Embodying the illusion of a strong, fit back in people with chronic low back pain. A pilot proof-of-concept study.

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Conflicts of interest

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- Participant A had altered body perception and negative back beliefs.
- Participant A embodied the Strong condition and pain and fear were less than for the other conditions.
- Participant B with normal perception and beliefs did not embody the Strong condition.
- Participant B reported similar levels of pain and fear across all three conditions.

Abstract

Objective

This proof-of-concept pilot study aimed to investigate if a visual illusion that altered the size and muscularity of the back could be embodied and alter perception of the back.

Methods

The back visual illusions were created using the MIRAGE multisensory illusion system. Participants watched real-time footage of a modified version of their own back from behind. Participants undertook one experimental condition, in which the image portrayed a muscled, fit-looking back (Strong), and two control conditions (Reshaped and Normal) during a lifting task. Embodiment, back perception as well as pain intensity and beliefs about the back during lifting were assessed.

Results

Two participants with low back pain were recruited for this study: one with

altered body perception and negative back beliefs (Participant A) and one with normal perception and beliefs (Participant B). Participant A embodied the Strong condition and pain and fear were less and both perceived strength and confidence were more than for the Normal or the Reshaped condition. Participant B did not embody the Strong condition and reported similar levels of pain, fear strength and confidence across all three conditions.

Discussion

An illusion that makes the back look strong successfully induced embodiment of a visually modified back during a lifting task in a low back pain patient with altered body perception. Both participants tolerated the illusion, there were no adverse effects, and we gained preliminary evidence that the approach may have therapeutic potential.

Introduction

In patients with chronic low back pain (LBP), there is substantial evidence of alterations in cortical structure and function (Kregel et al., 2017; Ng et al., 2017; Yuan et al., 2017), including areas involved in self-perception of the back (Wand et al., 2011; Kergel et al., 2015). Findings consistent with disruption of the mechanisms that underpin body-perception include: impaired lumbar tactile function (Catley et al., 2014a; Wand et al., 2010; Wand et al., 2013; Moseley, 2012); proprioception (Laird RA et al., 2014); back-specific action recognition (de Lussanet et al., 2012); motor imagery (Bray and Moseley., 2011; Bowering et al., 2014); and self-reported back-related self-perception (Moseley 2008; Nishigami et al., 2015; Wand et al., 2014a; Wand et al., 2016; Wand et al., 2017; Nishigami et al., 2017; Janssens 2017). People with LBP also commonly hold maladaptive beliefs about their back's robustness – perceiving it as vulnerable, easily damaged and difficult to heal (Darlow et al., 2014; Darlow et al., 2015).

Maladaptive back self-perception and beliefs about the fragility of the back are potentially mutually-reinforcing contributors to ongoing pain and disability (Wand 2012a) and may be potential treatment targets. For example, viewing the back during movement reduces pain intensity in people with back pain (Wand et al., 2012b) and viewing the back at rest reduces habitual pain intensity (Diers et al 2016). Thus improved self-perception of the back afforded by vision may contribute to analgesia. Interestingly, the enhancing effect of vision on touch perception (i.e., improved tactile acuity) observed elsewhere in the body (Taylor-Clarke et al., 2002, 2004; Eads et al., 2015), does not occur at the back (Catley et al., 2014b), suggesting against improved perception of touch as a mediating mechanism for vision-induced pain relief. Such findings raise the possibility that pain relief with vision of the back may also occur through providing reassuring information about the robustness of the back (i.e., I can see that my back is fine).

