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Supplemental Information

Psychometrics of Disembodiment and Its Differential Modulation by Visuomotor and Visuotactile Mismatches

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Supplementary figures and tables

Table S1 related to Table 1

Descriptive statistics and pairwise comparisons of additional questionnaire data used in the PCA, N = 15.

	Visuotactile Synchronous		Visuotactile Asynchronous				
	Median	IQR	Median	IQR	*Z*	*p*	*r*
Disownership	0.13	0.04 - 0.27	0.55	0.46 - 0.63	-3.74	<.001	-.68
q4	0.07	0.03 -0.16	0.67	0.38 - 0.76	-4.01	<.001	-.73
q6	0.10	0.03 -0.26	0.60	0.33 - 0.70	-3.01	.003	-.55
q9	0.17	0.03 - 0.39	0.58	0.37 - 0.70	-2.71	.007	-.49
Deafference	0.04	0.03 - 0.11	0.58	0.27 - 0.63	-3.52	<.001	-.64
q10	0.06	0.02 - 0.13	0.72	0.36 - 0.77	-3.33	<.001	-.61
q8	0.06	0.03 - 0.10	0.53	0.09 - 0.67	-2.64	.008	-.48
q7	0.04	0.02 - 0.09	0.34	0.06 - 0.65	-3.74	<.001	-.68
Embodiment	0.90	0.85 - 0.96	0.58	0.41 - 0.73	-4.01	<.001	-.73
q1	0.95	0.90 - 0.98	0.70	0.28 - 0.81	-4.01	<.001	-.73
q11	0.94	0.83 - 0.97	0.63	0.52 - 0.78	-3.42	<.001	-.63
q5	0.92	0.71 - 0.96	0.39	0.17 - 0.69	-3.33	<.001	-.61
Control item and manipulation check							
q3	0.96	0.94 - 0.99	0.93	0.85 - 0.97	-2.23	.026	-.41
q2	0.96	0.84 - 0.98	0.68	0.24 - 0.72	-2.57	.010	-.47
Components based on the PCA in the synchronous condition							
Component 1	0.21	0.17 - 0.31	0.50	0.39 - 0.56	-4.01	<.001	-.73
Component 2	0.94	0.87 - 0.97	0.70	0.44 - 0.79	-4.01	<.001	-.73

Note: VAS ratings on q5 were inversed, so that higher scored indicate higher embodiment.

Table S2 Related to Table 1

Descriptive statistics and pairwise comparisons of questionnaire data in Experiment 1, N = 30.

	Visuotactile Synchronous		Visuotactile Asynchronous				
	Median	IQR	Median	IQR	*Z*	*p*	*r*
Disownership	0.14	0.05 - 0.41	0.61	0.40 - 0.72	-5.08	<.001	-0.66
q4	0.11	0.03 – 0.30	0.59	0.25 – 0.78	-4.59	.005	-0.59
q6	0.07	0.03 – 0.23	0.54	0.18 – 0.70	-4.96	<.001	-0.64
q9	0.20	0.05 – 0.53	0.61	0.31 – 0.78	-4.34	<.001	-0.56
Deafference	0.14	0.04 - 0.41	0.30	0.22 - 0.52	-5.83	<.001	-0.75
q10	0.11	0.03 – 0.43	0.29	0.12 – 0.69	-4.17	<.001	-0.53
q8	0.26	0.04 – 0.40	0.52	0.21 – 0.70	-4.20	<.001	-0.54
q7	0.07	0.03 – 0.17	0.18	0.07 – 0.46	-4.34	<.001	-0.56
Embodiment	0.89	0.75 - 0.95	0.72	0.62 - 0.82	-3.81	<.001	-0.49
q1	0.91	0.88 – 0.98	0.78	0.67 – 0.86	-4.17	<.001	-0.54
q11	0.94	0.79 – 0.96	0.76	0.67 – 0.84	-3.58	<.001	-0.46
q5	0.90	0.72 - 0.96	0.73	0.38 - 0.87	-2.78	<.001	-0.36
Control item and manipulation check							
q3	0.93	0.84 – 0.97	0.91	0.81 – 0.97	-1.31	.191	-0.16
q2	0.85	0.57 – 0.97	0.51	0.28 – 0.75	-3.28	.001	-0.42
Components based on the PCA in the synchronous condition							
Component 1	0.25	0.18 - 0.45	0.48	0.39 - 0.57	-5.57	<.001	-.72
Component 2	0.93	0.84 - 0.96	0.78	0.67 - 0.82	-3.84	<.001	-.50

Note: VAS ratings on q5 were inversed, so that higher scored indicate higher embodiment.

