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Original experimental

A preliminary investigation into psychophysiological effects of threatening a perceptually embodied rubber hand in healthy human participants

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HIGHLIGHTS

- We approached a perceptually embodied rubber hand with a needle and brush.
- An increase in anxiety was selective for needle but an increase in arousal was not.
- 50% of participants reported somatic sensation when stimuli approached the rubber hand.
- 'Tingling' was the most common somatic sensation reported.

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ABSTRACT

Background and aims: Threatening a perceptually embodied rubber hand with noxious stimuli has been shown to generate levels of anxiety similar to that experienced when a real hand is threatened. The aim of this study was to investigate skin conductance response, self-reported anxiety and the incidence, type and location of sensations when a perceptually embodied rubber hand was exposed to threatening and non-threatening stimuli.
Methods: A repeated measures cross-over design was used whereby 20 participants (≥18 years, 14 females) received a threatening (syringe needle) and non-threatening (soft brush) stimulus to a perceptually embodied rubber hand. Perceptual embodiment was achieved using a soft brush to synchronously stroke the participant's real hand (out of view) and a rubber hand (in view). Then the investigator approached the rubber hand with a syringe needle (threat) or soft brush (non-threat).
Results: Repeated measures ANOVA found that approaching the perceptually embodied rubber hand with either stimulus produced statistically significant reductions in the rated intensity of response to the following questions ($p<0.01$): 'How strongly does it feel like the rubber hand is yours?'; 'How strongly does it feel like the rubber hand is part of your body?'; and 'How strongly does it feel you can move the rubber hand?'. However, there were no statistically significant differences in scores between needle and brush stimuli. Repeated measures ANOVA on skin conductance response found statistically significant effects for experimental Events (baseline; stroking; perceptual embodiment; stimuli approaching rubber hand; stimuli touching rubber hand; $p<0.001$) but not for Condition (needle versus brush $p=0.964$) or experimental Event × Condition interaction ($p=0.160$). Ten of the 20 participants (50%) reported that they experienced a sensation arising from the rubber hand when the rubber hand was approached and touched by either the needle and/or brush but these sensations lacked precision in location, timing, and nature.
Conclusion and implications: Our preliminary findings suggest that the increase in arousal in response to stimuli entering the peripersonal space may not be selective for threat. There was tentative evidence that more intense sensations were experienced when a perceptually embodied rubber hand was approached by a threatening stimulus. Our findings provide initial insights and should serve as a catalyst for further research.

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[1] http://www.st-gemma.co.uk/?page_id=1910.

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1. Introduction

The sense of self and body ownership is essential for the performance of complex movements and is driven by the integration of visual, tactile and proprioceptive inputs in cortical and sub cortical areas responsible for multisensory processing [1–4]. Embodiment refers to the subjective experience of having a sense of one's own body [5] and can be studied using techniques that elicit perceptual embodiment of inanimate objects. The 'rubber hand illusion' is a technique where a rubber hand is embodied so that the individual experiences a sense that the rubber hand is part of their own body [6]. Perceptual embodiment of a rubber hand is achieved by participants observing the rubber hand being brushed (in view) whilst their real hand is synchronously brushed out of view. After a short time the brush sensation feels as if it is arising from the rubber hand and the rubber hand feels as if it is part of the body (i.e. perceptually embodied)[7,8]. It is possible to perceptually embody a rubber hand using painful-tactile stimuli (e.g. a sharp pin) in much the same way as using non-painful-tactile stimuli (e.g. a brush) [9].

The sense of self and body ownership may have a role in protection from injury. Lloyd et al. [10] provided evidence that regions of the contralateral posterior parietal cortex were involved in discrimination of painful and non-painful stimulation of a perceptually embodied rubber hand in the peripersonal hand space. Activity in the superior and inferior regions of the parietal cortex increased when individuals observed a sharp painful stimulus applied to a rubber hand that had been placed over their real hand, but only when the rubber hand was spatially congruent to the real hand. Threatening a perceptually embodied rubber hand with injury has been shown to evoke feelings that are similar to those experienced when threatening real limbs. Ehrsson et al. [11] found that threatening perceptually embodied objects generated levels of anxiety similar to that experienced when a real hand was threatened. The desire to withdraw the rubber hand from the threat was stronger when the intensity of perceptual embodiment was high. Armel et al. [12] found that strong skin conductance responses, which reflect levels of physiological arousal, occurred when a perceptually embodied rubber hand was threatened by an apparently injurious stimulus such as forceful bending of a finger of the rubber hand. Likewise, Hagni et al. [13] reported elevated skin conductance in participants playing a first-person perspective virtual reality game that involved two virtual arms interacting with virtual balls rolling towards the viewer. When the right virtual arm was apparently stabbed by a knife causing 'bleeding' larger increases in skin conductance were observed when participants imagined virtual arms to be their own compared with not imagining virtual arms to be their own. However, studies investigating the effect of threatening a perceptually embodied rubber hand are few and do not control for general arousal that may arise from non-threatening stimuli entering the peripersonal space.