Simultaneously targeting maladaptive body perception and beliefs about fragility may have additive effects on pain. One potential method to do this is via mediated reality, where altering live video-feed changes one's *own seen body* in real-time. This differs from virtual reality (using an avatar within an immersive virtual world) and augmented reality (adding visual features into video feedback of the real-world) in that visual changes are egocentric (i.e., happening to me). Using the MIRAGE-mediated reality system (Newport., 2009), illusions that alter the appearance of deformed osteoarthritic hand have been shown to normalise participants' perception of hand size (Gilpin et al.,

2015) and reduce joint pain intensity (Preston et al., 2011). We have now used this system to manipulate visual contouring and size of the back such that it looks stronger than it really is. Such an illusion could provide evidence against beliefs of heightened fragility, improve impaired body perception and provide evidence against beliefs of heightened fragility – Weeth et al. (2017) found that an illusion of wearing armour decreases experimental pain intensity in healthy volunteers, which lends support to this idea..

Our proof-of-concept study aimed to answer the critical first questions: can an illusion that alters the back's size and muscular appearance be embodied and modify self-perception of the back? We tested two LBP patients – one with and one without impaired back self-perception. To determine tolerability and potential therapeutic promise, we also investigated pain intensity, fear, perceived back strength and confidence during lifting.

Methods

Design

A proof-of-concept pilot study, approved by the Institutional Human Research Ethics

Committee. Participants provided signed, informed consent. All procedures conformed to the declaration of Helsinki.

Participants

Participants were recruited from the general public via advertisements. Both had chronic LBP, experienced back soreness during lifting, and were cleared of any serious spinal pathology/radicular pain. Participant A had distorted back perception (high scores on the Fremantle Back Awareness Questionnaire) (Wand et al., 2014a), maladaptive beliefs about the back, high pain intensity and severe disability. Participant B had non-distorted back perception, little-to-no maladaptive beliefs about his back, and mild pain and disability.

Procedure

Baseline measures of disability (Roland Morris Disability Questionnaire (Roland and Morris., 1983)), LBP intensity at rest and during any motion (0-10 numerical rating scale), kinesiophobia (Tampa Scale of Kinesiophobia (Vlaeyen et al., 1995)), pain-related catastrophisation (Pain Catastrophizing Scale (Sullivan et al., 1995)), distress (21-item Depression Anxiety and Stress Scale (Lovibond., 1995; Antony et al., 1998)), back perception (Fremantle Back Awareness Questionnaire (Wand et al., 2014a) and maladaptive beliefs about the back (Back Beliefs Questionnaire (Symonds et al., 1996)) were assessed.

Proprioceptive body representation was evaluated using lumbar Left/Right judgment accuracy via *'Recognise'* (NeuroOrthopaedic Institute, Adelaide, Australia), taking the average percentage correct of two sets of 30-image trials. Tactile acuity was evaluated using mechanical calipers to assess horizontal and vertical two-point discrimination threshold bilaterally at the level of L3 (Wand et al., 2014b).

During each trial, participants lifted a weighted basket and held it in a semi-stooped posture for 60-seconds. The basket's weight was 80% of the weight at which they reported back pain of ≥40/100 while lifting.

Equipment and experimental conditions:

The back visual illusions were created using software adapted from the MIRAGE-multisensory illusions system (National Instruments 2015; Austin, TX), in which real-time video footage is viewed through a head mounted display (HMD) at 60Hz (Preston and Newport, 2012). Participants watched live video-feed of their own body from the rear. A customized in-house LabVIEW program using National Instrument Vision Acquisition software (National Instruments 2015; Austin, TX) enabled real-time alterations to video feedback, allowing for manipulation of back size and for the overlay of images onto the viewed back. In this instance, the software took live images of the body, automatically identified and extracted the back, then either morphed the shape of the back (Reshaped; see below) or morphed and merged an overlay of a generic, muscled back (of the same shape and size) with the existing back and fitted the new back onto the viewed body. (Strong; see below).

Participants undertook one experimental condition (Strong) and two control conditions (Reshaped and Normal) during lifting, each performed three times, in a randomised order (See Figure 1). In the Strong condition, an image of a muscled back was overlaid, the shoulders were widened (125% of normal) and the waist narrowed (75% of normal), thus creating a fit, muscled-looking back. The Reshaped condition widened the shoulders and narrowed the waist without muscular overlay. The Normal condition showed an unmodified view of their back.

