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The Experimental Induction of Out-of-Body Experiences — Source link

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An out-of-body experience (OBE) has been defined as the experience in which a person who is awake sees his or her body from a location outside the physical body (*1*, *2*). OBEs have been reported in clinical conditions that disturb normal brain functioning, such as strokes, partial epileptic seizures, and drug abuse (*1*–*4*). Here, I report that this illusory experience can be induced in healthy participants. I report a perceptual illusion in which individuals experience that their center of awareness, or "self," is located outside their physical bodies and that they look at their bodies from the perspective of another person. This illusion demonstrates that the sense of being localized within the physical body can be fully determined by perceptual processes, that is, by the visual perspective in conjunction with multisensory stimulation on the body.

In the first experiment, participants sat on a chair, wearing a pair of head-mounted displays that were connected to two video cameras placed side by side 2 m behind the participant's back (Fig. 1A). The images from the left video camera were presented on the left eye display and the images from the right camera on the right display. Thus, the person would see his or her back with the perspective of a person sitting behind him or her with stereoscopic vision. The experimenter stood just beside the participant (in their view) and used two plastic rods to touch simultaneously the person's actual chest, which was out of view, and the chest of the "illusory body," by moving one rod toward a location just below the cameras in view (*5*).

After 2 min of stimulation, the participants were asked to complete a questionnaire on which they had to affirm or deny 10 possible perceptual effects with a seven-point visual analog scale. Three statements were designed to capture the experience of the illusion, and the other seven served as controls for suggestibility and task compliance (SOM text). The participants affirmed illusion statements and denied the controls, and the difference in ratings was significant [$P < 0.0001$, $F(1, 170) = 189.92$, $P < 0.00001$ (fig. S1 and SOM text)]. Thus, the participants reported the experience of sitting behind their physical bodies and looking at them from this location.

I hypothesized that the illusion is caused by the first-person visual perspective in combination with the correlated visual and tactile information from the body. To test this and to provide objective evidence for the illusion, I registered the skin-conductance response (SCR) as a measure of the emotional response when the illusory body was "hurt" by hitting it with hammer after a period of stimulation (SOM text). I compared the illusion condition (with synchronous touches) to an asynchronous condition in which the person's real and illusory chests were touched alternatingly. I observed significantly greater threat-evoked SCRs after the illusion condition ($P < 0.013$; paired t test) (Fig. 1B and SOM text) and stronger ratings of the illusion ($P < 0.05$; paired t test) (SOM text). A control experiment was conducted to rule out that the SCR difference was due to a conditioned response after a period of synchronously presented stimuli (SOM text, experiment 3). The observed SCR difference provides objective evidence that the participants were emotionally responding as if they were located behind their physical bodies.

The present illusion is fundamentally important because it informs us about the perceptual processes that underlie the sense of being located inside the body. There are two key components to this process. First, visual information from the first-person perspective provides indirect information about the location of one's own body in the environment (*6*). The first-person visual information also updates the proprioceptive representations and defines the origo of the body-centered reference frames that are used to represent near-personal space (*7*, *8*). The second key factor is the detection of correlated tactile and visual events on the (illusory) body. Multisensory correlations are known to be important for self-attribution of single body parts in near-personal space (*9*, *10*). Thus, these correlations, in conjunction with the first-person visual perspective, are sufficient to determine the perceived location of one's own whole body. This finding represents a fundamental advance because the natural "in-body experience" forms the foundation for self-consciousness.

