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Investigating the effects of pain observation on approach and withdrawal actions

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Abstract

Previous research has shown that observing another individual receiving a painful stimulus leads to motor facilitation as indexed by faster reaction times. The current study explores whether the *type* of action that is executed modulates this facilitation effect. Specifically, we examined whether approach-like and withdraw-like movements are differentially influenced by pain observation. In experiment 1, participants performed key presses (approach) and releases (withdraw) after observing another person in pain (vs. no pain). In experiment 2, participants used a joystick to make forward (approach) and backward (withdraw) movements after observing another person in pain (vs. no pain). Across both experiments, we did not find evidence for differential effects of pain observation on approach-like and withdraw-like movements. We do however report a robust response-general effect of pain observation on motor behaviour (i.e., faster reaction times after pain observation vs. no pain, regardless of movement type). We discuss these results in relation to the wider emotion, attention, and social neuroscience of empathy literatures.

Keywords: Pain observation; Approach; Withdrawal; Go/NoGo; Simple RT; Empathy

Word Count: 4933 (excluding references and figure captions)

1. Introduction

When observing another in pain, our own nervous system seems to activate similar regions present when we ourselves are in pain (e.g., Singer et al., 2004; Avenanti et al., 2005; Singer & Lamm, 2009; Lamm et al., 2011; Riecansky & Lamm, 2019). This "shared network" hypothesis (Singer & Lamm, 2009) suggests that such a mapping of states may form the building blocks of empathy (also see the Perception-Action Model of Empathy; Preston & de Waal, 2002; de Waal & Preston, 2017). Some evidence for the shared network hypothesis[1] comes from work using fMRI (functional magnetic resonance imaging), which has shown that observing or imagining another person in pain activates the same cortical regions (e.g., Bilateral Anterior Insular Cortex and Medial/Anterior Cingulate Cortex) that are active during the first-person experience of pain (e.g., Singer et al., 2004; Botvinick et al., 2005; Jackson et al., 2005; Lamm et al., 2011). Further evidence for the shared network hypothesis comes from work using TMS (transcranial magnetic stimulation), which has shown that observing "flesh and bone" stimuli of another person in pain (e.g., a needle stabbing a hand) leads to similar cortico-spinal activity present during the first-person experience of pain (e.g., Avenanti et al., 2005; 2010; De Coster et al., 2014; De Guzman et al., 2016).

While such neurophysiological measures shed light on the mechanisms that might underlie empathy during pain observation, they do not tell us anything about the behavioural consequences of such mechanisms. One line of research that has investigated this question has explored how

[1] We note that similar activation of cortical regions observed in fMRI cannot confirm the involvement of identical neural networks in two tasks. However, we highlight this research as it has been used in the extant literature to argue in favor of shared representations in self and other related episodes.

basic motor responses, usually in the form of a key press, are influenced by pain observation (also see Christov-Moore & Iacoboni, 2016; Christov-Moore et al., 2017). An early study by Morrison et al. (2007a) found that pain observation (i.e., a needle stabbing finger tips) leads to faster key releases and slower key presses – exclusively when the imperative cue (e.g., an orange square) to move was shown 500ms after the experimental stimuli (no effects were found when the cue was shown at 100ms). They suggested that these results could reflect an adaptive response wherein a facilitation of withdrawal (i.e., key releases) and an attenuation of approach (i.e., key presses) responses are elicited after observing another in pain.

In another study, Morrison et al. (2007b) found that key presses were facilitated after pain observation. However, in this case participants had to respond immediately after seeing the object hit or miss a hand. Faster responses were found when noxious objects (e.g., a hammer) hit the hand vs. an innocuous object (e.g., a spoon), and vs. misses of either object type. They also report that noxious misses elicited faster response times compared to innocuous misses, suggesting that merely observing a potentially harmful object near another person is enough to elicit faster response times from the observer.

More recent work has shown that observing another person in pain leads to a general and temporally extended response facilitation effect (Galang et al., 2017; Galang & Obhi, 2020). In Galang et al. (2017), participants observed videos of a hand getting stabbed by a needle or touched by a Q-tip (the same videos used in previous TMS studies; Avenanti et al., 2010). After each video, an imperative cue (i.e., an orange square) would appear that would either indicate the participant to respond or to withhold a response (i.e., a Go/No-Go task). Importantly, these cues either

appeared immediately after the video stimuli or with a 500ms delay, and participants either responded with a key press with their right index finger, or a foot press using a pedal. The former manipulation combines the temporal parameters of the effects that were found in Morrison et al. (2007a; 500ms) and Morrison et al. (2007b; immediately at the end of stimuli observation), while the latter manipulation can test for effector-specific effects (as TMS studies often report a muscle-specific effect of pain observation on cortico-spinal activity; e.g., Avenanti et al., 2005).

Galang et al. (2017) reported that participants responded faster to the imperative cue after pain observation (vs. no pain) *regardless* of when the cue was presented, and which effector was used to make a response. These results are in contrast to those reported by Morrison et al. (2007a), wherein they reported *slower* response times to key presses when the imperative cue was shown 500ms after pain observation; however, the results do seem to corroborate Morrison et al.'s (2007b) results (a general facilitation of motor responses after pain observation). The effector-general effect is also in contrast to the muscle-specific effect found in TMS studies – namely a reduced amplitude of muscle specific motor evoked potentials during pain observation; however, we do not discuss this point further here as we do so elsewhere (Galang & Obhi, 2020; also see Riecansky & Lamm, 2019). Follow-up experiments reported in Galang & Obhi (2020) corroborated these initial findings, and further showed that instructing participants to explicitly empathize with the model in the video (vs. no empathy instructions) led to stronger motor response effects.

