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Exploring the Effects of Visual Perspective on the ERP Components of Empathy for Pain

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Abstract

Previous neurophysiological research suggests that there are event-related potential (ERP) components are associated with empathy for pain: early affective component (N2) and two late cognitive components (P3/LPP). The current study investigated whether and how the visual perspective from which a painful event is observed affects these ERP components. Participants viewed images of hands in pain vs. not in pain from a first-person or third-person perspective. We found that visual perspective influences *both* the early and late components. In the early component (N2), there was a larger mean amplitude during observation of pain vs no-pain *exclusively* when images were shown from a first-person perspective. We suggest that this effect may be driven by misattributing the on-screen hand to oneself. For the late component (P3), we found a larger effect of pain on mean amplitudes in response to third-person relative to first-person images. We speculate that the P3 may reflect a later process that enables effective recognition of others' pain in the absence of misattribution. We discuss our results in relation to self- vs other-related processing by questioning whether these ERP components are truly indexing empathy (an other-directed process) or a simple misattribution of another's pain as one's own (a self-directed process).

Keywords: empathy; pain; ERP; attention; sensory misattribution

Word Count: 8797 (Including References)

1. Introduction

Empathy researchers often distinguish between two types of empathy: affective empathy and cognitive empathy. Affective empathy refers to the emotional sharing, or “resonating”, between the subject and object of empathy; cognitive empathy, on the other hand, refers to a person’s ability to engage in self-other processing such as being able to take the perspective of others and/or “mentalize” (e.g., Rameson & Lieberman, 2009; Tremblay et al., 2018). Evidence supporting the presence of such a distinction has come from work using Event-Related Potentials (ERPs) to explore the temporal dynamics of empathy for pain¹.

In a seminal study, Fan & Han (2008) found that early ERP components (i.e., N1, P1, and N2) and late components (i.e., P3 and LPP (Late Positive Potential)) differentiated between stimuli depicting someone in pain vs. not in pain. Specifically, they reported a “positive shift” in the early components - smaller mean amplitudes at N1 and N2, and larger at P1 - and larger mean amplitudes in the late component when participants observed others in pain compared to not in pain. The early components were deemed to be task-independent, as the effects were present regardless of whether the participant was judging the presence of pain in the picture or judging the number of hands in the picture. In contrast, the late P3/LPP components were deemed to be task-dependent because the effect was found exclusively during the pain categorization task. Based on these results, Fan

¹ It must be acknowledged that conceptual/definitional confusion abounds regarding what empathy actually is (e.g., Batson, 2009; Coll et al., 2017b) and there are likely to be different views about whether modulation in the ERP waveforms we consider in the current study reflect anything to do with empathy, or whether they are better described as relating to vicarious pain processing (e.g., Coll, 2018). Thus, in the current paper, we use the term empathy in a manner consistent with how other researchers have used the term, whilst acknowledging the conceptual/definitional confusion that surrounds it.

72 & Han concluded that the early components are markers of early automatic processes linked to
73 empathy. These processes appear to be sensitive to stimulus valence and arousal (affective
74 empathy). In contrast, Fan & Han concluded that the later components index more controlled
75 processes linked to empathy, which are sensitive to attention and task demands (cognitive
76 empathy).

77
78 Experiments following Fan & Han's study have provided further evidence that these early and late
79 ERP components may index a distinction between affective and cognitive empathy. For example,
80 Li & Han (2010) found that imagining another's perspective ("Imagine that hands shown in the
81 picture are unfamiliar others"), compared to taking one's own perspective ("Imagine that hands
82 shown in the picture are your own"), attenuates differences in mean amplitudes in the ascending
83 phase of the P3 during pain vs. no-pain observation. However, the early components were not
84 affected by this imagined perspective manipulation. More recently, Coll et al. (2017a) found that
85 cathodal stimulation of the right temporo-parietal junction (rTPJ), a region associated with
86 perspective taking and self-other control (Santesteban et al., 2012; Hogeveen et al, 2015),
87 attenuated the effects of pain observation in the LPP, but not the early components (interestingly,
88 stimulation of the rTPJ specifically affected this pain observation effect for hands but not for
89 faces). Since perspective taking and self-other processing are within the purview of cognitive
90 empathy, these results appear to demonstrate that the late component is specifically related to
91 cognitive, and not affective, empathy.

92
93 Regarding the early components, Cui et al. (2016a) have recently shown that the effect of pain
94 observation on the N2 is attenuated when participants are told that the person in pain is morally

reprehensible (e.g., a killer). The late component (LPP) was not affected by this information. Cui et al. suggest that this was due to the suppression of affective responses towards others who do not deserve empathy (or at least are perceived as such). Sessa et al. (2014) found similar results regarding racial bias, wherein the effects of pain observation on the N2/N3 were attenuated when observing someone belonging to a racial out-group in pain, while the effects of pain observation on late components did not interact with race. They suggest that these results may be due to a lack of ‘experience sharing’ towards a racial out-group in pain, and since affective suppression and experience sharing pertain to affective empathy, these results would appear to demonstrate that the early components are specifically related to affective empathy, and not to cognitive empathy. These results also reopen the issue of whether the early ERP components associated with pain observation are truly automatic; an important aim for further research is to determine the conditions under which the early components are modulated.