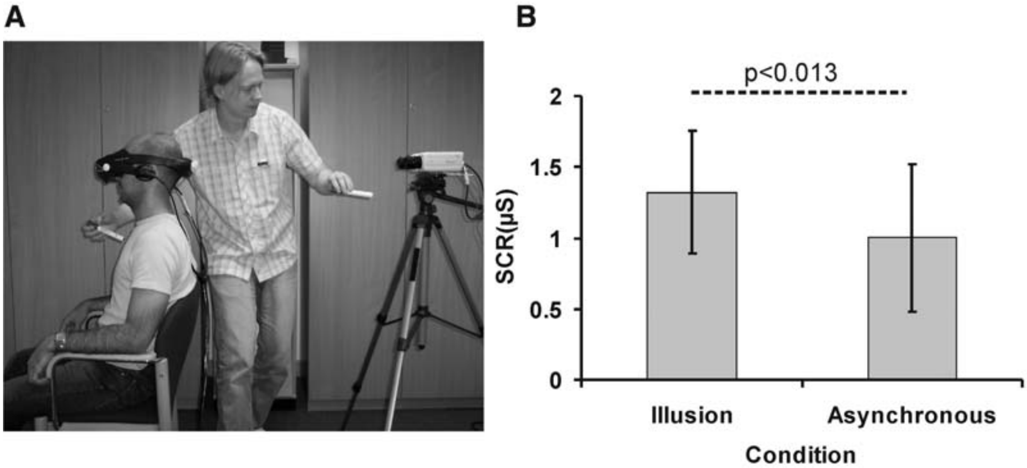

Fig. 1. (**A**) The setup used to induce the out-of-body illusion. (**B**) The SCRs from the 12 participants when the illusory body was "hurt." Mean values and standard deviations (error bars) are presented.

References and Notes

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Supporting Online Material
www.sciencemag.org/cgi/content/full/317/5841/1048/DC1
Materials and Methods
SOM Text
Figs. S1 and S2
References

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Supporting Online Material for

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This PDF file includes:

- Materials and Methods
- SOM Text
- Figs. S1 and S2
- References

Supplementary Online Material (SOM)

Material and Methods

Participants

Eighteen volunteers participated in the first experiment (seven males and eleven females, aged between nineteen and thirty-two years), and two different groups of volunteers participated in the second (eight males and four females, all aged between twenty-one and thirty-six) and third experiments (eight males and three females, aged between twenty-two and thirty-two years). All participants were healthy. They were unaware of the specific aim of the study. All participants had given their written consent, and the study was approved by the joint National Hospital for Neurology and Neurosurgery/Institute of Neurology Ethics Committee, London, UK.

Set-up and head-mounted displays

The experiments took place in a testing room (3.5 meters by 6 meters) with some furniture. The participants were briefly familiarized with the room before the experiments commenced. The participants were seated in the center of the room in a relaxed position and instructed not to move. They wore a pair of head-mounted displays (Cybermind Visette Pro PAL, Cybermind Interactive, Maastricht, Netherlands; Display Resolution = 640 x 480) with a wide field-of-view (Diagonal field of view = 71.5°). These were connected to two synchronized CCTV cameras (Protos IV, Vista, Wokingham, Berkshire, UK) placed side-by-side (adjusted to match the distance between the eyes, 8-10 cms) two meters behind each participant's back at the same height as the person's actual eyes (Figure 1A). This arrangement meant that the person saw his or her back from the perspective of a person sitting behind him or her with stereoscopic vision without noticeable delay (less than 25 milliseconds). Two plastic rods (1 cm diameter and 20 cms long) were used to repeatedly touch the person's physical chest, which was out-of-view, and the position just below the cameras where the 'illusory chest' was located in full view. The participant could not see the experimenter's right arm which was touching his or her chest, because the experimenter's right arm was occluded by the participant's own body and the experimenter's body. Thus the participant could only see the experimenter's left arm approaching the cameras (the illusory body) in full view, and then disappearing just below the field of view of the cameras to touch the apparent location of the 'illusory chest'. Thus in this setup the person could not see the any part of illusory body, but had a good view of the room and the seen physical body sitting on the chair in the middle of it. The rods were moved either synchronously ('illusion condition' in experiments one and two) or asynchronously (control condition in experiment two). The movements were paced at one Hertz to control the number of movements in each condition, with the experimenter wearing ear-phones in order to listen to a metronome. We used a regular pattern because this made it easy for the experimenter in the asynchronous control condition to apply the same number of movements, with the same force, speed, velocity, and temporal intervals as in the synchronous condition by just switching to an alternating pattern (see below).

Questionnaire (experiment one)

Directly after two minutes' stimulation of the illusion condition, the participants were required to complete a questionnaire (experiment one). Ten questions were designed which required a rating of the strength of agreement or disagreement with nine suggested perceptual experiences (adopted from (S1, S2)). The questions were presented in a randomized order. Three statements were designed to correspond to the illusion (see Supplementary Figure 1, questions 1-3). The seven other statements, which were unrelated to the illusion, served as control statements for suggestibility and compliance with task demands (see Supplementary Figure 1, questions 4-10). The participants used a seven-point visual analogue scale to rate the extent to which these statements did or did not apply. On this scale, -3 meant 'absolutely certain that it did not apply', 0 meant 'uncertain whether or not it applied', and +3 meant 'absolutely certain that it applied'. Thus a score of ≥ +1 meant that the participants affirmed the statement, a score of ≤ -1 meant that they denied it, and a score of 0 meant that they were uncertain if the statement applied. An ANOVA was used to analyze the data with an *a priori* defined contrast comparing the three illusion questions to the seven controls.

