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Original experimental

# An investigation into enlarging and reducing the size of mirror reflections of the hand on experimentally-induced cold-pressor pain in healthy human participants

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## HIGHLIGHTS

- Mirror visual feedback produces relief of pain.
- We assessed different sized hand reflections on cold-pressor pain.
- Changing the size of mirror reflections of the hand did not affect pain variables.
- Studies on relationships between embodiment, reflections and pain are needed.

## ARTICLE INFO

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## ABSTRACT

**Background and aims:** Mirror visual feedback may be a useful clinical tool for reducing pain. Research suggests that reducing the size of a non-painful reflected hand can alleviate complex regional pain syndrome in the affected hand that is out of view. In contrast, research on healthy humans exposed to experimentally induced pain suggests that reducing the appearance of the size of a reflected body part can increase pain. The aim of this study was to investigate the effect of enlarging and reducing the visual appearance of the size of a hand using mirror visual feedback on pain threshold, intensity and tolerance in healthy human participants exposed to cold-pressor pain.

**Methods:** Participants were a convenience sample of 20 unpaid, healthy pain free volunteers aged 18 years or above. Each participant took part in one experiment where they completed cold-pressor pain tests whilst observing normal, enlarged and reduced size reflections of a hand congruent to a hand immersed in the ice cold water. A $4 \times 2$ factorial repeated measures analysis of variance (ANOVA) was performed on time to pain threshold and pain tolerance, and pain intensity with Condition (four levels: no reflection, reduced reflection, normal reflection, enlarged reflection) being the within-subject factors and Sex (two levels: female, male) between-subject factors.

**Results:** There were no significant effects for Condition, Sex, or Condition $\times$ Sex interaction for pain threshold, intensity or tolerance ($p > 0.05$). There were no significant differences between the 3 mirror reflection conditions for agreement with the statements: "It felt like I was looking directly at my hand rather than at a mirror image"; "It felt like the hand I was looking at was my hand"; and "Did it seem like the hand you saw was a right hand or a left hand?".

**Conclusion:** Enlarging or reducing the size of a hand using mirror visual feedback did not alter pain perception in healthy human participants exposed to cold-pressor pain. The different sizes of hands generated by mirror visual feedback created an illusion of looking at their own hand but this was not as strong as looking directly at the hand.

**Implications:** In future, investigators and clinicians using mirror visual feedback may consider including an adaptive phase to ensure the reflection has been perceptually embodied. Reasons for the lack of effects are explored to inspire further research in the field.



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## 1. Introduction

Pain is a complex sensory, emotional and cognitive phenomenon that is influenced by a variety of biopsychosocial factors including fear, anxiety, attention and expectation. Painful conditions including phantom limb pain and complex regional pain syndrome are known to distort the sense of body image [1–3]. In complex regional pain syndrome the affected limb may be perceived as large, swollen, heavy or stuck in one position and this may lead to neglect and/or learned non-use of the limb [4,5]. Pain perception can be modulated by observing a mirror reflection of a non-painful limb whilst a painful limb is hidden behind the mirror (i.e. out of view), termed mirror visual feedback (mirror therapy). Mirror visual feedback using normal size reflections of non-painful limbs has been found to reduce clinical and experimentally-induced pain of hands and feet [6–10].

The findings of studies on patients in pain suggest that reducing the visual appearance of the size of the painful body part reduces pain. Moseley et al. [11] used binoculars to change the visual appearance of chronically painful hands and found that enlarging the view of the hand increased pain and swelling evoked by movement and reducing the view of the hand decreased pain and swelling evoked by movement. Ramachandran et al. [12] used mirror visual feedback to reduce the size of a reflected hand and found that this reduced phantom limb pain. In contrast, a study using healthy human participants by Mancini et al. [13] found that enlarging a reflected view of the hand reduced experimentally-induced contact heat pain (i.e. increased pain threshold) and reducing the size of the reflected view of the hand pain increased pain. One possible reason for the difference in findings was that there were no cues of the presence of injury or of an impending noxious threat in the study by Mancini et al. [13] because the Peltier-type contact thermode used to elicit experimental heat pain was visually inert.