Table S3 Related to Table 1

Results of the PCA on questionnaire responses in the synchronous condition

		Varimax rotated factor loadings	
	Component 1	Component 2	commonalities
q4	**0.87**	0.27	0.83
q10	**0.87**	0.06	0.76
q7	**0.81**	0.27	0.73
q6	**0.79**	**0.44**	0.82
q8	**0.72**	0.38	0.66
q9	**0.71**	0.41	0.67
q5	**0.67**	0.12	0.46
q11	0.10	**0.87**	0.77
q1	0.34	**0.72**	0.64
Eigenvalues	4.39	1.95	
% of variance	49	22	

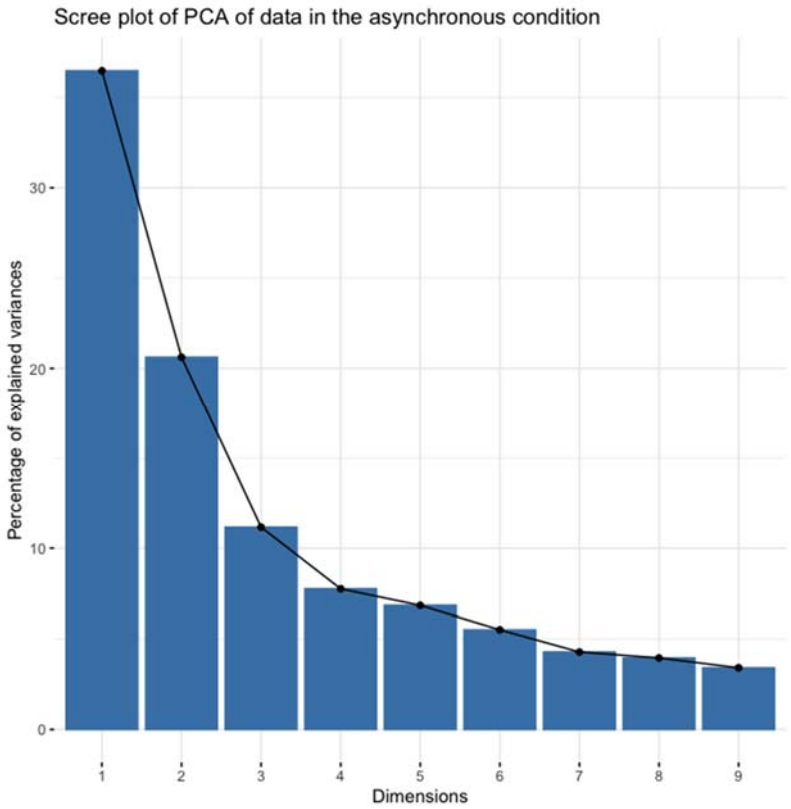

Figure S1 Related to Table 1: The scree plot of the PCA in the asynchronous condition justifies retaining three components for the secondary PCA.