Other recent work has largely corroborated the finding that pain observation leads to faster response times; for example, in their behavioural study, Fabi & Leuthold (2017) report that

participants responded faster (via a key press), and with more force, after observing another person in a painful situation (e.g., a hammer hitting a hand; also see Fabi & Leuthold, 2018; Galang et al., 2019). Interestingly, the stimuli were pictures (in contrast to the videos or apparent motion used in the studies described thus far) and were displayed for only 200ms. This suggests that the effects of pain observation on motor behaviour can be elicited even when pain observation occurs rapidly and for only a short duration.

Despite these recent findings that observing another in pain leads to faster responses from the observer, it remains unclear why recent studies do not corroborate Morrison et al.'s (2007a) original results: faster key releases but slower key presses. Of course, recent studies have primarily focused on key presses over releases, and most have participants immediately respond after the experimental stimuli is presented. However, Galang et al. (2017) and Galang & Obhi (2020; experiment 1) both had conditions that delayed the imperative cue by 500ms, and yet key presses were still found to be faster after pain observation. One possibility discussed in Galang et al. (2017) is that Morrison et al. (2007a) provided participants with a natural mapping of an adaptive behaviour – approach and withdraw. In contrast, all other studies essentially force participants into one movement type. As such, it is possible that, when provided with the possibility of performing more adaptive behaviours, then the pattern of results reported in Morrison et al. (2007a) emerges; in lieu of such a choice, it may be the case that *any* behavioural response will necessarily be facilitated after pain observation; we refer to this as the Natural-Mappings hypothesis throughout the paper. Note that this is an important question, as the functional significance of these response time effects have yet to be fully explored. And as such, showing that adaptive behaviours emerge as a result of pain observation (when given the opportunity) will help us shed further light on this

topic.

As such, the aim of the current study is to test the Natural-Mappings hypothesis. To do so, participants completed a Go/No-Go task responding (or not) to coloured squares. Videos of a hand getting stabbed by a needle or touched by a Q-tip (the same as those used in Galang et al., 2017 and Galang & Obhi, 2020) were interleaved between each imperative cue. Furthermore, the imperative cue either appeared immediately after the video stimuli or after a 500ms delay. To better match Morrison et al.'s (2007a) original design, in experiment 1, participants alternated between key presses (approach) and releases (withdrawal). However, in experiment 2, participants used a joystick to perform more natural approach and withdraw movements.

Given this design, the Natural-Mappings hypothesis predicts that participants will perform slower key presses/joystick forward movements and faster key releases/joystick backward movements after pain observation. A strict interpretation of the Natural-Mappings hypothesis would predict that this effect should specifically be found when the imperative cue appears after 500ms delay (matching Morrison et al.'s (2007a) original results). However, a more general interpretation predicts that such an effect will occur regardless of delay. Of course, it is also possible that the Natural-Mapping hypothesis is not supported in these experiments. In this case, however, we at the very least expect to replicate recent work and find faster responses after pain observation (vs. no pain), regardless of all other conditions.

2. Experiment 1

2.1 Methods

2.1.1 Participants

60 right-handed participants were recruited to participate in this study for course credit (male = 13; mean age = 20.4 [*SD* = 5.2]). Prior to participation, participants provided written informed consent. The study was approved by the McMaster Research Ethics Board (MREB).

2.1.2 Apparatus and Stimuli

The experiment was programmed and presented using SuperLab v4.5 (Cedrus Corporation, San Pedro, CA, U.S.A.) and was run on a Lenovo P910 ThinkStation. Participants responded to a Dell keyboard spacebar using their right index finger. We used short videos developed by Avenanti et al. (2010) depicting a Caucasian hand being stabbed by a needle or lightly touched by a Q-tip on the area of skin overlaying the first dorsal interosseous (FDI). Each Video Type (Needle vs. Q-tip) consisted of three separate videos with the colour of the syringe or Q- tip handle varying. As per Avenanti et al. (2010), this was done to minimise effects of habituation. At the end of the experiment, participants completed the Interpersonal Reactivity Index (IRI; Davis, 1980, 1983).

2.1.3 Design

The experiment used a 2x2x2 within-subjects ANOVA design, wherein Video Type (Needle, Q-tip), Movement Type (Press, Release), and Delay (Immediate, 500ms), were the factors of interest. The crossed Video Type x Delay factors (i.e., Needle-Immediate, Needle-500ms, Q-tip-Immediate, Q-tip-500ms) were fully randomized throughout the experiment; however, following Morrison et al.'s (2007a) procedures, participants alternated between Presses and Releases throughout the experiment (participants would press the spacebar and hold it until the next trial where they would then release it). To avoid possible order effects, we counterbalanced which

Movement Type participants started with across participants. Participants completed 8 blocks of 60 trials each. 80% of total trials were Go signals (384/480 trials). This leads to 48 Go trials per fully crossed Video Type x Movement Type x Delay factors (i.e., Needle-Press-Immediate, Needle-Press-500ms, Needle-Release-Immediate, Needle-Release-500ms, Q-tip-Press-Immediate, Q-tip-Press-500ms, Q-tip-Release-Immediate, Q-tip-Release-500ms).

