pain intensity for the three pain expression levels ($F(3,32) = 574.45$; $\epsilon = .74$; NDf(2.22, 21.9), $p < .0001$). Differences between ratings were in the expected direction. Specifically, contrasts revealed that high expressive pain faces were rated significantly higher ($M = 7.43$; $SD = .97$) than moderate expressive pain faces ($M = 5.55$, $SD = 1.30$; $F(1,34) = 631.76$, $p < .0001$). Moderate expressive pain faces, in turn, were rated significantly higher than low expressive pain faces ($M = 3.81$, $SD = 1.22$; $F(1,34) = 608.96$, $p < .0001$) and low expressive pain faces were also rated significantly higher than neutral faces ($M = .89$, $SD = .95$; $F(1,34) =426.06$, $p < .0001$). Adding pain catastrophizing and pain intensity as covariates to the repeated measures ANOVA revealed no significant main effects or interactions (all $F \leq |1.52|$, ns) indicating that ratings of faces' pain intensity were not affected by observer's own pain catastrophizing and experienced personal pain intensity.

3.3 Eye movement data

3.3.1 Time to First Fixation

Examination of *Time to First Fixation* showed a significant main effect of facial expressiveness ($F(3,29) = 3.94$, $p < .05$), indicating participants oriented attention more quickly to pain faces (overall $M = 570$ ms) than to neutral faces ($M = 633$ ms). However, there was also a significant interaction between facial expressiveness and pain catastrophizing ($F(3,29) = 3.23$, $p < .05$). There were no other significant main or interaction effects (all $F(3.29) \leq 1.94$, ns). To interpret the significant two-way interaction, two repeated measures ANCOVAs were performed with facial expressiveness as within subject factor (NFE, LFE, MFE, HFE) and high (+1SD above the mean) or low values (-1SD below the mean) of pain catastrophizing as covariate (i.e., conditional moderator variable). These analyses indicated that the effect of varying levels of facial expressiveness upon Time to First Fixation was significant for participants who reported *low* levels of catastrophizing thoughts about pain

($F(3,30) = 6.08$, $p < .001$). Contrasts indicated that participants who reported low levels of catastrophizing thoughts about pain initially oriented their attention to pain faces rather than to neutral faces. That is, low catastrophizing participants' initial fixation on the pain face was faster (i.e., occurred earlier in time) compared to the initial fixation they made on the neutral face. Furthermore, for participants who reported low levels of catastrophizing, Time to First Fixation significantly decreased with higher levels of facial pain expression (See Figure 2). Specifically, mean fixation time to HFE (523 ms) was significantly shorter than mean fixation time to MFE (536 ms; $F(1,32) = 6.23$, $p < .05$). In addition, mean fixation time to MFE was significantly shorter than mean fixation time to LFE (572 ms; $F(1,32) = 6.29$, $p < .05$), which was, in turn, significantly shorter than mean fixation time to NFE (670 ms; $F(1,32) = 6.06$, $p < .05$). For participants who reported high catastrophizing thoughts about pain, no such pattern was observed ($F(1,32) = 1.38$, ns).

Additional repeated measures ANCOVAs with the *gaze direction bias indices* for LFE, MFE and HFE as dependent variables and pain catastrophizing and personal pain intensity as covariates were conducted to further interpret differences between those who reported high levels of pain catastrophizing and those who reported low levels of catastrophizing. Findings revealed a main effect of pain catastrophizing ($F(2,30) = 5.16$, $p < .05$), indicating slower initial orienting to pain with increasing levels of pain catastrophizing. No other significant main or interaction effects were observed (all $F(2,30) \leq 2.35$, ns).

-INSERT FIGURE 2 ABOUT HERE -

3.3.2 First Fixation Duration

Examination of *First Fixation Duration* revealed no main effect of facial expressiveness ($F(3,29) = 1.54$, ns), self-reported pain intensity (($F(1,31) = .05$, ns) or pain catastrophizing ($F(1,31) = 1.69$, ns) There were also no significant two or three-way interactions (all ($F < 2.67$, ns).

3.3.3 Gaze Duration

Examination of the average Gaze Duration data revealed a significant interaction between reported mean pain intensity and facial expressiveness ($F(3,29) = 4.22$; $\epsilon = .73$; NDf(2.19, 21.17); $p < .05$). We also found a significant interaction between pain catastrophizing and self-reported pain intensity ($F(3,29) = 6.62, p < .05$). No other significant main or interaction effects were found (all $F(3,29) \leq 1.26$, ns). Below, we first report on the interaction between pain catastrophizing and self-reported pain intensity and then report on the interaction between self-reported pain intensity and pain expression.