Table S4 Related to Figure 2

Descriptive statistics of questionnaire data in Experiment 2, N = 32

	Visuotactile Synchronous		Visuotactile Asynchronous		Visuomotor Synchronous		Visuomotor Asynchronous	
	Median	IQR	Median	IQR	Median	IQR	Median	IQR
Disownership	0.28	0.16 - 0.43	0.57	0.43 – 0.70	0.32	0.17 – 0.46	0.66	0.49 – 0.77
q4	0.17	0.09 - 0.36	0.60	0.34 - 0.69	0.20	0.10 - 0.30	0.72	0.56 - 0.82
q6	0.21	0.09 - 0.29	0.62	0.32 - 0.73	0.18	0.07 - 0.33	0.69	0.57 - 0.85
q9	0.50	0.24 - 0.68	0.67	0.40 - 0.76	0.58	0.26 - 0.74	0.62	0.33 - 0.80
Deafference	0.19	0.08 – 0.45	0.34	0.15 – 0.48	0.20	0.10 – 0.38	0.42	0.22 – 0.56
q10	0.16	0.06 - 0.30	0.25	0.17 - 0.43	0.17	0.08 - 0.41	0.38	0.22 - 0.64
q8	0.19	0.10 - 0.59	0.4	0.14 - 0.69	0.24	0.08 - 0.61	0.37	0.19 - 0.66
q7	0.12	0.06 - 0.28	0.23	0.06 - 0.40	0.10	0.05 - 0.28	0.31	0.15 - 0.48
Embodiment	0.81	0.70 - 0.93	0.58	0.44 – 0.71	0.86	0.71 - 0.91	0.43	0.34 - 0.54
q1	0.90	0.81 - 0.97	0.65	0.41 - 0.78	0.91	0.81 - 0.95	0.42	0.28 - 0.68
q11	0.85	0.78 - 0.93	0.7	0.37 - 0.82	0.89	0.80 - 0.96	0.54	0.29 - 0.69
q5	0.81	0.59 - 0.91	0.43	0.26 - 0.66	0.81	0.61 - 0.92	0.31	0.15 - 0.54
Control item and manipulation check								
q3	0.91	0.84 - 0.97	0.86	0.80 - 0.94	0.89	0.78 - 0.97	0.86	0.68 - 0.96
q2	0.85	0.57 - 0.95	0.53	0.18 - 0.69	0.89	0.77 - 0.95	0.66	0.56 - 0.81
Components based on the PCA in the synchronous condition (see Table S3)								
Component 1	0.30	0.22 - 0.47	0.48	0.36 - 0.56	0.34	0.24 - 0.44	0.49	0.42 - 0.61
Component 2	0.87	0.80 - 0.93	0.64	0.47 - 0.75	0.89	0.82 - 0.93	0.47	0.34 - 0.60

Note: VAS ratings on q5 were inversed, so that higher scored indicate higher embodiment.

Table S5 Related to Figure 2

Results of Friedman tests and post-hoc comparisons of questionnaire in Experiment 2, using Wilcoxon Signed-Rank tests, FDR corrected p-values

	Friedman test			VTsyn - VTasyn			VMsyn - VMasyn			VTsyn - VMsyn			VTasyn - VMasyn		
	χ^2	df	p	Z	$p_{corrected}$	r	Z	$p_{corrected}$	r	Z	$p_{corrected}$	r	Z	$p_{corrected}$	r
Disownership	35.51	3	<.001	-4.42	<.001	-0.55	-5.12	<.001	-0.64	-0.05	.963	-0.01	-2.31	.021	-0.29
q4	39.38	3	<.001	-4.19	<.001	-0.52	-5.09	<.001	-0.63	-0.06	.949	-0.01	-2.52	.016	-0.31
q6	43.46	3	<.001	-4.72	<.001	-0.59	-5.30	<.001	-0.66	-0.25	.803	-0.03	-3.04	.003	-0.38
q9	7.76	3	.051												
Deafference	26.78	3	<.001	-3.36	<.001	-0.42	-3.77	<.001	-0.47	-0.69	.488	-0.09	-1.98	.048	-0.25
q10	28.56	3	<.001	-3.63	.001	-.045	-3.41	.001	-0.43	-1.71	.087	-0.21	-3.50	.001	-0.44
q8	5.66	3	.129												
q7	19.95	3	<.001	-2.16	.062	-0.27	-4.72	<.001	-0.59	-0.10	.919	-0.01	-1.94	.069	-0.24
Embodiment	59.36	3	<.001	-4.58	<.001	-0.57	-5.92	<.001	-0.74	-0.97	.331	-0.12	-2.85	.005	-0.36
q1	55.65	3	<.001	-4.19	<.001	-0.52	-5.86	<.001	-0.73	-0.05	.963	-0.01	-2.54	.015	-0.05
q11	52.46	3	<.001	-4.24	<.001	-0.53	-6.23	<.001	-0.78	-1.54	.139	-0.19	-1.48	.139	-0.19
q5	49.24	3	<.001	-3.63	.001	-0.45	-4.90	<.001	-0.61	-0.18	.861	-0.02	-2.76	.008	-0.34
Control item and manipulation check															
q2				-3.61	<.001	-0.45	-3.68	<.001	-0.46						
q3	9.19	3	.027	-1.96	.100	-0.24	-2.46	.056	-0.31	-0.05	.963	-0.01	-1.69	.121	-0.21
Components based on the PCA in the synchronous condition (see Table S3)															
Component 1	30.41	3	<.001	-3.87	<.001	-.48	-4.31	<.001	-.54	-.92	.36	-.11	-2.22	.04	-.28
Component 2	60.86	3	<.001	-4.81	<.001	-.60	-6.23	<.001	-.78	-1.37	.17	-.17	-2.48	.02	-.31