Physiological recordings (experiment two and three)

In the second experiment two skin conductance electrodes were attached to the second and third fingers and recorded the skin conductance using a portable system

(AT64 Portable SCR; Advanced Technology, Illinois, USA). The data was sampled (one Hertz), stored and analyzed on a Dell-laptop (InstaCalc and TracerDaq, Measurement Computing, Middleboro, USA). Before the experiments commenced the participants had been informed that they would never be hit by the hammer and that we would never actually threaten their real body (see below).

Two conditions were defined: (1) the illusion condition with synchronous seen and felt touches on the 'illusory body' (as used in experiment one); and (2) the asynchronous condition where the seen movements towards the illusory chest and the felt touches on the unseen real chest were presented alternately. We reasoned that synchronous visual and tactile stimulation would be particularly powerful in inducing ownership of the whole illusory body because we know that synchronous visual-tactile stimulation modulates ownership of a limb in the rubber hand illusion (S1, S2). Indeed, pilot experiments suggested that the asynchronous stimulation reduced or eliminated the illusion. The general motivation for including a control condition was to exclude general arousal associated with seeing the hammer being swung.

The two conditions were repeated three times in a pseudo-randomized order [(1, 2, 2, 1, 1, 2) or (2, 1, 1, 2, 2, 1)] to minimize the effect of presentation order. Further, the order of presentations was balanced across individuals. Each condition lasted for a random period between forty to eighty seconds, with period length matched between the conditions. At the end of the simulation the illusory body was suddenly 'hurt'.

As a threatening stimulus a hammer was used to hit a point below the two cameras that corresponded to the center of the lower face of the illusory body. Great care was taken to swing the hammer in the same way from trial to trial. The threat-stimulus was presented for about one second.

For each trial I identified the peak value of the skin conductance response (SCR) within one to four seconds after the onset of the hammer stimuli (which lasted one second). As baseline I used the value one second before the stimuli. I included all trials and analyzed the data from the two conditions in exactly the same way, by which I mean that I compared the magnitude of the SCR (S3).

For the statistical analysis I compared the mean SCR associated with the two conditions across individuals using a paired t-test. A one-tailed test was used because I had an *a priori* hypothesis of greater autonomic arousal in the illusion condition.

Subjective ratings of anxiety

The SCR was registered to objectively measure the changes in fear experienced by the participants in the presence or absence of the illusion. To quantify the consciously experienced emotional responses in the two conditions I asked the twelve participants in experiment two to rate the anxiety they had experienced when they saw the hitting hammer. Directly after the SCR experiment I presented a 10-point visual analogue scale where 1 meant 'no anxiety at all' and 10 meant 'strongest possible anxiety imaginable'. The participants were requested to report the average anxiety across the three threat events for each condition.

Subjective ratings of illusion and control conditions

Separate tests were carried out to verify that the experimental manipulations in experiment two caused changes in the subjective ratings of the illusion. Thus the illusion condition and the asynchronous condition were tested in the group of eighteen subjects directly after experiment one. The participants were exposed to sixty seconds of the illusion condition and sixty seconds of the asynchronous condition, with the order of conditions balanced across subjects. Directly after this stimulation they had to rate to one illusion-statement ("I experienced that I was located at some distance behind the visual image of myself, almost as if I was looking at someone else") and one control-statement ("I experienced a movement-sensation that I was floating from my real body to the location of the cameras") on the seven-point scale described above. The scores were compared using paired t-tests. Because we had an *a priori* hypothesis of greater illusion scores after the illusion condition we used a one-way test.

Supplementary Results

Spontaneous remarks (experiments one and two)

During the experiments some subjects made remarks and expressed behaviors that were strongly suggestive that they were experiencing a vivid illusion. Even before being presented with the questionnaires in experiment one, many of the participants made spontaneous remarks like: "Wow! I felt as though I was outside my body and looking at myself from the back!"; "It was weird, almost as if I was looking at someone else or some kind of dummy!"; or "I was sitting over there, behind myself." Further, some of the subjects started to giggle and verbally express amusement at the beginning of testing the illusion condition.

