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Illusions of supernumerary fingers are not constrained by posture congruency

Denise Cadete[1], Federico Brusa[2], Leonardo Mendolicchio[2], Anna Sedda[3] and Matthew R. Longo[1]

Abstract

Perceptual illusions of having extra body parts offer an experimental method to investigate the limits of body perception. It is well established that the illusory perception of an artificial hand as one's own is dependent on spatial congruency. That is, the seen hand needs to be in a posture congruent with the actual hand. In this study, we aimed to investigate how constrained the representation of a supernumerary body part is by systematically varying the perceived rotation of an illusory sixth finger. Surprisingly, participants felt a sixth finger on their hand consistently for all induced orientations of finger extension and abduction (0°, 90°, 135°, 180°). The illusion showed no apparent decrease with increased induced rotation of the extra finger. We also measured the perceived orientation of the sixth finger, and our results show that participants felt an extended and an abducted sixth finger increasingly more rotated as the induced rotation also increased, while feeling their actual little finger in a normal position. Our results indicate that one can feel a supernumerary finger in an incongruent spatial location from one's actual fingers and hand, to an extent of 180° of extension (finger up) and 180° of abduction (finger to the side). We therefore propose that the representation of the supernumerary finger has a strong independence from the actual finger and hand-frame reference.

Keywords

Body perception; posture constraint; embodiment; extra body parts

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Introduction

Recent bodily illusions have explored the perception of having supernumerary body parts, that is, feeling body parts in addition to the ones we have by default, in the human body plan. This is possible through synchronous multisensory stimuli, where sensory signals from various modalities are integrated, leading to alterations or extensions in body perception. The classic rubber hand illusion (RHI) (Botvinick & Cohen, 1998), in which a rubber hand is stroked simultaneously with the actual hand, creates the feeling that the artificial hand is actually one's own. This paradigm has been adapted to induce the feeling of having a third hand (Ehrsson, 2009; Fan et al., 2021; Guterstam et al., 2011). Embodying a supernumerary hand has also been induced using a video image of one's own limb and its replica performing an action, in real time with the participant's hand (Newport et al., 2010). Embodiment includes the sense of ownership, self-location and agency over one's body or body part (Longo et al., 2008); in this study, when we mention embodiment, we are referring to the sense of ownership and self-location over a body part. A novel paradigm exploiting the mirror box illusion (Ramachandran & Rogers-Ramachandran, 1996) and synchronous stroking of the unseen real hand and seen empty space, create the feeling of having a sixth finger (Cadete & Longo, 2020; Newport et al., 2016). These studies show that humans can be instantly induced to feel like they have extra body parts.

A key aspect of developing new paradigms for studying the embodiment of supernumerary body parts is the ability to test how the perception of these extra body parts differs from, or resembles, the perception of one's

[1]School of Psychological Sciences, Birkbeck, University of London, UK
[2]I.R.C.C.S. Istituto Auxologico Italiano, Experimental Laboratory for Metabolic Neurosciences Research, Piancavallo, VCO, Italy
[3]Centre for Applied Behavioural Sciences, Department of Psychology, School of Social Sciences, Heriot-Watt University, UK

Corresponding author:
Denise Cadete, School of Psychological Sciences, Birkbeck, University of London, Malet St, London, WC1E 7HX, UK.
Email: d.cadete@bbk.ac.uk

actual body parts. This comparison helps identify the mechanisms that are shared between the two processes and those that differ. For instance, we can embody an extra hand without disembodying the limb being duplicated (Guterstam et al., 2011). Supernumerary limb illusions do not entail a replacement of the existing limb for an object or empty space, the embodiment of one's own body part is maintained at the same time as feeling an extra one. We have shown that the representation of the supernumerary finger is not only flexible but also independent of the existing fingers, enabling us to feel curved (Cadete et al., 2022), short or long (Cadete & Longo, 2022) sixth fingers at the same time as feeling the actual finger with its normal shape and size. The extent of this independence is yet to be probed.

Over the last 20 years, two major assumptions have been established as necessary to induce the embodiment of artificial limbs: temporal congruency and spatial congruency. A rubber hand is only felt to be part of one's body when the touch on the actual hand and the seen touch on the rubber hand occur in synchrony, which sustains the temporal congruency constraint of embodiment. Spatial congruency as a constraint in embodiment has been observed in studies demonstrating that a rubber hand can only be perceived as part of one's body if it is in a posture congruent with the actual hand. The embodiment of a rubber hand is compromised when the position of the artificial hand is incongruent with the participant's real hand, at 90° of rotation from the hand (Farnè et al., 2000; Pavani et al., 2000; Tsakiris & Haggard, 2005), or 180° (Ehrsson, 2004; Lloyd et al., 2006). The rubber hand can be misaligned from the actual hand up to a difference of 30° and still be embodied, as long as the orientation of the felt and seen touches on both hands match in a hand-centred frame (Costantini & Haggard, 2007). Makin and colleagues (2008) proposed a hand-centred model in which synchronous visual and tactile events within the real hand peripersonal space only bind if they are located near the seen (false) hand, and this false hand is in an anatomically congruent position. These studies show that the embodiment of a false hand as our own is constrained to be seen in a congruent position to our actual hand. This is true for body parts with natural appearance, which is not exactly the case with invisible fingers in implausible postures. Yet, Ratcliffe and Newport (2017) showed that even though appearance did modulate the sense of ownership, a grossly distorted hand was still embodied when it was temporally and spatially congruent with the real hand. Again, the spatial and temporal constraints outweigh appearance in determining the embodiment of a hand. It is unclear, however, whether these constraints are specific to existing body parts.

The posture constraint to the embodiment of fake hands arises when proprioceptive information of hand position from the hidden real hand is integrated in multisensory cortical areas computing the position of the hand (Makin et al., 2008). If the proprioceptive and vestibular cues (Gallagher et al., 2021), of the real hand are congruent with visual information of the fake hand, then there is more weight in accepting the seen hand as one's own hand. This posture constraint makes sense when the illusion creates the misperception that a fake hand is now one's real hand. We call this a *bodily replacement* illusion, wherein a fake body part is accepted *as* the real one, and *instead* of the real one. Therefore, the illusion dissipates when proprioceptive information of the real hand does not match the seen position of the fake hand. This is not the case when it comes to supernumerary body parts. If a sixth finger is indeed represented as a supernumerary body part, it does not need to match the proprioceptive information of the existing fingers. The sixth finger is not replacing the little finger; it is an additional finger, and it may be positioned in a different location from the actual fingers. At the same time, it is a finger, and fingers cannot execute full 180° rotations, in which case, they may be constrained to only be positioned at a rotation that is anatomically possible for that body part. We therefore hypothesised that supernumerary fingers would be embodied in incongruent postures to the actual fingers, unconstrained from being congruent with the stimulated finger, up to 90°. We also hypothesised that the embodiment of the sixth finger would decrease or even extinguish, beyond 90°, as its position would be anatomically implausible, not because it is incongruent with the fingers, but because fingers cannot reach extreme angles of rotation from the hands (Erdogan & Bakirci, 2023; Mohamed Ibrahim et al., 2024; Tubiana, 1988).

In this study, we aimed to systematically investigate if the posture congruency constraint also applies to the embodiment of extra fingers, and if so, to what extent. This is not the first time that illusory sixth fingers in incongruent postures have been investigated. Ambron and Medina (2023) aimed to induce an illusory sixth finger in positions incongruent with the actual hand, specifically a vertical finger, a finger at 90°, 120° and 180° of rotation from the hand, among other conditions, to test the effects of shape, location or numerosity. At 180° and 120° from the hand, participants indeed reported negative scores for feeling a sixth finger; however, at 90° from the hand, in a perpendicular position from the actual finger, the illusion remained. Importantly, posture incongruency has been applied to supernumerary body parts previously. When Guterstam and colleagues (2011) induced the feeling of having a third arm, they also included a condition where the supernumerary hand was positioned at 180° from the actual hand, as a second control condition. In that condition, a second right hand was seen as coming from the opposite side of their actual body position and the actual right hand. The threat-evoked skin conductance responses to the extra rubber hand rotated at 180° were as low as those for the rubber right foot placed next to the right hand, and significantly lower than the experimental condition of a right rubber hand seen next to the actual right hand. In the questionnaire data, the lowest reported scores for feeling two right hands were for the rotated rubber hand, followed by the asynchronous stroking condition, which is the standard control condition in the RHI. In that study, a 180° rotated extra rubber hand cancelled the illusion of having a second right hand, in line with the classical RHI findings, that we cannot embody a rubber hand when its posture is incongruent with the position of the actual hand.

Given these previous studies, it seems that we are more prone to embody an extra finger in different positions compared to the constrained positions of actual body parts. It may also be that we have more flexibility for the perceived posture of fingers compared to whole hands, and that the body part type is what actually drives the embodiment of fingers in implausible postures. In this study, we frame the hypothesis in terms of actual versus supernumerary body parts, and not fingers versus hands, however, we will address this interpretation in the context of our findings. By systematically including a linear progression of orientations, gradually varying the angles of extension and abduction of the sixth finger from the metacarpophalangeal joint, we can determine at which point we are less likely to feel like the extra finger is part of our body. By adding gradual changes of finger postures, we will be able to identify the angle of rotation that establishes the boundary of the posture constraint for supernumerary body parts, both for abduction and extension orientations.