2.1.4 Procedure

Participants first read over a letter of information going over the tasks in the study. If they were comfortable with the procedures, they were asked to sign a consent form. For the main experimental task, participants were told that they would see visual cues in the form of coloured squares. One colour (e.g., orange) would represent the Go signal, while another colour (e.g., purple) would represent the No-Go signal (the colours were counterbalanced across participants). Furthermore, they were told that they would be shown videos of a hand being stabbed by a needle or touched by a Q-tip before each visual cue. They were told to imagine "what the stimulated individuals might have felt" while watching the videos. After confirming that the participant understood the instructions, they were given 24 practice trials before beginning the main part of the experiment. The main part of the experiment consisted of 8 blocks of 60 trials each. Participants were given a self-paced break after each block. A single trial consisted of the following order of events: Fixation Cross (500ms) → Video Stimuli (1800ms) → Delay (None or 500ms) → Go Signal (Until Response)/No-Go Signal (500ms or sooner if participant erroneously responds) → ISI (500ms) (See Figure 1). Afterwards, the participants completed the IRI. Lastly, participants were debriefed about the purpose of the study before ending the experiment.

FIGURE 1 ABOUT HERE

2.2 Results

2.2.1 Reaction Times

Average mean error (responding to the No-Go signal) rate was ~4.1%. Correct reaction times less than 150ms (anticipations) or greater than 1000ms (missed trials) were removed before final analysis (~1%). The 2x2x2 repeated measures ANOVA yielded a significant main effect of Video Type [$F(1,59) = 49.8$, $p < 0.00001$, *partial-eta* = 0.46], wherein participants responded after watching the Needle videos [$M = 416$ms, $SE = 8.35$] compared to Q-tip videos [$M = 427$ms, $SE = 8.42$] (See Figure 2a); a significant main effect of Movement Type [$F(1,59) = 60.8$, $p < 0.00001$, *partial-eta* = 0.51], wherein participants responded faster when conducting a key press [$M = 400$ms, $SE = 7.78$] compared to a key release [$M = 443$ms, $SE = 9.67$] (See Figure 2b); and a significant main effect of Delay [$F(1,59) = 486$, $p < 0.0001$, *partial-eta* = 0.9], wherein participants responded faster to the Go signal when it was presented with a 500ms delay [$M = 390$ms, $SE = 8.03$] compared to no delay [$M = 453$ms, $SE = 8.89$] (See Figure 2c). We also found a significant Movement Type x Delay Interaction [$F(1,59) = 60$, $p < 0.00001$, *partial-eta* = 0.48]. This two-way interaction indicates that main effect of Movement Type (faster RTs for key presses vs. key releases) is weaker, but still significant, when the Go signal is presented with a 500ms delay [Key Release: $M = 407$ms, $SE = 9.2$; Key Press: $M = 373$ms, $SE = 7.56$; $t(59) = 6.45$, $p < 0.00001$, $d = 0.8$] compared to when it is presented with no delay [Key Release: $M = 479$ms, $SE = 10.4$; Key Press: $M = 428$ms, $SE = 8.16$; $t(59) = 8.7$, $p < 0.00001$, $d = 1.2$].

FIGURE 2 ABOUT HERE

2.2.2 IRI

The IRI is broken down into 4 subscales: Perspective Taking (PT), Empathic Concern (EC), Fantasy Scale (FS), and Personal Distress (PD). As the only significant effect related to pain observation was a main effect of Video Type, we opted to take the difference score of reaction times across the collapsed Needle and Q-tip conditions and correlate this pain observation effect with each of the IRI subscales. 1 participant did not fully complete the IRI and, thus, was not included in this analysis. No significant correlations were found [all $p > 0.3$].

2.3 Discussion

Experiment 1 provides evidence for significant main effects of all three factors. The main effect of Movement Type shows that participants responded significantly faster to the Go signal if they responded with a key press vs. a key release, which is consistent with Morrison et al. (2007a). The main effect of Delay shows that participants responded significantly faster if the Go signal appeared after a 500ms delay (compared to no delay), which is consistent with Galang et al. (2017). Crucially, the main effect of Video Type shows that participants responded significantly faster to the Go signal if it was preceded by a Needle video vs. a Q-tip video, which replicates previous work showing that pain observation leads to a general facilitation of motor responses (e.g., Galang et al., 2017; Galang & Obhi, 2020). There were no significant correlations with the IRI subscales (discussed further in "General Discussion").

Note that, given the lack of a Video Type x Movement Type x Delay or a Video Type x Movement Type interaction, the results of experiment 1 do not support the Natural-Mappings hypothesis

(indeed, we report only a significant but theoretically uninteresting Movement Type x Delay interaction effect). One possible reason for our failure to find evidence for the Natural-Mappings hypothesis is that the key presses and releases may not have been accurate enough representations of approach and withdrawal behaviour. Of course, this does not explain how such movements yielded the pattern of effects reported in Morrison et al. (2007a). Nevertheless, it is possible that having participants perform more naturalistic movements will lead to Movement Type modulation during pain observation. Experiment 2 tests this possibility.

3. Experiment 2

3.1 Methods

3.1.1 Participants

60 separate right-handed participants were recruited to participate in this study for course credit (male = 12; age = 18.2). One participant was removed and replaced due to voluntarily withdrawing halfway through the experiment, and another participant was removed and replaced due to making >95% error during the task. As we replaced both participants, our sample size remains at 60. Prior to participation, participants provided written informed consent. The study was approved by the McMaster Research Ethics Board (MREB).

3.1.2 Apparatus and Stimuli

Experiment 2 generally followed experiment 1; however, two important differences were made. First, rather than responding via the spacebar on a keyboard, participants in experiment 2 used a Joystick (Thrustmaster) to perform forward (approach) and backward (withdrawal) movements. Second, rather than completing a Go/No-Go task and alternating between key presses and releases

per trial, we opted to cue participant Movement Type via a symbol (i.e., a circle or a hexagon - counterbalanced) that appeared before each video stimuli. Participants then made simple reaction time responses to an orange square.

