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The Sixth Finger Illusion in Anorexia Nervosa

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Abstract

People with anorexia nervosa (AN) exhibit altered responses to embodiment and motor imagery tasks, indicating a more malleable mental representation of their body compared to healthy controls (HC). While this has been observed with the actual body, little is known about the mental representation of supernumerary body parts. Recently, it was demonstrated in HC that illusions of supernumerary fingers are not constrained by posture congruency. The current study aimed to evaluate the differences in the malleability of body representation for supernumerary body parts comparing 30 participants with AN and 30 HC using the sixth finger illusion which is a body illusion based on conflicting visual and tactile signals that lead to create the illusory perception of having an extra finger (i.e. a sixth finger). Synchronous visual–tactile stroking was delivered at four abduction orientations: 0°, 90°, 135° and 180°, plus a control condition. Participants were asked to complete an ownership questionnaire to judge the little finger's perceived orientation and the sixth finger's felt orientation when they agreed to feel six fingers. Both groups experienced the sixth finger in all orientations, despite biomechanical constraints. However, AN participants perceived the sixth finger closer to the hand's position. Previous studies in AN report higher flexibility of some body representation domains, such as embodiment and motor imagery. Interestingly, our study highlights that this higher flexibility does not seem to apply to all domains of the representation of the bodily self: AN participants showed reduced flexibility for the perceived orientation of the extra finger.

Keywords

eating disorders, body representation, embodiment, multisensory illusion, supernumerary body parts

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Introduction

Body representation refers to the mental image or schema that individuals have of their own bodies (de Vignemont, 2010). It includes perception (how individuals sense their bodies in space), memory (recollection of past bodily experiences) and cognition (thoughts and beliefs about one's body). Body representation is indeed grounded in sensory and perceptual processes (Holmes & Spence, 2004), and it is crucial to plan action and to interact with the environment. Body representation can be explored using behavioural tasks such as motor imagery tasks (Brusa et al., 2021, 2023a, 2024; Ionta et al., 2007; Meregalli et al., 2023; Purcell et al., 2018) as well as body illusions (Botvinick & Cohen, 1998; Brusa et al., 2023b; Burin et al., 2017; Cadete & Longo, 2020, 2022; Crucianelli et al., 2018; Ehrsson, 2022; Ocklenburg et al., 2011).

Evidence from healthy individuals shows that we depend on physical constraints when we imagine actions we can do with our body: we are faster and more accurate in imagining an action that we can perform. This phenomenon is called the 'biomechanical constraints effect', and it is an index that our brain is performing motor imagery when imaging actions with our body (Brusa et al., 2021, 2023a, 2024; Conson et al., 2010; Coslett et al., 2010; Curtze et al., 2010; Parsons, 1987a, 1987b, 1994; Scarpina et al., 2019). When the spinal cord is damaged, for example, this effect is not present anymore, supporting the idea that what occurs in our brain is strongly dependent on what we can do in the real world (Fiori et al., 2014).

However, this dependency on the real world does not mean that the representation of the body in the mind is an exact copy of the physical body. For example, findings from experiments using body illusions show that we have a flexible representation of our body (Azañón et al., 2016), even in the absence of any lesion: people can embody external body objects such as a rubber hand (Botvinick & Cohen, 1998; Brusa et al., 2023b; Tsakiris & Haggard, 2005) or experience supernumerary body parts, such as a sixth finger (Cadete & Longo, 2020, 2023; Newport et al., 2016). In both cases, evidence from studies on healthy individuals as well as participants with damage to the central nervous system shows that body representation is not set in stone: how we imagine our bodies is a dynamic and continuously updated process, to reflect changes in our own body as well as the environment.

Recent bodily illusions highlight this flexibility of body representation by inducing the feeling of having supernumerary body parts, that is, more body parts than the ones we have. A third hand has been induced using a supernumerary rubber hand paradigm (Ehrsson, 2009; Guterstam et al., 2011) and a sixth finger using visual-tactile stimulation and the mirror box illusion (Cadete & Longo, 2020; Newport et al., 2016). Illusions of supernumerary body parts show our ability to experience one's body differently from one's actual body, but also to experience it differently from the human body plan. In the six-finger illusion, the experimenter strokes empty space next to the participant's reflected hand in the mirror, at the same time as they stroke their actual hidden hand, inducing instantly the feeling of having six fingers on their hand. Remarkably, the felt sixth finger can be represented independently from the existing fingers, with its own size, either longer or shorter than their actual little finger (Cadete & Longo, 2022), or its own shape (Ambron & Medina, 2023; Cadete et al., 2022). The representation of the supernumerary finger is so flexible that the illusion does not vanish when induced with different speed, number of fingers, location or shape of the sixth finger (Ambron & Medina, 2023).

This flexibility persists even in the face of the strict posture constraints that characterise the classical rubber-hand illusion, where rotating the fake hand by 90° (Farne et al., 2000; Pavani et al., 2000; Tsakiris & Haggard, 2005) or 180° (Ehrsson, 2004; Lloyd et al., 2006) relative to the real one reduces or extinguishes the illusion. In a recent study (Cadete et al., in press), we applied synchronous visual-tactile stroking at four orientation angles (0°, 90°, 135°, 180°) of finger abduction (sideways) and finger extension (upward) from the hand position. Participants embodied the sixth finger in all orientation angles as vividly as in a congruent posture with the actual little finger, both upwards and sideways, up to 180°. This occurred despite several of those orientations being biomechanically implausible, that is, real human fingers cannot bend that far. Given the central role of posture congruency in shaping embodiment, we extended this paradigm to compare responses in individuals with anorexia nervosa (AN) versus healthy controls (HC), to determine whether the same resistance to biomechanical constraints holds in a population known for increased bodily malleability.

Such remarkable flexibility in the representation of extra body parts raises intriguing questions about how this phenomenon might differ in populations with altered body representations, even in the absence of central nervous system or brain impairments, such as AN (Eshkevari et al., 2012, 2014; Hasenack et al., 2021; Keizer & Engel, 2022; Meregalli et al., 2023; Purcell et al., 2018; Scarpina et al., 2022). In people with AN, motor imagery is compromised (Meregalli et al., 2023; Scarpina et al., 2022), and evidence suggests that their bodies may be represented more akin to how external objects are processed in mental rotation tasks involving seen body parts, lacking the usual influence of biomechanical constraints (Scarpina et al., 2022).

Similarly, when subjected to illusions of ownership (i.e. embodying a rubber hand), participants have been shown to experience the illusion more strongly than healthy controls, as first demonstrated by Eshkevari et al. (2012, 2014). This pattern is supported by Keizer et al. (2014), who found that

AN participants reported significantly greater ownership over a rubber hand than healthy individuals in the synchronous, however that did not occur in the asynchronous condition, which goes against the idea of a general higher malleability, only supporting a more specific malleability in perceiving a fake hand as part of their body. Moreover, unlike Eshkevari's findings, Keizer and colleagues found no group difference in proprioceptive drift. AN participants initially overestimated their own hand size, but this overestimation disappeared after both synchronous and asynchronous conditions, suggesting that other mechanisms beyond illusion susceptibility may also be at play. More recently, Portingale et al. (2025) examined the *enfacement illusion* and found no increased susceptibility in participants with Eating Disorders, suggesting that not all forms of multisensory body representation are equally affected in eating disorders. Together, these studies highlight the importance of considering both the type of illusion and the specific body part involved when interpreting findings on embodiment in eating disorders. It also highlights the need to avoid generalising effects, such as ascribing higher embodiment ratings in the rubber hand illusion to a global and encompassing higher malleability of body ownership and body perception in these clinical conditions.