In the SCR experiments I observed that several participants flinched when I hit the 'illusory body' with the hammer, but only in the illusion condition. Before being asked any questions some participants told me that they experienced more fear in the illusion condition.

SCR (experiment two)

I first analyzed the SRC data from experiment two where I compared the illusion condition and the asynchronous condition. The results are presented in Figure 1 of the Brevia (left panel). As can be seen in this figure there is a greater threat-evoked response after the illusion condition (paired 1-tailed t-test, d.f.=11, $p<0.013$). This provides objective evidence that the participants experienced greater fear and anxiety when the location of the illusory body was hit in the illusion condition.

Subjective ratings of anxiety (experiment two)

The subjective reports correspond well with the SCR data. As expected, the participants reported greater anxiety when the hammer was hit towards the location just below the cameras after the illusion condition ($p<0.02$ paired t-test; illusion condition:

4.3±2.2; mean ± SD; asynchronous condition: 2.6±1.8). Thus 'hurting' the illusory body during the out-of-body illusion elicits emotional responses that can be registered with both subjective and objective methods.

Illusion ratings in experiment two

I also collected questionnaire data to verify that the participants were indeed experiencing a stronger illusion in the illusion condition than in the asynchronous condition, as indicated by pilot experiments. The participants more strongly affirmed the illusion statement after the illusion condition as compared with the asynchronous condition (1-tailed t-test p=0.002; illusion condition: +2.1 ± 1.0 (mean ± SD); asynchronous condition: +0.5 ±1.7). No such increase was observed for the control-statement, actually it showed the opposite pattern with higher ratings after the asynchronous condition (2-tailed t-test p=0.02; illusion condition: -2.1 ± 1.6; asynchronous condition: -1.3 ± 1.8) between the two conditions.

Experiment Three

Methods and rationale

A control experiment was designed to exclude the putative confounder that the SCR difference in experiment two was due to a conditioned response after a period of synchronous visual and tactile stimulation. The concern is that the brain would have learned to associate the visual and tactile stimuli, and therefore come to expect that it would be hit when the hammer is presented regardless of the perceived location of the body.

In this third experiment we used the same illusion-condition as in experiment two, but included a new control condition where the person's real body was touched on the shoulder in full view, without any object moving towards the cameras ('direct condition'). The key point here is that the visual and tactile stimuli are synchronous, although presented on the real body rather than on the illusory body, which reduces the illusion (see below). The theoretical motivation for a reduction in the illusion is that the seen touches applied directly on the real body should enhance self-recognition of it according to the view that visual-tactile correlations modulate body ownership (S1, S2) and self-recognition (S4).

SCR results (experiment three)

I contrasted the illusion condition to the direct condition where the person's real body was touched in full view on the shoulder. The results are presented in Supplementary Fig 2 (SFig. 2) where it can be seen that the physical threat stimulus produced greater SCR after the illusion condition compared to the direct condition (paired 1-tailed t-test, d.f.=10, $p<0.018$). This finding eliminates the possibility that the SCR difference in experiment two was due to a conditioned response, rather than reflecting emotional defence responses directly related to the illusion (see Supplementary Discussion below).

Subjective ratings (experiment three)

The participants more strongly affirmed the illusion statement after the illusion condition as compared with after the direct condition (1-tailed t-test p=0.002; illusion condition: +1.8 ± 1.0 (mean ± SD); direct condition: +0.3 ±1.9). No such difference was observed for the control-statement (2-tailed t-test p=0.13; illusion condition: -1.8 ± 1.8; direct condition: -1.2 ± 2.2). These findings are thus consistent with subjective report data from experiments one and two.

Supplementary Discussion

The SCR difference is most likely to reflect the difference in the levels of consciously experienced fear and anxiety due to the presence and absence of the illusion. However, it can be argued that the difference in skin conductance responses between the synchronous and asynchronous conditions in experiment two could reflect a conditioned response (associative learning) rather than the illusion. The argument goes that after a period of synchronous stimulation the brain would learn to associate the visual and tactile stimuli, and therefore come to expect that it would be hit when the hammer is presented. However, the results from experiment three exclude this possibility because in the direct condition synchronous visual and tactile stimuli are also presented (on the real body).