Table S6 Related to Figure 3

Summary of the initial mixed model, including the fixed effects for delay and modality, and their two-way interaction

		Confidence interval					
fixed effects	*b*	lower	upper	*SE*	*df*	*t*	*p*
intercept	0.923	0.866	0.981	0.029	46.29	31.49	<.001
Delay	-0.718	-0.772	-0.665	0.027	2525	-8.84	<.001
Modality	0.038	0.002	0.074	0.018	2525	2.29	.04
Delay x Modality	-0.154	-0.230	-0.079	0.039	2525	-4.47	<.001

Notes: Modality (0 = Visuotactile, 1 = Visuomotor)

Table S7 Related to Figure 3

Summary of the final mixed model, including the predictors delay, modality, and PSE, and the two-way and three-way interactions.

		Confidence interval					
fixed effects	*b*	lower	upper	*SE*	*df*	*t*	*p*
intercept	0.830	0.788	0.871	0.027	37.23	34.32	<.001
Delay	-0.717	-0.880	-0.553	0.082	33.82	-8.69	<.001
Modality	0.007	-0.017	0.031	0.017	2473.88	1.84	.066
PSE	0.790	0.485	1.099	0.210	1393.73	4.24	<.001
Delay x Modality	-0.164	-0.232	-0.096	0.035	2471.39	-4.73	<.001
Delay x PSE	-0.724	-1.609	0.149	0.446	1633.18	-1.62	.105
Modality x PSE	-0.511	-0.878	-0.148	0.251	2086.97	-3.26	.001
Delay x Modality x PSE	2.188	1.153	3.233	0.530	2213.69	4.13	<.001

Notes: Modality (0 = Visuotactile, 1 = Visuomotor), PSE was mean-centered around 0, lower values correspond to high sensitivity, and higher values to low sensitivity.

Transparent Methods

Experiment 1

Participants. Thirty healthy volunteers participated in Experiment 1 (10 males; *M* = 25, *SD* = 3.8 years). Participants provided informed consent and received either course credit or financial compensation.

For the PCA of the questionnaire responses after synchronous versus asynchronous stroking, we additionally included the participants of Experiment 2 (see section *Participants* for Experiment 2), as well as 15 participants (3 males; *M* = 22.2, *SD* = 2.4 years) from a previously unpublished experiment resulting in a total of 77 participants (27 males; *M* = 22.9, *SD* = 4.0 years). These were recorded in the same setting and using the same experimental materials as the other studies, with the only difference being that for 5 individuals the stroking lasted 60 s and for ten individuals 90 s. The participants were not included in the general analysis as we did not record the physiological measures in that sample.

All protocols were approved by the Ethics Committee of the Faculty of Arts and Social Sciences at the University of Zurich (Approval Number 17.12.15). The studies were performed in accordance with the ethical standards of the Declaration of Helsinki.

Apparatus for stimulation. An Oculus CV1 HMD (Oculus VR, Irvine, CA, USA) was used for the visual stimulation. An ELP 180˚ webcam (Ailipu Technology Co., Ltd, Guangdong, China) was positioned on the front of the HMD, set to 30 frames per second and resolution of 1024 x 768 pixels. The camera was positioned with the wide side of view (1024 pixels) on the vertical axis in order to more clearly show the full-body. The control system was designed using Unity 2017 for delaying the camera feed, rotating the image, mapping it to a 3D model approximately matching the distortion of the camera-lens, and projecting the image on the HMD. A qualitative calibration was done before the experiment to approximately match the visual field of view in the HMD to that without the HMD as well as to the seen and

felt (proprioceptive) position of the body. The questionnaires and randomization were also built within Unity 2017. The system was run on an Alienware 15 R3 computer (Nvidia Geforce GTX 1080 8GB; 16GB RAM; Intel Core i7; Windows 10). The mean intrinsic delay of the camera feed added by the system was of 139.1ms (*SD* = 18.3 ms).