Nevertheless, the presented evidence suggests that in AN, the representation of the body is different from that of healthy individuals: they are more susceptible to some body illusions, with lower thresholds for experiencing a fake hand as their own. The relationship between altered body perception and the maintenance or relapse of AN symptoms remains unclear and likely involves complex interactions with affective (Horndasch et al., 2020) and interoceptive processes (Jenkinson et al., 2018) the body schema (Purcell et al., 2018) and awareness of bodily signals (Pollatos et al., 2008). Further research is needed to clarify whether and how body representation differences contribute to clinical outcomes in AN. Some authors have proposed that body illusions and visuo-tactile stimulation could be used to modulate body perception in AN (Eshkevari et al., 2012, 2014). Others have suggested that multisensory integration and perceptual retraining may help explain disturbances in body image and embodiment (Meregalli et al., 2023; Scarpina et al., 2022). In addition, Purcell et al. (2018) found distortions in the implicit body schema using a motor imagery task, pointing to possible differences in sensorimotor representations. Together, these studies support the idea that both perceptual and motor components of body representation may be affected in AN, and that studying these mechanisms can help build a better understanding of the condition. The challenge remains to develop a more comprehensive knowledge of body representation components in AN (Meregalli et al., 2023; Scarpina et al., 2022), as emotional components more related to body image seem to be the focus of most studies (Glashouwer et al., 2019). However, understanding also components related to motor control would allow to develop interventions such as those based on virtual reality (Magrini et al., 2022; Porras-Garcia et al., 2021) that could help more with the persistence of symptoms and relapses too.

In the current study, we bridged the knowledge from the literature on motor imagery and sense of ownership in AN. More in detail, our study aims to explore the presence of differences in the malleability of the body representation, explored through the body illusion of the sixth finger (Cadete & Longo, 2020, 2022; Cadete et al., 2022), between a group of people with AN (American Psychiatric Association [APA], 2013) and a group of healthy individuals (HC), considering that both our physical and mentally represented bodies are influenced by biomechanical constraints that mirrors anatomical constraints too (i.e. I cannot twist my left wrist of 270° without injuring it, similarly, this influence my fastness and accuracy in judging its laterality in motor imagery tasks). In a previous study, we showed that healthy participants can feel a sixth finger in various orientations that were incongruent with the posture of their actual fingers and hand (Cadete et al., in press). We induced a sixth finger at 0°, 90°, 135°, 180° of extension (finger moving up) or abduction (finger moving to the side), with participants feeling it just as much in all conditions, with the felt orientation of the sixth finger matching the induced orientation. This is strikingly contrasting with the embodiment of actual body parts, which are constrained by posture congruency. In this study, we applied the same method to assess in what ways the embodiment of an extra finger is different in AN participants from HCs. We also aimed to understand how extra fingers that are induced in incongruent postures can be perceived differently between groups. In our study, the sixth finger illusion was elicited with a degree of rotation from the hand at 0°, 90°, 135° and 180° of finger abduction in the visuo-tactile stimuli plus the control condition, in which the participants should not report the experience of having a sixth finger.

To summarise, body illusions allow us to study the plasticity of the mental representation of the body because they elicit a temporary perturbation of it. The illusory experience of a sixth finger would tell us about the malleability of body representation in our sample, at least on the mental representation of hands. Although body illusions occur in HC, the imagined body in our mind follows the biomechanical constraints of our physical body (Brusa et al., 2021, 2023a, 2024; Conson et al., 2010; Parsons, 1987b, 1987a, 1994; Scarpina et al., 2022). Differently, in people with AN, greater malleability of mental body representations has been observed, in comparison to HCs, and these mental representations appear more detached from the physical constraints of the real body (Eshkevari et al., 2012, 2014; Scarpina et al., 2022). The fact that people with AN might show greater malleability/flexibility of their body representation, embodying a supernumerary body part, would

strength the idea of using such an implication to create rehabilitation programs based on embodiment. For example, researchers might use virtual reality-based treatments to manipulate and correct distorted body image perceptions. By immersing individuals in virtual environments where their body appears differently, therapists could potentially help them reevaluate and adjust their perceptions of their own bodies. These rehabilitation programs could indeed focus on embodiment techniques, where individuals are encouraged to engage with and manipulate virtual representations of their bodies. Through repeated exposure and interaction, individuals may develop a more accurate and positive perception of their bodies, potentially reducing symptoms and preventing relapses.

Even though the literature on biomechanical constraints of the body (Brusa et al., 2021, 2023a, 2024; Conson et al., 2010; Scarpina et al., 2022; Tsakiris et al., 2010) would suggest a reduced embodiment of fingers in implausible postures, in our previous study, participants embodied equally a sixth finger at 0°, 90°, 135° and 180° of finger abduction and extension (Cadete et al., in press). However, Ambron and Medina (2023) successfully induced a sixth finger at 90° from the hand, but not at 120°, neither at 180° of finger abduction. We, therefore, did not have a strong hypothesis for the embodiment of felt orientation of the sixth finger in the HC group. Differently, we hypothesised that people with AN would report the experience of feeling a sixth finger in all of the conditions, because of the greater response to bodily illusions, as well as because of their mental representation of the body being less attached to the physical constraints of the physical body (Eshkevari et al., 2012, 2014; Scarpina et al., 2022).

Materials and Methods

Sample

The study was approved by the Ethical Committee of the IRCCS Istituto Auxologico Italiano (Milan, Italy, Reference number: 2023_04_18_07). We performed the experiment in accordance with the Declaration of Helsinki. Participants gave written informed consent before taking part in the experiment and were volunteers. They were free to withdraw at any point during the study and were naïve to the rationale of the experiment.

Participants were eligible to take part in the study if they were female, between 18 and 55 years of age, and had no history of head/brain injury, no history of drug/alcohol abuse, no learning disability and had no medical illness with symptom overlap with eating disorders. Moreover, only right-handed participants were enrolled to mitigate potential confounding variables stemming from the presumed divergent cerebral lateralisation of cognitive functions and the potential variance in cognitive effects observed in left-handed individuals (Ionta & Blanke, 2009).