To interpret the significant two-way interaction between pain catastrophizing and self-reported pain intensity, two univariate ANOVAs were performed with pain catastrophizing as predictor variable and high (+1SD above the mean) or low values (-1SD below the mean) of self-reported pain intensity as covariate. Mean gaze duration (averaged across NFE, LFE, MFE and HFE) was entered as dependent variable. Findings indicated that the impact of pain catastrophizing upon mean gaze duration was significant at high levels of self-reported pain ($F(1,31) = 5.90, p < .05$); for individuals with higher pain experience, higher levels of pain catastrophizing were associated with increased overall gaze duration to all faces (i.e., both neutral and all levels of pain expressiveness; See Figure 3). The impact of pain catastrophizing upon mean gaze duration was not significant at low levels of self-reported pain ($F(1,31) = 2.34$, ns).

- INSERT FIGURE 3 ABOUT HERE –

To interpret the significant interaction between self-reported pain intensity and facial expressiveness, two repeated measures ANOVAs were performed with facial expressiveness as a within subject factor (NFE, LFE, MFE, HFE) and high (+1SD above the mean) or low values (-1SD below the mean) of pain intensity as covariate. Findings indicated that the effect of varying levels of facial expressiveness upon gaze duration was significant for those

participants who reported high levels of pain ($F(3,30) = 3.43$; $\epsilon = .74$; NDf(2.22, 21.9), $p < .05$), but not for participants reporting low levels of pain ($F(3,30) = 2.07$; $\epsilon = .74$; NDf(2.22, 21.9), ns). Contrasts indicated that participants reporting high levels of pain had *lower* gaze duration for pain faces as compared to neutral faces (see Figure 4). Specifically, for participants reporting higher pain intensity, Gaze Duration for LFE ($M = .32$; $SD = .14$) was significantly lower than Gaze Duration for NFE ($M = .36$; $SD = .11$) $F(1,32) = 9.67$, $p < .005$). Gaze Duration for MFE ($M = .33$; $SD = .11$) and HFE ($M = .33$; $SD = .10$) were also lower than Gaze duration for NFE, yet differences only approached significance (both $F(1,32) \geq 3.35$, $p = .08$). Gaze duration for MFE and HFE did not significantly differ from each other and from Gaze Duration for LFE (all $F(1,32) < .82$, ns).

Additional repeated measures ANCOVA with the *gaze maintenance bias indices* for LFE, MFE and HFE as dependent variables and pain intensity as covariate revealed a main effect of pain intensity ($F(2,30) = 6.71$, $p < .05$), indicating decreasing maintenance of attention for all levels of facial pain expression with increasing levels of self-reported pain intensity. No other significant main or interaction effects were observed (all $F(2,30) \leq 1.69$, ns).

In sum, analyses on Gaze Duration revealed decreased attention maintenance to pain faces compared to neutral faces in case of high pain, independent of whether participants' score on the measure of catastrophizing was high or low. Catastrophizing and pain intensity impacted findings such that gaze duration to all facial expression categories (NFE, LFE, MFE, HFE) was enhanced for participants who reported high catastrophizing thoughts and high pain.

-INSERT FIGURE 4 ABOUT HERE –

4. DISCUSSION

The present study investigated the role of observers' pain catastrophizing and pain experience as moderators of attention to varying levels of facial pain expression in others. We hypothesized that higher levels of catastrophizing and personal pain would be associated with greater attention to pain faces, particularly in the case of greater facial pain expression. Additionally, we explored whether observers' attention to others' pain was characterized by initial orienting to pain and/or maintained attention. Participants' attention was assessed by monitoring participants' eye movements during a naturalistic viewing task. Initial orienting of attention was assessed by measuring the latency and duration of first fixation to one of two target pictures (neutral face versus low, moderate, or high pain face). Attentional maintenance was measured by gaze duration. Although caution is needed when interpreting the present findings due to the small sample size and use of simulated rather than genuine facial displays of pain, results indicated that attentional processing of another's pain is sensitive to bottom-up factors (observed pain expression severity), top-down factors (observers' catastrophizing and pain intensity), and their interaction. Findings were, however, not entirely as expected. In particular, with respect to *initial orienting to pain*, participants reporting low catastrophizing directed their attention more quickly (i.e., first) to pain faces than to neutral faces (Time to First Fixation) with initial fixation on pain faces becoming increasingly faster with increasing levels of pain expression. In comparison, participants reporting high catastrophizing showed decreased tendency to initially orient to pain faces, fixating equally quickly on neutral and pain faces. Duration of the first fixation revealed no significant effects. With respect to *attentional maintenance*, participants reporting high catastrophizing and pain intensity demonstrated significantly longer gaze duration for all face types (neutral and pain expression), relative to low catastrophizing counterparts. Finally, independent of catastrophizing, higher reported pain intensity contributed to decreased attentional maintenance to pain faces versus neutral faces.