Procedure.

Heartbeat counting task. At the beginning of the experiment, participants performed a heartbeat counting task (Schandry, 1981), see Figure 1a (in the main text) for general procedure and order of the experiment. Participants were instructed to count their heartbeats, without taking their pulse. They were informed that the time of the intervals would vary, to prevent them relying on time estimation instead of actual counting of the heartbeats. Three intervals of 25, 35, and 45 s were presented in randomized order, and the start and end of each interval was indicated by a tone. During the task, electrocardiograms (ECG) were recorded with a Biopac MP150 system and ECG100C amplifier (Goleta, USA) at 1000 Hz sampling rate. Three ECG electrodes (Red Dot, 3M, Neuss, Germany) were placed on the left and right clavicle and on the lowest left rib. The electrodes were left to measure ECG throughout the experimental procedure.

The heartbeat perception score, which reflects the normalized difference between recorded and perceived heartbeats in a way that higher scores indicate higher accuracy, was calculated using the following equation:

$$\text{heartbeat perception score} = 1/3 \sum 1 - \frac{|\text{recorded heartbeats} - \text{perceived heartbeats}|}{\text{recorded heartbeats}}$$

Data from 10 participants were excluded due to technical difficulties with the ECG recording equipment, missing markers, or because they did not understand the task.

Visuotactile stimulation. After performing the heartbeat counting task, the thermocouples and additional electrodes for measuring electrodermal activity were put on. Participants received verbal instructions about the visuotactile stimulation procedure and

were helped to put on the HMD. After reading instructions on the HMD, they performed a test trial where they selected “strongly agree” on a visual analogue scale (VAS) from “strongly disagree” to “strongly agree” to indicate that they were ready. A few seconds of exposure to a synchronous video feed of their own bodies on the table followed to acquaint participants with the task and the virtual environment. For the experiment participants were instructed to not move and keep especially the head in a fixed position.

First a block with synchronous and asynchronous visuotactile stimulation of 60 s each was presented. Asynchrony was achieved by adding a 594 ms delay to the ~139 ms intrinsic delay, we refer to the synchronous condition as such despite the fact that it included the system delay of ~139 ms. The stroking in both conditions was performed by the experimenter following the same strategy with a stroking rate of approximately 1 Hz in randomized directions for all fingers while monitoring the participant's perspective on a computer screen. The order of synchrony was counterbalanced across participants. After the 60 s of stimulation, the experimenter threatened the participant’s left hand with a plastic knife in a stabbing motion, which was followed by a 30 s rest period where the video feedback was displayed without any tactile stimulation, to assess change in heartrate. Participants were informed about the knife threat before starting the experiment, but did not know when it would occur. Both the synchronous and asynchronous condition were followed by the (dis)embodiment questionnaire. A block of 180 s of synchronous and asynchronous visuotactile stimulation followed. After 180 s of visuotactile stimulation, the experimenter threatened the participant’s left hand with the plastic knife in a sliding motion. The 30 s rest period followed again. The 180 s blocks were aimed at assessing HRV during the manipulation of embodiment, and were not followed by the embodiment questionnaire. Again, the order of synchrony was counterbalanced across participants.

The experiment was concluded with a brief semi-structured interview on the experiences of the participant and a short debriefing. The full procedure took about 45 minutes.

Measures of illusion strength.