The study included people diagnosed with AN (APA, 2013) and HC. Psychiatrists established the diagnosis of AN through clinical interviews, evaluation of medical history, assessment of physical parameters and psychodiagnostic test results. Therefore, we grouped participants into an eating disorder group, the AN group and the HC group. Individuals in the AN group were consecutively recruited at admission to the hospital, where they received eating disorder treatment at the time of the experiment. In addition to the inclusion/exclusion criteria above-mentioned, individuals in the AN group were required to meet the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition's diagnostic criteria for AN (APA, 2013): (a) restriction of food intake leading to weight loss or a failure to gain weight resulting in a 'significantly low body weight' of what would be expected for someone's age, sex, and height; (b) fear of becoming fat or gaining weight; (c) have a distorted view of themselves and of their condition. Both 'restricting type' and 'binge-eating/purging type' (APA, 2013) were included in this study. We did not recruit participants presenting a psychotic episode at the time of the potential administration (i.e. the testing occurred during moments of preserved orientation and reality-testing) of the task or those chronically using medication other than psychiatric medication as part of their treatment to avoid confounding effects of such factors on the way the body illusion was experienced, as well as a precautionary measure (e.g. might be dangerous for a person that is not in touch with the reality to experience body illusion) (Prikken et al., 2019). Overall mood was low, but it was regularly monitored and managed by the clinical team when required. Psychiatric comorbidities – mainly anxiety and depression – were observed in some participants, though regarded as secondary to the primary diagnosis of AN. We discussed the possible enrolment of participants with the psychiatrists assigned to the patients during their recovery.

Participants in the HC group were required to have a body mass index (BMI) between 18.5 and 25 kg/m^2, not currently to be on a diet to lose weight or have had a history of being underweight (BMI $<17.5\,kg/m^2$), to not have any history of an eating disorder or disordered eating behaviour, and to not have a current or prior history of psychiatric illness (as defined in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition's) (APA, 2013). HCs were recruited on a volunteer basis.

During their hospitalisation, people with AN were assessed for their eating behaviour and psychological functioning with the Eating Disorder Inventory–3 (Garner, 2004), which focuses on the symptomatology associated with eating disorders, the Binge Eating Scale (Gormally et al., 1982) to assess the presence of binge eating behaviour, the Body Uneasiness Test to evaluate the discomfort experienced towards one's own body, and body image (Cuzzolaro et al., 2006), the Symptom Checklist-90 (Derogatis, 1994), which allows evaluation of the self-reported severity of psychopathological symptoms, the Frost Multidimensional Perfectionism Scale (Frost &

Marten, 1990) to evaluate the tendency to perfectionism, and the Psychological General Well-Being Index (Dupuy, 1984), which measures the psychological well-being of participants.

We also calculated the BMI expressed as body mass(kg)/height $(m)^2$; weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively.

Sample Size Calculation

Eshkevari et al. (2012) induced the rubber hand illusion to participants with eating disorders and HC, and in another study compared these two groups with a group of participants in recovery from eating disorders (Eshkevari et al., 2014). Using pairwise comparisons, they compared the HC group with the eating disorders group in the rubber hand embodiment scores (Eshkevari et al., 2014), with an effect size of Cohen's $d = .52$, in a sample of 139 participants. A power analysis using G*Power 3.1 (Faul et al., 2007), with a two-tailed alpha of .05 and a .8 power, indicated that 118 participants (60 in each group) were required to have an effect size of Cohen's $d = 0.52$ in the embodiment scores between a clinical group with an eating disorder and a HC group. Conducting this study in a clinical population, our access to such a large sample size was limited, and therefore, we would not be able to reach the power necessary to achieve a similar effect size when comparing the results between both groups. For this reason, we could not commit to testing a large sample size, and therefore we committed instead to reaching a minimum sample size, of 30 participants per group, based on the power calculations using the effect size within-group, described below.

Eshkevari and colleagues also compared the bias towards the rubber hand against zero for each group, to assess whether each group was embodying the rubber hand (Eshkevari et al., 2012). These one-sample *t*-tests had an effect size of $d_z = 0.776$ for the HC group and $d_z = 0.712$ for the AN group. To have the power to detect an effect size of $d_z = 0.776$, we would need 24 HC participants and a $d_z = 0.712$, we would need 28 participants with eating disorders, as calculated using G*Power 3.1, with a 2-tailed alpha of .05 and 95% power. Therefore, we enrolled 30 participants per group, AN and HCs.

The Sixth Finger Illusion

Description of the Task. To induce the sixth finger illusion and the control condition, we used the same procedure of previous studies (Cadete & Longo, 2020, 2022; Newport et al., 2016) (Figure 1). The setup described below is based on the principles of another technique utilised for exploring multisensory integration and body ownership (Crivelli et al., 2021; Leach & Medina, 2022; Medina et al., 2015), known as the mirror box illusion (Ramachandran & Rogers-Ramachandran, 1996; Ramachandran et al., 1992). In this illusion, an individual positions one hand on each side of a mirror, aligned with the participant's midsagittal plane. Upon viewing the mirror, the reflection of the hand placed in front of it appears to be the unseen hand positioned behind the mirror.

In our setup, the participant sat in front of a table with a mirror positioned on the table aligned with their body midline. They 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 border of the table and 20 cm from the mirror, marked by two dots where the participant was asked to place the tip of each index finger. The participant was asked to look into the mirror at the hand throughout each trial. The mirror box effect was explained before the trials, by stating that the right hand reflected in the mirror would look like their left hand.

The left hand was hidden behind the mirror and the mirror reflection of the right hand, which will be hereafter referred to as the seen hand, was perceived as a direct view of the left hand due to the reverse optical effect of mirrors. We used the continuous version of the sixth finger illusion (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 empty space next to the seen little finger. The sixth finger stroking needs to be synchronous with the stroking of the actual little finger, that is hidden from sight. Whilst the little finger was stroked, the experimenter also stroked the empty space next to the seen hand in the orientation of each condition. So, in the 180° condition, 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 knuckle to the wrist, instead of the direction from the little finger's knuckle to the fingertip.

We had a set of four conditions, consisting of different orientations of the visuo-tactile stimuli, with a degree of rotation from the hand at 0°, 90°, 135° and 180° of finger 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, plus the control condition (Figure 2). The control condition 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.