3.1.3 Design

Experiment 2 follows the same 2x2x2 within-subjects design used in experiment 1. However, as participants no longer needed to alternate between key presses and releases every other trial, we could now fully randomize all fully crossed conditions (i.e., Needle-Forward-Immediate, Needle-Forward-500ms, Needle-Backward-Immediate, Needle-Backward-500ms, Q-tip-Forward-Immediate, Q-tip-Forward-500ms, Q-tip-Backward-Immediate, Q-tip-Backward-500ms) throughout the experiment. Participants completed 8 blocks of 40 trials. This leads to 40 trials per fully crossed conditions.

3.1.4 Procedure

Experiment 2 generally followed the same procedures as experiment 1. However, rather than being instructed on key presses and releases, participants were first trained to perform an approach or withdrawal movement with a joystick. At the start of the experiment, we instructed participants to either move the joystick forward if they saw one symbol (e.g., a circle) and move it backwards if they saw different symbol (e.g., a hexagon). We counterbalanced symbol-movement associations across participants. They were given 12 practice trials to get used to this association. The main part of the experiment consisted of 8 blocks of 40 trials each. Participants were given a self-paced break after each block. A single trial consisted of the following order of events: Forwards/Backwards Symbol (2000ms) → Fixation Cross (1000ms) → Video Stimuli (1800ms)

→ Delay (None or 500ms) → Response Cue (i.e., an orange square; until response) → ISI (500ms) (See Figure 3). Participants completed the IRI before finishing the experiment.

FIGURE 3 ABOUT HERE

3.2 Results

3.2.1 Reaction Times

Average mean error (making the wrong movement type) rate was ~5.2%. Correct reaction times less than 150ms (anticipations) and greater than 1000ms (missed trials) were removed before final analysis (~6.9%). The 2x2x2 repeated measures ANOVA yielded a significant main effect of Video Type [$F(1,59) = 26.9$, $p < 0.00001$, *partial-eta* = 0.31], wherein participants made faster responses after viewing the Needle videos [$M = 483$ms, $SE = 9.19$] compared to Q-tip videos [$M = 495$ms, $SE = 9.04$] (See Figure 4a); a significant main effect of Movement Type [$F(1,59) = 20.9$, $p = 0.00002$, *partial-eta* = 0.26], wherein participants made faster backward movements [$M = 482$ms, $SE = 8.43$] compared to forward movements [$M = 497$ms, $SE = 9.88$] (See Figure 4b); and a significant main effect of Delay [$F(1,59) = 623$, $p < 0.00001$, *partial-eta* = 0.91], wherein participants made faster responses when the imperative cue was shown after a 500ms delay [$M = 442$ms, $SE = 8.6$] compared to no delay [$M = 536$ms, $SE = 9.8$] (See Figure 4c). We also found a significant Movement Type x Delay interaction [$F(1,59) = 11$, $p = 0.0016$, *partial-eta* = 0.16]. This two-way interaction indicates that the main effect of Movement Type (faster backward movements compared to forward) is being driven primarily by the no delay condition [Forward: $M = 547$ms, $SE = 10.6$; Backward: $M = 525$ms, $SE = 9.2$; $t(59) = 5.9$, $p < 0.00001$, $d = 0.77$] compared to the 500ms delay condition [Forward: $M = 446.2$ms, $SE = 9.6$; Backward: $M = 438$ms,

SE = 8.1; $t(59) = 1.94$, $p = 0.057$].

FIGURE 4 ABOUT HERE

3.2.2 IRI

Following experiment 1, the only significant effect related to pain observation was a main effect of Video Type, and as such, we opted to take the difference score of reaction times across the collapsed Needle and Q-tip conditions and correlate this pain observation effect with each of the IRI subscales. 3 participants did not fully complete the IRI and, thus, were not included in this analysis No significant correlations were found [all $p > 0.23$].

3.3 Discussion

Experiment 2 yielded the same pattern of results as experiment 1: a significant main effect of Movement Type, which shows that participants made faster backward movements compared to forward movements; a significant main effect of Delay which shows that participants made faster overall movements if the response cue was delayed by 500ms (compared to no delay); and a significant main effect of Video Type, wherein participants made faster overall movements after observing the Needle videos vs. Q-tip videos. We again found no significant correlations with the IRI subscales (discussed further in "General Discussion"), and crucially, we found no evidence supporting the Natural-Mappings hypothesis (although we again found a significant but theoretically uninteresting Movement Type x Delay interaction effect).

4. General Discussion

The aim of the current study was to empirically test the Natural-Mappings hypothesis, which predicts that, when participants are aware that there is a possibility of performing adaptive behaviours, pain observation should lead to slower approach-like movements and faster withdraw-like movements. Neither experiment 1 nor experiment 2 yielded data to support this hypothesis. Instead, the results corroborated recent work showing that pain observation leads to a response-general facilitation effect of motor behaviour (e.g., Galang et al., 2017; Galang & Obhi, 2020; Fabi & Leuthold, 2017). Given this, we can now state with some confidence that pain observation does *not* differentially facilitate adaptive approach/withdraw movements. Thus, such adaptive behaviour cannot be used to explain the functional significance of motor facilitation after pain observation.

