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Supporting Online Material for

Video Ergo Sum: Manipulating Bodily Self-Consciousness

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Supporting Online Material

Material and methods

Fourteen participants (mean age 23.1 years ± 4.4SEM, 9 women) participated in Study I. An independent group of 14 participants (mean age 24.8years ± 5.1SEM, 7 women) took part in Study II. All participants were right-handed and had no history of neurological or psychiatric disorders. Participants were naïve to the purpose of the study and gave written informed consent. The study protocol was approved by the local ethics research committee at the University of Lausanne, Switzerland and has been performed in accordance with the ethical standards laid down in the Declaration of Helsinki.

Experimental set-up and procedure

Study I

Participants were wearing a white t-shirt and standing upright with their back facing a video camera (JVC 5 Mega Pixel Digital Media Video Camera). A Virtual FX 3D converter (I-O Display Systems) converted the standard 2D video image into a true, holographic-like 3D projection. The camera was placed on a tripod stand, two meters behind the participants. The back of the participants was filmed while it was irregularly stroked with a large orange pen. The video was projected real time onto a head mounted display (HMD; i-glasses Video 3D Pro; Resolution 800x600, horizontal field of view 25.6°, vertical field of view 17.1°) which enabled the participants to view the interlaced 3D video in stereoscopic 3D. The HMD was covered by black tissue occluding all surrounding visual input. Participants listened to white noise presented through headphones to exclude surrounding auditory input that could have given additional cues about the location of the stroking or the own body in space.
Accordingly, participants felt the stroking during 60 seconds on their back while seeing their own virtual back being stroked at a distance of 2m in front of them (virtual own body; Fig.1A). After the stroking the video was turned off and subjects were instructed to do small-size steps as if they were walking on a treadmill. Simultaneously they were guided slowly backwards by the experimenter (resulting step-size ~20cm). Then the subjects were asked to walk with normal-sized steps back to the initial position.

After completion of a training session to familiarize participants with the exact procedure and the displacement, participants carried out two different experimental conditions: in the synchronous condition the video signal was projected in real time to the HMD so that visual and the somatosensory signals were perfectly synchronised. In the asynchronous condition the video signal that had been recorded in the training session was re-played to the HMD while the participant was stroked such that visual and somatosensory input were not synchronized.

Two measures that have previously been used to quantify the degree of the rubber hand illusion (RHI) were adapted. After each condition we measured the distance between the actual position during the stroking and the position indicated by the participant (drift in cm; self-localization). We also used a 7-item questionnaire (score between -3 and 3) modified from the "RHI questionnaire" (*S1*) to measure the degree of self-attribution of the virtual character. The questionnaire contained the following questions:

During the experiment there were times when…

Q1 It seemed as if I were feeling the touch of the highlighter in the location where I saw the virtual body/ mannequin/ object touched.

Q2 It seemed as though the touch I felt was caused by the highlighter touching the virtual body/ mannequin/ object.

Q3 It felt as if the virtual body/ mannequin/ object was my body.

Q4 It felt as if my (real) body was drifting towards the front (towards the virtual body/ mannequin/ object).

Q5 It seemed as if I might have had more than one body.

Q6 It seemed as if the touch I was feeling came from somewhere between my own body and the virtual body/ mannequin/ object.

Q7 It appeared (visually) as if the virtual body/ mannequin/ object were drifting backwards (towards the real body).

