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The phantom head

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Abstract. A student volunteer was asked to stand just behind a mannequin so that the student was looking at the back of the mannequin's plastic head. The experimenter stood off to one side and used her two hands to stroke and tap the back of the student's head in perfect synchrony with the back of the mannequin's head. After 1 – 2 min the majority of naive subjects tested began experiencing the sensations as emerging from the mannequin's head rather than from their own, demonstrating a novel 'phantom-head' illusion. The fact that sensory referral here occurs to a part of the body that is not normally visually accessible challenges the leading Hebbian explanation of the well-studied rubber-hand illusion.

> "You never identify yourself with the shadow cast by your body, or with its reflection, or with the body you see in your dream or in your imagination. Therefore you should not identify yourself with this living body either."
>
> Adi Shankara [9th century AD, India]

1 Introduction

You take your body—that 'muddy vesture of decay' surrounding you—for granted. You do not doubt that your body is your own, or attribute your sensations to other people. Yet there are many clinical cases and artificially contrived laboratory situations in which this assumption is called into question and your body image is profoundly disrupted (eg Brugger 2002; Brugger et al 1996; Critchley 1953). For example, visual input can powerfully modulate body image. It has been shown that, if you palpate a cube while looking through a lens, it actually *feels* bigger (Rock and Victor 1964; 'visual capture'). Similar effects can be used to resurrect, magnify, animate, and 'touch' phantom limbs.

Imagine a patient's left arm has been amputated, leading to a phantom arm. The patient is asked to look at the reflection of his intact right hand in a mirror. If the patient moves his right hand so the phantom looks like it is moving, it feels like it is moving as well, despite never having moved for (say) 10 years. Similarly, if you touch the normal hand (so the phantom looks as if it is being touched), the phantom feels the touch as well (Ramachandran and Rogers-Ramachandran 1996). Using other optical tricks you can make the phantom feel like it is occupying anatomically impossible positions (eg bending backwards—Ramachandran and Hirstein 1998), even though such positions have never been computed or experienced before by the subject's brain. Equally surprising: if a patient merely watches your intact arm being touched, he experiences the tactile sensations as arising from his phantom arm (and watching you massage your hand relieves his phantom pain—Ramachandran and Brang 2009). Finally, optically shrinking a phantom with minifying lenses and mirrors seems, in some cases, to 'shrink' the phantom pain as well (Ramachandran et al 2009).

One can use a system of multiple reflecting mirrors or a half-silvered mirror to create the illusion in normal people that they have an optical twin or that they are out there occupying the other body or head (Altschuler and Ramachandran 2007; Ramachandran

and Hirstein 1997). Similar 'out of body' illusions can also be induced with video cameras instead of mirrors (eg Petkova and Ehrsson 2008). Tactile stimulation of the participant, such that he feels his back being touched and also sees it being touched in the video projection in front of him, strengthens this illusion (Lenggenhager et al 2007). Especially striking is the rubber-hand illusion (Botvinick and Cohen 1998). Put a rubber (right) hand on the table in front of a normal volunteer and have him place his real right hand parallel to it. Prop up a vertical cardboard partition so that the subject's real right hand is hidden from view. Now, alternately stroke and tap the rubber hand and real hand in perfect synchrony so he feels the real hand being stimulated but sees only the dummy. In many subjects, the sensations soon feel as though they are arising from the dummy hand (Botvinick and Cohen 1998). Once this assimilation of the dummy into one's body has occurred, 'threatening' the dummy with a hammer, or bending it back, creates a big jolt in skin conductance response (SCR—Armel and Ramachandran 2003), showing that the dummy has indeed been assimilated into the limbic/emotional centers linked to the subject's body image; SCR cannot be faked.