(Dis)embodiment questionnaire. The subjective experience of the illusion was assessed with a questionnaire (see Table 1 for illusion related questions, and additional control questions). Two questions were used as control items, respectively q2 (It felt as if the stroking I felt on my hand was due to the seen stroking) and q3 (It seemed as if the seen hand resembled my own hand in terms of its shape and structure). For the former we expected changes between conditions given that it was foreseen to change with the manipulation, but not in respect of body perception; while for the latter we expected no changes between conditions. The questionnaire was based on other studies, including the original rubber hand illusion (Botvinick & Cohen, 1998), a full-body illusion (Lenggenhager, Tadi, Metzinger, & Blanke, 2007), the psychometric approach developed by Longo and colleagues ((Longo, Schüür, Kammers, Tsakiris, & Haggard, 2008), other psychometric approaches (Dobricki & Rosa, 2013) and additional new items to specifically assess disembodiment. Participants indicated on a VAS scale ranging from “completely disagree” to “completely agree” (respectively mapped to values ranging between 0 and 1) how much they agreed with each of the 11 statements. Based on the PCA (see section *The effect of visuomotor as compared to visuotactile mismatch on the phenomenology of disembodiment* in the main text), three subscales of disownership, deafference, and embodiment were identified. The questionnaire was displayed in the HMD and participants responded by means of head movements: they would select the corresponding position on the scale by looking at it for 1 s, after which they had to look at another button for 1 s to proceed to the next item.

Skin temperature. Skin temperature was measured with an HH309A Data Logger thermometer (Omega, Stanford, CT, USA) at a 0.5 Hz sampling rate with a resolution of 0.1° C per thermocouple. Such device has been previously used to assess changes in skin temperature in embodiment-related experimental paradigms (Macauda et al., 2015; Salomon, Lim, Pfeiffer, Gassert, & Blanke, 2013). Two thermocouples were placed on the left and right ventral side of the wrist, and a third on the back of the neck. A fourth thermocouple was used to monitor room temperature. While not systematically measured, the time since entering the room, setting up the equipment and doing the tasks previous to the temperature recording, served for the participant's adaptation to the room temperature. Temperature was measured for the full length of the visuotactile stimulation in each condition. For each thermocouple, a baseline was calculated as the average temperature of the first 6 s of recording. This average value was subtracted from the subsequent recordings to represent the relative change in skin temperature across the stimulation period. In the short conditions, average temperature change was computed over 54 s (60 – 6 s baseline). In the long conditions, the average temperature change was computed over 174 s. One participant had to be excluded from the analyses due to technical problems. Two additional participants in the 60 s-blocks, and four in the 180 s-blocks were excluded due to missing data. We controlled for changes in room temperature by assessing differences in room temperature change between the asynchronous and synchronous condition, which were not significant in both the short block ($p = .54$) and the long block ($p = .33$).

Skin conductance responses. Threat evoked SCRs were recorded with a Biopac MP150 system and EDA100C amplifier (Goleta, USA) at a 1000 Hz sampling rate. Two electrodes with electrode paste were placed on the participant's index and middle finger of the non-stimulated right hand. The experimenters threatened the left hand of the participant, by making a stabbing motion in the short block, and a sliding motion in the long block,

without touching the hand. A sound signal on the experimenter's headphones indicated the onset of the threat at the corresponding time depending on the condition, and a manual marker was placed in the raw data file immediately after presenting the threat. The data was processed in Acqknowledge software (Version 4.1, Biopac, Goleta, USA). The SCR was identified as the maximum peak-to-peak value in electrodermal activity between 2 s before, to 6 s after the marker. The 2 s before were taken into account, as it reflects the time from the threat to the actual manual pressing of the marker. The SCR response was then computed as a relative value, taking into account the average raw SCR of all four threat responses. It was computed by dividing the SCR in each condition, by the average SCR of all four conditions in order to standardize the values. The data was gathered separately by two experimenters, blindly analyzed and compared. Absent responses were registered as missing values. Data from five participants were excluded from the analysis due to missing responses or technical difficulties.

Heart Rate Variability. A synchronous and asynchronous block of three-minute-long visuotactile stimulation was added to the procedure to assess HRV. ECG was recorded with the Biopac MP150 system as described previously. 160 seconds of recording were used, with an onset 10 s after the stimulation onset up to 10 s before the threat marker. The R-package RHRV (Rodriguez-Linares et al., 2017) was used to detect R-peaks and extract the Root Mean Square of the Successive Differences (RMSSD) as a measure of HRV. Data from four participants were excluded from the analysis due to technical difficulties.