There at least two possibilities for what the functional significance of this effect could be. One possibility arises out of work by Han et al. (2017), which has recently shown that motor facilitation as a result of pain observation, in the form of a stronger response force, may be functionally related to inducing self-distress relief via attenuating neural responses (specifically the bilateral secondary somatosensory cortex) associated with pain observation. Such a mechanism may enhance empathic experiences towards another in pain, as current models of empathy suggest that, to appropriately empathize with another, one must focus on the other's state and not confuse it with one's own (e.g., Bird & Viding 2014). This self to other shift in attention may become easier if one's own distress is not distracting, and as such, having a mechanism to decrease one's own distress would be useful if one were attempting to empathize with another. It is important to note, however, that Han et al. (2017) had participants respond (and continue to respond) by pressing a key *during* pain observation, and their main dependent variable indexing motor facilitation was

response force. As such, it is unclear whether motor facilitation, as indexed by reaction times, *after* pain observation provides the same self-relief mechanism.

The other possibility comes from work showing that higher arousal levels can lead to faster reaction times (e.g., Martinie et al., 2010). As such, it is possible that the general motor facilitation effects seen in these (and previous) studies is primarily due to general arousal levels increasing while watching the Needle videos, which then leads to faster reaction times when responding to the imperative cue. While this might at first appear to be a plausible explanation, it is important to note that high arousal does not always lead to faster reaction times. For example, work by de Houwer & Tibboel (2010) found that participants responded slower to a Go signal after observing a highly arousing image (both negatively and positively valanced). This comparison between de Houwer & Tibboel (2010) and motor facilitation after pain observation effects (e.g., Galang et al., 2017) is apt, as both use similar paradigms: in both cases, participants completed some sort of reaction time task (e.g., Go/No-Go Task), however, whereas previous motor facilitation after pain observation studies (e.g., Galang et al., 2017) showed videos of either a needle stabbing a hand or a Q-tip touching a hand before each imperative cue, de Houwer & Tibboel (2010) instead showed pictures from the International Affective Picture System (IAPS; Lang et al., 2008) (also see Vergruggen & de Houwer, 2007). They provide an attentional account of these results, pointing out that high emotional/arousing stimuli command more attentional resources, and as such, detract from attentional processing of a subsequent cue (e.g. a Go signal). As such, if our results were due to high arousal levels, we ought to have found *slower* reaction times after pain observation – given that we found the opposite, de Houwer & Tibboel's (2010) results provide some evidence that the current results are not solely due to arousal levels.

It should also be noted that differences in stimuli may have also affected the current results when compared to those reported by Morrison et al. (2007a): whereas the current experiments used stimuli of a hand getting stabbed by a needle (or touched by a Q-tip) in the first dorsal interosseous, Morrison et al. (2007a) used stimuli of a hand getting stabbed/touched on the finger tips; furthermore, the former stimuli were shot from an 1st person perspective, while the latter from a 3rd person perspective. As such, it is possible that such differences may have played a role in our results contrasting those of reported by Morrison et al. (2007a). Future studies will be needed to see if location of painful stimulation and the perspective of the observed pain influences approach and withdraw like movements during pain observation.

It is also interesting to note that previous work in the emotion and attention literature has shown that positive-valenced and negative-valenced stimuli are mapped on to approach-like and withdraw-like movements, respectively (e.g., Duckworth et al., 2002; Warriner et al., 2017; Fini et al., 2020). As such, in addition to de Houwer & Tibboel's (2010) results, the fact that the current experiments do not provide evidence for this mapping emphasizes a discrepancy between the pain observation and emotion and attention literatures. One might wonder if the type of stimuli used in each paradigm plays a role in this discrepancy; whereas those in the latter use emotional pictures and words, those in the former prefer videos. However, note that previous work showing others in pain via a picture format have yielded the same motor facilitation after pain observation effects found in their video stimuli counterparts (e.g., Fabi & Leuthold, 2017; Fabi et al., 2018; Galang et al., 2019). As such, it is unlikely that the stimulus format is the key factor driving this discrepancy. Future work will be needed to shed further light on this issue.

Regarding the lack of significant correlations between the IRI subscales and the motor facilitation effect found in both experiments – this finding corroborates what has been reported in previous work (Galang et al., 2017; Galang & Obhi, 2020). Note that one might argue that the lack of significant correlations is due to not having a sufficiently large sample size, and indeed, a sensitivity analysis via G*Power (Faul et al., 2007; 2009) shows that n = 60 is sensitive enough to detect $r = 0.3$ (medium effect size) at 65% power and $r = 0.2$ (small effect size) at 33% power. As such, there could possibly be an association that the current (and past) studies are not sensitive enough to detect. However, Hedge et al. (2018) have recently shown that cognitive tasks, such as the Go/No-Go task, are not well suited for correlation analysis, as cognitive tasks are designed to limit between-subjects variance, while trait measures emphasize between-subjects variance (also see Dang et al., 2020). As such, it is possible that the behavioural tasks used in the current experiments (and past studies) are not suited to detect individual differences in trait levels of empathy. More work will be needed to further explore this topic.

It is also interesting to connect the current behavioural results with the neurophysiological indices of skeletomotor activity during pain observation (Riecansky & Lamm, 2019). One such measure is the use of TMS to explore cortico-spinal activity during pain observation – interestingly, this approach shows that there is a muscle-specific *decrease* in cortico-spinal activity during pain observation (e.g., Avenanti et al., 2005). This contrasts with the motor facilitation effect reported in the behavioural literature; however, given that this reaction time effect occurs *after* pain observation, and the TMS effect occurs *during* pain observation, it is possible that there is a muscle-specific decrease in activity during pain observation which leads to a response-general

motor facilitation effect after pain observation. Furthermore, previous TMS research has shown that the direction of cortico-spinal excitability varies as a function of personal distress, with lower personal distress predicting cortico-spinal *inhibition* during pain observation (and vice versa for higher personal distress; e.g., Avenanti et al., 2009; De Coster et al., 2014; de Guzman et al., 2016). Given that trait-levels of personal distress do not seem to correlate with the behavioural results of pain observation, it is possible that the behavioural and TMS results are not tightly related.

