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# Perceptual bias in pain: A switch looks closer when it will relieve pain than when it won't

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ABSTRACT

Pain is fundamental to survival, as are our perceptions of the environment. It is often assumed that we see our world as a read-out of the sensory information that we receive; yet despite the same physical makeup of our surroundings, individuals perceive differently. What if we "see" our world differently when we experience pain? Until now, the causal effect of experimental pain on the perception of an external stimulus has not been investigated. Eighteen (11 female) healthy volunteers participated in this randomised repeated-measures experiment, in which participants estimated the distance to a switch placed on the table in front of them. We varied whether or not the switch would instantly stop a stimulus, set to the participant's pain threshold, being delivered to their hand, and whether or not they were required to reach for the switch. The critical result was a strong interaction between *reaching* and *pain* [$F(1, 181) = 4.8$, $P = 0.03$], such that when participants experienced pain and were required to reach for a switch that would turn off the experimental stimulus, they judged the distance to that switch to be closer, as compared to the other 3 conditions (mean of the true distance 92.6%, 95% confidence interval 89.7%–95.6%). The judged distance was smaller than estimates in the other 3 conditions (mean ± SD difference >5.7% ± 2.1%, $t(181) > 3.5$, $P < 0.01$ for all 3 comparisons). We conclude that the perception of distance to an object is modulated by the behavioural relevance of the object to ongoing pain.


## 1. Introduction

As an experience that signals the need to take action to protect the tissues of our body, pain is crucial to survival. The perception of our world is also fundamental to survival [30,39]. Indeed, the complex interplay of signals, from both within our own body and from the external environment, provides powerful homeostatic drives, which motivate and shape human behaviour [7,18].

Environmental cues can have an impact on pain; whether it is associations with colour [1,15,24] or the timing of nociceptive stimuli [6], it seems that if we attribute particular meaning to aspects of our environment, the experience of pain is modified [22,23]. In this sense we update our position through learning processes, forging generalisations that extend beyond the initial noxious stimulus to nonnoxious stimuli [21,37,38] that consequently result in pain. Yet, what if the experience of pain alters the meaning and indeed the perceptions we hold of the environment? That is, does experiencing pain involve preconscious sensory processing that changes the information from our environment before our perception of that information emerges into consciousness?

Preconscious processing allows relevant inferences to be made about one's environment. We are able to quickly interpret noisy bottom-up signals to form a unitary experience [40]. However, these signals are subject to top-down effects, whereby information is weighted according to the prior state of the person and the predicted outcome [12,13]. The mismatch between the expected and the actual outcome is described as prediction error [10,29,33]; a concept not only essential in learning, but also in understanding how our perceptions are not accurate read-outs of the sensory signals we receive. Rather, they are modified interpretations of these signals, a process that occurs prior to conscious awareness [8].

It has been shown that people who experience chronic knee pain demonstrate a perceptual bias, perceiving the distance required to walk to a target as further away than people who do not experience knee pain [39]. Considering the classical approaches to perception [11,12,14], this finding stresses the

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importance of considering the effect that experiencing pain has on information processing and consequently, on the way we see our environment.

In the present study, we investigated whether pain modulates our perceptions, altering the way we perceive our environment, in a manner that is consistent with optimising protection. Using an experimental pain and relief paradigm, we tested the hypothesis that if one experiences pain and estimates the distance to a switch that can deliver complete analgesia, the switch would seem closer than when one is not experiencing pain.

## 2. Materials and methods

### *2.1. Participants*

A convenience sample of 18 healthy naïve volunteers participated (11 female; mean: 21 years; SD ± 2). Participants were excluded on the basis of a history of pain lasting more than 3 months or pain present at the time of testing. All participants confirmed no abnormal neurological symptoms and provided written informed consent. The experimental protocol was approved by the ethics committee of the University of South Australia and conformed to the Declaration of Helsinki and the Australian Code for the Responsible Conduct of Research.

### *2.2. Experimental environment*

Each test was conducted within a large, multipurpose laboratory; ceiling lighting, room temperature, and personnel were consistent throughout the testing. Each piece of equipment used, including the table, Medoc system (Medoc Ltd, Ramat Yishai, Israel; http://www.medoc-web.com), camera, and chairs remained in situ for the entire duration of the experiment. Uninterrupted access was established for the testing, although additional, unrelated equipment was stored behind a screen in the corner of the room.

### *2.3. Stimulus material and apparatus*

A noxious heat stimulus was delivered using a Medoc system with a Pathway ATS thermal pain model, driven by TSA-2001 software via a laptop. Individual heat pain thresholds were established using the threshold by limits method (see Section 2.4.1.). A common wireless computer mouse was the switch in each condition.