Questionnaire. The five conditions, four orientations and control stimuli were counterbalanced across participants, using a Latin Square design: the first participant started with an ABCDE distribution, the second BCDEA, the third

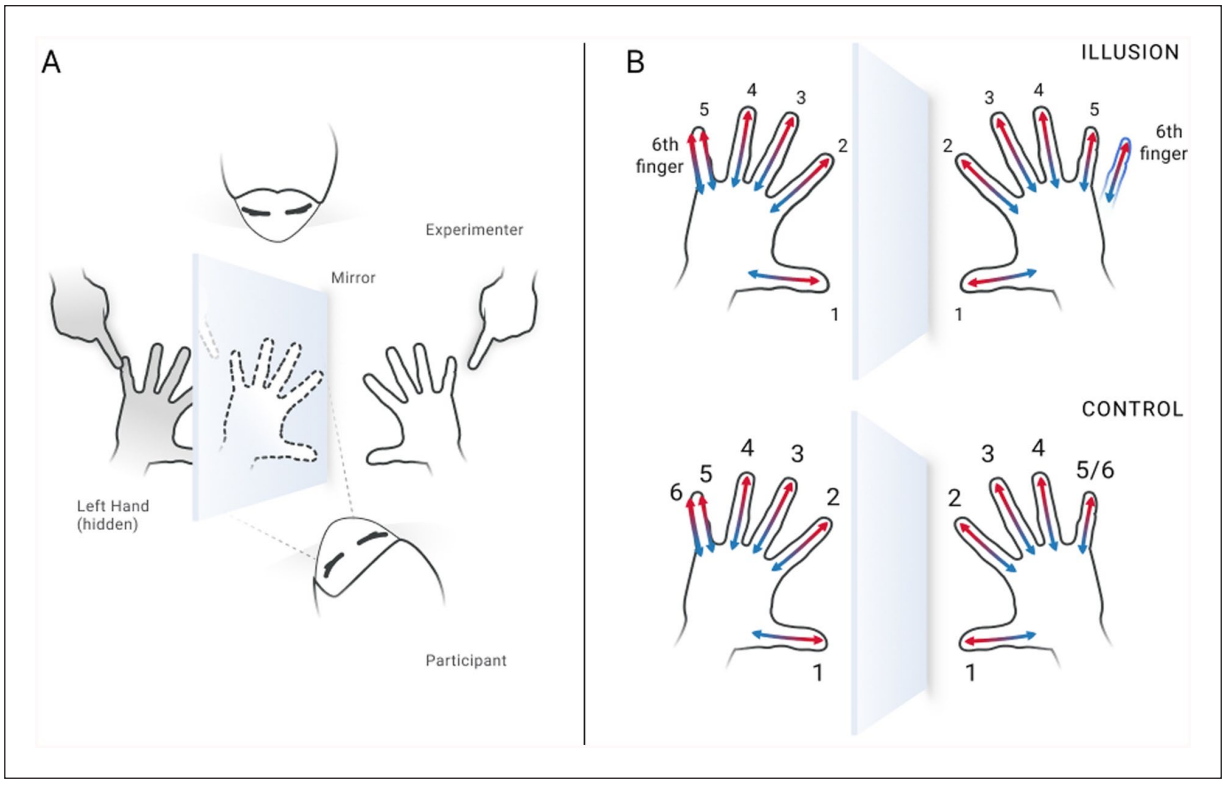

Figure 1. The experimental setup. The participant watches the reflection of their right hand in the mirror while their left hand is occluded behind the mirror. The participant sees the right hand through the reflection in the mirror, resembling the left hand due to the mirror's optical reverse effect. 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 is then stroked on the inside lateral at the same time as the top of the little finger on the seen hand, followed by 20 double strokes on the outer lateral side of the occluded little finger synchronously to touching the empty space next to the seen little finger, with the orientation of each condition. Participants look in the mirror, and when they see the experimenter stroking the empty space next to their little finger at the same time as they feel a touch on their little finger (of the hidden hand), they can feel like they have a sixth finger. The control condition follows 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. 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.

CDEAB, the fourth DEABC, the fifth EABCD, and then the cycle was repeated. Participants reported the embodiment of a sixth finger using a scale, in which 0 corresponded 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 six-finger illusion (Cadete & Longo, 2020, 2022; Newport et al., 2016), from item 1 to 5, and we added item 6 in this study, since a smaller subset of participants reports feeling a larger little finger instead of a sixth finger (Cadete et al., 2022) (Table 1).

Perceived Finger Orientation. Participants judged the perceived orientation of the little finger after all trials. On trials in which they scored at least 1 out of 10 on Question 1, participants were also asked to judge the felt orientation of the sixth finger. For participants who reported feeling a larger little finger, we asked them to judge the felt orientation of the little finger. To do that, we used the visual judgement task of Cadete et al.'s study (in press) for reporting felt abduction of the sixth finger and the actual little finger. Similar tasks with scaled visual stimuli were used in previous studies to capture the body perception experience induced by an illusion (Cadete et al., 2022; Guterstam et al., 2015) (Figure 3). Guterstam et al. (2015) 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).

In this study, we presented to the participant a set of 3D fingers in a scale of orientation angles of 0°, 15°, 30°, 45°, 60°, 75°, 90°, 105°, 120°, 135°, 150°, 165° and 180° of finger abduction, 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.

We used these visual judgements to assess whether the participants felt the illusory finger in a specific orientation,

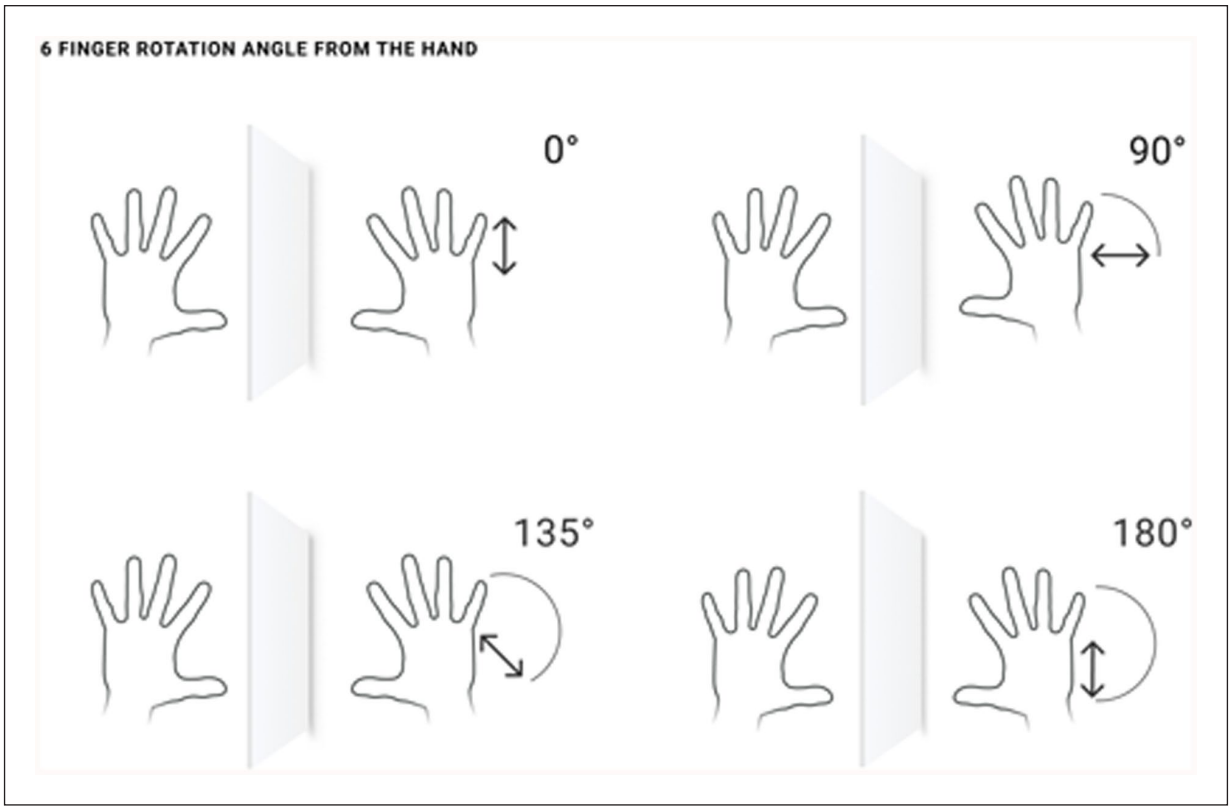

Figure 2. Sixth finger orientations of the visual-tactile stimulus: 0°, 90°, 135° and 180° of finger abduction. A sixth finger at 90° of abduction looks like a finger rotated around a quarter of a clock, placed horizontally and perpendicularly to the hand. The 180° looks like a sixth finger rotated in the opposite direction of the participant's fingers, with the fingertip close to the wrist. The orientation of the visual stimulus was performed next to the right hand; however, it was perceived with the opposite laterality, as it was reversed in the mirror.