Interestingly, and in contrast to TMS studies, EEG (electroencephalography) studies have found stronger desynchronization in the *Beta* and *Mu* frequency bands during pain observation (e.g., Yang et al., 2009; Fabi & Leuthold, 2017; Riecansky et al., 2015; 2019). As *Beta* and *Mu* desynchronization are thought to index increased motor and somatosensory activity, respectively (e.g., Pfurscheller et al., 1999; Fox et al., 2016; although see: Coll et al., 2015; Coll et al., 2017), these results suggest that there is an increase in sensorimotor activity *during* pain observation. As such, while contrary to TMS studies, these results better match their behavioural counterpart: increased sensorimotor activity during pain observation leads to motor facilitation after pain observation. However, no work that we are aware of has explicitly explored the relationship between these measures and behavioural responses; and as such, future work will be needed to fully explicate this relationship. Furthermore, while we did not find evidence for the Natural-Mappings hypothesis at the behavioural level, it is possible that differential effects of approach-related and withdraw-related movements may be observed with neural measures of empathic pain observation (e.g., TMS, Mu/Beta desynchronization, etc.). For example, including EEG to the current experimental set-up would have allowed us to observe whether preparing an approach vs. withdraw movement during pain observation influences Mu/Beta synchronization (also see Fini et

al., 2020 for recent work suggesting a direct link between positive/negative valenced stimuli and approach/avoidance tendencies, respectively, using TMS). Future studies will be needed to explore this possibility.

In conclusion, both experiments reported in this study did not find evidence to support the Natural-Mappings hypothesis. Instead, participants showed a response-general effect of pain observation on motor behaviour, such that they responded faster after observing someone in pain (vs. no pain), regardless of movement type. Future work is still needed to fully explicate the functional significance of this effect.

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Conflicts of Interest

The authors declare no conflicts of interest.

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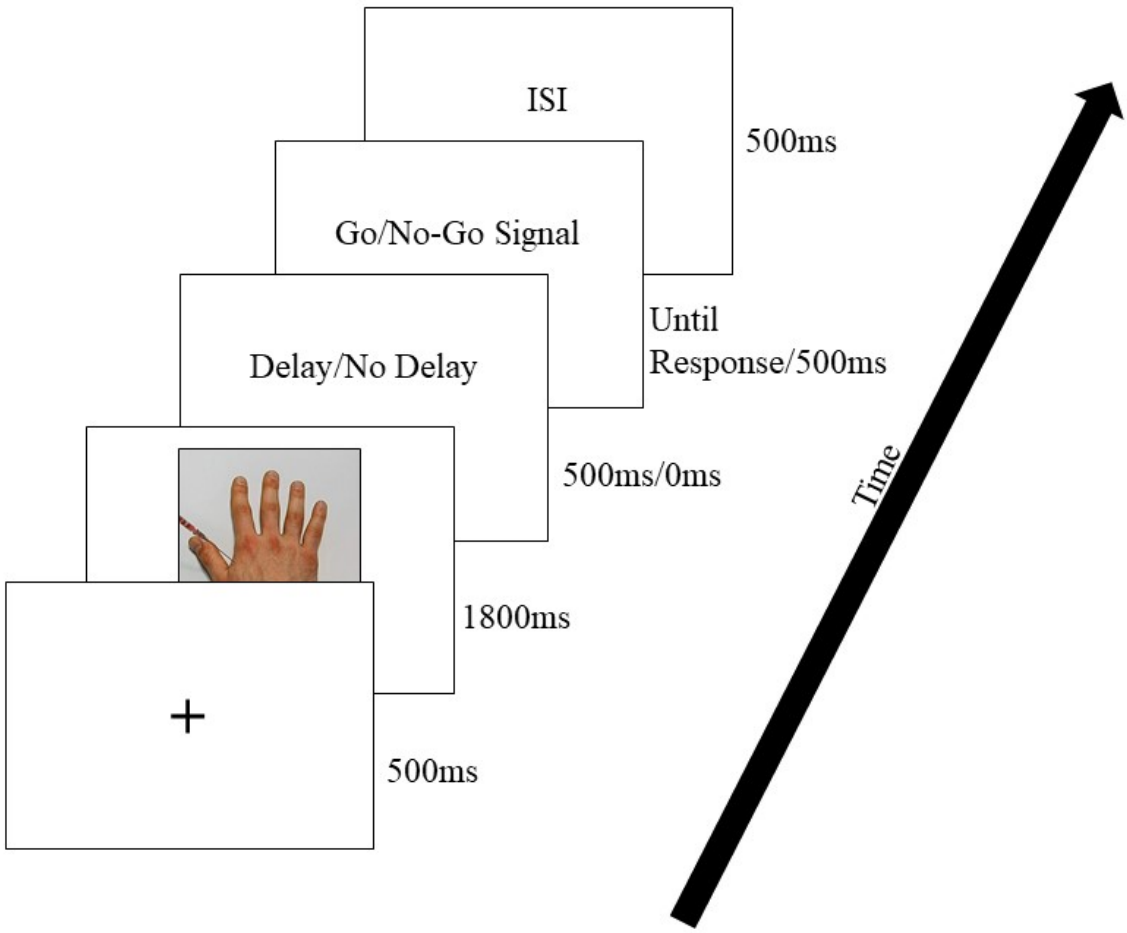

FIGURE 1. Schematic of a single trial in Experiment 1.