Study II

As in Study I participants were placed in front of the camera and saw their body being stroked either synchronously or asynchronously in the HMD ("own body" condition; Fig.1A). In the other conditions participants were again placed 2m in front of the camera, but shifted ~1.5m to the left (outside the visual field of the camera). Instead of their own back, we projected either a video of the back of a human-size fake body (mannequin) wearing a white t-shirt ("fake body" condition, Fig.1B) or the back of a white human-size rectangular object ("object" condition, Fig.1C), stroked synchronously or asynchronously, to the HMD. All conditions were randomized between participants. For asynchronous stimulation we now used a delaying device (Delay Line Time, Ovation Systems, UK) to induce a systematic time lag of 200ms to the video signal before projecting it onto the HMD. The time-lag was chosen according to the results of Franck and colleagues (*S2*) who showed that with a delay of 200ms healthy participants can clearly discriminate between their movement and the visual feedback. The use of a delay allowed a randomised presentation of the conditions without the need for a pre-recorded session. We also measured data in an additional "empty room" condition where participants felt the stroking on their back while seeing the same visual scene but without any body or object in it. In a further condition ("motor control" condition) the drift was measured after having displaced the participants with eyes closed without any prior visual input or stroking.

Data acquisition and processing

The scores on the modified RHI-questionnaire as well as the drift were analysed using repeated-measures analyses of variance (ANOVAs) and t-tests. In Study I the drift was calculated relative to the initial position (=0) while in Study II it was measured relative to the motor control condition by subtracting it for each condition and participant separately. One-sample t-tests were made to compare the drifts to the corresponding baseline (Study I: initial position during stroking, Study II: motor control condition). Results were considered statistically significant for $p<0.05$.

Additionally ANOVAs were done for results of both the drift and the questionnaires (see supporting online text). For the drift we used the within-factors Synchrony (synchronous / asynchronous), the within-factor Axis (anterior-posterior / left-right) and the within-factor Condition (own body/fake body/object). For the results of the questionnaire we added the within-factor Question (Q1-Q7). Paired and two-tailed t-tests were used to further analyse the significant effects on the ANOVAs.

Supporting Text

Supplementary results Study I

Self-localization

In the synchronous condition participants showed on the anterior-posterior axis a mean drift of 24.1cm (±9.0SEM) towards the virtual body. This position differed significantly from the initial position ($p=0.02$ $t=2.67$; one sample t-test). As predicted, the drift to the front was smaller in the asynchronous condition (12.5cm ±8.5) and did not deviate significantly from the participants' initial position ($p=0.17$, $t=1.45$; one sample t-test). Also, no significant drift (synchronous $p=0.59$, $t= 0.55$; asynchronous $p=0.69$, $t= 0.41$; one sample t-tests) was observed along the left-right axis (synchronous 3.5cm ± 6.2; asynchronous 2.2cm ±5.7).

A 2x2 repeated measures ANOVA with the within factors Synchrony (synchronous, asynchronous) and Direction (anterior-posterior, left-right) revealed a significant main effect of Synchrony ($p=0.02$, $F=6.67$). With respect to the anterior-posterior axis, paired t-tests revealed a significantly stronger drift towards the virtual body in the synchronous condition compared to the asynchronous condition ($p=0.01$, $t =2.92$; Fig. 2A). No such difference was found on the lateral axis ($p=0.75$, $t=0.52$; fig. S1A).

Self-attribution

In the synchronous condition, participants scored positively (on a scale from -3 to 3) in the first three questions: Q1: 2.6 ±0.8SEM; Q2: 2.2 ±0.6SEM; Q3: 2.1 ±0.6SEM. All other questions and all questions after asynchronous stroking were answered negatively (Fig. 2B).

A 2x2 repeated measures ANOVA with the within factors Synchrony (synchronous, asynchronous) and Question (Q1-Q7) revealed a significant main effect of Synchrony (p=0.003, F=12.83), a significant main effect of Questions (p=0.001, F=4.31) and a significant interaction (p=0.0001, F=8.64). Paired t-test showed in the positively answered questions (Q1-Q3) a significantly higher rating in the synchronous condition than in the asynchronous condition (p<0.01, t<3.24).