The current study extends this line of research by exploring the effects of visual perspective on the ERP components of empathy for pain. Visual perspective refers to viewing a scene or situation from different angles; this contrasts with cognitive perspective taking which refers to imagining being the other person (for an overview of this distinction, see: Canizales et al., 2013). Previous research has suggested that visual perspective can influence different indices of empathy for pain (Canizales et al., 2013; Bucchioni et al., 2016). Canizales et al. have shown that observing someone in pain from the first-person perspective leads to a significantly larger decrease of the somatosensory steady-state response (SSSR) compared to observing from the third-person. Using Transcranial Magnetic Stimulation (TMS), Bucchioni et al. have further shown that a decrease in motor excitability is only present when viewing a person in pain from the first-person perspective

but not the third-person perspective; this decrease in motor excitability has previously been suggested as an index of ‘sensorimotor empathy’ or ‘empathic sensorimotor resonance’, which refers to a mapping of representational states (e.g., the source, location, intensity of a person’s pain) to the observer from the observed that may lead to empathic feelings/responses (Avenanti et al., 2005). Following Mahayana et al. (2014), Buccioni et al. also interpret their results as a form of sensory misattribution. Mahayana et al. found that empathic sensorimotor resonance was attenuated when the stimuli were moved outside of the participants’ peripersonal space, and they interpreted this to mean that empathic responses to someone else in pain are partially dependent on misattributing the sensory experience of others as one’s own (such misattribution may also account for the effects of observing someone in pain from a first vs. third-person perspective). In this way, manipulations of visual perspective could affect whether the painful stimulus is misidentified as “self-related” (i.e., self-other confusion) or correctly interpreted as “other-related”. It is quite possible that the early and/or late ERP components would be differentially modulated depending on whether the potential for self-other confusion is high (i.e., first-person visual perspective) or low (i.e., third-person visual perspective).

As far as we are aware, no study has explored the effects of visual perspective on the ERP components of empathy for pain. As such, the aim of the current study is to extend our understanding of the neural correlates of empathy for pain by exploring this topic. Importantly, unlike other measures discussed thus far (e.g., TMS, SSSR), the use of ERPs allows us to investigate the temporal influence of visual perspective during pain observation. It should be noted that most studies depicting hands in pain have used stimuli presented in the first-person perspective (e.g., Fan & Han, 2008; Han et al., 2008; Li & Han, 2010; Suzuki et al., 2015; Cui et al., 2017),

with only a few studies using a third-person perspective (e.g., Cui et al., 2016b; Coll et al., 2017a). As such, the current study aims to shed important light on how first-person and third-person perspectives affect the early and late ERP components that have been associated with different aspects of processing linked to pain observation. Given the link between visual perspective and self-other-relatedness, our study also allows us to address whether the early and late ERP components might be differentially modulated as a function of the self-other-relatedness of a stimulus.

To investigate the relationship between visual perspective and pain observation, we presented participants with images depicting a person in pain or not in pain, from both first- and third-person perspectives. To assess the task dependence of any ERP effects, participants completed two tasks: pain categorization vs. orientation categorization. In the pain categorization task, participants categorized the stimulus as depicting someone else in pain or not in pain. In the orientation categorization task, participants categorized the presented images as either upright (first-person) or inverted (third-person). Although Fan & Han (2008) used a finger counting task for their alternative task, the orientation categorization task fulfils a similar purpose wherein attention is taken away from the other person's pain. EEG was recorded throughout both tasks.

We predict that early components will be sensitive to visual perspective, such that the pain/no-pain difference will be present for first-person images but not for third-person images. This is because the first-person images could lead to the misattribution of the observed pain as self-related, which we expect to be reflected in early processes. Regarding task dependence, given previous results, it is possible that this first-person modulation effect will occur in both the pain categorization and

orientation categorization conditions. However, we are unable to predict this effect exclusively, as there are demonstrations of task factors modulating early processing. Thus, we remain open to the possibility of a three-way interaction between task, pain status of the stimulus, and visual perspective, but also to the alternative possibility that task factor has no effect.

In contrast to the early processing, it is possible that late components will differentiate between the pain and no-pain stimuli for both the third-person and first-person viewing. This is because, in the case of first-person viewing, if self-misattribution occurs, a later process may be required to specify that the pain is actually other-related (i.e., to resolve self-other confusion). Correspondingly, in third-person observation, wherein self-other confusion may not occur, a later process registering that another is in pain could be required. In this way, the late component may reflect self-other processing in both first- and third-person contexts, but in one case it is resolving self-other confusion, and in the other, it is simply registering the pain of the other. However, an alternative prediction is also possible: If early N2 modulation reflects misattribution of pain to the self and this is adequate to register the presence of pain, then a later process that resolves the self-other confusion may not be required. By this view, modulation of late components may not occur for first-person viewing conditions. This predicts a modulation of the P3/LPP only when the stimulus is viewed from a third-person perspective. Following previous studies demonstrating the task-sensitivity of such late cognitive effects, we also predict that these effects will only be present in the pain categorization condition.