Our interpretation of the rubber-hand effect invokes the Bayesian logic of all perceptual systems. The brain regards it as highly improbable that the random taps and strokes seen on the dummy hand are identical to what is felt on the hand simply by chance, so assumes the sensations are arising from the dummy (Armel and Ramachandran 2003). One way this unconscious interpretation could have arisen is through a lifetime of Hebbian learning: "Whenever I saw my own hand being touched, I felt it being touched as well". Here we report a new 'phantom head' illusion that challenges this Hebbian perspective. Since we are not used to visually perceiving touch stimuli administered to the back of our head, no association can have developed between the visual and tactile components of stimuli applied to the back. The experimental subject—say you, the reader—stands in front of a bald mannequin or dummy (or a person wearing a 3-D Halloween mask), so that what you see in front of you is the back of the dummy's head. While you watch the mannequin's head, I stand to the side and use my left hand to repeatedly tap and stroke the back of your own head, varying the velocity, distance, and direction of strokes in random order. While I do this, I simultaneously stroke and tap the back of the dummy's head in perfect synchrony. If the dummy is bald and you are not, touching your hair may ruin the illusion, but pulling, stroking, and pinching the back of the neck, shoulder, and ears should be sufficient. If you are lucky, you will start experiencing the astonishing illusion of the tactile sensations as arising from the back of the dummy head, not from your own.

2 Methods

We tested the phantom-head illusion in twenty-two subjects. The experiment was carried out with approval from the UCSD Institutional Review Board and in accordance with the World Medical Association Helsinki Declaration as revised in October 2008. We initially tested thirteen subjects on the rubber-hand illusion and found that nine of the subjects experienced the effect. (This result matches the usual proportion seen in classroom demonstrations.) The effect was elicited by verbal report; no objective measures (such as SCR) were used. All subjects then participated in the dummy-head experiment. After 1–2 min of synchronous stimulation of the back of the head and dummy, nine of the thirteen subjects started feeling the sensations as arising from the dummy. Subjects remarked that the illusion was especially powerful if they 'imagined' that their own head was occupying the dummy. When the mannequin's bald head was touched along with the subject's head (typically covered with hair), a sensory conflict was induced that tended to drastically weaken the illusion. This difference in subjectively reported experience of the illusion between the head and neck provides clear evidence against confabulation or expectation effects that would be expected to generalize across these

body parts. As a further control, we repeated the entire procedure with nonsynchronous, uncorrelated stimulation. Even after several minutes of stimulation there was no illusion. The eight participants who experienced the phantom-head illusion with synchronous stimulation gave a mean rating of 3.1 on a 1–5 scale where '1' was described as "nothing unusual" and '5' was described as "I completely feel that I am the dummy or feel the sensation as arising from the dummy". All participants rated the asynchronous condition a '1' except one subject who rated it a '2'. Ratings of the rubber-hand illusion were similar in magnitude to ratings of the synchronous phantom-head condition and strongly correlated ($r_{18} = 0.56$, $p = 0.01$). The correlation was strong for participants who saw the rubber-hand illusion first ($r_9 = 0.59$, $p = 0.06$), but was not statistically significant for those who viewed it second ($r_7 = 0.24$, ns).

To eliminate concerns that beginning with the rubber-hand illusion created expectation effects in the phantom-head illusion, we repeated the study on nine more subjects reversing the order of trials. Participants in this study reported an even stronger phantom-head illusion (mean rating 3.3) and reported a very similar magnitude of rubber-hand illusion (mean rating 3.4) when subsequently tested on the rubber hand. Interestingly, more participants in this order experienced a phantom-head illusion during the asynchronous condition (mean rating 2.9) than did those tested with the rubber hand first. This was especially true when the participant and dummy head were stroked in the same place but moving in opposite directions. When stimulation was temporally uncorrelated, these reports ceased. Even though substantially less referral was seen in the asynchronous condition, the fact that any referral was seen is surprising. Significantly, this occurred only when the 'asynchrony' was in direction and speed, but not when there was genuine asynchrony in time. Given the statistics of the natural world, temporal synchrony (in contrast to other similarities or dissimilarities) seems to be a much more powerful glue for binding events than other similarities, such as direction of movement.

We attribute the overall higher ratings in this follow-up study to increased experimenter skill at administering highly synchronized touch and to the fact that participants had just participated in an unrelated study requiring detailed description of subjective sensation. Such priming effects are not unusual in psychology and can be attributed to the subjects becoming more adept (and receptive) 'tuning' into their own novel perceptions.