In the present study, we systematically investigated the embodiment of a supernumerary finger in two sets of rotation angles from the hand. One set consists of abduction rotation angles, that is, horizontal/lateral rotations from the actual hand, as if the finger was moving to the side. The second set consists of extension rotation angles, that is, vertical/ascending rotations from the hand, as if the finger was moving up. For each set, we included the angles: 0°, 90°, 135° and 180°. In line with Ambron and Medina's study, we predicted that participants would embody a sixth finger at 0° and 90° of both extension and abduction rotations, and would not embody it at 135° and 180° for both rotation types. Unexpectedly, our results suggest that we are quite flexible in the perception of supernumerary body parts, embodying a sixth finger in all orientations of finger extension and abduction. The perceived orientation of the sixth finger confirmed that participants felt the sixth finger in the induced orientation, while feeling the actual little finger in the normal position, showing we can feel extra fingers in an incongruent position to the actual finger.

Methods

Participants

Twenty people ($M \pm SD = 32.8 \pm 10.4$ years; 11 females and 9 males) participated after giving written informed consent. The study was performed in accordance with the Declaration of Helsinki and approved by the School of Psychological Sciences Ethics Committee at Birkbeck. All participants but one, were right-handed, as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971), $M = 78.6$, range from 0 to 100.

In our previous study (Cadete & Longo, 2022), we tested whether the felt length of the sixth finger was significantly different from the felt size of the actual little finger. In a condition that induced a long sixth finger, the effect size of that contrast was of $d_z = 1.19$. A power analysis using G*Power 3.1 (Faul et al., 2007), with a two-tailed alpha of 0.05 and power of 0.95 indicated that 12 participants were required. Thus, our sample size of 20 should be well powered to replicate the illusion (0° condition) and to probe the embodiment of six fingers in rotated orientations, for questionnaire and visual judgement data.

Design and procedure

To induce the sixth finger illusion and the control condition, we used the same procedure used in previous studies (Cadete & Longo, 2020, 2022; Newport et al., 2016). The participant sat at a table with a mirror positioned on the table aligned with their body midline. We used the mirror box illusion, which was first created with the intention to treat phantom limb patients (Ramachandran & Rogers-Ramachandran, 1996), by placing a mirror in the middle of one's body and watching the reflection of the spare limb in the mirror, it created the illusion that the reflected limb was the lost one. Participants placed their left hand behind the mirror and their right hand in front of it. When they looked into the mirror, the reflection of their right hand thus appeared to be a direct view of their occluded left hand, as shown in Figure 1. The tip of the index finger of both hands was positioned 24 cm from the edge of the table and 20 cm from the mirror, marked by two dots where they were asked to place the tip of each index finger. The participant was asked to look into the mirror at their hand throughout each trial. The mirror box effect was explained before the trials by stating that the right hand reflected in the mirror will look like their left hand. To prevent demand characteristics, participants were only informed that the study investigated tactile perception, with no mention of supernumerary limbs or what they might experience from the stimulation, following standard practice in body illusions research.

The left hand was hidden behind the mirror, and the right hand, which will be hereafter referred to as the seen hand, was perceived as the left hand due to the reverse optical effect of mirrors. We used the continuous version of the sixth finger illusion, which we previously developed (Cadete & Longo, 2020). Each finger was stroked synchronously back and forth twice (thumb with thumb, index with index and so forth), the lateral side of the hidden finger was then touched at the same time as the seen little finger, followed by 20 strokes on the outer lateral side of the hidden little finger, at the same time as the space next to the seen little finger. The *sixth finger* stroking (in front

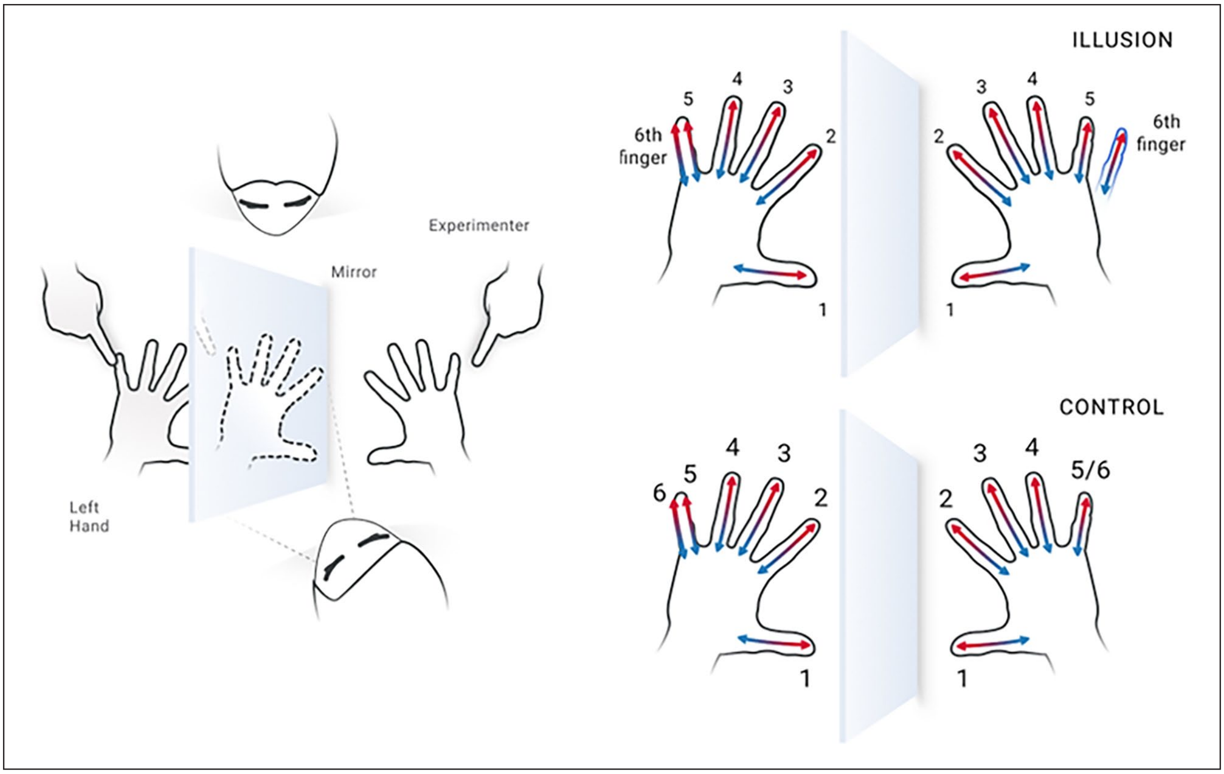

Figure 1. The experimental setup. The participant watches the reflection of their right hand in the mirror while their left hand is occluded behind the mirror. The participant sees the right hand through the reflection in the mirror, resembling the left hand due to the inverting optical effect of the mirror. The experimenter strokes the top of each finger twice back and forth, in both hands synchronously, from the knuckle to the tip, starting on the thumb to the ring finger. The occluded little finger (left hand) is then stroked on the inside lateral at the same time as the top of the right hand's finger (the hand being reflected in the mirror), followed by 20 double strokes on the outer lateral side of the occluded little finger synchronously to touching the empty space next to the little finger of the reflected hand, with the orientation of each condition. The stroke on empty space was conducted in a randomised orientation of finger abduction, horizontally rotated from the hand, and extension, vertically rotated from the hand (Figure 2). Participants looked in the mirror and when they saw the experimenter stroking the empty space next to their little finger at the same time as they felt a touch on their hidden little finger, they experienced the sensation of having a sixth finger. The control condition followed the same procedure up to the little finger, but stroking the seen little finger once again instead of the *sixth finger* on the last stroke. The reflected little finger was stroked on the top while the hidden finger was stroked on the outer lateral side, resulting in both little fingers of both hands being stroked simultaneously, at slightly different locations. By doing the sixth stroke on the little finger, the touch should be mapped onto the little finger, therefore, no illusion should occur. The arrows represent the double back-and-forth stroking. The stroking sequence is numbered in the figure; stroke 1 in the left hand occurs at the same time as stroke 1 in the right hand, and so forth.

of the mirror) had to be synchronous with the stroking of the actual little finger (behind the mirror). Whilst the little finger was stroked, the experimenter stroked empty space next to the seen hand in the orientation of each condition. So, in the 180° condition, which is the same for both rotation types, for instance, the experimenter stroked the participant's hidden little finger synchronously to stroking empty space next to the seen hand, simulating a sixth finger stroke in the direction of the little finger metacarpophalangeal joint to the wrist, instead of the direction from the little finger's knuckle to the fingertip. In the 90° extension angle, the finger was visually located vertically and perpendicular to the actual finger's position, whereas the 90° abduction angle was induced horizontally and perpendicular to the hand.

There was a total of eight experimental conditions, four orientations of the visual–tactile stimuli: 0°, 90°, 135°, 180°, for each rotation (extension and abduction), aiming at inducing a sixth finger placed next to the participant's hand in the rotation induced by the experimenter's strokes in empty space. We expected that the touch on the left little finger would be mapped onto the empty space in certain orientations of the synchronous seen strokes watched through the mirror by the participant.