Finally, while we can predict general patterns of modulation of ERP activity, the direction of these predicted effects is less clear. For example, while some studies find that observing another in pain

leads to smaller mean N2 amplitudes (e.g., Fan & Han, 2008; Han et al., 2008; Li et al., 2010; Coll et al., 2017a), other studies have found larger N2 amplitudes (e.g., Suzuki et al., 2015; Cui et al., 2016a; 2016b; 2016c; 2016d; Decety et al., 2017). In contrast, the P3/LPP has been more consistent, with all studies reviewed here (reporting significant effects relating to the P3/LPP) finding larger P3/LPP amplitudes during pain observation compared to no-pain.

2. Methods

2.1 Participants

32 right-handed participants were recruited from the McMaster University Psychology participant pool (Age = 19.6, Gender = 7 males) for course credit. Sample size was determined based on previous research. It should be noted that one participant was removed from analysis and replaced due to a high amount of errors (>35%, a lot of which were due to no responses being made) during the task. Furthermore, three participants could not be tested due to technical difficulties with the EEG (e.g., could not get impedance levels low enough for the experiment). Data was not collected for these participants and they were subsequently replaced. As such, the total number of participants remains at 32. Prior to participation, participants provided written informed consent. The study was approved by the McMaster Research Ethics Board (MREB).

2.2 Apparatus and Stimuli

The experiment was programmed and presented using SuperLab v4.5 (Cedrus Corporation, San Pedro, CA, USA), and was run on a Lenovo P910 ThinkStation. Participants responded with their right and left index fingers using a Cedrus RB series Response Pad. The visual stimuli consisted

of a picture depicting a male Caucasian hand either being stabbed by a needle or touched by a Q-tip from either the first-person perspective or third-person perspective (adapted from video stimuli used by Avenanti et al., 2010). We manipulated visual perspective taking by presenting both picture stimuli either upright to showcase a first-person perspective or inverted for a third-person perspective (a similar method to manipulate visual perspective was used by Buccioni et al., 2016). The pictures were grey scaled to limit the influence of colour in the tasks (See Figure 1A). EEG was recorded using a 64 channel Neuroscan Quik-Cap throughout the experiment. Participants also completed the Interpersonal Reactivity Index (Davis, 1980; 1983) and Empathy Quotient (Baron-Cohen and Wheelwright, 2004) at the end of the experiment.

FIGURE 1 HERE

2.3 ERP Components

While Fan & Han (2008) analyzed multiple components in their initial analysis, follow up studies have not always examined the same components. For example, some studies have only replicated the effects of pain observation in the P3/LPP (Lyu et al., 2014; Sessa et al., 2015), while others find only a subset of the early components (e.g., N1, P2 but no presence of N2; Decety et al., 2010). Furthermore, some studies split up the P3 into its ascending phase, peak, and descending phase for separate analysis (e.g., Li & Han, 2010; Suzuki et al., 2015), while others focus on the total P3/LPP waveform (Coll et al., 2017a). A recent meta-analysis and review by Coll (2018) suggests that the N2 and P3/LPP are the most common components found to significantly differentiate between pain and no-pain observations, with the later components being more reliable

(Coll in fact found non-significant overall effects of the N2; however, this may be due to the ambiguity of the direction of the effect, with some studies finding more negative effects and others more positive when comparing pain vs. no-pain, as discussed in the introduction). Furthermore, the N2 is most commonly found using frontal-central electrodes, while the P3/LPP are mostly found using central-parietal electrodes. Unfortunately, and as Coll points out, there does not seem to be a consensus regarding the time-window of each component. Visual inspection is often used to determine this.

Based on this, we focus our analysis on the N2 and P3/LPP. After visual inspection and consulting previous research (e.g., Fan & Han, 2008; Cui et al., 2016a; Fabi & Leuthold, 2016), we determined the N2 to be between 200ms-300ms, the P3 to be between 350ms-450ms, and the LPP to be between 500-800ms after stimulus onset. The N2 was analyzed using the average waveforms from the Fz, F3, F4, FCz, FC3, and FC4 electrodes (“Frontal-Central region”) and the P3/LPP were analyzed using the average waveforms from Cz, C3, C4, CPz, CP3, CP4, Pz, and P3 electrodes (“Central-Parietal region”); these regions of interest are based on those originally used by Fan & Han (2008).

2.4 Design

The experiment used a 2x2x2 within-subjects design, wherein Picture Valence (Pain, No-Pain (NP)), Visual Perspective (1st Person (1P), 3rd Person (3P)), and Task (Pain Categorization, Orientation Categorization) were the factors. Each task was conducted in separate blocks counter-balanced between participants (i.e., half the participants completed the Pain Categorization task

first and vice versa for the other half). The four stimuli making up the Picture Valence x Visual Perspective factors (1P-Pain, 1P-NP, 3P-Pain, 3P-NP) were presented randomly within these blocks. Each of these four stimuli were presented 60 times in each task (Pain Categorization, Orientation Categorization), giving an overall trial count of 480. The 2x2x2 within-subjects design was applied to the two ERP components discussed above: the N2 and the P3/LPP. We also report correlations between the components and measures of trait empathy obtained from the Interpersonal Reactivity Index (Davis, 1980; 1983) and Empathy Quotient (Baron-Cohen and Wheelright, 2004).