Supplementary results Study II

Self-localization

Compared to the motor control condition we found a mean drift towards the virtual own body of 17.1cm (±6.1SEM) and towards the virtual fake body of 25.4cm (±8.4SEM) in the posterior-anterior axis when participants were stroked synchronously. Using one sample t-tests both drifts differed significantly from the motor control condition (own body: p=0.02 t=2.78; fake body: p=0.01, t=3.02). The drift was weaker (14.3cm ±7.3SEM) and no longer significant (p=0.07, t=1.95) when a non-corporeal object was used (Fig.3A). When using a room without any object in it, no drift was found (1.12cm±5.7SEM, p=0.83 t=0.21). Asynchronous stroking did not lead to any significant anterior drift in any of the conditions (drift between 1.5cm and 11.7cm, p>0.10; Fig.3A,). In the left-right axis the measured drifts varied between 0.1 and 8.5cm and we did not find any significant drift compared to the control condition (fig. S1B).

In the posterior-anterior axis the 2x3 ANOVA with the within-factors Synchrony and Condition revealed a significant interaction effect (p=0.04, F=3.70). Further, paired t-tests revealed that only the fake body condition showed a significant difference between synchronous and asynchronous conditions (p=0.0004, t=4.70, Fig. 3A) and that in the synchronous conditions only the fake body and the object differed significantly (p=0.04, t=2.26) whereas the asynchronous conditions did not differ between own body, fake body and object (p>0.05, t<1.41). In the left-right axis no such interaction was found (fig. S1B). As fake body and object condition are completely comparable concerning the experimental set-up (filming of the own body may lead to visual feedback of small bodily movements that are absent in fake body and object conditions) we suggest that the comparison between object and fake body conditions is most relevant for studying the influence of cognitive knowledge about bodies in illusory self location. In addition, similar conditions to the fake body and object condition have also been tested in the RHI (Tsakiris and Haggard, 2005).

Self-attribution

Results on the modified RHI-questionnaire were similar to those of to study I. The first (virtual body: 2.5 ±0.3SEM, mannequin: 2.2 ±0.3SEM, object: 2.6 ±0.2SEM) and the second questions (virtual body 1.4 ±0.4SEM, mannequin 1.6 ±0.5SEM, object 1.9 ±0.4SEM) were answered positively in all synchronous conditions and negatively in the asynchronous condition. Yet, the third question (Q3; "I felt as if the virtual body/object/mannequin was my real body") lead to different results. Whereas in both conditions with bodily characters (own body: 2.1 ±0.5SEM; fake body: 0.6 ±0.6SEM) the result was the same as in Q1 and Q2, this was not the case in the object condition where subjects gave negative scores even in the synchronous condition (-0.4 ±0.6SEM) revealing no significant difference between synchronous and asynchronous stroking. In the asynchronous condition all questions were rated negatively (fig. S2). These data suggest that the first two questions seem more related to the feeling and location of touch, whereas the third question asks about identification with the virtual character. We suggest that when an object is shown, subjects feel the touch outside their body, but do not experience the virtual character as if it were their own.

A 2x3 ANOVA showed a significant main effect of Synchrony ($p<0.01$, $F>43.46$), Question ($p<0.001$, $F>25.25$) and interaction of Synchrony and Question ($p<0.001$, $F>7.65$). Paired t-tests revealed significant differences between synchronous and asynchronous conditions for the bodily characters in the first three questions (fig. S2, table S 1).

Corroborating results from Study I participants showed stronger errors in self-localization and self-attribution in the synchronous conditions, particularly when a bodily object was used. Although the direct comparison between the synchronous and the asynchronous conditions revealed a significant difference only for the fake but not the own body condition, both synchronous conditions using a bodily character led to significantly larger drifts with respect to the motor control condition. This was supported by higher self-attribution scores when asked whether "it felt as if the virtual character/mannequin was my body" (Q3) in both conditions employing a bodily stimulus. Furthermore, we could extend our findings from Study I by showing that illusory self-localization to a position outside the physical body is stronger when bodily character is stroked than when a non-corporeal character is stroked. The empty room condition and the motor control condition also allowed us to exclude that these effects on self-localization are due to a motor bias characterized by a general tendency to overshoot the target position. Indeed in these conditions the drift was negative. The differences between the synchronous and asynchronous conditions were smaller in Study II compared to Study I. A potential reason could be the different method of achieving asynchronous stimulation in the two studies. In Study I stimulation was completely random, whereas in Study II we used a constant time lag leading to a situation with more predictable visual input. The asynchronous condition of Study II was for the subjects thus more predictable and the relation between the felt and the seen event might have been perceived as stronger leading to larger drifts. This is also suggested by the questionnaire scores in Study I and II: Comparing Fig 2C with Fig. S2A subjects indicated higher self-attribution Q 3) and a stronger feeling of the touch on the virtual body (Q2, Q3) in the asynchronous condition of Study II than of Study I.