Table 1. The Table Reports the Items of the Questionnaire Used in the Current Study. Given That the Study was Conducted in Italy, the Questions Were Translated into Italian.

Question	English	Italian
1	It felt like I had six fingers on my left hand.	Mi sono sentito come se avessi sei dita nella mano sinistra.
2	It felt like I had two little fingers on my left hand.	Mi sono sentito come se avessi due mignoli nella mano sinistra.
3	I felt a touch where I do not normally feel a touch.	Mi sono sentito toccare dove normalmente non mi sento toccare.
4	I felt a touch that was not on my body.	Ho sentito un contatto che non era sul mio corpo.
5	It felt like I had an extra hand.	Mi sono sentito come se avessi una mano in più.
6	It felt like I had a larger little finger.	Mi sono sentito come se avessi un mignolo più grande.

as it is plausible that one may feel a sixth finger that is 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. To analyse whether there was a significant difference between groups for the felt orientation of the actual finger and the sixth finger across orientations, we conducted a mixed model analysis where the null model has orientation and finger type as factors, and the model has orientation, finger type and group.

Data Analysis

Demographic and Anthropometric Measures. Independent sample *t*-tests were used to check for differences between the two groups in terms of all the demographic features (age, years of education and BMI).

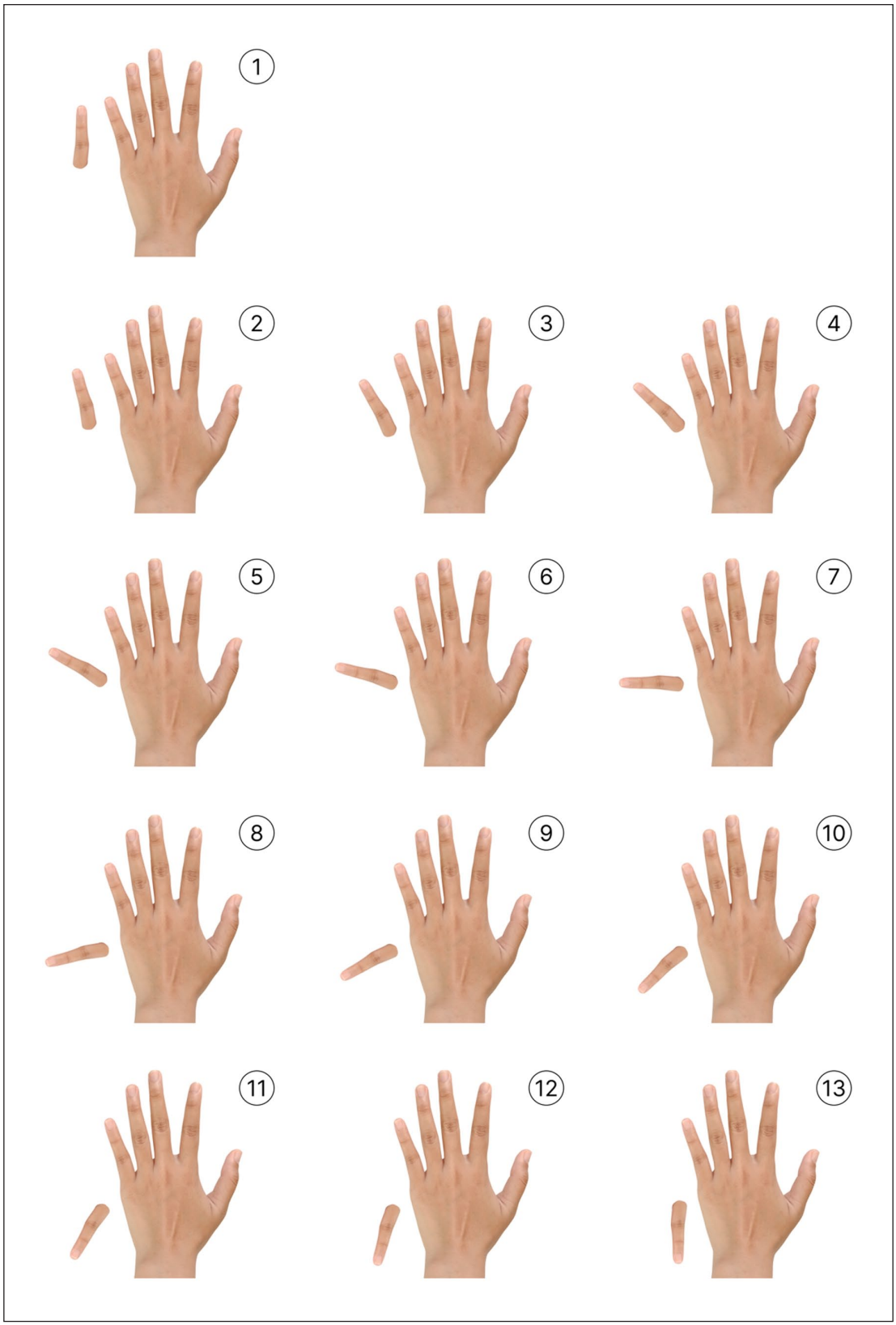

Figure 3. Finger orientation stimuli. Set of images of sixth fingers in a scale of orientation angles of 0°, 15°, 30°, 45°, 60°, 75°, 90°, 105°, 120°, 135°, 150°, 165° and 180° of finger abduction (similar to a spinning top type of rotation). The images represent the sixth finger's angle of rotation from the position of the participant's hand. The sixth finger was placed next to the little finger of the participant's left hand, as it was the side on which the illusion was perceived.
Source. Original hand image by Penpak Ngamsathian, at Vecteezy.com.

The Sixth Finger Illusion: Questionnaire. We tested the embodiment of a sixth finger in several orientations in AN and HC participants asking them to answer a self-report questionnaire on the illusion experience. To assess whether participants felt a sixth finger, we compared the scores of the first questionnaire item in the zero degrees condition against the control condition, with a paired *t*-test, for each group separately. We also compared the scores of the first questionnaire item in the zero degrees condition between the AN and HC participants, with an independent-samples *t*-test. The same pair of analyses was run with the last questionnaire item, as it verifies a different aspect of the illusion.