Testing procedure:

In each condition, participants viewed their back through the HMD and underwent a standardized procedure to promote embodiment. Tactile stimulation was applied to the back; participants watched their back being touched in real-time for 5 minutes. Participants then shrugged their shoulders and moved their backs while watching this movement for two minutes. Following this, participants performed the lifting task three times for each condition. Participants held the weight for a maximum of 60 seconds. All outcomes (below) were measured for each condition (analysis: average of three trials/condition). After each condition, participants removed the HMD and manually completed the following questionnaires.

Primary outcomes

Embodiment and back self-perception were assessed after each condition. A modified embodiment questionnaire (Longo et al., 2008; Tsakiris et al., 2010) was used. Using a 7-point Likert scale, participants were asked to rate their agreement (-3 = strongly disagree; 0 = Neutral; +3 = strongly agree) with statements which assessed participants' sense of ownership (During the task it felt as though: …I was looking directly at my own back; …the image was part of my body), agency (…the image was under my control; …the image moved when I moved) and location (…I had the sensation of touching in my back; …I felt the touch I could see on my back) (Supplementary file). To assess back self-perception after each condition, participants were asked to select the picture (from six randomly arranged snapshot images of a back) which best represented how their back *felt* during the lifting task (Figure 2). Participants were purposefully and explicitly instructed to choose the picture representing how their back *felt,* not how their back *looked.*

Secondary outcomes

After each condition, participants were also provided with 100mm visual analogue scales (VAS) to manually rate their pain intensity, perceived fear, perceived back strength, and perceived confidence (in relation to the back). Pain intensity was assessed by asking participants, "How would you rate the pain in your back during the task?", where 0 = no pain and 100 = unbearable pain. Perceived fear was assessed by asking participants, "How fearful are you of performing this task (considering the ability/strength of your back)?", where 0=no fear, 100=worst possible fear. Perceived back strength was assessed by asking participants, "How strong does your back feel at the moment?" where 0=not strong at all, 100=strongest imaginable. Last, perceived confidence was assessed by asking participants, "How confident are you about performing every day activities?", where 0=no confidence at all, 100=most confidence imaginable.

Results

Table 1 presents demographic/clinical details for both participants. Table 2 provides the embodiment (total and subscale scores), back self-perception, pain, fear, perceived strength, and confidence scores for each testing condition.

Participant A experienced high levels of embodiment for each condition, and the perception of his back was updated, matching the viewed image. Pain intensity was similar for the two control conditions. Pain and fear were lower and perceived strength and confidence were higher, in the Strong condition than in the Normal or Reshaped conditions (Table 2).

Participant B experienced high levels of embodiment in the Normal and Reshaped condition, but not in the Strong condition. Perception of his back was less clearly related to the viewed image as compared with the images chosen by Participant A. Pain was similar in all conditions. He had low fear in relation to lifting for all conditions. Perceived strength ratings were similar in all conditions. Confidence was greater during the Reshaped condition than during the other conditions.

Discussion

This proof-of-concept pilot study tested whether the back illusion can be embodied and modify back self-perception, also exploring tolerability, and therapeutic potential. Our results appear promising given Participant A's response - clearly embodying the muscular appearance of his back, and reporting less pain, less fear and greater perceived strength and confidence during the Strong condition. Such findings clearly suggest that the illusion provided sufficiently compelling and synchronized visual input to shift how his body felt, his confidence in his body and his system's need to protect his back (as indicated by less pain). Participant B, who did not have distorted back perception and only mild pain/disability, did not embody the Strong illusion and reported little difference in strength, fear or pain across the three conditions. Importantly however, the protocol did not induce aversive effects in either participant.