We had a set of eight conditions, consisting of different orientations of the visual–tactile stimuli, with a degree of rotation from the hand at 0°, 90°, 135°, 180°, for each rotation type, plus the control condition. The control condition is the same as used in previous studies (Cadete & Longo, 2020, 2022; adapted from Newport et al., 2016), and

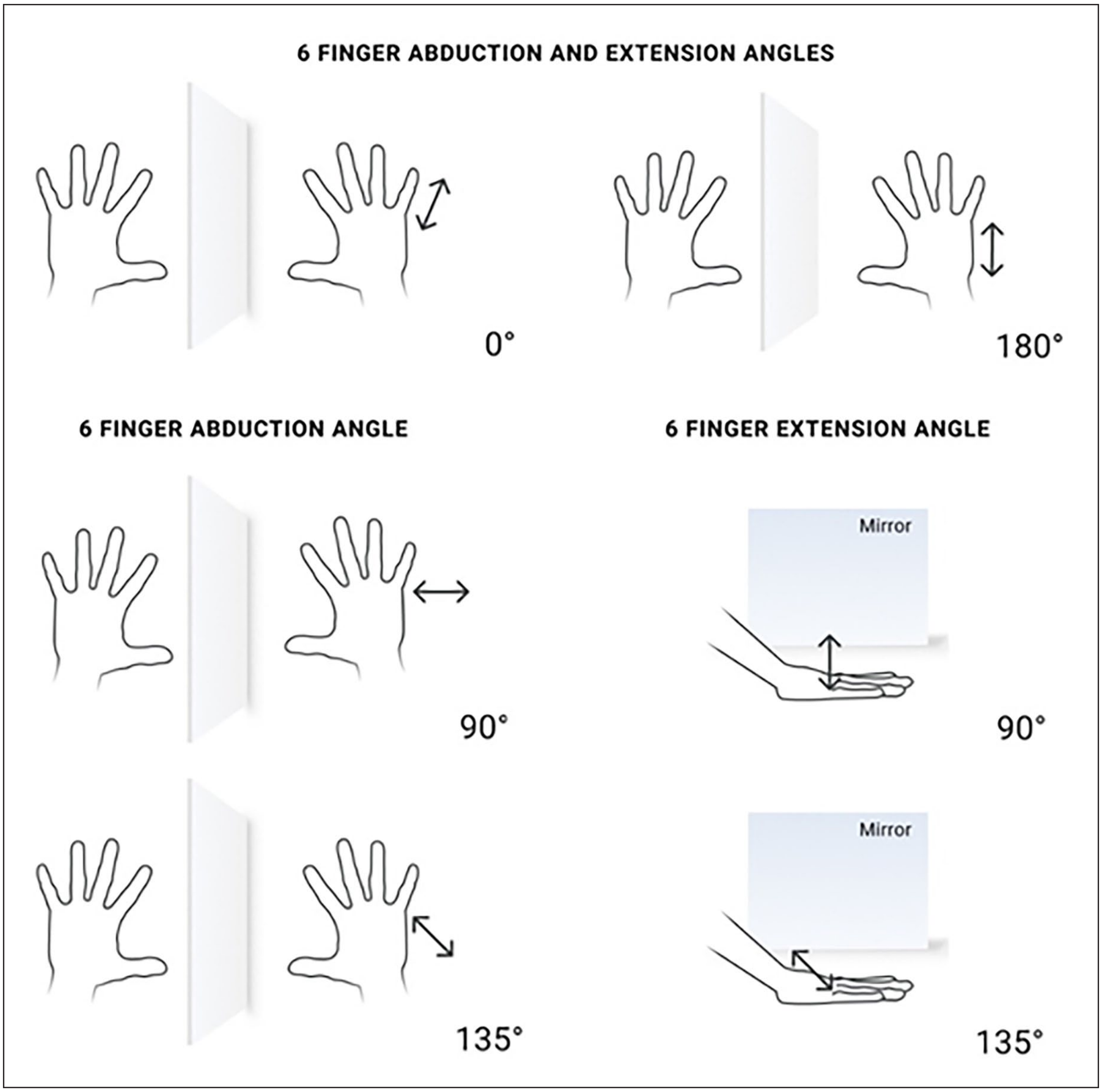

Figure 2. Sixth finger orientations of the visual–tactile stimulus. Each condition had a degree of finger abduction or extension: 0°, 90°, 135°, 180°. The 0° and the 180° conditions share the same visual–tactile stimulation for both extension and abduction, as these orientations share the same starting and ending positions.

consisted of 20 strokes on the little finger instead of the *sixth finger*, that is, instead of the space next to the little finger, which excluded the visual component of the illusion induction. While the hidden little finger (left hand) is stroked continuously on the outer lateral side, the hand reflected in the mirror (right hand) is stroked continuously on the top of the little finger. As the little fingers of both hands are stroked, no touch is mapped onto another finger or empty space. The conditions were randomised, with different orders across participants. After each trial, we applied the embodiment questionnaire, followed by the visual judgement task, to assess the orientation in which participants perceived the sixth finger and the actual finger. We showed the figures of the rotation type corresponding to the condition.

Questionnaire

Participants reported the embodiment of a sixth finger using a Likert Scale, in which 0 corresponds to 'strongly disagree', and 10 to 'strongly agree'. At the end of each trial, we used the same questionnaire used in previous studies of the sixth finger illusion (Cadete & Longo, 2020, 2022; Newport et al., 2016), from item A to F, and we added item F in this study, since a small ($N=4$) subset of participants reported feeling a larger little finger instead of a sixth finger, in a previous study (Cadete et al., 2022).

A. It felt like I had six fingers on my left hand.
B. It felt like I had two little fingers on my left hand.

C. I felt a touch where I do not normally feel a touch.
D. I felt a touch that was not on my body.
E. It felt like I had an extra hand.
F. It felt like I had a larger little finger on my left hand.

Perceived finger orientation

We asked participants to judge the perceived orientation of the little finger after each trial and asked them to also judge the felt orientation of the sixth finger when they answered 4 or more in the Likert Scale to the first questionnaire item, agreeing to having felt a sixth finger. We chose this threshold based on the findings from Guterstam et al. (2011), who induced the embodiment of a third hand, and used a ten-point scale ranging from 0 ('I do not agree at all') to 9 ('I agree completely'). There was a mean of slightly above 3 in experiment 1 and slightly above 4 in experiments 3 and 4, for feeling the two right hands, all significantly different from the control, $p < .001$. This shows that ratings as low as 4 can significantly differ from controls, indicating that moderate scores are sufficient to reflect meaningful embodiment, making this threshold a reasonable and sensitive criterion for proceeding with additional questions. For participants who reported not feeling a sixth finger, we only asked them to judge the felt orientation of the little finger. To do that, we used a visual judgement task similar to the scaled visual stimuli used in previous studies to capture the body perception experience induced by an illusion (Cadete et al., 2022; Guterstam et al., 2015). Guterstam and colleagues used a set of images with different levels of visibility, ranging from an invisible body to an opaque body. Similarly, in a previous study, we used a set of seven images of curved 3D fingers ranging from straight to a 270° laterally curved finger (Cadete et al., 2022). This method allowed us to measure the perceived orientation angle of the sixth finger and the actual little finger in each condition. With this, we can assess whether participants indeed felt the illusory extra finger to be in the induced position, or whether the representation of the extra finger is constrained to a certain orientation angle.

In this study, we presented a set of realistic fingers in a scale of orientation angles of 0°, 15°, 30°, 45°, 60°, 75°, 90°, 105°, 120°, 135°, 150°, 165° and 180° for abduction and rotation, as shown in Figure 3. Each finger orientation had a number assigned, which the participant used to report the felt orientation of both the little finger and the sixth finger. The same scale was used for both fingers to maintain consistency. We asked participants: 'How did you experience your little finger?/How did you experience the sixth finger? Here is a schematic set of figures. Please select the finger on the image which best corresponds to your experience'.

We used these visual judgements to assess that the participants did feel the illusory finger in a specific orientation, as it is plausible that one may feel a sixth finger in the same orientation as the little finger, even when they are induced an illusory finger in a different orientation of the position of their hand. We then compared the felt orientation of the sixth finger with the felt orientation of their little finger in the same condition.

Analysis

Embodiment questionnaire

We tested the embodiment of a sixth finger in four orientations of finger abduction and four orientations of finger extension, using a questionnaire. To assess whether participants felt a sixth finger, we compared the scores of the first questionnaire item in each orientation condition against the control condition, with a paired t-test, for each rotation type.