For each questionnaire item, we conducted a 2×4 mixed analysis of variance with group (AN vs. HC) as a between-subject factor, and orientation (0°, 90°, 135° and 180°) as a within-subject factor. There may be a different pattern of embodiment scores between groups, as AN participants report higher scores for embodying a rubber hand (Eshkevari et al., 2012). Ambron and Medina (2023) successfully induced a sixth finger at 90° of abduction from the hand, but not at 120° neither at 180°. However, in our study, inducing rotated six fingers in healthy participants, they felt the extra finger consistently in all orientations, at 0°, 90°, 135° and 180° of extension and abduction, without compromising the strength of the illusion (Cadete et al., in press). The highly implausible orientations of the sixth finger did not decrease the illusion, though we may find a different trend in patients with AN due to group differences in bodily constraints. For this reason, we did not have a strong a priori prediction for the main effect of orientation. However, we did anticipate an interaction between group and orientation, as it may be that AN participants would have higher scores for sixth fingers in implausible positions, compared to the HC group. We conducted pairwise comparisons with Holm–Bonferroni correction for multiple comparisons to compare agreement between orientation angle conditions.

The Sixth Finger Illusion: Perceived Finger Orientation. When participants scored at least 1 out of 10 in Question 1, we measured the perceived orientation of the sixth finger. Not all of the participants reported feeling a sixth finger (i.e. answered 0 in the scale to the first questionnaire item). That is, we analysed the difference between the orientation judgements for the felt sixth finger and for the felt little finger, as well as the difference between the felt sixth finger in 0° and the other orientations, using a mixed-effects model (Baayen et al., 2008), with the lme4 toolbox for R (Bates et al., 2015). Unlike standard ANOVA, this model does not require that data for each condition be present for each participant. To directly compare the perceived orientation of the sixth finger and the actual little finger within each condition, mixed-effects models were fitted separately for each orientation. In these models, illusion (sixth vs actual finger) was included as a fixed effect, with a random intercept for subjects. To analyse whether there was a main effect of group, we used a model that included illusion (sixth vs. actual finger), orientation (0°, 90°, 135° and 180°), group (AN vs. HC), and all their interactions as fixed effects, with a random intercept for subjects to account for repeated measures. We tested the significance of each fixed effect using Type III ANOVA with Satterthwaite's approximation for degrees of freedom (Kuznetsova et al., 2017), reporting *F*-values and partial eta-squared (η_p^2) as measures of effect size. These analyses are available in the OSF link: https://osf.io/dt43m/.

Results

Demographic and Anthropomorphic Measures

We recruited 60 females participants (AN: $N=30$, 24 restrictive type and 6 binge-purging type, age = 27 years (standard deviation [*SD*] = 7 years, range 18–42 years), BMI = 14.46 kg/m^2 (*SD* = 1.84 kg/m^2, range 11.3–17.4), level of education = 14 years (*SD* = 2, 8–18 years) versus HC: $N=30$, age = 30 years (*SD* = 6 years, range 24–51 years), BMI: 20.95 kg/m^2 (*SD* = 1.75 kg/m^2, range 19–24.8), level of education = 17 years (*SD* = 2, 13–19 years). Participants with AN and the HCs did not significantly differ for age ($t(58)=-1.76$; $p=.083$; $d=-0.46$); however, HCs showed a higher level of education ($t(58)=-5.60$; $p<.001$; $d=-1.44$). However, we are confident that all participants comprehended the task, as they were all at least at a high school level. As expected, people with AN showed a significantly lower BMI than HCs ($t(58)=-7.13$; $p<.001$; $d=-3.61$).

In Supplemental Material 1, we report the results relative to the psychological assessment of our participants with AN.

The Sixth Finger Illusion: Questionnaire

For the main questionnaire item: 'It felt like I had six fingers on my left hand', both AN and HC participants felt the sixth finger in all orientations, consistently significantly different from the control condition ($p<.0001$), as shown in Table 2. A two-way mixed ANOVA with group as the between factor and orientation as the within factor showed that embodiment scores for feeling a sixth finger significantly differed across orientations, $F(3, 174)=16.87$, $p<.0001$, $\eta_p^2=.23$, decreasing continuously as the rotation from the actual hand increased, as is apparent in Figure 4. A similar pattern was seen in both groups.

There was no main effect of group, $F(1, 58)=0.05$, $p=.82$, $\eta_p^2=.00$, showing that AN and HC participants did not differ in perceiving a six-fingered hand. There was also

Table 2. Paired *t*-tests Between the Control Condition Embodiment Scores, and the Embodiment Scores for Each Orientation Condition, for the AN and the HC Groups Separately.

It felt like I had two little fingers on my left hand								
		Control		Orientation				
AN group		*M*	*SE*	*M*	*SE*	*t*(29)	*p*	Cohen's *d*
	0°	0.70	0.29	7.20	0.45	13.18	<.0001	2.41
	90°			6.37	0.66	8.68	<.0001	1.59
	135°			5.43	0.71	6.54	<.0001	1.19
	180°			4.70	0.76	5.90	<.0001	1.01
It felt like I had two little fingers on my left hand								
		Control		Orientation				
HC group		*M*	*SE*	*M*	*SE*	*t*(29)	*p*	Cohen's *d*
	0°	0.13	0.09	7.07	0.36	19.00	<.0001	3.47
	90°			6.40	0.47	13.14	<.0001	2.40
	135°			5.07	0.60	8.24	<.0001	1.50
	180°			4.53	0.56	7.80	<.0001	1.42

Note. Participants embodied a sixth finger in all orientations, significantly more than in the control condition. *M* = mean; *SE* = standard error of the mean; AN = anorexia nervosa; HC = health control.

no significant interaction between group and orientation, $F(3, 174) = 0.10$, $p = .97$, $\eta_p^2 = .00$, showing that the scores per orientation did not differ as a function of group type.

In the planned contrasts, there were no significant differences in feeling a sixth finger between groups in any condition, $p > .05$. Looking at the pairwise comparisons with Holm–Bonferroni corrections between the different orientation conditions, there was no significant difference between the 0° and the 90° conditions in the AN group, $t(29) = 1.43$, $p = .33$, $d = 0.29$, whereas for the control group there was, $t(29) = 2.45$, $p = .04$, $d = 0.29$. The only orientation pair that was significant after corrections, in the AN group, was between 0° and 180°, showing that embodiment was significantly different only between the two extreme angles. For the control group, orientations significantly differed between 0° and 135°, $t(29) = 4.75$ $p < .0001$, $d = 0.74$, 0° and 180°, $t(29) = 6.11$, $p < .0001$, $d = 0.98$, 90° and 135°, $t(29) = 2.78$ $p = .03$, $d = 0.45$, 90° and 180°, $t(29) = 3.47$, $p = .01$, $d = 0.17$. The only pair that did not significantly differ in the control group was between 135° and 180°, $p = .22$.