2.5 EEG Acquisition and Processing

EEG was recorded using a 64 channel Neuroscan Quik-Cap. We recorded vertical and horizontal eye movements using two electrodes placed above and below the left eye (VEOG) and two electrodes place near each temple (HEOG). Impedance levels were below 15k Ω before the start of the experiment. The EEG and VEOG/HEOG were sampled at 1000Hz, and the EEG was referenced to an electrode near Cz. After collection was completed, the data was transferred to EEGLab (Delorme and Makeig, 2004). In EEGLab, the data was re-referenced to the average of the mastoids and bandpass filtered between 1-20Hz (this filter was used specifically to improve ICA results). A particularly bad electrode was removed from all participants (P4, which seems to be due to hardware problems). The data was then epoched based on each condition (using the ERPLab plugin – Lopez-Calderon and Luck, 2014); epochs were time locked to a photo-receptor marker for increased accuracy of stimulus onset. Independent Component Analysis (ICA) was then run on each dataset using EEGLab's SOBI function (Second-Order Blind Identification; Sahonero-Alvarez and Calderon, 2017). The ICA matrices created were then transferred to a dataset using

more conservative filter settings (bandpass filter: 0.1-40Hz). The MARA (Multiple Artifact Rejection Algorithm; Winkler et al., 2011; 2014) plugin was then used to automatically classify and subsequently remove components classified as artifacts (e.g., eye blinks/movements, muscle activity, etc.). Epochs that corresponded to bad behavioural trials (i.e., anticipatory responses (< 200ms), slow responses (> 1500ms), errors, or missing responses) were removed (less than 4% of all trials per participant). As a final quality check, all epochs that contained +/- 100 μ V waveforms were removed (~1.14%).

Using the ERPLab plugin, subject ERPs were created by averaging together epochs within each condition. Given the design of the experiment, this led to 8 different ERP waveforms corresponding to each of the experimental conditions (Pain Categorization: 1P-Pain, 1P-NP, 3P-Pain, 3P-NP; Orientation Categorization: 1P-Pain, 1P-NP, 3P-Pain, 3P-NP). Following previous studies (e.g., Fabi & Leuthold, 2017), we pooled together electrodes into regions of interest for analysis. Specifically, Fz, F3, F4, FCz, FC3, and FC4 were averaged together to create the “Frontal-Central” region for analysis of the N2 component, and Cz, C3, C4, CPz, CP3, CP4, Pz, and P3 were averaged together to create the “Central-Parietal” region for analysis of the P3/LPP components. Subject ERPs were then averaged together to create the Grand Average ERPs used for visualization and analysis of the components. Finally, ERPLab’s ERP measurement tool was used to obtain mean amplitudes between 200-300ms for the N2 in the Frontal-Central region and 350-450ms/500-800ms for the P3/LPP components, respectively, in the central-Parietal region.

2.6 Procedure

Participants first read over a letter of information detailing the procedures of the study. If acceptable, they signed a consent form. Two experimenters (the same for each participant) then proceeded to set up the EEG – this process took on average 25 minutes. Afterwards, the SuperLab program containing the experiment was played and the participant was presented with task instructions. The instructions were also verbally explained by the experimenters. In the Pain Categorization task, participants were instructed to press either the right or left key if they saw a picture with someone in pain and to press the opposite key if they saw a picture with someone not in pain. In the Orientation Categorization task, participants were instructed to respond based on whether the pictures were upright or inverted. Task order was counterbalanced between participants. Key mappings of categories were counterbalanced between blocks; for example, if in one block the right button was assigned to painful pictures, then in the next it was assigned to non-painful pictures. The order of the key mappings (i.e., which button maps onto which category first) was counter balanced between participants. All possible combinations of order were accounted for in our counter balancing. At the start of each new key mapping and/or task, instructions were presented detailing the change. To make sure participants got used to the key mappings, 20 practice trials were always provided at the start of each block. In contrast to the Task and key mappings, the picture stimulus was pseudo-randomly (each set of 4 consecutive trials always contained one of each image) shown throughout the experiment. That is, the fully crossed Picture Valence (Pain, NP) and Visual Perspective (1P, 3P) stimuli were pseudo-randomly shown within each block.

Each trial started with a 500ms ISI in the form of a black screen. A picture stimulus then appeared for 200ms; however, the participant was instructed to press the button as soon as they could correctly categorize the stimulus (up to 1500ms after the stimuli onset; see Figure 1B). Each

categorization task contained 240 trials (with each key mapping containing 120 trials). This led to a total of 480 trials per participant. This also led to 60 trials per picture stimulus (1P-Pain 1P-NP, 3P-Pain, 3P-NP) within each categorization task. Participants were given a self-paced break every 60 trials.

At the end of the computer task, the EEG cap was removed, and participants completed the Interpersonal Reactivity Index (Davis, 1980; 1983) and Empathy Quotient (Baron-Cohen and Wheelwright, 2004). The order of the questionnaires was counterbalanced across participants. Lastly, participants were debriefed about the nature of the study.