Studies using experimentally induced pain afford a greater degree of control over the environment reducing the impact of confounding variables and maximizing the internal validity of the research [14]. Experimentally induced cold-pressor pain involves immersing an extremity into iced water to produce a deep aching pain. Cold-pressor pain has excellent test-retest stability to assess pain threshold and pain tolerance in student populations [15] and generates higher pain intensity ratings than contact thermode-delivered cold stimuli [16]. Most individuals expect exposure to ice to generate pain and therefore cold-pressor pain is likely to be perceived as a more authentic noxious stimulus than that delivered by a contact thermode. The aim of our study was to compare the effect of enlarging and reducing the visual appearance of a hand using mirror visual feedback on pain threshold, intensity and tolerance in healthy human participants exposed to cold-pressor pain.

## 2. Methods

### 2.1. Study design

A repeated measures crossover design was used to compare pain threshold, intensity and tolerance response whilst participants observed a normal size, enlarged size and reduced size reflection of their hand. Ethical approval was received from the Research Ethics Committee of Leeds Beckett University.

### 2.2. Recruitment of participants

A convenience sample of 20 unpaid, healthy pain free volunteers aged 18 years or above were sought based on previous similar study design [13]. The study was advertised to staff and students at our university using a poster and announcements in lectures. The recruitment protocol included initial screening for eligibility when volunteers expressing interest in the study made initial contact with the investigators. At this time volunteers expressing interest received a participant information pack that stated "*During the experiment you will take part in four tests. Each test involves you placing your hand in a container filled with crushed ice and water. Whilst your hand is placed within the iced water you will observe a reflection of your other hand in a mirror that is attached to the side of the container with the iced water. We will be measuring your pain threshold and pain tolerance during each test. We will also be altering the visual appearance of the size of the reflected hand for each test.*" (Supplementary Appendix 1). Then they were given 48 h to consider participation before a formal invitation to enrol in the study was made. Block randomisation was used to allocate equal numbers of women and men into the study because there is evidence of gender differences in response to cold-pressor pain [17,18]. There was no restriction on ethnicity although this was recorded.

Each participant attended our pain research laboratory for one experimental visit lasting no longer than two hours. Each experiment was conducted by the principal investigator (MG: 28 year old male, physiotherapist, Indian national) who was fluent in English language and who read instructions verbatim from a crib sheet that ensured that there were no leading statements that could bias outcome. On arrival participants were greeted and briefed about the study, including hazards and control measures. They were then screened for eligibility against a list of self-exclusion criteria. Volunteers were requested not to take part in the study if they did not consider themselves 'healthy', had a long-term illness, were currently seeking medical care, were experiencing pain or sensory disturbances, taking any medication, were known to be pregnant, had a dermatological condition or participated in sports that involved regular exposure of hands to cold (e.g. <5 °C) conditions. Eligible volunteers were then enrolled by signing a written consent form. Participants were reminded that they could withdraw consent at any time and without reason and that they could stop the experimental pain stimulus at any time during the experiment by removing their hand from the ice-water slurry.

### 2.3. Experimental procedure

Each participant took part in one experiment that measured pain threshold, intensity and tolerance response in a hand immersed in ice-water slurry under four conditions (Fig. 1):

- Whilst viewing the painful (immersed) hand (i.e. no reflection control)
- Whilst viewing a normal size reflection of a hand aligned with the painful (immersed) hand (i.e. normal mirror image)
- Whilst viewing an enlarged size reflection of a hand aligned with the painful (immersed) hand (i.e. enlarged size mirror image)
- Whilst viewing a reduced size reflection of a hand aligned with the painful (immersed) hand (i.e. reduced size mirror image)

Block randomization was used to sequence the order of presentation of the four experimental conditions between participants (operationalized using computerised random numbers and sealed enveloped) and a washout period between conditions of 5 min was used to minimise contamination of findings from potential carry-over effects and a learning effect from repetitive exposure to cold pressor pain.

#### 2.3.1. Cold pressor pain

During each cold-pressor pain test the participant sat on a seat with both arms resting on a desk and flexed at the elbows. They then immersed their non-dominant hand (19 left hand, 1 right hand) in warm water maintained at 37 °C for 3 min to neutralize hand