The physiological and subjective data from experiments two and three both support the conclusion that multisensory correlations in near-personal space are one key component of the illusion, in combination with the visual perspective. Experiment two shows that the synchronicity of the visual and tactile stimuli on the illusory body is a factor in the illusion. Experiment three demonstrates that the spatial location of the multisensory stimulation, on the illusory body versus on the real body, is important. These observations fit in well with the theoretical framework that multisensory correlations in near-personal space modulate the feeling of body ownership of individual limbs (1, 2) and body self-recognition (4). For example, in the direct condition the correlated multisensory signals are produced on the seen physical body which enhances self-recognition of it and reduces the experience of an illusory body at a different location in the room (it merely feels like you are looking at yourself through a video-system). Finally, the importance of the first-person visual perspective should be emphasized. The importance of this factor can be seen in the questionnaire data where the participants reported that they were 'uncertain' (scores around 0) rather than strongly rejecting the illusion in the control conditions that used this perspective (scores -3).

It is, of course, an open question as to whether the multisensory mechanisms that produce the present illusion are those involved in the cases of out-of-body experiences described in the neurological and psychiatric literature. But it is noteworthy that patients with damage or dysfunction to multisensory areas, such as the posterior parietal cortex, are particularly prone to out-of-body experiences (S5, S6). It has also been reported that direct electrical stimulation of a multisensory area in a patient during pre-surgical mapping can elicit out-of-body sensations (S7). Thus, on the assumption that multisensory mechanisms for the normal in-body experience require integration across distributed brain areas, it is possible that these could be impaired in a wide range of those brain conditions that cause OBEs.

Supplementary References

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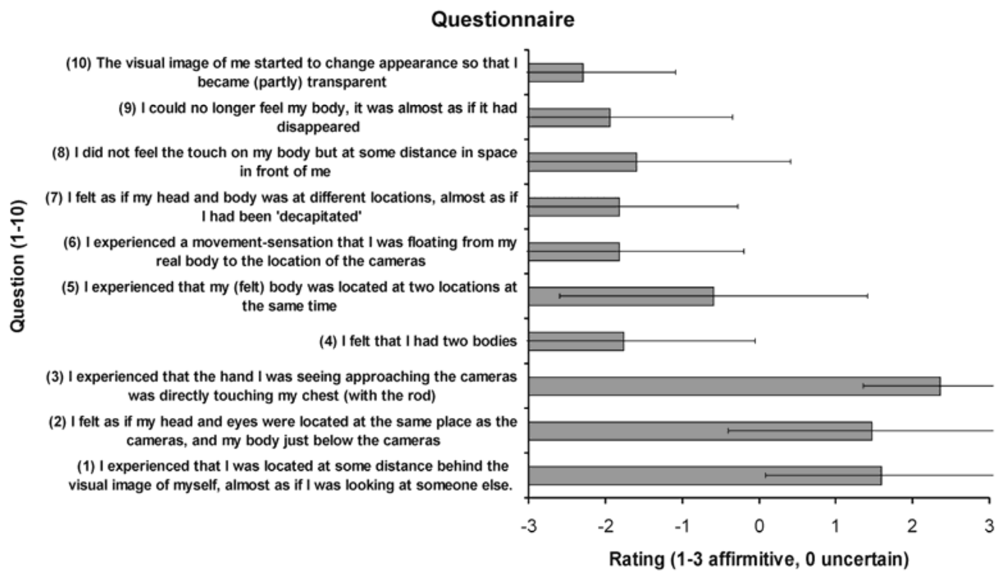
Supplementary Figure Legends

Supplementary Figure 1. The results of the questionnaire used to quantify the illusion in the first experiment (18 participants, see text for details). Questions 1-3 relate to the illusion, and questions 4-10 serve as controls. Error bars denote standard deviation. The difference in ratings between the illusion and control statements was significant [ANOVA, $F(9, 170) = 22.565$, $p<0.00001$; contrast comparing the three illusion questions to the seven controls, $F(1, 170)=189.92$, $p<0.00001$; paired post-hoc 2-tailed t-tests $p<0.01$]. Thus the participants reported that their body was located just below the cameras at a different location, distinct from their physical body, and that they felt as if they were looking at someone else from behind.

Supplementary Figure 2. The skin conductance responses (SCR) from the 11 subjects in experiment three, when the illusory body was 'hurt.' The difference between the illusion condition and the control condition where the experimenter is directly touching the real body in full view ('direct') is significant (paired 1-tailed t-test d.f. = 10; $p<0.019$). Mean values and standard deviation are presented.

Supplementary Figure 1



Supplementary Figure 2