3. Results

3.1 ERP Components

3.1.2 The N2 (200-300ms)

The 2x2x2 Within-Subjects ANOVA yielded a significant main effect of Task [$F(1,31) = 14.7, p = 0.0006, \eta^2_p = 0.32$], wherein participants showed a more negative N2 during the Pain Categorization task [$M = -4.15\mu V, SD = 4.25, SE = 0.75$] compared to during the Orientation Categorization task [$M = -2.42\mu V, SD = 4.73, SE = 0.84$]; a main effect of Picture Valence [$F(1,31) = 10.7, p = 0.003, \eta^2_p = 0.26$], wherein participants showed a more negative N2 when observing another person in pain [$M = -3.54\mu V, SD = 4.42, SE = 0.78$] compared to not in pain [$M = -3.03\mu V, SD = 4.25, SE = 0.75$]; a significant two-way interaction between Task and Visual Perspective [$F(1,31) = 5.9, p = 0.02, \eta^2_p = 0.16$], wherein the relative difference (of the N2 waveform) between

First-Person and Third-Person images (with larger N2 mean amplitudes for Third-Person images, collapsed across Picture Valence) was larger during the Orientation Categorization task [$M = 0.3\mu\text{V}$, $SD = 1.5$, $SE = 0.27$] compared to the Pain Categorization task [$M = -0.52\mu\text{V}$, $SD = 1.82$, $SE = 0.32$]; and lastly, a significant three-way interaction between Task, Visual Perspective, and Picture Valence [$F(1,31) = 8.2$, $p = 0.008$, $\eta^2_p = 0.21$]. All other main effects and interactions were non-significant (all $p > 0.29$).

The three-way interaction was decomposed using two-way within-subjects ANOVAs testing for the Visual Perspective x Picture Valence interaction within each Task condition. The analysis revealed a significant Visual Perspective x Picture Valence interaction during the Pain Categorization task [$F(1,31) = 8.56$, $p = 0.006$, $\eta^2_p = 0.22$]. Follow-up t -tests were conducted (Holms-Bonferroni corrected), which suggest that, when the images were in first-person, observing someone in pain [$M = -5.02\mu\text{V}$, $SD = 4.83$, $SE = 0.85$] led to a more negative N2 compared to not in pain [$M = -3.79\mu\text{V}$, $SD = 4.28$, $SE = 0.76$] [$t(31) = 3.31$, $p = 0.005$, $d = 0.59$]. No such difference was found when the images were in third-person [Pain: $M = -3.94\mu\text{V}$, $SD = 4.28$, $SE = 0.76$; NP: $M = -3.84\mu\text{V}$, $SD = 4.37$, $SE = 0.77$; $t(31) = 0.36$, $p = 0.72$]. In contrast to the Pain Categorization task, no such interaction was found during the Orientation Categorization task [$F(1,31) = 2.6$, $p = 0.12$]; however, a main effect of Picture Valence was found [$F(1,31) = 6.2$, $p = 0.019$, $\eta^2_p = 0.17$], wherein observing someone in pain [$M = -2.6\mu\text{V}$, $SD = 4.81$, $SE = 0.85$] led to a more negative N2 compared to not in pain [$M = -2.24\mu\text{V}$, $SD = 4.68$, $SE = 0.83$]. See Figure 2.

FIGURE 2 HERE

3.1.3 The P3 (350-450ms)

The 2x2x2 Within-Subjects ANOVA yielded a significant three-way interaction between Task, Visual Perspective, and Picture Valence [$F(1,31) = 10.8$, $p = 0.0025$, $\eta^2_p = 0.26$]. All other main effects and interactions were non-significant (all $p > 0.08$). The three-way interaction was decomposed using two-way within-subjects ANOVAs testing for the Visual Perspective x Picture Valence interaction within each Task condition. The analysis revealed a significant Visual Perspective x Picture Valence interaction during the Pain Categorization task [$F(1,31) = 5.8$, $p = 0.02$, $\eta^2_p = 0.26$]. Follow-up t -tests were conducted (Holms-Bonferroni corrected), which suggest that, when the images were in third-person, observing someone in pain [$M = 7.15\mu V$, $SD = 5.94$, $SE = 1.05$] led to a more positive P3 compared to not in pain [$M = 6.31\mu V$, $SD = 6.1$, $SE = 1.08$] [$t(31) = 2.97$, $p = 0.011$, $d = 0.53$]. No such difference was found when the images were in first-person [Pain: $M = 6.92\mu V$, $SD = 6.2$, $SE = 1.1$; NP: $M = 7.01\mu V$, $SD = 6.03$, $SE = 1.07$; $t(31) = 0.27$, $p = 0.79$]. In contrast to the Pain Categorization task, no significant effects were found during the Orientation Categorization task (all $p > 0.08$). See Figure 3.

FIGURE 3 HERE

3.1.4 The LPP (500-800ms)

The 2x2x2 Within-Subjects ANOVA yielded a significant a main effect of Task [$F(1,31) = 9.6$, $p = 0.004$, $\eta^2_p = 0.24$], wherein participants showed more positive LPP during the Pain

Categorization task [$M = 4.7\mu V$, $SD = 5.2$, $SE = 0.9$] compared to during the Orientation Categorization task [$M = 3.5\mu V$, $SD = 3.9$, $SE = 0.7$]; and a significant three-way interaction between Task, Visual Perspective, and Picture Valence [$F(1,31) = 5.6$, $p = 0.015$, $\eta^2_p = 0.18$]. All other main effects interactions were non-significant ($p > 0.46$). The three-way interaction was decomposed using two-way within-subjects ANOVAs testing for the Visual Perspective x Picture Valence interaction within each Task condition. The analysis revealed a significant Visual Perspective x Picture Valence interaction during the Pain Categorization task [$F(1,31) = 4.7$, $p = 0.038$, $\eta^2_p = 0.13$]. Follow-up t -tests were conducted (Holms-Bonferroni corrected) which suggests that *neither* images in the first or third person showed significant differences between pain and no pain conditions [First Person: $t(31) = 1.38$, $p = 0.18$; Third Person: $t(31) = 1.53$, $p = 0.14$]. In contrast to the Pain Categorization task, no significant effects were found during the Orientation Categorization task (all $p > 0.38$). See Figure 4.