Supporting figures

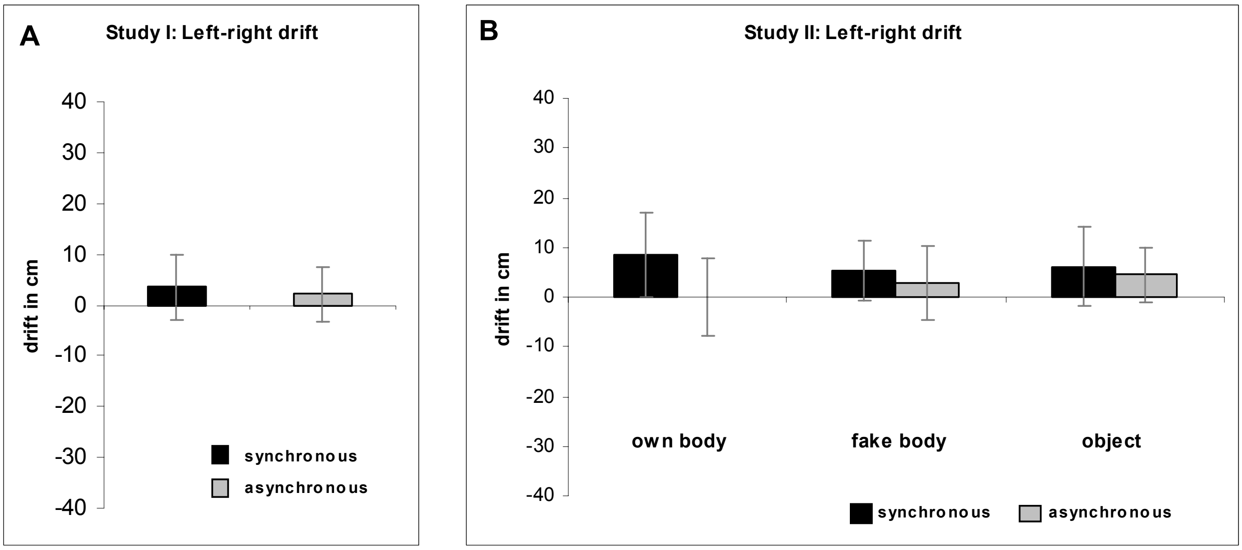

Figure S1: Data from Study I (A) and II (B). Drift on the left-right axis measured in cm [mean ±SEM] in the synchronous (black) and in the asynchronous stroking condition (gray): no significant effects were found. Positive values correspond to rightward deviations, negative values to leftward deviation.