In terms of initial attentional allocation, preferential orientation to pain faces among participants reporting low catastrophizing thoughts corroborates findings that attention is preferentially allocated to stimuli appraised as threatening or dangerous [1;11;25;60]. Unexpectedly, this preferential orienting was *not* apparent for those reporting high catastrophizing thoughts. Rather, in comparison to low catastrophizing participants, individuals who reported higher catastrophizing showed a *decreased* tendency to initially orient to pain. A number of explanations may account for this surprising observation. As discussed extensively within the emotion literature [41;67], initial orientation differences may reflect differential *preattentive* and *covert attentive* processing of stimuli accompanied by differential emotional/behavioural sequelae. Preattentive processing refers to the unconscious accumulation of environmental information and is known to facilitate both stimuli detection (e.g., threat) and emotional reaction (i.e., fear) when stimuli are relevant to one's existing cognitive-affective schema [41]. Among participants reporting high catastrophizing, schemata containing excessively threatening information regarding pain may facilitate preattentive or preconscious processing of pain-relevant face stimuli, thus activating negative emotional response and avoidant tendencies. Indeed, studies demonstrate that, particularly among those reporting high catastrophizing, observing someone else in pain may automatically activate a threat detection system that elicits an aversive state of personal distress and associated avoidance rather than empathic concern and approach motivation [2;3;4;20;65].

Preattentive mechanisms may be complemented by covert attentional processing, referring to conscious shifts in attentional focus prior to overt eye movement [62]. Mean latency of initial fixation to face stimuli was significantly longer (between 541 and 634 ms) than typically observed for reflexive saccades (between 150 and 175 ms [40]), suggesting participants took time to determine gaze direction and implying some control prior to initial fixation. For observers reporting high catastrophizing, preattentive and covert processing may

function as early filtering mechanisms that block potentially threatening information from capturing selective attention [5;46] thus aiming to counter negative emotion elicited by viewing someone in pain [2;3;4;20]. Paradoxically, this may preclude adjustment of observers' initial threat/pain appraisals, thereby maintaining a fearful state and exacerbating pain problems. This is consistent with evidence that attentional avoidance of negative stimuli such as pain contributes to worse outcomes for the person in pain [27;28]. Among those reporting low catastrophizing, absence of such initial filtering may allow early attentional capture by pain and thus further elaboration of someone else's pain [41].

To the extent that avoidant tendencies may, among those reporting high catastrophizing, delay initial orientation to pain images, absolute attentional avoidance was not achieved. Specifically, whereas individuals reporting high catastrophizing showed a decreased tendency to initially orient to pain faces, they fixated equally quickly on pain and non-pain faces. Additionally, at later stages of attentional processing, individuals who reported high catastrophizing and greater personal pain showed an increased tendency to maintain attention to all face stimuli. Although this latter pattern may reflect disengagement difficulty [31;44;56;57], it is unclear why catastrophizers' pattern of attentional allocation (at both orientation and maintenance) was not specific to pain stimuli.

An alternative explanation is that, despite different pain intensity ratings of pain vs. neutral faces, attentional patterns among participants reporting high catastrophizing may reflect an *implicit* bias of interpreting neutral stimuli as threatening (i.e., a threat-related interpretive bias occurring outside conscious awareness) [10;51]. Presented together with pain expressions, neutral faces might be interpreted as containing pain information and be prone to elaboration by individuals inclined to negative interpretation of innocuous stimuli and preferential processing of threat [6;32;49]. This account is consistent with overgeneralization of threat/pain with respect to pain-producing stimuli [19] and greater associative threat

learning among individuals with greater pain-related fear [19;54]. Thus, though not accessible through self-report, it is possible that participants with a tendency to catastrophize may experience "contagion" between pain and neutral stimuli.