FIGURE 4 HERE

3.2 Behavioural Data

Reaction time and error rate data were entered into a 2x2x2 within-subjects ANOVA with Task (Pain Categorization, Orientation Categorization), Visual Perspective (1st Person, 3rd Person), and Picture Valence (Pain, No-Pain) as factors.

3.2.1 Reaction Time

The 2x2x2 within-subjects ANOVA yielded a significant main effect of Task ($F(1,31) = 18.31$, $p < 0.001$, $\eta^2_p = 0.371$), wherein faster responses were elicited during the Orientation Categorization task ($M = 522.86\text{ms}$, $SD = 78.52$, $SE = 13.88$) compared to the Pain Categorization task ($M = 569.87\text{ms}$, $SD = 83.27$, $SE = 14.72$); a significant main effect of Visual Perspective ($F(1,31) = 12.24$, $p = 0.001$, $\eta^2_p = 0.283$), wherein faster responses were elicited when participants observed the images in first-person ($M = 542.84\text{ms}$, $SD = 74.5$, $SE = 13.17$) vs. third-person ($M = 549.89\text{ms}$, $SD = 75.38$, $SE = 13.32$); a significant main effect of Picture Valence ($F(1,31) = 6.35$, $p = 0.017$, $\eta^2_p = 0.17$), wherein faster responses were elicited when observing pain ($M = 543.97\text{ms}$, $SD = 76.53$, $SE = 13.53$) vs. no-pain ($M = 548.76\text{ms}$, $SD = 73.27$, $SE = 12.95$); and lastly, a significant Task x Visual Perspective interaction ($F(1,31)$, $p = 0.037$, $\eta^2_p = 0.133$). Follow-up t-tests were conducted (Holms-Bonferroni corrected), which suggest that, during the Orientation Categorization task, faster responses were elicited for first-person images ($M = 516.21\text{ms}$, $SD = 78.07$, $SE = 13.8$) compared to third-person ($M = 529.49\text{ms}$, $SD = 80.24$, $SE = 14.18$) ($t(31) = 3.7$, $p = 0.0017$, $d = 0.655$); in contrast, no such difference was found during the Pain Categorization task (1P: $M = 569.44\text{ms}$, $SD = 83.61$, $SE = 14.78$; 3P: $M = 570.3\text{ms}$, $SD = 84.05$, $SE = 14.86$; $t(31) = 0.25$, $p > 0.8$). All other main effects and interactions were non-significant (all $p > 0.08$).

3.2.2 Error Rate

The 2x2x2 within-subjects ANOVA yielded a significant main effect of Task ($F(1,31) = 14.77$, $p < 0.001$, $\eta^2_p = 0.323$), wherein more errors were made during the Orientation Categorization task ($M = 4.22\%$, $SD = 5.62$, $SE = 0.99$) compared to the Pain Categorization task ($M = 3.66\%$, $SD = 5.71$, $SE = 1.01$); and a significant two-way interaction between Visual Perspective and Picture Valence ($F(1,31) = 4.52$, $p = 0.042$, $\eta^2_p = 0.127$). Follow-up t-tests were conducted (Holms-

Bonferroni corrected) which suggest that error rates during pain observation does not significantly differ from those during no-pain, regardless of the perspective of the images (1P: $t(31) = 1.49$, $p = 0.28$ or 3P: $t(31) = 1.82$, $p = 0.16$). All other main effects and interactions were non-significant (all $p > 0.17$).

3.3 Correlations

The IRI contains four subscales: Perspective Taking (PT), Empathic Concern (EC), Personal Distress (PD), and Fantasy Scale (FS); in addition to the Empathy Quotient (EQ), we correlate each of these measures to the difference score between No-pain and Pain Picture Valence conditions in each fully crossed Task and Visual Perspective conditions. We do this for both the N2 and P3/LPP. This led to a total of 40 correlations. The only significant correlation found is a positive correlation between PD and the N2 (No-pain – Pain) during the Pain Categorization task with upright images ($r = 0.4$, $p = 0.034$); however, this result does not remain significant after correction (Holms-Bonferroni; $p > 0.99$). All other correlations were non-significant before correction.

4. Discussion

The aim of the current study was to explore if and how visual perspective influences the early (N2) and late (P3/LPP) components ostensibly related to empathy for pain. Our results are consistent with previous studies in that we found both early (200ms-300ms) negative waveforms in the frontal-central electrodes and late (350ms-450ms) positive waveforms in the central-parietal electrodes that were sensitive to observing others in pain. Importantly, we found significant three-

way interactions for both the early and late components: For the N2, during the pain categorization task, observing someone in pain led to a larger mean amplitude compared to no-pain *exclusively* when the images were shown in first-person. In contrast, during the orientation categorization task, observing someone in pain led to a significantly larger mean amplitude compared to no-pain *regardless* if the images were shown in first- or third-person. For the P3, during the pain categorization task, there was an effect of pain observation only for images shown in third person, wherein a larger mean amplitude was found for pain vs. no-pain observations; this difference did not exist for first-person images. In contrast, no significant effects were found during the orientation categorization task. This pattern of results was also seen in the LPP; however, given the lack of significant follow-up t-tests, we refrain from interpreting these results and instead focus our discussion on the N2 and P3.