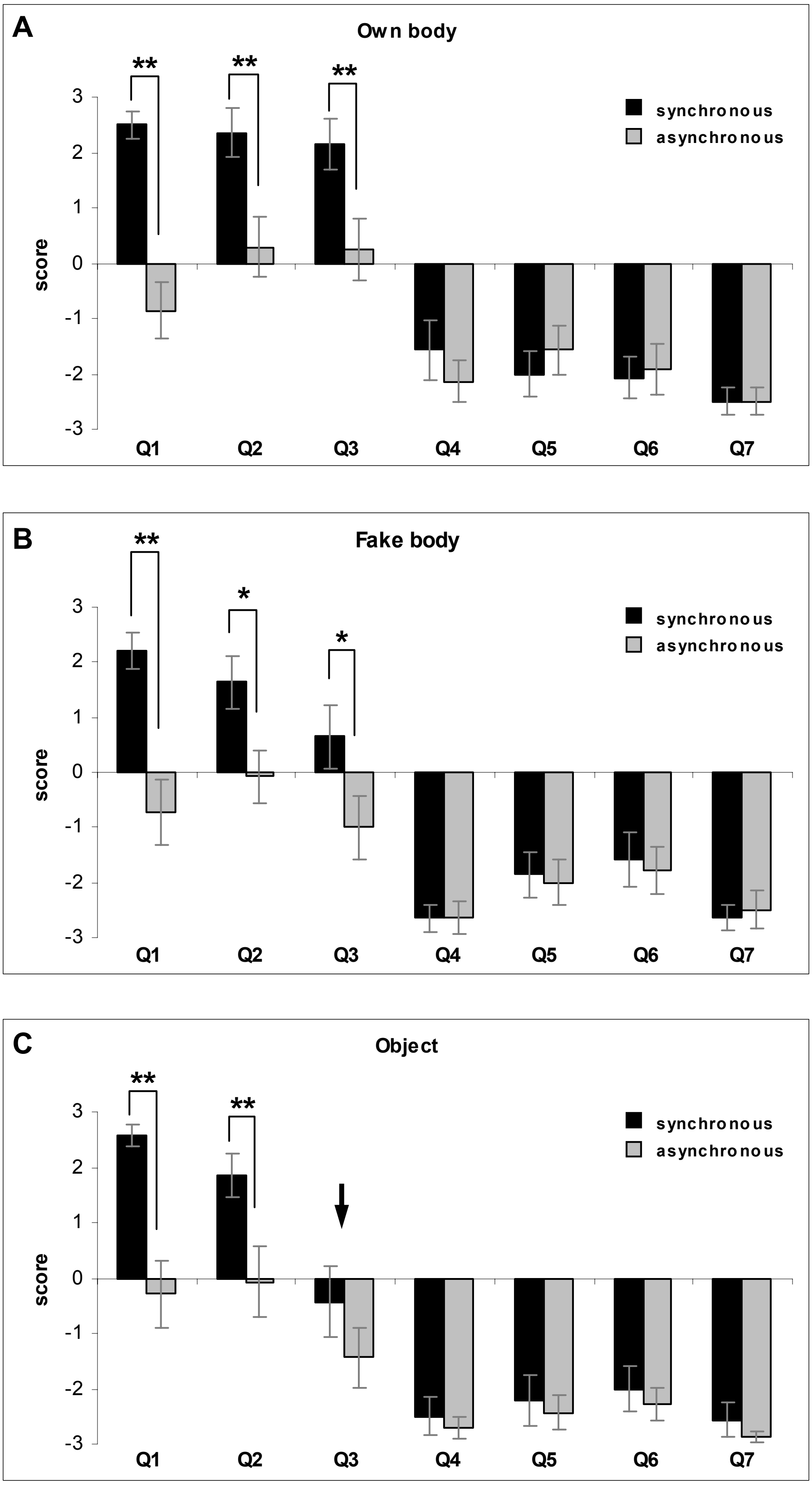

Figure S2: Data from Study II. Mean scores [±SEM] of self-attribution measured by questionnaire in the different conditions: (A) own body, (B) fake body, and (C) object. Self-identification (Q3; indicated by arrow) is stronger for bodily characters than for an object. Q1-Q7 refer to the different questions, compare text).

Supporting Table

	Own body		Fake body		Object	
	p-value	t-value	p-value	t-value	p-value	t-value
Question 1	0.0001	5.5	0.001	4.01	0.006	4.49
Question 2	0.01	2.56	0.017	2.70	0.009	3.09
Question 3	0.001	4.16	0.032	2.56	n.s.	1.55

Table S 1: T-tests for the interaction effect between Question and Synchrony. P- and t-values for the paired t-test between the score in the first three questions for the synchronous and the asynchronous conditions in the own body, the fake body and the object condition.

Supporting references

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