For each questionnaire item, we conducted a 2×4 linear trend mixed-effects analysis with rotation type (extension & abduction), and orientation (0°, 90°, 135°, 180°) as within-subject factors, using the lmer4 package (Bates et al., 2015) for R within Jupyter lab. Orientation was coded with custom numeric weights (+3, +1, −1, −3) to test for linear trends across conditions. The model included orientation linear trend, rotation type and their interaction as fixed effects, with a random intercept for subjects to account for repeated measures. ANOVA was applied to test the significance of the effects. The ANOVA function applied to a mixed-effects model compares the goodness-of-fit between nested models, using the lmerTest package (Kuznetsova et al., 2017), which uses Satterthwaite's method for approximating degrees of freedom for the F tests. For each fixed effect or interaction term, it assesses whether including the term significantly improves the model fit. This is achieved by calculating an F-statistic for each term and providing a corresponding p-value. Orientation was coded using the linear trend with the λ values reflecting a prediction of decreased embodiment scores from 0° to 180°: λ set [0° = +3, 90° = +1, 135° = −1, 180° = −3]. This prediction was based on a previous study showing that a sixth finger was embodied at 90° of abduction, and the same did not occur at 120° and 180° (Ambron & Medina, 2023). This analysis identifies whether there is a main effect of rotation type and a linear trend for orientation on the embodiment questionnaire scores, as well as an interaction between the two factors. Additionally, we conducted Aligned Rank Transform (ART) ANOVAs (Wobbrock et al., 2011) analyses as a non-parametric validation. These analyses, which are independent of distributional assumptions, yielded the same significance patterns as the primary parametric models.

Perceived finger orientation

When participants felt a sixth finger, we measured its perceived orientation. As five participants did not experience a sixth finger and answered 3 or less in the Likert Scale to

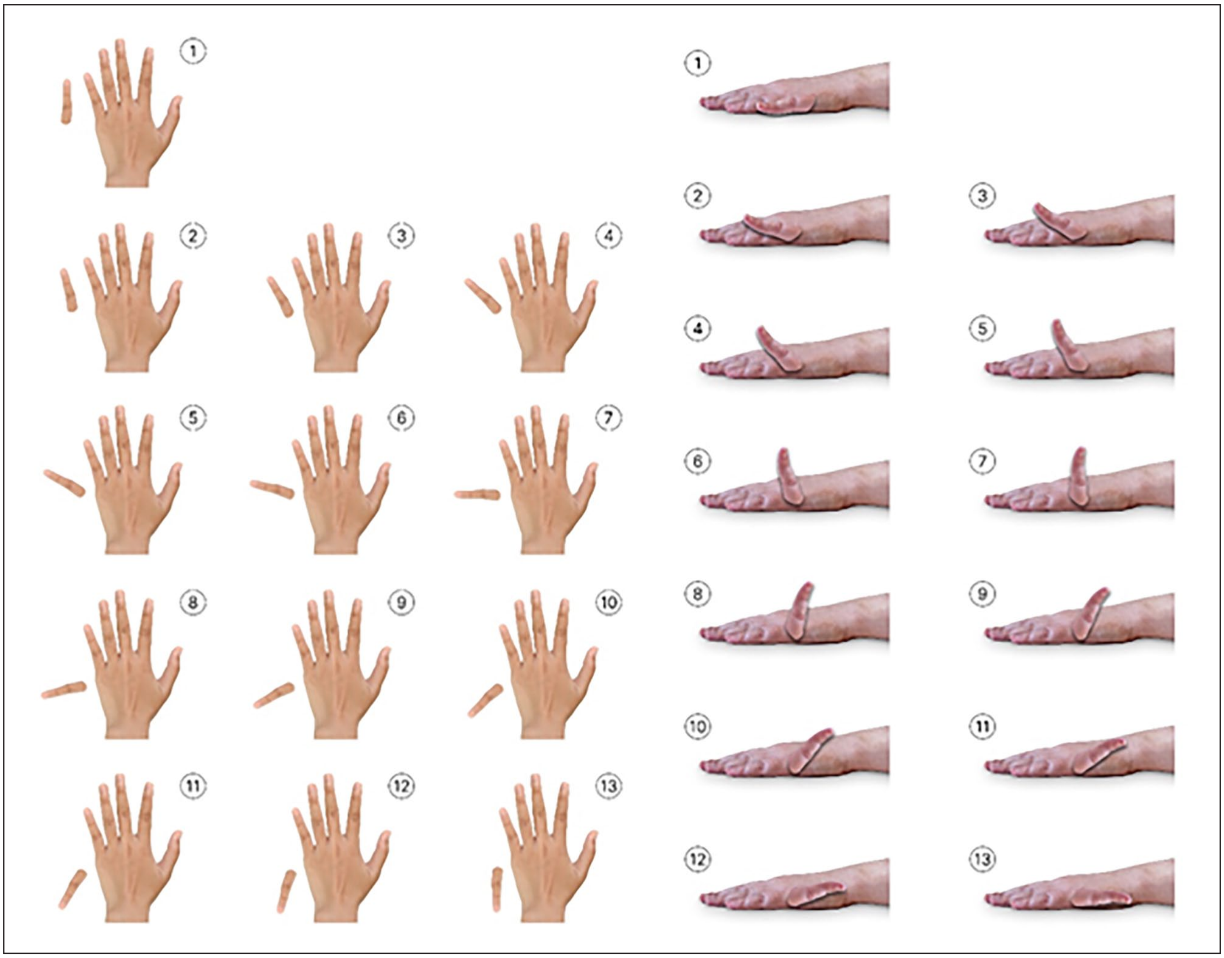

Figure 3. Finger abduction (left) and extension (right) orientation stimuli. Set of images of sixth fingers in a scale of orientation angles of 0°, 15°, 30°, 45°, 60°, 75°, 90°, 105°, 120°, 135°, 150°, 165° and 180° of abduction (rotating the finger laterally) and extension (lifting the finger up). The images represent the sixth finger's angle of rotation from the position of the participant's hand. The sixth finger is shown detached to clearly illustrate its orientation, rather than explicitly tying it to the little finger or a sixth finger, and is placed next to the little finger of the participant's left hand, as this is the side where the illusion is perceived. Ideally, it would have been presented without a hand, but this was necessary to define its rotation relative to the hand and avoid ambiguity about its reference frame. In the actual setting, no physical finger was used, instead there was only empty space that is stroked by the experimenter. Original hand image (used in left panel) by Penpak Ngamsathian, at Vecteezy.com.

the first questionnaire item, we do not have data in every data point, in the scores for the perceived finger orientation. For that reason, we ran a two-way linear trend mixed-effects analysis, using the lme4 toolbox for R (Bates et al., 2015), as it does not require that data for each condition to be present for each participant (Baayen et al., 2008). The factor *illusion* had two levels: the sixth finger and little finger, and the factor *orientation* had four levels: 0°, 90°, 135°, 180°. We conducted separate analyses for each rotation type: extension and abduction. Orientation was coded using the linear trend with the λ values reflecting a prediction of increased felt rotation in the conditions ranging from 0° to 180°: λ set [0° = −3, 90° = −1, 135° = +1, 180° = +3]. As the visual–tactile orientation angle of the sixth finger increases, it is expected that the felt orientation of the sixth finger also increases. For paired comparisons between the felt orientation of the sixth finger and the little finger, we ran one-way mixed-effects models with the factor illusion (sixth finger vs. little finger) for each orientation level, also with the lme4 toolbox for R.

Results

Questionnaire

Results for the key questionnaire item, 'It felt like I had six fingers on my left hand' are shown in Figure 4. Participants felt like they had six fingers on their hand in the experimental conditions significantly more than in the control condition for all orientations (0°, 90°, 135°, 180°) in both rotation types, $p < .0001$, as shown in Table 1, top left. The values and paired comparisons between the control condition and each of the four orientation conditions, for every questionnaire item, are reported in Table 1. The same trend