Data analysis. Data were analyzed with R (R Core Team, 2018) version 3.5.1. Alpha level was set at 0.05, or 95% confidence intervals, excluding 0, and p-values were adjusted for multiple comparisons using false discovery rate (FDR) corrections (Benjamini & Hochberg, 1995). Data were tested for normality, and appropriate tests were used accordingly. Details of preprocessing of the physiological data are described above.

Principal Component Analysis. A PCA was used to investigate the structure of participants' experience, and to quantify the complex experience during this illusion. The PCA was conducted on the questionnaire data after synchronous or asynchronous visuotactile stimulation. In order to maximize the number of participants we took the questionnaire data from Experiment 1 and questionnaire data from the long visuotactile stroking of Experiment 2 (see below) as well as additional data of 15 participants in an unpublished experiment (see Table S1, for descriptive statistics and item comparisons of these additional participants). Exposure time was 60 s in experiment 1 (n = 30), 90 s in experiment 2 (n = 32), and differed for the additional data between 60 s (n = 6) and 90 s (n = 9).

Before running the PCA, the ratings of q1 and q11 were inversed, so that all items were coded in the same direction, with higher ratings indicating decreased embodiment. Two PCAs were separately run for the asynchronous and synchronous conditions. Adequacy of using PCA was assessed by Bartlett's test of sphericity, which was highly significant for both the asynchronous ($X^2(55) = 238.6$, $p < .0001$), and synchronous condition ($X^2(55) = 506.9$, $p < .0001$), indicating that correlations between individual items were sufficiently large for PCA. The overall Kayser-Meyer-Olkin (KMO) measure verified that the sample size was adequate, both for the asynchronous (KMO = 0.71), and synchronous (KMO = 0.85) condition. The two control items (q2 and q3) were excluded from the PCA, based on the low expected correlation with any of the other questionnaire items in the asynchronous conditions, as well as their poor individual KMO (both < 0.55) (Kaiser, 1974). An initial PCA was computed with 9 components. Inspection of the eigenvalues of each component and the scree plot (Figure S1) justified retaining three components for the secondary PCA. For subsequent comparisons between conditions component scores were calculated as the mean of q4, q6, and q9 for Component 1; q7, q8, and q10 for Component 2; and q1, q11, and (1 -

q5) for Component 3. For the component scores, q5 was inversed to ensure that higher ratings correspond to increased embodiment for all items within Component 3.

Experiment 2

Participants. Thirty-two healthy volunteers participated in Experiment 2 (7 males; $M = 21.2$, $SD = 3.9$ years old). None of the participants took part in Experiment 1, and all gave informed consent and received either course credits or a financial compensation. The protocol was approved by the Ethics Committee of the Faculty of Arts and Social Sciences at the University of Zurich (Approval Number 17.12.15). The study was performed in accordance with the ethical standards of the Declaration of Helsinki.

Apparatus for stimulation. The apparatus to present visual stimulation was identical to Experiment 1 (*Apparatus for stimulation* for Experiment 1). An additional laptop was used to play a metronome sound with its built-in speakers.

Procedure. The experiment consisted of two different parts: first, two blocks with multiple trials of short stimulation, either visuotactile or visuomotor were presented, then four conditions of longer stimulations, either visuomotor or visuotactile both either synchronous or delayed were presented (see Figure 1b in the main text for an overview of the procedure). When participants were ready, they were helped to put on the HMD and read instructions on the screen. Similar to Experiment 1, the testing procedure was preceded by a test trial to practice giving responses on the VAS scale, and exposure to a synchronous image of the participant's body with their hands on the table for a few seconds.