### *2.4. Assessments*

#### *2.4.1. Pain threshold*

Prior to testing, the heat pain threshold of each participant was determined. The thermode (30 × 30 mm) was placed on the back of the participant's nondominant hand, with the standard control button held in their dominant hand. We informed the participant that the temperature of the thermode would steadily increase and that when the stimulus first became painful, (s)he was to click the control switch, which would return the temperature of the thermode to baseline temperature (30°C). This process was repeated 4 times. Pain thresholds were calculated by averaging outcomes of trials 2–4. The temperature of trial 1 was discarded to allow for habituation.

#### *2.4.2. Distance estimates*

Participants were shown a 1-cm measure followed by a metre rule; these were removed prior to testing. Participants were instructed to verbalise a distance estimate (to the nearest centimetre) from their nondominant hand to the base of the switch that was placed at varying distances, within an arm's reach, in front of them.

### *2.5. Experimental protocol*

We used a 2 (reach/no-reach) × 2 (pain/no-pain) factorial repeated-measures design, including 4 conditions, which were run within-subjects in a random order. In each condition, the participant was instructed to place both hands behind a line drawn on a large, blank table and close his/her eyes. The investigator placed the switch randomly at 5 set distances: 25 cm, 30 cm, 35 cm, 40 cm, and 45 cm; live video feedback via a ceiling-mounted Webcam linked to a laptop was used to guide accurate placement. The participant was blinded to the predetermined distances and the visual feedback throughout the trial. In each condition the switch was placed 10 times, twice at each distance. The participant was allocated 3 seconds to view the distance before being asked to provide a prompt distance estimate (Fig. 1).

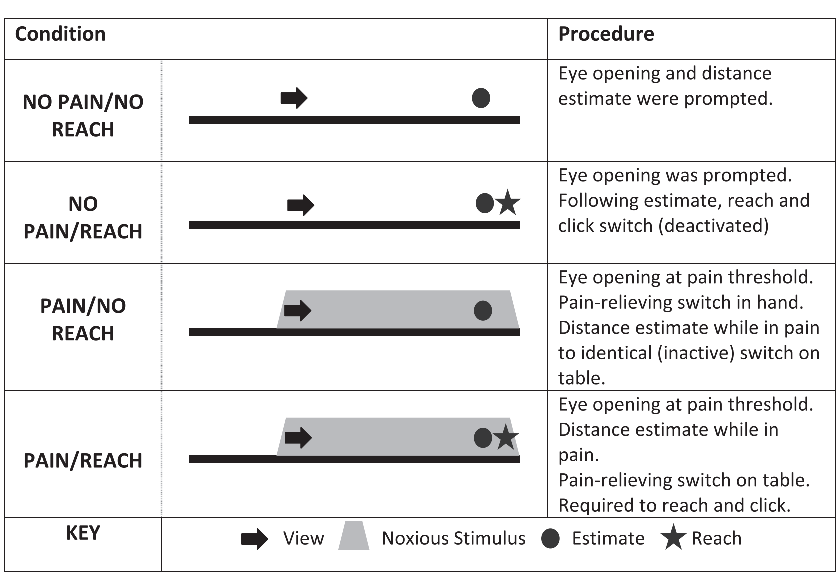


**Fig. 1.** Testing procedure.

### 2.6. Statistical analysis

All analyses were conducted using PASW Statistics (v18.0.0; IBM Corporation, Armonk, NY, USA). The primary hypothesis was tested using a 2 (reach/no-reach) × 2 (pain/no-pain) repeated-measures factorial analysis of variance on the estimated distance to the switch, which was expressed as a percentage of the true distance to the switch. If the data did not meet the assumptions of parametric statistics, the equivalent nonparametric tests were used. Partial $\eta^2$ was used as an estimate of effect size. Significance of all statistical tests was set at $\alpha = 0.05$.

## 3. Results

### 3.1. Testing the primary hypothesis

The mean threshold temperature at which participants reported pain from the heat stimulus was 48.6°C (SD ± 2.8).

When participants experienced pain and estimated the distance to a control switch that could deliver complete pain relief, they judged the switch to be closer than when they were not experiencing pain. The critical result was an interaction between reaching and pain [$F(1, 181) = 4.8$, $P = 0.03$]. That is, the estimated distance was lower when participants were experiencing pain and they needed to reach to the switch to turn off the noxious stimulus and thus relieve their pain (mean 92.6%, 95% confidence interval [CI] 89.7%–95.6%) than in any of the other 3 conditions [mean ± SD difference >5.7% ± 2.1%, $t(181) > 3.5$, $P < 0.01$ for all 3 comparisons]. The interaction between reach and pain explained 2.6% of the variance over and above that explained by either reach or pain (partial $\eta^2 = 0.026$).