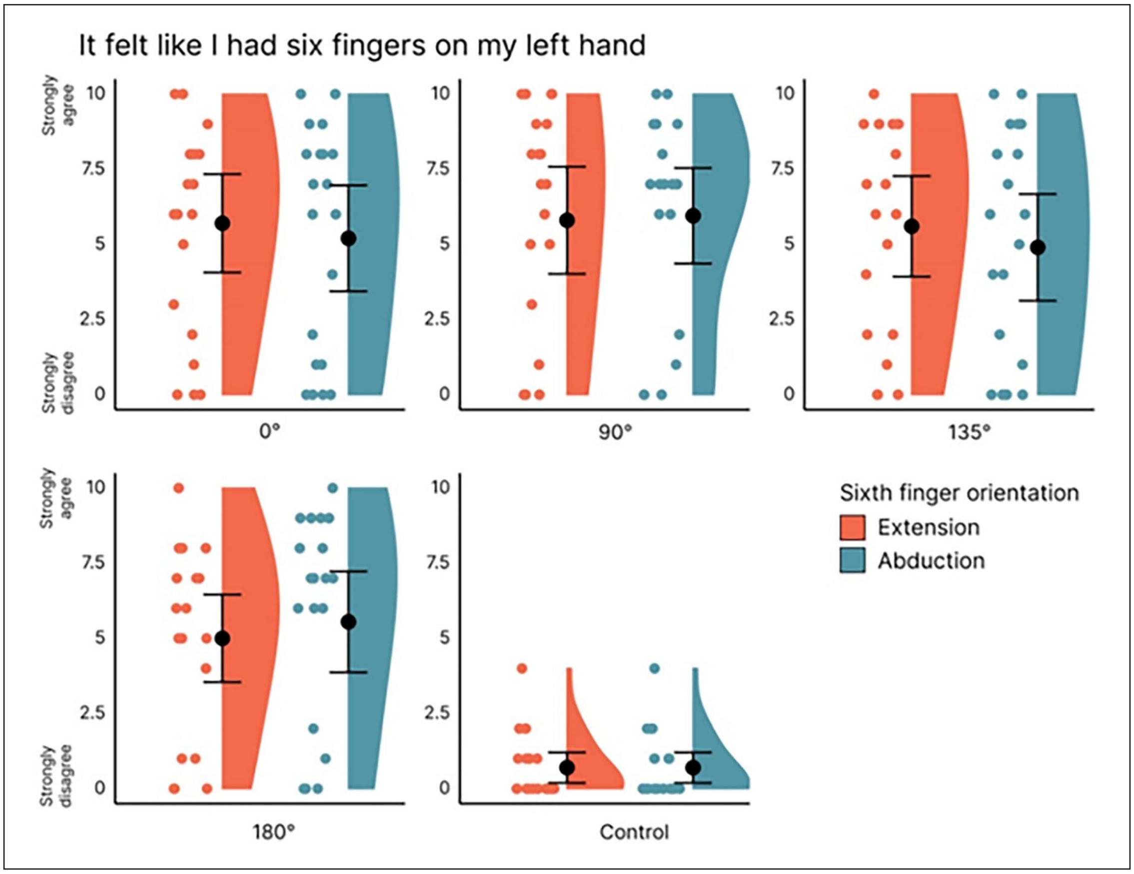

Figure 4. Embodiment scores for feeling a six-fingered hand across orientations, for finger abduction and finger extension, as well as the control condition. Participants agreed to feeling like they had six fingers on their hand, when it was induced in different angles of rotation from the actual hand position, from 0° to 180° orientations, both horizontally and vertically to the hand. Dots represent individual data scores, and the clouds show the probability density of responses in each condition. The bars represent 95% confidence intervals, and the central dot marks each condition's mean.

was found for the other questionnaire items, with lower scores for feeling a touch off their body and feeling a larger little finger, as shown in Figure 5. The control question, for feeling an extra hand, was the only one with a non-significant difference from the control condition in the 0° extension orientation, and overall the lowest questionnaire scores in all orientations. There were four participants who answered '0' or '1' to feeling a sixth finger, for all orientations, and only two participants who instead only disagreed with feeling a sixth finger in 1 condition (1 at 135° abduction and another at 0° abduction). Critically, there were no participants who reported 4 or more in the scale, to feeling 6 fingers in the 0° condition, who reported less than 4 at 90° or at 180°.

Participants embodied a normal sixth finger, congruent with the hand posture, and they also embodied a sixth finger at 90°, 135° and 180° of rotation from the hand, for both rotation types. A linear repeated-measures analysis using a linear mixed-effects model approach showed there was no main effect of orientation, $F(1, 137)=1.18$, $p=.28$, $\eta_p^2=.01$, or rotation type, $F(1, 137)=.28$, $p=.60$, $\eta_p^2=.00$, for feeling six fingers, neither a significant interaction between rotation and orientation, $F(1, 137)=1.19$, $p=.28$, $\eta_p^2=.01$. We also compared the embodiment scores for the 0° orientation condition with each of the other orientations, and there was no significant difference for either of the rotation types, $p>.05$. Overall, a sixth finger was embodied to a similar extent in all orientations, in both rotations.

The other questionnaire items followed the same trend, with no significant effect of orientation or rotation type. There was no significant linear trend for feeling two little fingers, $F(1, 137)=0.06$, $p=.81$, $\eta_p^2=.00$, with no main effect of rotation type, $F(1, 137)=0.96$, $p=.33$, $\eta_p^2=.01$, nor a significant interaction between rotation type and orientation, $F(1, 137)=0.91$, $p=.34$, $\eta_p^2=.01$. For feeling a touch where it is not normally felt, again there was no significant linear trend of orientation, $F(1, 137)=1.25$, $p=.27$, $\eta_p^2=.01$, or rotation $F(1, 137)=1.31$ $p=.25$, $\eta_p^2=.01$, neither a significant interaction between rotation and orientation, $F(1, 137)=0.73$, $p=.40$, $\eta_p^2=.00$. For feeling a touch out of the body, there was no significant linear trend of orientation, $F(1, 137)=0.58$, $p=.45$, $\eta_p^2=.00$, or rotation, $F(1, 137)=0.46$, $p=.50$, $\eta_p^2=.00$, neither a significant

Table 1. Paired comparisons between the control condition scores and the four orientation scores, for each questionnaire item.

It felt like I had six fingers on my left hand

		control		orientation				
		M	SD	*M*	SD	*t(19)*	*p*	*d*
Abduction	0°	0.70	1.08	5.20	3.76	5.72	<.001	1.28
	90°			5.95	3.39	7.13	<.001	1.60
	135°			4.90	3.80	4.69	<.001	1.05
	180°			5.55	3.59	6.05	<.001	1.35
Extension	0°	0.70	1.08	5.70	3.50	6.43	<.001	1.44
	90°			5.80	3.81	6.24	<.001	1.40
	135°			5.60	3.57	6.50	<.001	1.45
	180°			5.00	3.11	6.39	<.001	1.43

It felt like I had two little fingers on my left hand

		control		orientation				
		M	SD	*M*	SD	*t(19)*	*p*	*d*
Abduction	0°	0.60	1.05	4.50	3.65	4.81	<.001	1.08
	90°			5.70	3.47	6.56	<.001	1.47
	135°			4.35	3.83	4.36	<.001	0.97
	180°			5.25	3.61	5.43	<.001	1.21
Extension	0°	0.60	1.05	5.08	3.68	4.60	<.001	1.03
	90°			5.70	3.83	6.12	<.001	1.37
	135°			5.40	3.62	5.75	<.001	1.28
	180°			4.70	3.15	5.90	<.001	1.32

I felt a touch where I do not normally feel a touch

		control		orientation				
		M	SD	*M*	SD	*t(19)*	*p*	*d*
Abduction	0°	1.30	2.20	4.30	3.18	2.48	.023	0.62
	90°			4.85	3.56	4.85	<.001	1.21
	135°			3.60	3.76	4.72	.028	1.18
	180°			4.60	3.59	2.91	.009	0.73
Extension	0°	1.30	2.20	4.53	3.34	3.12	.006	0.70
	90°			5.45	3.79	4.94	<.001	1.10
	135°			4.95	3.43	4.46	<.001	1.00
	180°			3.80	3.30	3.08	.006	0.69

I felt a touch that was not on my body

		control		orientation				
		M	SD	*M*	SD	*t(19)*	*p*	*d*
Abduction	0°	0.70	1.42	3.30	2.92	3.75	.001	0.84
	90°			2.95	3.15	3.24	.004	0.72
	135°			2.85	3.48	2.44	.025	0.55
	180°			3.25	3.35	3.20	.005	0.72
Extension	0°	0.70	1.42	3.66	3.29	3.12	.006	0.70
	90°			3.05	3.65	2.82	.011	0.63
	135°			3.55	3.35	3.79	.001	0.85
	180°			2.90	3.40	2.98	.008	0.67

(Continued)

Table 1. (Continued)

It felt like I had an extra hand

		control		orientation				
		M	SD	*M*	SD	*t(19)*	*p*	*d*
Abduction	0°	0.60	1.05	2.53	3.26	2.64	.016	0.59
	90°			2.45	2.87	3.43	.003	0.77
	135°			1.80	2.57	2.30	.033	0.51
	180°			2.15	2.87	2.72	.014	0.61
Extension	0°	0.60	1.05	1.88	2.48	1.82	.084	0.41
	90°			1.90	2.81	2.39	.033	0.53
	135°			2.10	2.36	3.38	.003	0.75
	180°			2.55	3.15	2.98	.008	0.67

It felt like I had a larger little finger on my left hand

		control		orientation				
		M	SD	*M*	SD	*t(19)*	*p*	*d*
Abduction	0°	1.65	2.46	5.10	3.26	5.14	<.001	1.15
	90°			4.80	3.58	4.62	<.001	1.03
	135°			3.80	3.82	3.39	.003	0.76
	180°			4.75	2.86	4.81	<.001	1.08
Extension	0°	1.65	2.46	5.21	3.24	3.16	.005	0.71
	90°			4.40	3.56	3.55	.002	0.79
	135°			4.25	3.29	4.43	<.001	0.99
	180°			4.65	3.28	6.03	<.001	1.35

interaction between rotation and orientation, $F(1, 137)=0.32$, $p=.57$, $\eta_p^2=.00$. For feeling an extra hand, there was no significant linear trend of orientation, $F(1, 137)=2.71$, $p=.10$, $\eta_p^2=.02$, or rotation $F(1, 137)=0.06$, $p=.81$, $\eta_p^2=.00$, neither a significant interaction between rotation type and orientation, $F(1, 137) = 2.25$, $p=.14$, $\eta_p^2=.02$. For feeling an larger little finger, there was no significant linear trend of orientation, $F(1, 137)=1.56$, $p=.21$, $\eta_p^2=.01$, or rotation, $F(1, 137)=0.00$, $p=.97$, $\eta_p^2=.00$, neither a significant interaction between rotation type and orientation, $F(1, 137)=0.04$, $p=.85$, $\eta_p^2=.00$. There were 11 participants who reported 4 or more both to feeling 6 fingers and to feeling a larger little finger, and only 2 who reported less than 4 to feeling 6 fingers and 4 or more to feeling a larger little finger.