During later attentional stages, moderation by pain intensity may reflect the established role of pain as an important contextual variable that activates pain/threat schema, thereby highlighting differences between participants reporting high and those reporting low catastrophizing [50;52;53]. The findings also support distinction between attentional allocation and maintenance as partially independent processes, with later stages of attentional processing potentially allowing greater elaboration of biased schema which come to include the effect of personal pain experience [7;31].

The importance of personal pain experience as a contextual variable is likewise demonstrated by the interaction between facial pain expression and personal pain intensity, as higher levels of personal pain contributed to decreased maintenance of attention to pain faces compared to neutral faces, independent of catastrophizing. This finding stands in contrast with evidence of increased attention to pain stimuli with increasing levels of personal pain [12;31]. However, biases away from pain have also been reported [36;61], even among those with chronic pain [24]. Among observers reporting high personal pain, reduced attentional maintenance to pain may again reflect efforts to regulate distress. This is in line with findings that modifying attention to pain using distraction leads to diminished pain aversiveness [15;33;35;45]. Additional research is needed to examine whether and how attentional avoidance serves emotion regulatory goals in the interpersonal pain context as well as higher-order interactions with catastrophizing.

The current findings support differential responses to pain versus neutral stimuli among high and low catastrophizing participants both at initial and later stages of observing another in pain. Mechanisms underlying these differences (including emotional regulation,

biased stimulus interpretation) as well as behavioral implications of these mechanisms remain to be examined [30]. Delayed or non-preferential orientation to pain (observed among participants reporting high catastrophizing) may hamper prompt and efficient responding to another's pain; increased attentional maintenance to both pain and non-pain states (observed among participants reporting high catastrophizing and pain) may reflect a fearful/freezing response that hampers flexible switching between various demands.

Some limitations and suggestions for future research must be noted. First, due to the small sample size, statistical power was limited to detecting only large effects (.80). Replication in larger and more gender-diverse samples (clinical and healthy) is warranted. Second, attention was assessed while viewing faces of unfamiliar actors simulating pain expressions. Recent brain imaging studies suggest increased attentional allocation to *familiar* faces [17;29]. Further, as stimuli were simulations it is possible that eye tracking reflected some features of expression particular to simulation. However, although genuine and simulated expressions (of pain) are found to differ [22;26;59], these detectable differences are low and pertain primarily to temporal and intensive features of expression [8;22;38;39], rather than specific actions comprising expression. Given that stimuli used in this study were evaluated as matching a pain expression prototype according to facial coding criteria [47] and that observers responded to still photographs, it seems unlikely that their simulated nature would strongly limit the representativeness of eye tracking responses. Finally, while tracking participants' eye movements allowed for more precise examination of temporal attentional dynamics, eye movement is not the sole indicator of attention. It remains possible that while an individuals' gaze is overtly directed to neutral faces, pain-related information is covertly processed [62]. Therefore, simultaneous use of manual-response tasks (e.g., dot-probe) to complement eye-tracking may prove fruitful within future research (see e.g., [66]).

Despite limitations, our findings attest to the critical distinction between attentional orientation and maintenance, as well as both bottom-up (pain expression), and top-down factors (pain catastrophizing, pain experience) in understanding observers' response to another's pain. Further research is needed to replicate and explore alternative perspectives suggested by the current findings.

Acknowledgements

FIGURE LEGEND

Figure 1.   Examples of study slides ((A)female - pain right /(B) male- pain left) containing neutral expression (NFE) paired with 1) low facial expression of pain (LFE) 2) moderate facial expression of pain (MFE) and 3) high facial expression of pain (HFE)

Figure 2. Time to first fixation (in ms) for Neutral expression (NFE), Low facial expression of pain (LFE), Moderate facial expression of pain (MFE) and High facial expression of pain (HFE) as a function of low and high levels of pain catastrophizing. Differences between NFE and LFE, MFE, and HFE were only observed for participants reporting high catastrophizing thoughts

*p $<$ .001

Figure 3. Mean gaze duration as a function of catastrophizing and low and high levels of self-reported pain intensity. Differences between lower and higher catastrophizing were only observed for participants reporting high intensity pain

*p $<$ .05

Figure 4. Gaze duration for Neutral expression (NFE), Low facial expression of pain (LFE), Moderate facial expression of pain (MFE) and High facial expression of pain (HFE) as a function of low and high levels of self-reported pain intensity. Differences between NFE and LFE, MFE, and HFE were only observed for participants reporting high intensity pain

*p $<$ .05

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Table 1. Descriptive statistics of demographic and pain-related variables