For the visuotactile block, participants were asked to fix their left hand between the two markers on the table while they were stroked with a small paintbrush outwards from their arm on their index and middle fingers at a rate of approximately 0.5 Hz with the aid of a metronome set to 1 Hz. The first click of the metronome would be to stroke down the finger and release, and the second click to go back without touching to start the next stroke. This would be repeated across the whole trial. For the visuomotor block they were asked to move

their left hand horizontally from the left to the right marker (set at a distance of approximately 60 cm from each other) and back repeatedly, following the rhythm of a metronome (set to 1 Hz), each back-and-forth movement would last 0.5 Hz. Participants started and ended each trajectory with their hand touching the table. Each trial lasted 7 s and was followed by the question "Was the touch/movement you saw and felt synchronous?", which could be answered by either selecting *yes* or *no*. This question was followed by the statement "It felt as if the hand that I saw was my own", which could be answered on a VAS scale ranging from *strongly disagree* to *strongly agree.* The first two blocks consisted of 40 trials with four repetitions of 10 possible delay steps of 66 ms each, resulting in a range from 139 to 733 ms (including the intrinsic delay). The order of the visuomotor and visuotactile blocks were counterbalanced across participants.

Finally, a block of longer stimulation followed, where we presented four conditions (synchronous visuotactile, synchronous visuomotor, asynchronous visuotactile and asynchronous visuomotor) in counterbalanced order. The asynchronous conditions had a delay of 594 ms (plus the intrinsic 139.1 ms delay). During the visuomotor conditions, participants moved their hands as in the previous block but for a longer period; similarly, for the visuotactile condition, participants were stroked on their hand with a paintbrush randomly over the full hand at a rate of approximately 1 stroke per second for a period of 90 s, the stroking was monitored on the computer screen by the experimenter to prevent the overlap of the previous seen stroke with the ongoing tactile stroke in the asynchronous condition. After each condition, they were asked to answer the (dis)embodiment questionnaire (see section *(Dis)embodiment questionnaire*).

Participants could take breaks and remove the HMD in between blocks. The experiment was concluded with a brief semi-structured interview on the experiences of the participant and a short debriefing. The overall procedure took about 50 minutes.

Measures of illusion strength. The assessment for the short stimulation was based on simultaneity judgment methods used to measure temporal windows of multisensory integration (Engel & Dougherty, 1971; Hirsh & Fraisse, 1964; Hoover & Harris, 2012, 2016), and an embodiment question derived from several studies (Botvinick & Cohen, 1998; Dobricki & Rosa, 2013; Lenggenhager et al., 2007). After each block of 90 s, participants completed an identical questionnaire as in Experiment 1. Item 3 corresponded to a control item and differed between conditions, and was "It felt as if the movement I felt was due to the seen movement" in the visuomotor condition, and "It felt as if the stroking I felt on my hand was due to the seen stroking" in the visuotactile condition.

Data analysis. The same software and parameters for significance were used as in Experiment 1. The questionnaire was analyzed using Wilcoxon signed-rank tests to assess the effect of synchrony (visuotactile synchronous vs. visuotactile asynchronous and visuomotor synchronous vs. visuomotor asynchronous) and the effect of modality (visuotactile synchronous vs. visuomotor synchronous and visuotactile asynchronous vs. visuomotor asynchronous).

Sensitivity to delay was assessed by determining the Point of Subjective Equality (PSE) for each participant in the visuomotor and visuotactile condition separately. To this end, logistic psychometric functions were fitted to the forced choice synchrony judgements of each participant, using a binomial Generalized Linear Model (glm) with delay as a predictor. The estimated coefficients of the glm were used to calculate the PSE: $-\beta_0 / \beta_1$, where β_0 corresponds to the intercept and β_1 to the slope. Goodness of fit was assessed with the Hosmer-Lemeshow test, and data of one participant in the visuotactile condition was excluded due to bad fit of the glm. All other psychometric curves did not yield a significant test result, and corresponding PSEs were thus used for further analyses.

Generalized linear mixed models were fitted with the lme4 package in R (Bates, Mächler, Bolker, & Walker, 2015). A generalized linear mixed model was fitted to the VAS ownership ratings in the short block, across different delays, which ensured for adequate power while considering the repeated measures within individuals. The intraclass correlation demonstrated that observations within individuals were non-independent (ICC(1) = .27, $F(31, 2528) = 31$, $p < .001$), thus justifying the use of a mixed model. Visual inspection of diagnostic plots of the residuals showed that these were normally distributed. The model that included both a random intercept and slope for individuals, where VAS ratings were explained as a function of delay, fitted the data better than the model that included only the random intercept and no random slope ($X^2(2) = 470$, $p < .001$). Therefore, we used the random intercept and slope model for further hypothesis testing.

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