The fact that a three-way interaction was observed for the N2 component is interesting. Following previous interpretations of a larger N2 during pain observation compared to no pain (e.g., Cui et al., 2016a), we interpret the significant difference between the first-person pain and no pain observations as indicative of the affective component of empathy. The lack of a significant difference during third-person observations suggests that this component of empathy is attenuated when observing others in pain from this perspective. Furthermore, this interaction was only seen during the pain categorization task, suggesting that this effect is specific to when participants are explicitly focusing on the pain/non-pain properties of the stimuli.

As discussed earlier, Buccioni et al. (2016) found that observing someone in pain from a third-person perspective attenuated empathic sensorimotor resonance. In addition, they also reported

that cortico-spinal activity during first-person observation of someone in pain predicted self-report ratings of body ownership (towards the stimuli) and RHI (rubber hand illusion) scores. As such, they suggest that it is a sense of body ownership that drives the effects of perspective on empathic sensorimotor resonance. They also suggest that a sense of body ownership may be due to sensory misattribution, in the sense that participants incorrectly attribute observed body parts as belonging to themselves. Mahayana et al. (2014) found that the effects of empathic sensorimotor resonance are dependent on the distance of the stimuli from the observer. When the stimuli are presented near the observer (as in most experimental setups), the effect is found; however, when the stimuli are presented at a distance (while controlling for stimulus size), the effects are attenuated. Mahayana et al. suggest that empathic sensorimotor resonance may be partially due to a misattribution of perceptual information when the stimuli are near the participant. When the stimuli are further away, this misattribution is less likely to occur.

Following this line of research, it is possible that our results can be interpreted in a similar fashion. One possibility is that observing a hand in pain from a third-person perspective decreases any sense of ownership over the observed hand and, as such, decreases the likelihood of misattribution occurring. This then leads to an attenuated effect of pain observation in the third-person. Conversely, when observing pain in the first-person, a higher likelihood of misattribution causes increased effects of pain observation. The fact that visual perspective did not influence the effect of pain in the orientation categorization task of the current study suggests that sensory misattribution only plays a role in pain observation when the painful aspects of a stimulus are attended to. When task conditions divert attention to non-pain related aspects of a stimulus (such as their orientation), the observed effect of pain observation on the N2 may not be driven by

497 sensory misattribution, but instead solely by arousal levels and negative valence; it has been shown
498 that the N2 can be elicited purely based on these low-level factors (e.g., Olofsson et al., 2008).
499 This suggests that the N2 is not as automatic as previous research (e.g., Fan & Han, 2008) suggests.
500 Rather, the evidence presented thus far suggests that the effect of the N2 on pain observation can
501 be modulated by contextual factors.

502
503 For the P3, we again found an interesting three-way interaction: larger (more positive) mean
504 amplitudes were found during pain observation compared to no-pain, specifically when the images
505 were shown from a third-person perspective, and exclusively during the pain categorization task.
506 One possible interpretation of this result (as alluded in the introduction) is that the P3 is indexing
507 additional processing necessary to recognize that the other person is in pain (e.g., perhaps a spatial
508 transformation of the stimuli from third-person to first-person). It is possible that misattribution
509 (indexed by the N2) that results from observing images in the first-person perspective is sufficient
510 for the observer to recognize pain; however, in the third-person perspective, a lack of
511 misattribution may require subsequent (controlled) processes resulting in a larger P3. As such,
512 relatively larger differences are seen between pain and no-pain observation from the third-person
513 perspective vs. the first-person. This could mean that the P3 is indexing a processing step that
514 increases pain recognition when it cannot be achieved on the basis of early affective processing
515 alone. However, it is important to note that effects of pain observation on the P3 have been found
516 when exclusively showcasing stimuli from a first-person perspective (e.g., Fan & Han, 2008) and
517 also exclusively from a third-person perspective (e.g., Cui et al., 2016b). As such, this relative
518 perspective effect may only be observed when showing both first-person and third-person
519 perspectives within a single experiment. As far as we are aware, we are the first to show both first-

and third-person perspective of pain and no-pain stimuli and to treat perspective as an explicit factor in the analysis. Nevertheless, future studies will be needed to see if the current findings hold (note that while most studies report a significant P3 effect, not all do; see Coll's (2018) meta-analysis).