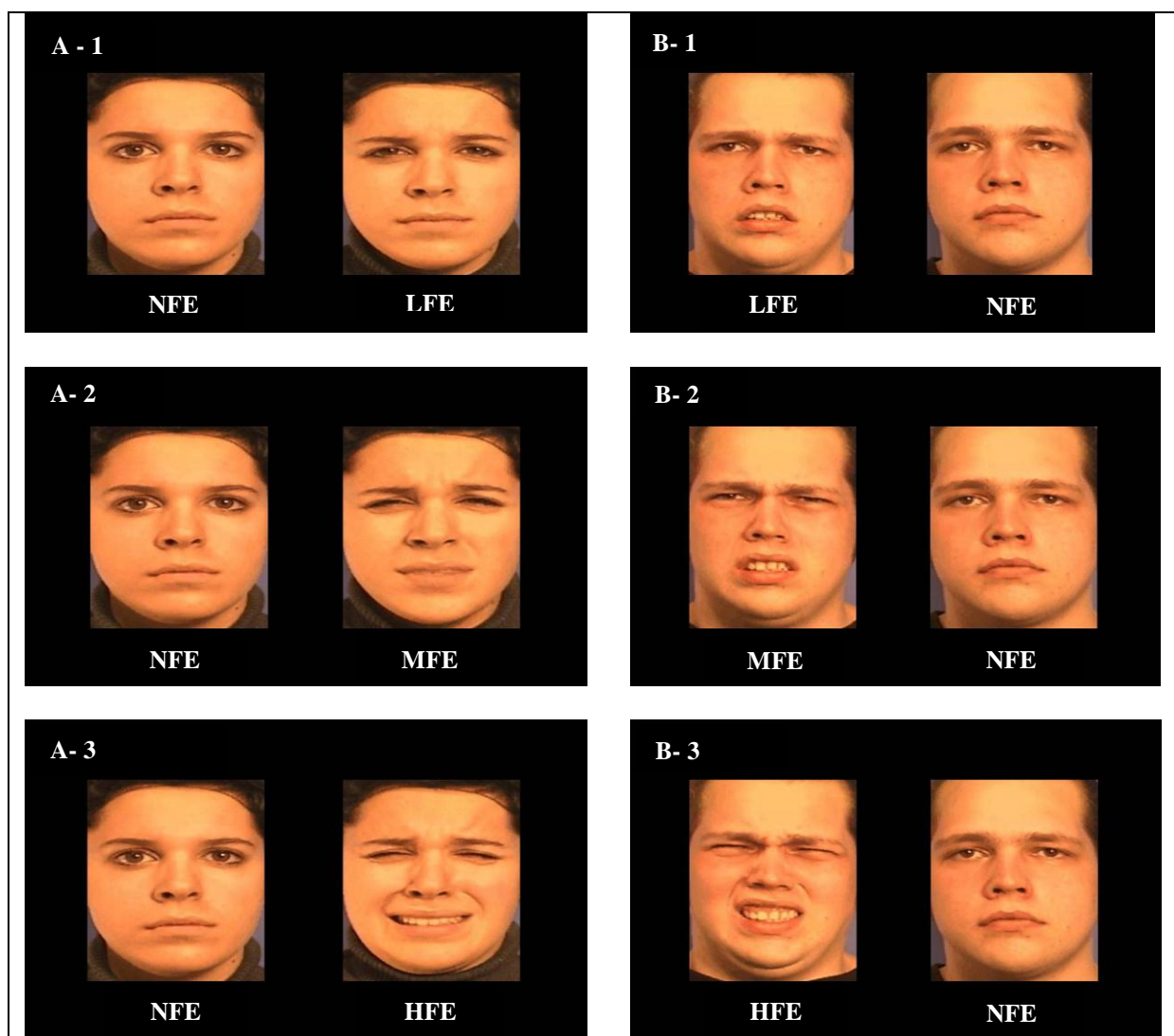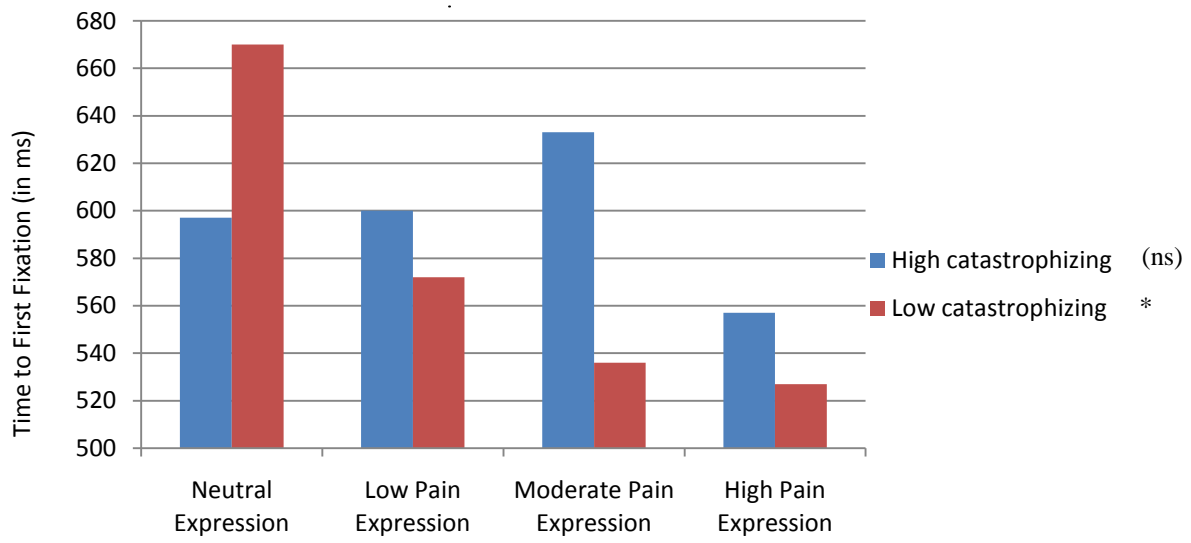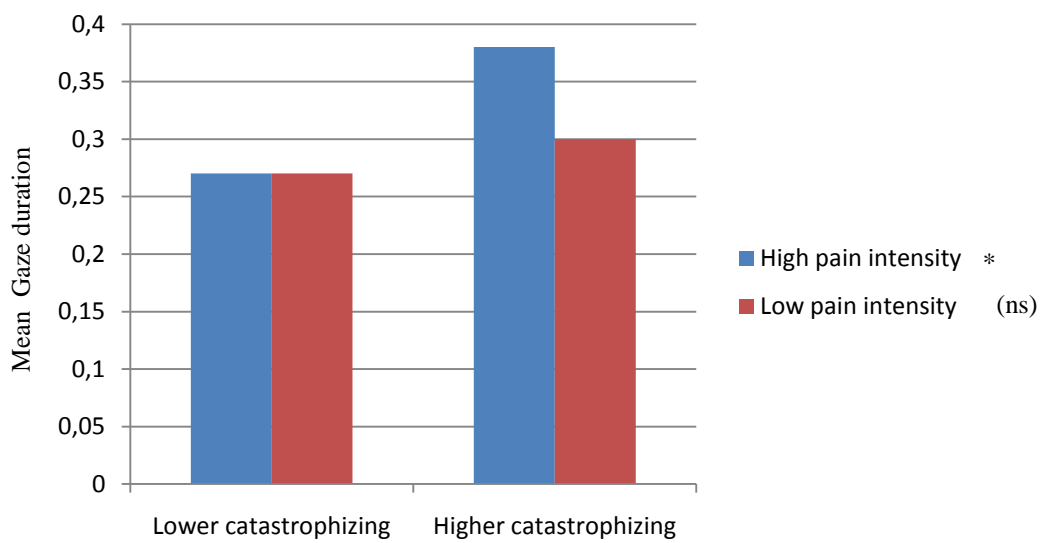| Measure	*M*	*SD*	*N*	*%*
Age (yrs)	19.85	4.54	--	--
Sex				
Female	--	--	49	89
Male	--	--	6	11
Marital status				
In a relationship	--	--	25	45.45
Married or co-habiting	--	--	0	0
Single	--	--	29	52.72
Divorced	--	--	1	1.81
Nationality				
Belgian	--	--	51	
Dutch	--		3	
German	--	--	1	
Having had pain during past 3 months	--	--	38	69.09
Number of days in pain during past 3 months	14.03	16.32	--	--
Location of most salient pain complaint during past 3 months				
Head	--	--	12	32.43
Stomach	--	--	6	16.22
Back/Neck	--	--	6	16.22
Throat			4	10.81
Legs/Feet			8	21.62
Arms			1	2.70
Current level of pain (NRS 0-10)	2.18	2.40	--	--
Average level of pain experienced during past 3 months (NRS 0-10)	2.76	2.46	--	--

Figure 1

Figure 2

Figure 3

Figure 4