The complete results show a significant effect of reaching. Estimated distance was lower when participants needed to subsequently reach for the switch (mean estimated distance/true distance 95.5%, 95% CI 93.1%–97.9%) than when they did not [mean 99.7%, 95% CI 97.3%–102.1%; main effect of reaching: $F(1, 181) = 11.46$, $P = 0.001$]. There was also a significant effect of pain – estimated distance was lower when participants were in pain (mean 95.9%, 95% CI 93.4%-98.3%) than when they were not in pain [mean 99.3%, 95% CI 96.9%-101.7%; main effect of pain: $F(1, 181) = 7.16$, $P = 0.008$]. However, visual inspection of the data clearly shows that both main effects were driven to a large extent by the interaction (Fig. 2).

## 4. Discussion

We aimed to determine whether experimental pain modulates our perceptions, altering the way we perceive our environment, in a manner that is consistent with optimising protection. We hypothesised that if one experiences pain and estimates the distance to a switch that can deliver complete analgesia, then they would underestimate that distance in comparison to when they are not experiencing pain. Our results support this hypothesis and provide clear evidence of an experimental pain state altering the perception of distance in our peripersonal environment. We postulate that there is a relative underestimation of distance associated with a switch that relieves the pain of the observer because of a perceptual bias that aids protection. That is, we see what we need, in this case a pain-relieving switch, as closer because this illusion encourages behaviour to interact with the object. This bares a direct opposite relation to the effect of chronic pain on perceptual alteration [39], where if a stimulus is associated with the generation of pain, it might be seen as further away than it really is. Taken together, these studies represent an important shift in our approach to understanding pain – as an experience that alters the way we fundamentally ‘‘see'' our environment.

A causal relationship between external cues and pain has already been widely demonstrated [6,15,24], supporting the notion that specific elements of our environment influence the pain we experience. In such cases, the emphasis has been placed on the effect of attributing meaning to stimuli and its subsequent effect on the pain response. The paradigm used in this study offers a different, although not exclusive, perspective. That is, experiencing pain itself alters the inference of the stimulus in the first instance so that we have an altered perspective of our environment. In this respect, the state of the person and the relationship they have with their environment is the key factor in determining how the environment is viewed [34]. In applying this theory, we touch on an important concept in modern neuroscience, that is, the perception of the world around us is uniquely constructed from experience, current information, and prediction [4,17,41]. From this view, the causal relationship between the person and their environment becomes less clear; promoting a cyclical model that is constantly updated depending on the integration of prior state and incoming information [9,16,20].

This is intriguing when we look at those people who suffer from persistent pain and the way that they view and interact with their environment. On the basis of our current findings and those of Witt et al. [39], it is conceivable that a persistent pain sufferer may view their environment with a form of perceptual bias, or in Bayesian terms, particular priors [5,13]. For example, stairs may appear steeper or a cupboard may seem higher, if these activities are associated with the exacerbation of pain; in these cases, a perception may be created to discourage activities that may cause pain, attempting to maintain or return the person to a pain-free equilibrium.

In the same vein, this study highlights the importance of looking beyond the salience of stimuli and their subsequent effects on the experience of pain, and further consider why particular stimuli are considered valent due to the prior state of the person. Perceptual bias may be essential for the protection of ourselves, allowing us to see the world in relation to our state in a way that avoids constant conscious evalutation of sensory input [8,40]. However, it poses a potential barrier when pain persists, when it is possible that continually updated and altered perceptions discourage interaction at a preconscious level and manifest as unhelpful alterations in behaviour and activity.

It is important to note that our protocol investigated only perceived distances within peripersonal space. As such, we are unable to confirm whether our results would be replicated with distances beyond this spatial boundary. We postulate that if the conditions remained the same and interaction within one's extrapersonal environment resulted in a positive outcome, the effect would stand. Conversely, if the interaction was considered costly, the effect would be in the opposite direction, as demonstrated by Witt et al. [39]. However, there is mounting evidence that stimuli occuring within peripersonal space are processed differently from those that occur outside of this space [3,36]. Relevant to this is the concept of the cortical body matrix [27], which subserves the regulation and protection of the body and the space around it, at both a physiological and perceptual level. Recent space-dependent discoveries have shown changes in tactile processing and temperature regulation in people with Complex Regional Pain Syndrome [25,26,28]; top-down control of temperature and histamine reactivity with modulations of body ownership [2]; and top-down modulation of the protective blink reflex in response to stimulation of the hand according to where the hand is in space [31,32]. That such modulations seem bound to representations of peripersonal space [19,27,35] raises the possibility that the perceptual bias we report here is also bound to, or influenced by, this space. This in itself indicates a direction for future investigation.