We overcame significant challenges in the provision of real-time, manipulated visual input of the back during a functional task. The image was sufficiently locked to the patient's real back to offer compelling synchronous input. We developed the standardized embodiment protocol and the back visual illusion (where visual changes to the back track with participant movement) on the grounds that visuo-tactile and visuo-motor synchrony (i.e., providing two sources of input at the same time) are strong drivers of ownership, agency and location (Piyankova et al., 2014; Ratcliffe and Newport, 2017). We did not attempt to integrate multiple modalities into a single procedure because we have previously shown that adding modalities to a synchronous input is not as important as maximising synchrony between at least two of them (Walsh et al., 2011). Our results point to the potential of exploring the use of a strong back visual illusion as a treatment for LBP, at least LBP during forward bending. In this sense, the current innovation builds on a body of research using visual illusions to understand and treat pain (Moseley et al., 2012; Boesch et al., 2016). Research initially targeted upper limb pain – most famously mirror therapy for phantom limb pain (Ramachandran and Rogers-Ramachandran., 1996, although see Moseley et al., 2008), is being extended to LBP (Wand et al., 2012b; Diers et al., 2016). Whilst current evidence of their broad effect is equivocal (Boesch et al., 2016) – further refinement and research is needed.

Our study was not to test efficacy, but it is worth noting that the illusion of a fit and muscled back appeared to decrease pain and fear in Participant A. Randomizing the order of conditions increases confidence that the pain reduction during the Strong condition was related to the nature of the visual image. The mechanisms by which analgesia occurs are unclear. That participants with LBP often view their back as being vulnerable (Darlow, 2015) suggests that a higher cognitive process might be relevant to Participant A's response – his back looked less vulnerable. This would be consistent with contemporary theories that emphasise the protective nature of pain (Gallagher et al., 2013; Moseley and Butler., 2015; Wallwork et al., 2016), with evidence that contextual cues can have profound effects on pain (e.g. Moseley and Arntz., 2007) and stiffness (Stanton et al., 2017) and the proposal that visually-induced analgesia is mediated via modulation of affective, rather than sensory, mechanisms (Longo et al., 2009). Other possibilities exist however: perhaps particular visual cues alter the expected location - in space - of noxious input (Stanton et al., 2016a); perhaps visual input simply improves spatial processing in general – after all, spatial processing is often disrupted in LBP (Moseley et al., 2012) and there is some evidence that changing the apparent location of painful body parts can induce analgesia (Gallace et al., 2011).

That Participant B did not embody the Strong back illusion, and reported no shift in other assessments, highlights important future questions, aside from testing efficacy. There may be merit in exploring whether baseline pain intensity, the presence of body distortion or maladaptive back-related beliefs relate to response to the illusion. Perhaps these stimulations can induce embodiment, even for non-veridical illusions, but only when innate perception of the back is altered. If so, and if the illusion works via an effect on distorted bodily perception, then this MIRAGE-based approach may have application to pain in other body areas, for which real-time illusions are challenging, e.g., the knee (Nishigami et al., 2017) or neck (Harvie et al., 2016; Stanton et al., 2016b).

One potential limitation of our study is that participants differed in age (34 vs 70 years old). This may impact the ability to experience and embody an illusion (Graham et al., 2015), and thus influence the degree to which back perception is altered. However, previous work has shown that the degree to which people experience visual illusions is generally stable over adulthood, and if anything, declines with older age (Leibowitz and Judisch., 1967). Further, evidence from the rubber hand illusion paradigm shows that there is no effect of age on embodiment measures (subjective measures and proprioceptive drift) (Campos et al., 2018). Thus the present findings that the older participant (Participant A) had both higher levels of embodiment and larger changes in back perception with the illusion than the younger participant (Participant B) would *not* be predicted based on age. Together, these findings make age unlikely to be a confounding factor in the present results.

Conclusion

In summary, our approach successfully induced embodiment of a visually modified back during a lifting task in a LBP participant whose body perception was disrupted. Both participants tolerated the illusion, there were no adverse effects, and we gained preliminary evidence that the approach may have therapeutic potential.

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