Perceived finger orientation

The results for perceived finger orientation are shown in Figures 6 (finger abduction) and 7 (finger extension), which illustrate the felt orientation of the sixth finger and the actual little finger across all conditions of extension and abduction. For each induced orientation of the sixth finger, participants reported the felt orientation of the sixth finger and the actual little finger, using a set of images for extension and another for abduction angles. Our results confirm that participants felt the sixth finger more extended and more abducted, as the visually induced sixth finger angle increased. In other words, when the experimenter induced a more rotated finger, the participants felt it indeed more rotated than in the condition of no rotation (0°), and critically more rotated than their actual little finger. The felt orientation data were collected when participants reported 4 or more to feeling a sixth finger. The choice of a score of 4 for this threshold is arbitrary, but the conclusions drawn do not depend critically on this choice. For example, we reran all the analyses using a threshold of 5, excluding data from participants who reported less than 5 to the question about feeling a sixth finger. These analyses yielded the same significance patterns as the original results (full data available via the OSF link).

Sixth finger extension

A linear trend repeated measures mixed-effects analysis showed a significant linear trend of orientation for felt extension, $F(1, 53)=34.59$, $p<.0001$, $\eta_p^2=.40$ (across the four induced extension angles (0°, 90°, 135°, 180°). This shows that the perceived finger extension increased linearly as the induced extension also increased. Critically, participants felt the sixth finger significantly more flexed than the actual finger across conditions, as shown in the main effect of illusion, $F(1, 19)=18.93$, $p<.0001$, $\eta_p^2=.51$. There was also a significant interaction between the linear trend of orientation and illusion, $F(1,$

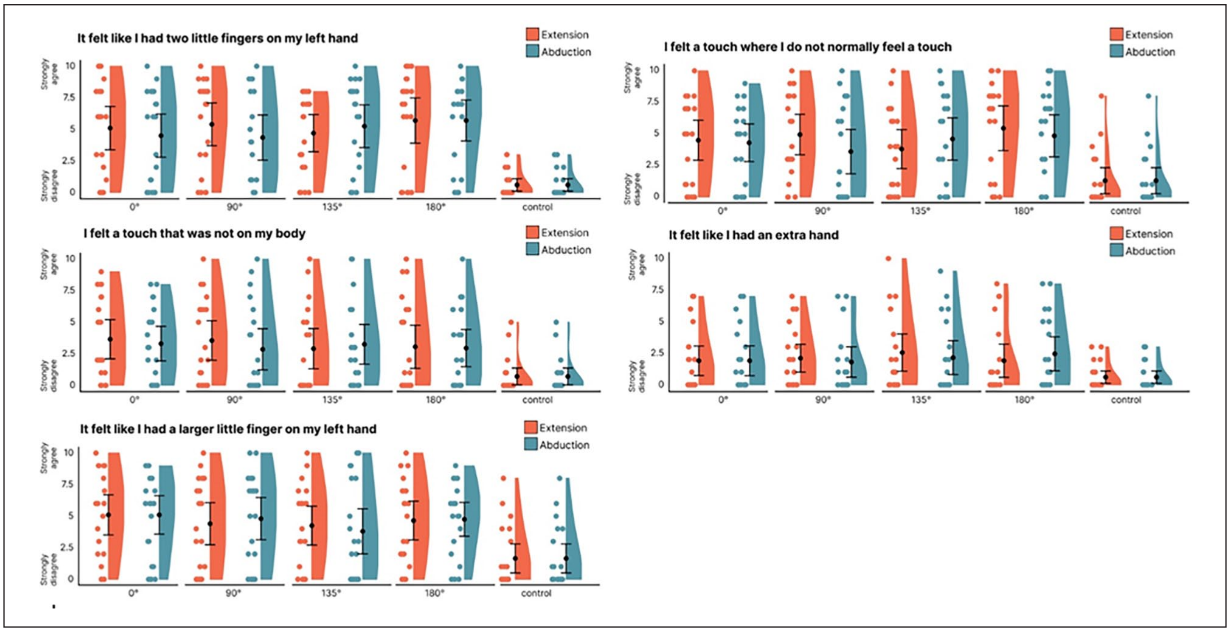

Figure 5. Embodiment scores for the embodiment questionnaire items across orientations, for extension and abduction rotations, as well as the control condition. Participants agreed to feeling like they had two little fingers on their hand, feeling a touch where it is not normally felt, and feeling a larger little finger, across orientations, both horizontally and vertically to the hand. Feeling a touch outside of the body had lower scores across orientations. Participants disagreed with feeling an extra hand. All conditions were significantly different from the control condition, except for the 0° orientation of extension, for feeling an extra hand. Dots represent individual data scores, and the clouds show the probability density of responses in each condition. The bars represent the confidence intervals, and the central dot marks each condition's mean.

53) = 10.18, $p = .002$, $\eta_p^2 = .16$, as participants only felt the sixth finger to be increasingly more flexed as the orientation condition also increased, which did not occur for the actual little finger.

To test whether the felt orientation of the sixth finger was significantly different from that of the little finger, we ran paired comparisons using a mixed-effects approach. When the sixth finger was induced at 0° of rotation from the hand, there was no significant difference between the felt orientation of the little finger ($M = 20.4$, SD = 40.9) and sixth finger ($M = 19.5$, SD = 44.7), as expected, $F(1, 9) = 0.06$, $p = .81$, $\eta_p^2 = .01$. At 90°, participants felt the sixth finger significantly more rotated vertically ($M = 70.4$, SD = 44.4) than the little finger ($M = 23.2$, SD = 39.7), $F(1, 18) = 13.52$, $p = .002$, $\eta_p^2 = .43$. When the sixth finger was induced with an extension of 135°, participants felt it significantly more extended ($M = 82.7$, SD = 44.9) than the actual little finger, ($M = 18.7$, SD = 31.9), $F(1, 32) = 23.69$, $p < .0001$, $\eta_p^2 = .43$. At 180°, the sixth finger was felt to be significantly more extended ($M = 122.8$, SD = 65.0), that the little finger, ($M = 53.2$, SD = 76.3), $F(1, 18) = 7.60$, $p = .01$, $\eta_p^2 = .29$. Overall, the sixth finger was felt to be significantly more rotated than the little finger for all extension orientations, except for the 0° condition, in which the sixth finger was not induced to be visually rotated from the hand.

Sixth finger abduction

A linear trend repeated measures mixed-effects analysis showed a significant linear trend of orientation for felt abduction, $F(1, 66) = 13.09$, $p = .001$, $\eta_p^2 = .17$ (across the 4 induced abduction angles (0°, 90°, 135°, 180°). Perceived finger abduction increased linearly as the induced abduction also increased. There was a significant main effect of illusion, $F(1, 31) = 29.46$, $p < .0001$, $\eta_p^2 = .49$, denoting a significant difference between the felt orientation of the little finger and the sixth finger, across orientations. There was also a significant interaction between the linear trend of orientation and illusion, $F(1, 46) = 20.51$, $p < .0001$, $\eta_p^2 = .44$, as the felt abduction linearly increased when the induced abduction also increased, only for the sixth finger and not for the little finger, which was felt to be in the same normal position throughout conditions.

To test whether the felt abduction of the sixth finger was significantly different from that of the little finger, we ran paired comparisons using a mixed-effects approach. When the sixth finger was induced at 0° of abduction (horizontal rotation from the hand), there was no significant difference between the felt orientation of the little finger ($M = 30.1$, SD = 38.7) and sixth finger ($M = 46.8$, SD = 41.7), as expected, $F(1, 31) = 1.38$, $p = .25$, $\eta_p^2 = .04$. At 90°, participants felt the sixth finger significantly more abducted (rotated horizontally) ($M = 78.2$, SD = 13.6) than the little finger ($M = 41.5$, SD = 37.4), $F(1, 16) = 13.18$,