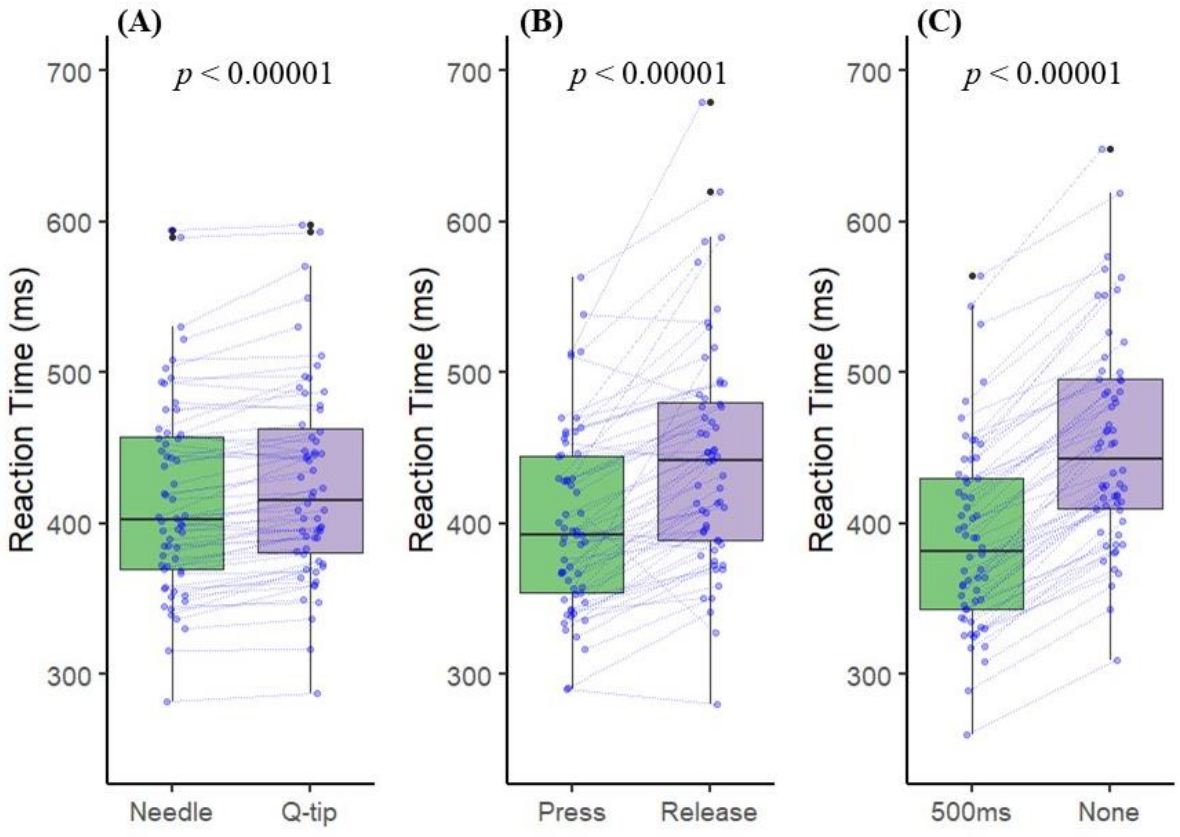

FIGURE 2. (A) Boxplot showcasing the main effect of Video Type (Needle vs. Q-tip). (B) Boxplot showcasing the main effect of Movement Type (Press vs. Release). (C) Boxplot showcasing the main effect of Delay (500ms, None). Each blue dot represents a single participant. The dotted line connects participant reaction times across conditions.