3 Discussion

The phantom-head illusion we describe here is similar to the rubber-hand effect, but even more radical in its implications and in some ways more surprising. You go through life making many assumptions about your existence—you have a name, a bank account, an address, parents, and so on. All this can be called into question (Do you *really* know who your father is?). But the axiomatic foundation of your existence is that you occupy your body and yours alone. Yet the phantom-head illusion calls even this basic axiom into question. In 2 min you project sensations from the back of your head to a dummy head. Lenggenhager et al (2007) reported a similar illusion—but sensory referral in their study occurred to a projected image of oneself: the subject 'knew' it was an optical displacement of his own body. In the current study, sensory referral occurs to a visually dissimilar head—the head of a mannequin. This arrangement much more closely parallels the rubber-hand illusion, in which sensations appear to rise from a visually dissimilar and disconnected hand, demonstrating the ability of the brain to accept sensory input from other bodies when multisensory input is synchronized.

Second, the phantom head eliminates a whole class of 'Hebbian learning' accounts of the rubber-hand illusion or the (corollary) notion that, given the proximity of the rubber hand to your own, the illusion is merely a form of visual capture of touch (eg every time you saw your hand touched you felt it touched as well). This argument cannot apply to the head because you have never—or extremely rarely—seen the back of your head touched.

The phantom-head illusion requires you to have constructed an internal model of the back of your head to which you attribute the sensation based on a Bayesian inference. The notion of 'visual capture' of the back of your head makes no sense.

In some subjects the effect is so powerful that they have the spooky sense of being temporarily decapitated. It would be interesting to see if threatening the mask with a dagger would evoke an SCR in the subjects as shown for the rubber hand by Armel and Ramachandran (2003).

The effect is also seen, although it is less striking, if you simply look at the back of another person's real head. This seems paradoxical but it probably derives from the fact that there is something inherently strange about sensations emerging from an inanimate object. So the illusion is more surprising and spooky to higher brain centers if the sensations emerge from plastic rather than a human head.

"To give airy nothings a habitation and a name"
William Shakespeare

References

Altschuler E L, Ramachandran V S, 2007 "A simple method to stand outside oneself" *Perception* **36** 632 – 634

Armel K C, Ramachandran V S, 2003 "Projecting sensations to external objects: Evidence from skin conductance response" *Proceedings of the Royal Society of London, Series B* **270** 1499 – 1506

Botvinick M, Cohen J, 1998 "Rubber hands 'feel' touch that eyes see" *Nature* **391** 19

Brugger P, 2002 "Reflective mirrors: Perspective-taking in autoscopic phenomena" *Cognitive Neuropsychiatry* **7** 179 – 194

Brugger P, Regard M, Landis T, 1996 "Unilaterally felt 'presences': The neuropsychiatry of one's invisible Doppelgänger" *Cognitive and Behavioral Neurology* **9** 114 – 122

Critchley M, 1953 *The Parietal Lobes* (London: Edward Arnold)

Lenggenhager B, Tadi T, Metzinger T, Blanke O, 2007 "Video ergo sum: manipulating bodily self-consciousness" *Science* **317**(5841) 1096 – 1099

Petkova V, Ehrsson H H, 2008 "If I were you: Perceptual illusion of body swapping" *PLoS One* **3** e3832

Ramachandran V S, Brang D J, 2009 "Sensations evoked in patients with amputation from watching an individual whose corresponding intact limb is being touched" *Archives of Neurology* **66** 1281 – 1284

Ramachandran V S, Brang D J, McGeoch P M, 2009 "Size reduction using mirror visual feedback (MVF) reduces phantom pain" *Neurocase* **15** 357 – 360

Ramachandran V S, Hirstein W, 1997 "Three laws of qualia: What neurology tells us about the biological functions of consciousness" *Journal of Consciousness Studies* **4** 429 – 457

Ramachandran V S, Hirstein W, 1998 "The perception of phantom limbs. The D. O. Hebb lecture" *Brain* **121** 1603 – 1630

Ramachandran V S, Rogers-Ramachandran D, 1996 "Synaesthesia in phantom limbs induced with mirrors" *Proceedings of the Royal Society of London, Series B* **263** 377 – 386

Rock I, Victor J, 1964 "Vision and touch: an experimentally created conflict between the two senses" *Science* **143** 594 – 596

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