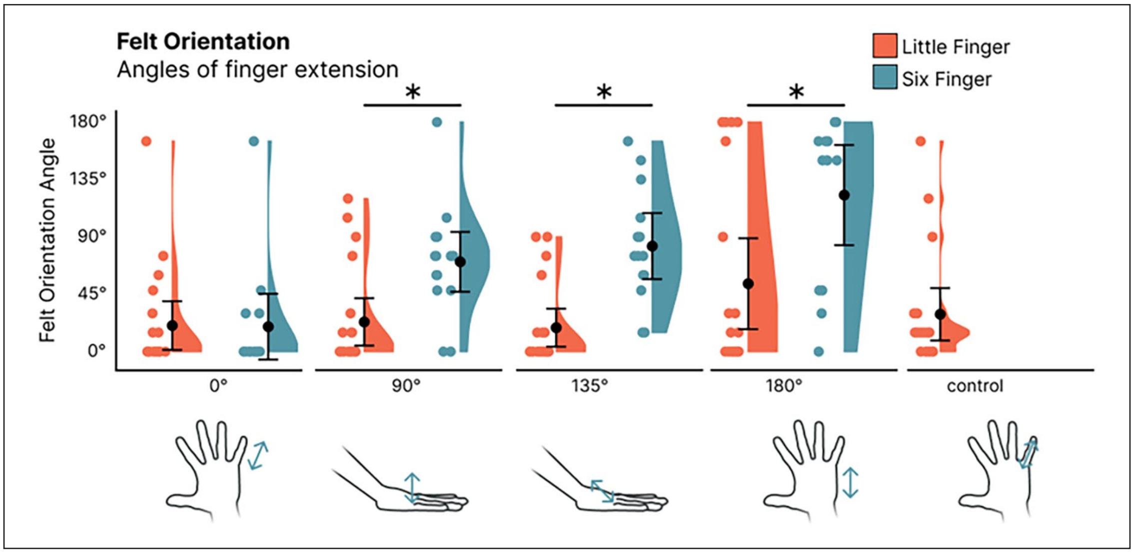

Figure 6. Felt extension of the sixth finger and the little finger in each orientation condition. The hand sketch illustrates the visual–tactile stimulus induced in each condition, and the plot represents the felt abduction angle of the actual little finger and the illusory sixth finger per condition. As the induced sixth finger extension angle increases, so does the felt orientation of the sixth finger. There is a significant difference between the felt abduction of the sixth and the little fingers in all orientations, except at 0° of rotation, as expected. In the control condition, participants did not report feeling a sixth finger; hence, there is no data for sixth felt orientation. Dots represent individual data scores, and the clouds show the probability density of responses in each condition. The bars represent the confidence intervals, and the central dot marks each condition's mean.

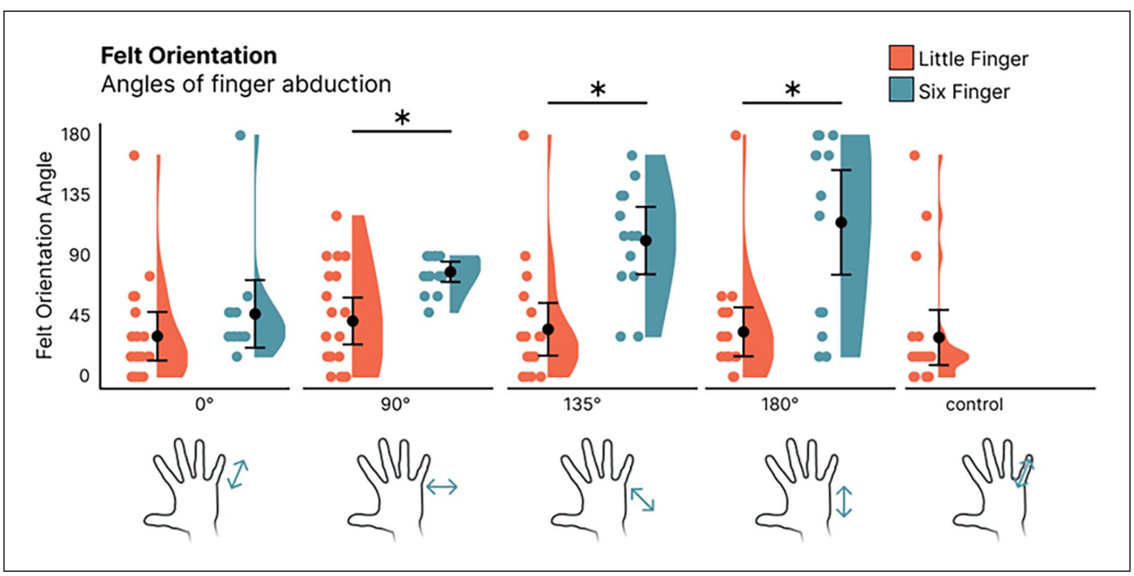

Figure 7. Felt abduction of the sixth finger and the little finger in each orientation condition. The hand sketch illustrates the visual–tactile stimulus induced in each condition, and the plot represents the felt extension angle of the actual little finger and the illusory sixth finger per condition. As the induced sixth finger abduction angle increases, so does the felt orientation of the sixth finger. There is a significant difference between the felt abduction of the sixth and the little fingers in all orientations, except at 0° of rotation, as expected. In the control condition, participants did not report feeling a sixth finger; hence, there is no data for sixth finger felt orientation. Dots represent individual data scores, and the clouds show the probability density of responses in each condition. The bars represent the confidence intervals, and the central dot marks each condition's mean.

$p = .002$, $\eta_p^2 = .45$. When the sixth finger was induced with an abduction of 135°, participants felt it significantly more rotated ($M = 101.5$, SD = 41.5) than the actual little finger, ($M = 35.4$, SD = 42.0), $F(1, 31) = 19.69$, $p < .0001$, $\eta_p^2 = .39$. At 180°, the sixth finger was felt to be significantly more rotated ($M = 115.07$, SD = 67.5), than the little finger, ($M = 33.45$, SD = 39.0), $F(1, 19) = 24.52$, $p < .0001$, $\eta_p^2 = .56$. Overall, the sixth finger was felt to be significantly more abducted than the little finger for all abduction orientation conditions, except for the 0° condition, in which the sixth finger was not induced to be visually rotated from the hand.

Discussion

The present study investigated whether posture congruence is a constraint in the embodiment of extra body parts, by systematically rotating the seen posture of illusory sixth fingers. Our results indicate that we can embody extended (rotating the finger up) and abducted (rotating the finger to the side) sixth fingers, including at an extreme of an 180° angle. When a touch on the little finger is simultaneously seen to be on empty space next to what seems to be the touched hand, one feels like they have a sixth finger. If the stroke in empty space is seen in a different orientation, the sixth finger is felt to be angled towards the visually induced angle of rotation from the hand. We measured the perceived felt orientation of the sixth finger and the actual little finger, and our results indicate that participants felt the sixth finger increasingly more extended and more abducted, when the induced extension and abduction also increased, while the actual little finger was felt to be in its normal position. This confirms that the perceived orientation of the sixth finger was indeed rotated, aligned with the visual–tactile stimulation. We predicted that participants would feel a sixth finger abducted or extended up to 90°, but not beyond, since an extra rubber hand was not embodied at 180° (Guterstam et al., 2011), nor was a sixth finger at 120° and 180° of abduction (Ambron & Medina, 2023). Unexpectedly, participants embodied a sixth finger in all orientations: 0°, 90°, 135°, 180°, for both extension and abduction orientations, with no significant decrease in illusion strength across orientations. Critically, we show that we can perceive supernumerary fingers in extremely implausible postures. The human little finger can extend up to approximately 30° (Kenhub, 2023), though some sources report a lower range of 23° (Mohamed Ibrahim et al., 2024). Our results show that participants perceived a mean extension of 123° for the sixth finger induced at 180°, which exceeds the anatomical extension range of the little finger by 93° (310% based on the higher range). As for abduction, the little finger can abduct up to a maximum of 23° (Erdogan & Bakirci, 2023), and our results show that participants perceived a mean abduction of 115° for the sixth finger induced at 180°, which exceeds the anatomical abduction range of the little finger by 92° (400%). These findings demonstrate that the embodiment of a supernumerary finger is not constrained by the anatomical limits of the human hand, with participants perceiving six fingers in extremely implausible postures.

Our results suggest we are far more flexible in the representation of supernumerary invisible fingers than in the representation of a fake hand as our own. Although the illusion of having a sixth finger is not directly comparable to the illusion of having a rubber hand, it is useful to denote that extra illusory fingers do not have the posture constraint that has been found and replicated for illusory hands, so that we can further pursue what is at the source of this distinction. A critical difference between the phenomenon of embodying a rubber hand and an extra sixth finger is that the sixth finger requires the detection of a mismatch. When the touch on the little finger is seen to occur in empty space, we detect *erroneous* signals of the little finger being at two different locations simultaneously, creating a mismatch when this is compared to the stored body model. The way the mismatch is solved is by creating the feeling of having an extra finger, as we argued elsewhere (Cadete & Longo, 2023). If our nervous system relied on the long-term representation of the body solely, then we would experience a doubled sixth finger, and not a sixth finger that is perceived to be at 90° or 180° from the hand and the actual touch on the hidden little finger. Our study adds to the evidence that the sixth finger representation relies on immediate sensory signals about the features and location of the supernumerary finger, rather than long-term representation of the body.