We could speculate that even though control participants embody six fingers in all orientations, the experience of embodiment starts to decrease immediately at the rotation of 90°, unlike in AN participants, that are similarly embodying the sixth finger in both orientations (i.e. 0° and 90°). We can mildly infer from this difference that there is a reduced constraint of finger orientation from normal to transversal (90°), than in HC controls, who exhibit a noticeable difference in embodiment from 0° to 90° orientation.

All other orientation scores differed significantly from the other orientations for both groups, except for the 135° compared to the 180° conditions, which did not differ between them in either of the groups.

For all other questionnaire items, there was no significant main effect of group or interaction between group and orientation, $p > .05$, while there was a significant difference in response scores across orientations, $p < .0001$. The only exception was Question 5: 'It felt like I had an extra hand', which is a control question, and therefore, there was no significant difference across orientations, and mean responses were very low, ranging from 1.07 to 2.33 across all orientation conditions for both groups. The last questionnaire item: 'It felt like I had a larger little finger on my left hand', also had mean responses lower than 3 out of 10 for all orientations in both groups. The questionnaire items for embodying two little fingers (Question 2) had high mean response scores ranging from 4.33 to 6.47 out of 10, as well as for feeling a touch out of the body and feeling a touch that was not on their body, between 4 and 6 out of 10 across orientations. Overall, both groups felt a sixth finger in all orientations, as well as a touch where is not normally felt and a touch out of the body, with gradually decreased embodiment as the orientation was more rotated from their actual hand position, with all orientations significantly differing from the control condition.

The Sixth Finger Illusion: Perceived Finger Orientation

Even though the majority of participants of both groups felt the sixth finger in all orientations, a small set of participants did not experience the sixth finger in extremely

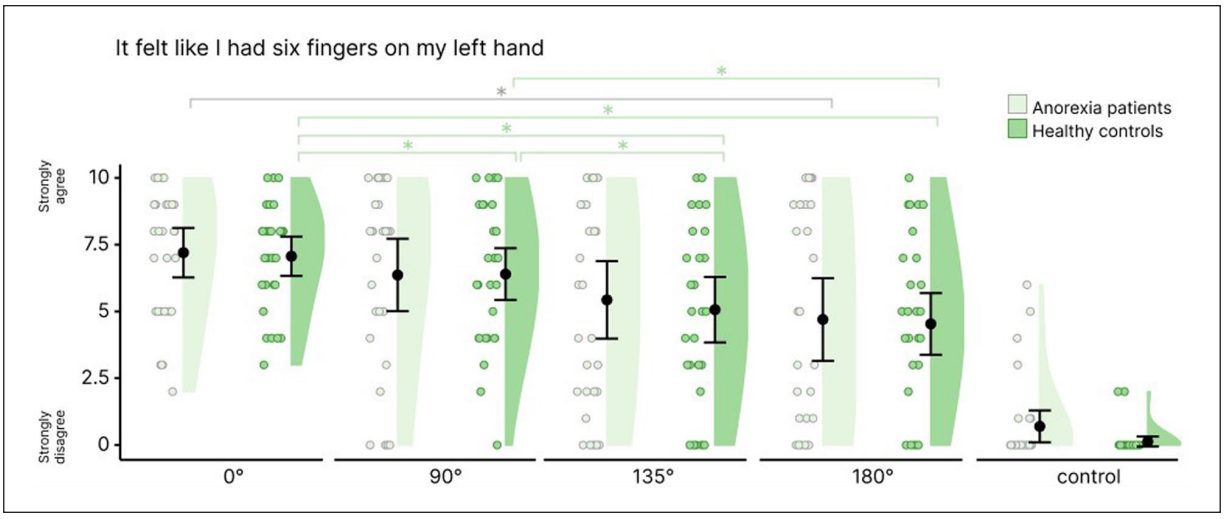

Figure 4. Scores for embodying a sixth finger by orientation angle, for AN and HC participants. The sixth finger was felt in all orientations, significantly different from the control condition ($p < .0001$), and we can observe a decrease in embodiment scores as the orientation angle increases. The more rotated the sixth finger is, the less it is embodied. Stars represent statistical difference at $<.05$ in contrasts after Holm–Bonferroni corrections. 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 mean.
Note. AN = anorexia nervosa; HC = health control.

rotated orientations. For instance, 6 HC and 8 AN participants reported not feeling the illusion at 180°. In such cases, the experimenter did not ask the perceived orientation of a finger they did not feel, not producing data beyond that point, as anticipated in our experimental design. Therefore, we analysed the difference between the actual and the extra finger conditions in the follow-up questions, modelling finger type as a fixed effect, with a mixed-effects model (Baayen et al., 2008) using the lme4 toolbox for R (Bates et al., 2015) on Jupyter Lab, as this method does not require that data for each condition be present for each participant. We also used this method to assess the difference between groups across conditions, and between the sixth and actual fingers. Analyses were conducted using Type III ANOVA with Satterthwaite's approximation for degrees of freedom (Kuznetsova et al., 2017), and results are reported as *F*-values and partial eta-squared (η_p^2). A similar analysis was conducted for felt orientation data in our previous study (Cadete et al., in press).

The results show a significant main effect of group, $F(1, 409.05) = 8.18$, $p = .004$, $\eta_p^2 = .020$, indicating a difference in how AN and HC participants experienced the postures of the sixth finger and the actual little finger across orientations. AN participants felt their little finger and the sixth finger consistently less rotated from their hand than HC participants, consistently across all induced orientations. The analysis also revealed significant main effects of illusion, $F(1, 410.25) = 277.29$, $p < .0001$, partial $\eta_p^2 = .403$), and orientation ($F(3, 407.63) = 64.19$, $p < .0001$, partial $\eta_p^2 = .136$). There was also a significant interaction between illusion and orientation, $F(3, 407.63) = 38.59$, $p < .0001$, partial $\eta_p^2 = .086$). No other interactions were significant ($p > .1$).

We conducted follow-up analyses comparing the felt orientation of the sixth finger and the actual little finger separately for each group and each induced orientation to assess whether the perceived orientation of the extra finger differed from that of the actual finger as a result of the illusion. In AN participants, there was no significant difference between the actual ($M = 16°$, $SE = 1.66°$) and the extra finger ($M = 18°$, $SE = 2.56°$) in terms of felt orientation, when a normal sixth finger (0°) was induced, $F(1, 29) = 1.63$, $p = .21$, partial $\eta_p^2 = .053$. In contrast, in HC participants, there was a marginal difference between the actual finger ($M = 20°$, $SE = 2.42°$) and the sixth finger ($M = 23°$, $SE = 2.24°$), $F(1, 29) = 4.17$, $p = .050$, $\eta_p^2 = .126$.