Moreover, there has been little research on sensations evoked by stimuli that threaten a perceptually embodied rubber hand. Lewis and Lloyd [14] found that they were able to produce phantom-like experiences in non-amputees by inducing a sense of embodiment in a rubber hand that had a finger removed. Twenty eight out of 30 participants reported experiencing a sense of presence of the absent finger and seven out of 28 of these participants reported tingling or numbness in the missing phantom finger. Guterstam et al. demonstrated that sensations could be referred to an empty space creating a sense of having an invisible hand [15] and creating a sense of two right (or left) hands [16]. Neither of these studies systematically document stimuli-evoked sensations misattributed to a perceptually embodied rubber hand. The aim of this study was to investigate skin conductance response, self-reported anxiety and the incidence, type and location of sensations when a perceptually embodied rubber hand was exposed to threatening and non-threatening stimuli. The study was designed to evaluate whether arousal associated with approaching a perceptually embodied rubber hand was selective for threatening objects. We hypothesised that there would be a larger increase in arousal when threatening stimuli entered the peripersonal space compared with non-threatening stimuli.

2. Methods

A repeated measure cross-over study was designed with each participant taking part in one experiment where they perceptually embodied a rubber hand which was exposed to a threatening (syringe needle) and non-threatening (soft brush) stimulus. The order of presentation of stimuli was randomised between experiments by a technician independent to the study using a computerised random number generator and sealed envelope method. Twelve participants received the threatening stimulus first. The study was approved by the Research Ethics Sub-Committee of Leeds Beckett University.

2.1. Participants, recruitment and selection

A convenience sample of unpaid healthy human volunteers (mean ± SD age = 21.0 ± 1.41 years, 14 females) was recruited by announcements in lectures throughout the university. This was a preliminary investigation and the sample size used was based on sample sizes used in similar studies [13,17].

All participants were students of undergraduate or postgraduate university courses. Interested individuals were briefed about the nature of the study and provided with a participant information pack that stated that the purpose of the study was to investigate whether it was possible to create the sense that a rubber hand could feel like it was part of the body and to take some physiological measurements during the process. Participants were also told that the rubber hand would be exposed to different stimuli. Volunteers were given 48 h before being formally invited to take part in the study. During the study visit volunteers were screened for eligibility (≥18 years with no existing medical condition). Volunteers were excluded if they: had an ongoing medical condition (e.g. diabetes, osteoarthritis) or previous history of heart and circulatory disorders (e.g. vasculitis, thrombosis); were currently seeking medical care; were taking any medication or were likely to take any medication during the week preceding the study visit; were pregnant; were currently experiencing pain; had an upper limb injury within the previous six months; experienced disturbances in skin sensations of the forearm; regularly exposed their hands to extremes of cold. Participants were asked to refrain from engaging in vigorous exercise, consuming alcohol or caffeine products, or smoking (e.g. tobacco) 12 h before the study visit. Participants signed written consent before the experiment and were reminded that they could withdraw at any time without any reason.

2.2. Procedure

Each experiment was conducted in a physiology laboratory by two female investigators of White British ethnic origin (ES and SY). Participants were seated throughout the experiment with both arms resting on a table with the left hand placed on a pillow. Sensors were attached to the middle and index finger of the left hand of the participant to monitor skin conductance response. The right hand of the participant was placed within a canvas box so that it was out of view and a rubber hand aligned parallel to the canvas box so that it looked like it could be part of the participants body (i.e. visually congruent to the real hand, Fig. 1). The same rubber hand was used for each participant with no attempt to match the physical appearance of the hand to that of the real hand. The skin tone