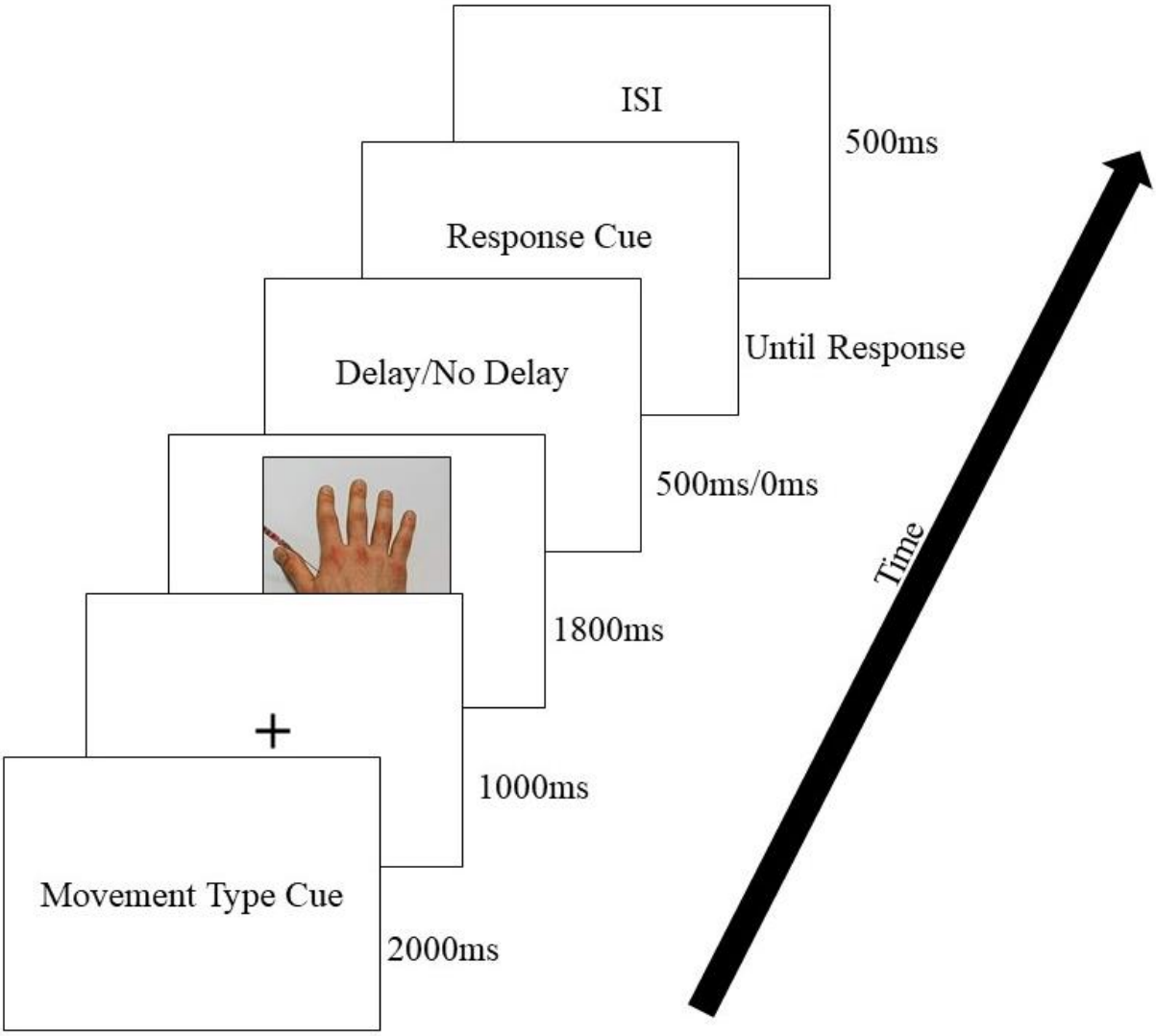

FIGURE 3. Schematic of a single trial in Experiment 2.

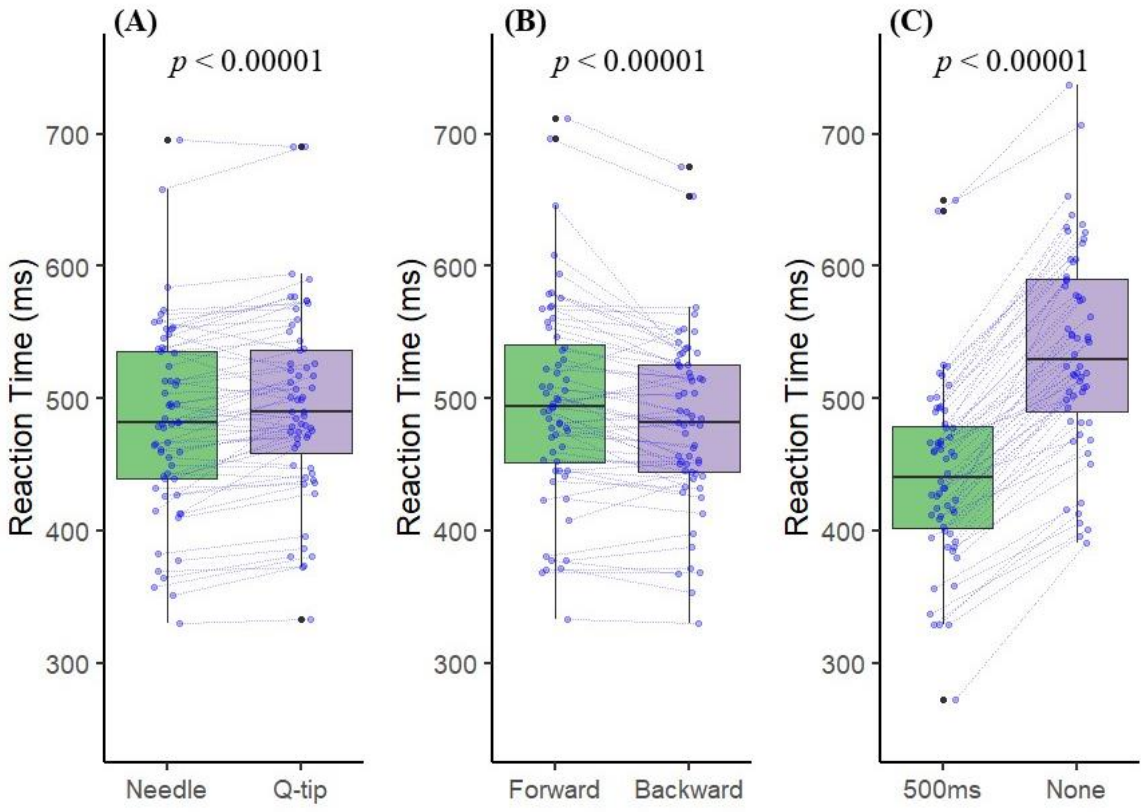

FIGURE 4. (A) Boxplot showcasing the main effect of Video Type (Needle vs. Q-tip). (B) Boxplot showcasing the main effect of Movement Type (Press vs. Release). (C) Boxplot showcasing the main effect of Delay (500ms, None). Each blue dot represents a single participant. The dotted line connects participant reaction times across conditions.