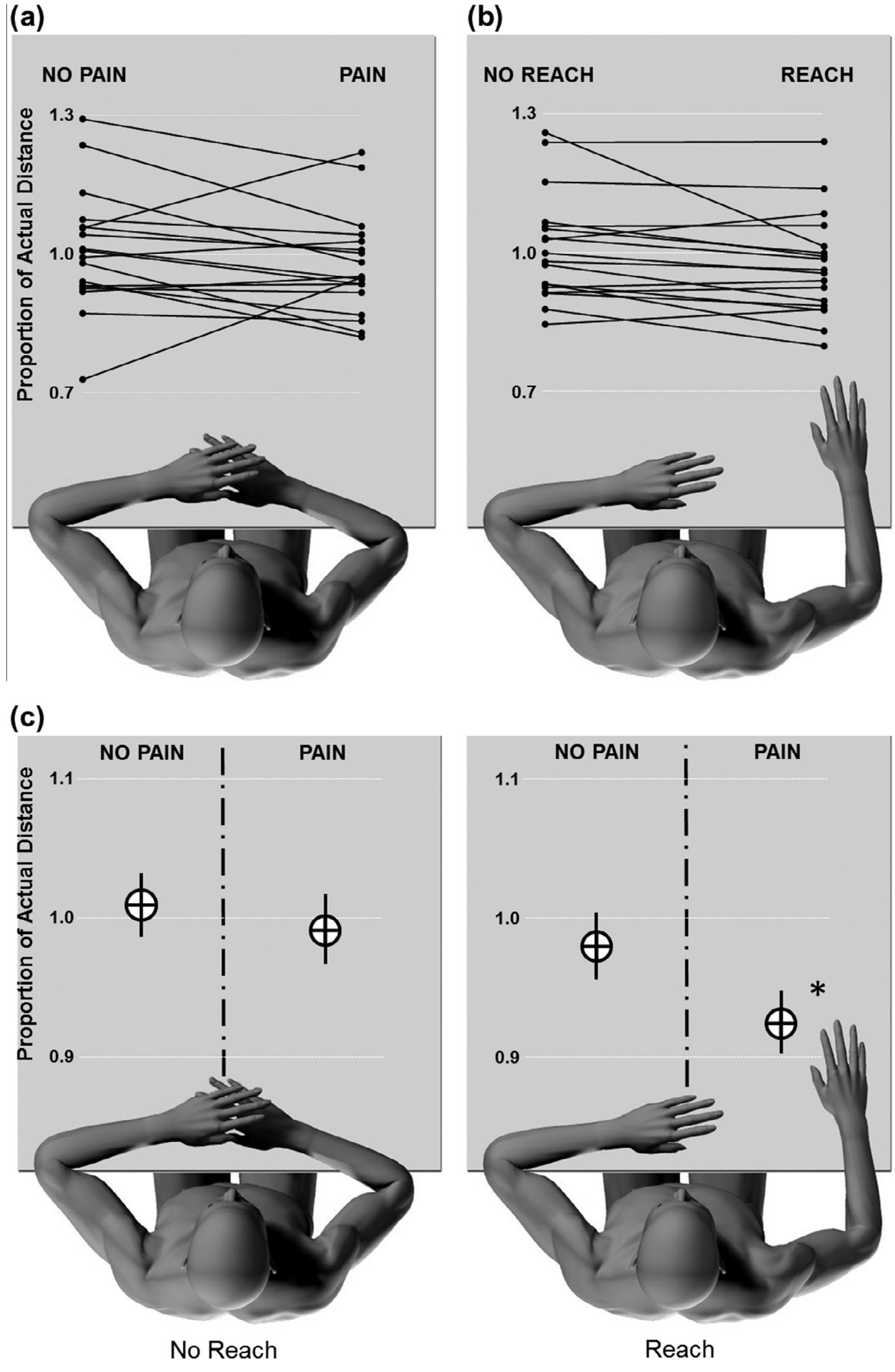


**Fig. 2.** Distance estimates as a proportion of actual distance. (a) Main effect of pain. (b) Main effect of reaching. (c) Significant interaction between pain and reaching, * $P = 0.03$.

The design of our study did not incorporate measures of arousal; although we included a control condition for pain, we are unable to comment on the overall effect that arousal may have on perception; this would be an important addition in future work. Despite the experimental nature of the pain condition used in this study, our results support the theories upheld in previous work and complement the findings of perceptual alteration in chronic pain. The underlying mechanisms of the effects that we have observed could be considered an evolutionary advantage, as well as an acquired adaptive behaviour, but it is beyond the scope of this study to separate the two. There would be much merit in exploring the evolving nature of perceptual change in acute through to persistent pain, so as to identify if and when perceptions become adaptive or indeed maldaptive in the course of pain.

To conclude, we have demonstrated that when people experience pain and must interact with their environment, they observe their environment differently, as compared to when they are not experiencing pain. As such, we suggest that there is an alteration in the processing of sensory information whilst experiencing pain, changing the way the world is seen and shaping the consequent interactions. This would seem an imperative consideration when investigating and treating those in pain.

## Conflict of interest

The authors report no conflict of interest.


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