It is important to note that empathy is often defined as requiring the ability to distinguish between oneself and another (e.g., Tremblay et al., 2018 – “Importantly, a prerequisite to empathy is self-consciousness, as a person must distinguish between himself and the other, to avoid confusion between his or her own feelings and the other's.” – pg. 152). However, the results of the current study suggest that the early ERP component of empathy for pain may instead index a *lack* (or a decrease) of self-other distinction: we have suggested that the N2 is primarily driven by misattribution of another's pain to one's self. This interpretation is consistent with the discussed works of Mahayana et al. (2014) and Bucchioni et al. (2016), wherein they suggest that empathic sensorimotor resonance is not exclusively driven by empathy and instead may have more to do with body ownership and/or sensory misattribution. In contrast, we have interpreted the P3 as indexing additional processing in cases where misattribution has occurred, with the end result leading to effective pain recognition at a later stage of processing. As such, it is this later ERP component that better matches our conceptual understanding of empathy. Furthermore, the misattribution that is being indexed by the N2 may primarily be due to associative learning mechanisms (e.g., Heyes, 2018): we are used to observing our hands in first-person at times when they are in pain, however, it is possible that observing our hands in third-person (e.g., using a mirror) while experiencing pain would form new associations that can lead to misattribution when observing others' in third-person. More work will be needed to determine to what extent the N2

and/or P3 are truly indexing a type of empathic processing as suggested by previous research. An interesting question for future research is whether processes involved in misattributed self pain can even be considered as empathic. This question goes to the heart of how we conceive empathy at the neurophysiological level.

Regarding reaction times, participants responded faster during the orientation task vs. the pain categorization task. This may be due to the difficulty of the tasks; judging whether someone is in pain or not may be more difficult than other control tasks (e.g., Fabi & Leuthold, 2016). Next, we found that participants responded faster when they saw the first-person vs. third-person images. However, this was qualified by a two-way interaction between Task and Visual Perspective, which suggests that this effect was only present during the orientation categorization task. When participants' attention was shifted away from the orientation of the images, this effect dissipated. This suggests that participants found it easier to categorize the images as upright than inverted when judging orientation. Lastly, we found that participants responded faster when they observed someone in pain vs. no-pain, regardless of both the perspective of the image and the task. Faster responses towards pain vs no-pain stimuli is consistent with previous findings in the literature (e.g., Fabi & Leuthold, 2016; Galang et al., 2017).

Regarding error rates, we found that participants made more errors during the orientation categorization task compared to the pain categorization task. It is unclear why this is the case; perhaps the slower responses during the pain categorization task led to fewer errors. We also found a significant interaction between Visual Perspective and Picture Valence, which suggests that more errors were made when observing someone in pain relative to no-pain when the images were

upright rather than inverted. This finding is counterintuitive as it suggests that participants are less effective at recognizing someone in pain when they see it in first-person vs. third-person. However, given that the average proportion of errors made by participants was extremely low (3.5%), we hesitate to further interpret this finding. More work will be needed to fully explore the implications of error rates in pain observation and the modulating role of visual perspective.

The lack of consistency between the ERP and behavioural results suggests that the effects of visual perspective during pain observation may only be observed at the neural level; it is possible that visual perspective exclusively modulates the early stages of processing, and as such, behavioural output is not noticeably influenced. At best our behavioural results found that participants made *more* errors were made when observing someone in pain vs. not in pain when the images were *upright*. Given that this occurred regardless of the task condition, it is unclear what the relationship is between these results and the ERP results. However, it may be worth noting that the simplistic and easy nature of the two tasks may reduce the meaningfulness of any behavioural effects. More studies will be needed to fully elucidate the relationship between behavioral and ERP results.

Finally, we found a positive correlation between the effects of pain observation on the N2 and the personal distress subscale of the IRI. However, this effect disappeared after correction (unsurprising given the large number of correlations calculated in this study). Some studies have reported significant correlations between trait measures of empathy and the ERP components of pain observation (e.g., Sessa et al., 2014, who reported that the N2 is correlated with the empathic concern subscale of the IRI). However, others do not find any such correlations (e.g., Li & Han, 2010, who did not find any significant correlations between ERP components and any of the IRI

subscales). Given the wide variety of components and time-windows used in this literature, it is difficult to compare correlation results across studies. More work will be needed to elucidate the relationship between trait measures of empathy and the ERP components of pain observation.

It could be argued that by simply rotating the images, we have added the orientation of the image as a potential alternative explanation for our results; it is possible that the smaller N2 observed in response to inverted images was due to participants having a harder time *recognizing* that the person is in pain, due simply to the inverted nature of the image. As noted, our manipulation of visual perspective is consistent with Bucchioni et al. (2016); a benefit of this approach is that, other than perspective, all other aspects of the stimuli are identical thus leading to better experimental control. Nevertheless, we concede that simply rotating the image may not lead to a “true” third-person perspective; and as such, future studies will be needed to resolve this issue.

In conclusion, the current study found that the visual perspective from which pain is observed (first-person vs. third-person) modulates ERP components that have previously been associated with empathy for pain (N2, P3). We interpret our results as showing that the early automatic component (N2) indexes a form of self-other confusion in which an other-related stimulus may be erroneously perceived as self-related. We question whether such a “misattribution to self” effect, if this is indeed what was occurring, constitutes a truly empathic response. We interpret the late cognitive component (P3) as reflecting registration of the state (i.e., in pain or not in pain) of a person viewed from a third-person perspective; in contrast, third-person viewing did not modulate early processing, potentially because the scope for self-other confusion in third-person viewing condition is low. Future research will be needed to both confirm our interpretation and determine

612 whether these ERP components are truly indexing empathic processing.

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Conflicts of Interest

The authors declare no conflicts of interest.

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