The consistent embodiment of a sixth finger, throughout the set of systematic incongruent postures, as if the finger was moved up or to the side, up to 180° of rotation from the actual finger, is strikingly contrasting to rubber hand illusion studies demonstrating posture congruency is necessary to the embodiment of a rubber hand. It is a widely reproduced finding that a rubber hand positioned at 90° (Farnè et al., 2000; Pavani et al., 2000; Tsakiris & Haggard, 2005) or 180° (Ehrsson, 2004; Lloyd et al., 2006) of orientation from the hand position (Costantini & Haggard, 2007) reduces or extinguishes the feeling that it is a part of one's body. This constraint does not seem to apply to supernumerary fingers. This was demonstrated with significantly higher scores for feeling six fingers in the embodiment scores for every orientation, and also with no participants that reported 4 or more to feeling six fingers in the 0° condition, having reported less than 4 at 90° or 180°. This shows that the more extreme angles of orientation from the hand-centred reference did not break the illusion. This is more surprising when considering that seeing distorted finger postures is an emotionally charged stimuli, as shown by occipitotemporal N1 responses using event-related potentials (Espírito Santo et al., 2017), and triggers feelings of disgust (Schürmann et al., 2011) while posterior parietal activations are sensitive to whether the finger postures are plausible or not (Costantini et al., 2005; Schürmann et al., 2011). At the same time, fingers abducted or extended in biomechanically impossible postures were still coded in motor-related areas mapping body actions (Costantini et al., 2005). This shows that while humans find fingers in implausible postures aversive, we nonetheless encode whether we can perform the movement or not. When the finger posture is impossible, it is still represented in cortical motor areas. In our study, we show that the implausible postures did not extinguish the illusion of having a sixth finger, as it happens in the standard rubber hand illusion. There are three immediate hypotheses for why this is: that the sixth finger is invisible; that it is a finger and not a hand; that it is a supernumerary finger.

The invisible aspect of the illusion leaves room for our perception to fill in the missing pieces of the bodily experience. The visual experience of the sixth finger is given by the stroking pattern in empty space, that the participant sees the experimenter performing, at the same time as their hidden little finger is stroked. It is possible that the invisible feature of the felt sixth finger allows for more flexibility than in other bodily illusions, as argued by Ambron and Medina (2023). It is also a methodological strength, as the visual stimulus does not include a representation of the finger, or even that it is a finger. This makes a case for how this illusion does not give away the content of what is being induced, and more importantly, it allows us to investigate which experiences arise when the brain has to solve the competing sensory signals into the most plausible solution, when it is not confined to the visual stimulus provided, such as a rubber hand or virtual fingers. However, while invisibility may provide higher embodiment flexibility, it does not guarantee the embodiment of a body part in an incongruent position. Guterstam et al. (2013) developed the illusion of having an invisible hand, using brushstrokes on the participant's real hand, hidden from view, matching the brushstrokes on empty space, performed as if an actual hand was there. The invisible hand illusion was only elicited when the brushstrokes were congruent with the real hand position and vanished when the invisible hand was induced at 90° from the actual hand. This indicates that invisibility is not the feature driving the flexibility to spatial congruency. Alternatively, the disruption of the invisible hand illusion at 90° may be due to more weighting against its embodiment, since the invisible hand was induced 20 cm away from the real hand, and induced from a fake stump, whereas in our study the hand is perceived to have congruent proprioception, while the finger is induced right next to the hand being reflected.

A second possibility is that flexibility for the spatial representation of supernumerary fingers is linked to a body part specificity, where fingers can be represented in positions that are incongruent with the actual fingers, and hands cannot. The fact that we have multiple fingers, with different sizes and different movement abilities, could be the source of having different representation constraints. Although this hypothesis could explain why a third hand was not felt to be part of one's body at 180° from the hand (Guterstam et al., 2011), and a sixth finger was, we argue instead that the reason lies in the different egocentric views. In the third-hand illusion, the rubber hand is positioned in a 180° rotation from the hand, with the seen wrist detached and away from the actual arm. This means that the embodiment of the third hand would require that the participant adopt an allocentric view, as the rubber hand is seen as coming from a body positioned in front of the participant. The sixth finger is also rotated at 180° from the hand, however, it is visually induced close to the little finger's metacarpophalangeal knuckle and thereby may be perceived as connected to the hand. Even though the allocentric view theory can explain the distinct findings between the two studies, it does not rule out that extra fingers may benefit from having higher flexibility than hands or feet in how they are represented. Specifically, the multiple digits flexibility hypothesis would explain our findings for flexibly embodying a sixth finger in different orientations. The left hand is symmetrical to the right hand, and the same occurs for the left foot, left leg and so on. Fingers are also symmetrical, index finger with index finger, thumb with thumb; however, there is a great deal of variability across the five fingers of one's hand, in terms of shape and function. It is therefore plausible that the representation of an extra digit would be less constrained by posture than hands are. Further studies ought to identify the boundaries of the spatial congruency constraint in supernumerary body parts.

The third hypothesis is that we can represent supernumerary fingers with more flexibility than existing fingers. In the same way that we can have our right hand lift up while the left hand is moving down, if we had a third hand, it could be in a different position from the existing hands. When we perceive an extra finger, it is not constrained to the felt position of the existing fingers, as it can be represented independently. Indeed, in two previous studies, we showed that the supernumerary finger is represented independently from the actual finger, allowing us to perceive a curved (Cadete et al., 2022) or a long and a short (Cadete & Longo, 2022) sixth finger while feeling the existing finger in a normal straight position or a normal size. Similarly, it is plausible that we can feel a sixth finger in a different position from the existing finger, as if the extra finger was extended or abducted up to 180°, whereas the existing finger was not. Still, this level of independence would only justify the perception of a sixth finger up to 45° from the hand position, or 90° if the supernumerary finger is represented with the same abduction ability as the thumb. If the extra finger is perceived to be part of one's hand, and it has similar abilities to the existing fingers, then we would not be able to feel it in a position that is functionally not feasible, as our fingers cannot abduct or extend up to 90° or 180° (Tubiana, 1988; Tubiana & Chamagne, 1988). For this reason, we will endorse a strong independence hypothesis. In this hypothesis, the supernumerary finger is not only independent from the short-term representation of the existing fingers, such as its current position, but also independent from its long-term representation, such as finger shape or rotation range. In this sense, the extra finger is not constrained to the various features of our five fingers, such as its action abilities or shape. Evidence supporting this interpretation is that we can feel a sixth finger that is laterally curved (Cadete et al., 2022) and in other odd shapes (Ambron & Medina, 2023). The supernumerary finger is represented as part of the body, yet unconstrained by how fingers are supposed to move or look. The somatosensory information of a sixth finger in various postures is accepted and used to represent a finger located in the induced orientation. The brain identifies whether fingers are in plausible or implausible postures (Costantini et al., 2005; Espírito Santo et al., 2017; Schürmann et al., 2011). It is uncertain whether the same encoding is happening for the sixth finger illusion, however, the sixth finger was felt in implausible postures in relation to the hand position, and the illusion of having six fingers remained. A sixth finger that has strong independence from the existing fingers can be represented with flexible abilities and rotation range, being perceived abducted or extended at 90°, 135° and 180° from the hand, and be felt as strongly as a sixth finger in a congruent position, at 0°.

If the strong independence hypothesis is correct, then it should hold true for any features that are specific to fingers, while it may still be constrained by more general bodily features. In the study by Ambron and Medina (2023), they show that the illusion was minimally constrained. The illusion only vanished in a few conditions: when the fifth finger was elongated, which makes sense as it is not a supernumerary finger illusion; when an additional arm was induced, which points to the representation of the body part as a finger. Contrary to the present findings, it also vanished when the sixth finger was induced at 120° and 180° of abduction. Further research is needed to strengthen these hypotheses and our understanding of the representation of illusory supernumerary fingers. For instance, the questions are framed in terms of feeling a sixth finger on the left hand; however, it needs to be experimentally tested whether the sixth finger feels to be part of the hand, indeed. In the control statement, participants had low scores for feeling an extra hand, ranging from 1.8 to 2.5 out of 10, yet still significantly different from the control condition for most orientation angles. If the sixth finger was to be experienced as part of a third hand, for example, then the fingers would not be necessarily incongruent with the hand, since it is another hand. Yet, they would still be incongruent with the existing hand and would still be incongruent with the fingers that are being stroked, mapping a 0° straight touch to several orientations. Participants reported the rotation of their actual finger slightly abducted and extended, yet this occurred across all orientations and in the control condition, showing it represents how they feel the natural posture of their little finger is, and not due to the manipulation. However, at 180° of extension, there is a mean of 53° of extension of the little finger (and 123° for the 6 finger). The finger extension up to 180° is the most extreme implausible posture in this experiment, so it may be that a constraint arises in some participants, by feeling both fingers rotated instead of only the sixth finger. Another aspect is that half of the participants reported both feeling a sixth finger and a larger little finger, which may indicate that these are not distinct experiences of the illusion, but related experiences.

Overall, our results suggest that we represent supernumerary fingers flexibly and unconstrained from posture congruency. An illusory sixth finger does not need to be in the same orientation as the actual hand to be perceived as part of one's body. We propose that the supernumerary finger is represented independently from short-term (e.g. current spatial location) and long-term representations of the existing finger (e.g. finger abduction to a maximum of 30° from the hand midline).

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ORCID iDs

Denise Cadete https://orcid.org/0000-0003-0511-3357
Federico Brusa https://orcid.org/0000-0002-5353-7296
Leonardo Mendolicchio https://orcid.org/0000-0002-0225-1407
Matthew R. Longo https://orcid.org/0000-0002-2450-4903

Data accessibility statement

The data and materials from the present experiment are publicly available at the Open Science Framework website: https://osf.io/9g5zp/

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