Yet, both groups felt the sixth finger induced at 0° slightly more rotated on average than the little finger. In the 90° sixth finger condition, there was a significant difference between the actual and the little finger felt orientation, $F(1, 28.94) = 56.34$, $p < .0001$, partial $\eta_p^2 = .661$ for the HC group (actual finger: $M = 30.0°$, $SE = 4.55°$; six finger: $M = 70.3°$, $SE = 3.11°$), as well as for the AN group, $F(1, 28.33) = 58.83$, $p < .0001$, partial $\eta_p^2 = .675$, (actual finger: $M = 24.5°$, $SE = 3.56°$; six finger: $M = 66.6°$, $SE = 4.94°$). In the 135° sixth finger condition, there was a significant difference between the actual and the little finger felt orientation, $F(1, 53) = 75.03$, $p < .0001$, partial $\eta_p^2 = .586$ for the HC group (actual finger: $M = 27.5°$, $SE = 4.38°$; six finger: $M = 105.63°$, $SE = 7.94°$), as well as for the AN group (actual finger: $M = 25.5°$, $SE = 5.72°$; six finger: $M = 88.2°$, $SE = 8.56°$), $F(1, 29.00) = 43.72$, $p < .0001$, partial $\eta_p^2 = .601$. When the sixth finger was induced at 180°, there was a significant difference between the actual and the little finger felt orientation, $F(1, 25.98) = 60.36$, $p < .0001$,

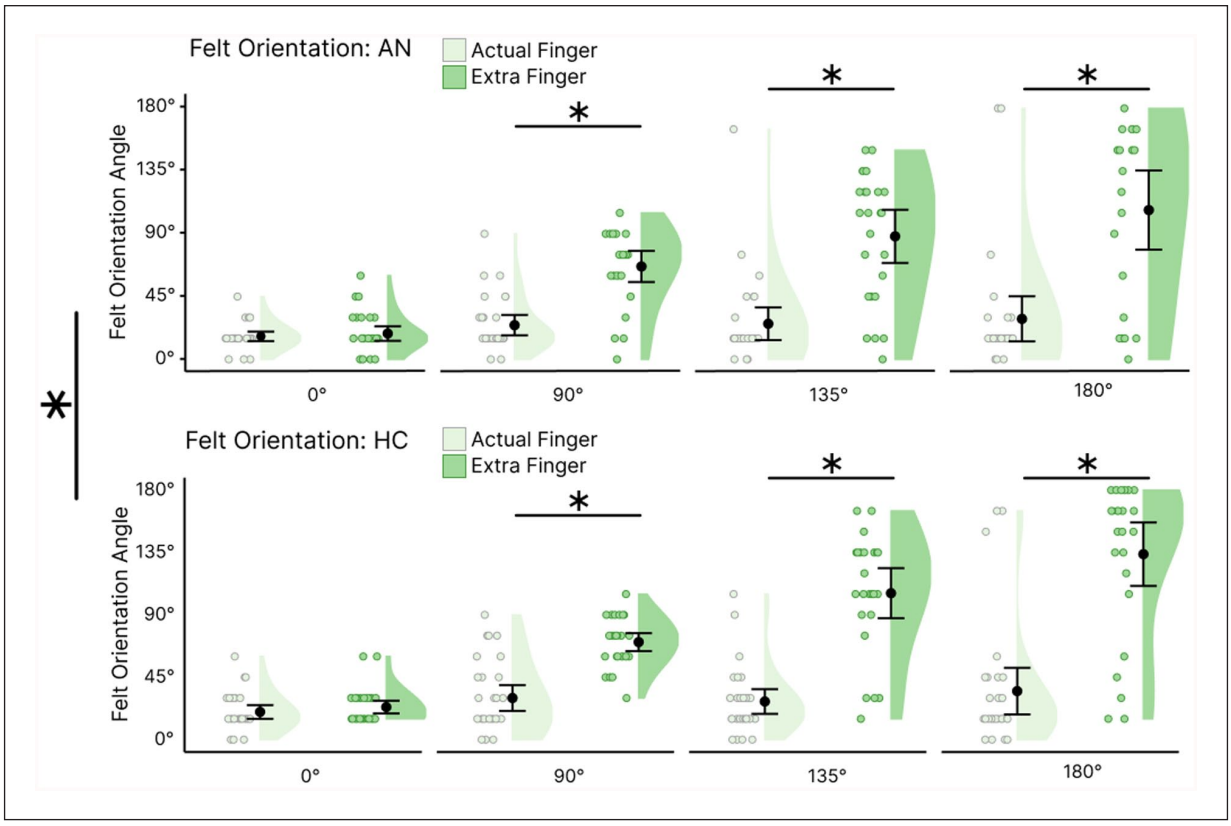

Figure 5. Angle of felt orientation of the illusory sixth finger and their actual little finger, per orientation condition. Both groups felt the sixth finger with an increased orientation angle as the induced orientation angle also increases, as a rotation from the actual hand; whereas the actual little finger maintains a perceived orientation below 45° in all conditions. However, the AN group felt the sixth finger consistently and significantly less rotated than the HC group, across all orientation conditions, $p < .0001$. 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 mean.
Note. AN = anorexia nervosa; HC = health control.

partial $\eta_p^2 = .699$ for the HC group (actual finger: $M = 35.0°$, $SE = 8.21°$; six finger: $M = 134.0°$, $SE = 9.96°$), as well as for the AN group, $F(1, 24.42) = 38.18$, $p < .0001$, partial = .610, (actual finger: $M = 29.0°$, $SE = 7.91°$; six finger: $M = 107.0°$, $SE = 11.5°$). Overall, the felt orientation of the sixth finger was perceived to be significantly more abducted than the actual little finger, for all the conditions in which the sixth finger was visually induced in a rotated posture, that is, from 90° to 180°.

Conclusion

It has been argued that the bodily self is more plastic in people with eating disorders, both when it comes to the whole body and for specific body parts such as the hands (Eshkevari et al., 2012; Keizer et al., 2016). Particularly for hands, people with AN when exposed to the rubber hand illusion (Botvinick & Cohen, 1998), wherein the sensation of a rubber hand being part of one's own body (sense of ownership) is induced by synchronously stroking a visible rubber hand alongside the participant's occluded hand, report higher embodiment of the rubber hand during synchronous stimulation, in perceptual and subjective measures. Moreover, the mental representation of hands of people with AN seems to be more detached from the physical constraints of the physical body, as shown by exploring motor imagery processes (Scarpina et al., 2022). In the current study, we explored the flexibility/malleability of the mental representation of hands in people with AN using a body illusion, the sixth finger illusion. Interestingly, our finding highlights how the higher flexibility observed for the mental representation of people with AN does not seem to apply to all domains of the representation of the bodily self, at least when hands are considered. Our results show good flexibility in adapting to the embodiment of an extra finger. In contrast, we also found a remarkable reduced flexibility for the perceived orientation of that extra finger. People with AN perceived the sixth finger to be less rotated than the HC group, consistently for all orientation conditions.

This finding of two opposing trends for bodily flexibility in people with AN between feeling an extra body part and feeling that body part in varied orientations is relevant

in two ways. For one, it can shed light on our understanding of the complex representation of one's own body in AN, by starting to identify in what ways that representation is flexible and in what ways it is not. Second, it points to distinct mechanisms for how flexibly we perceive the bodily self, one for embodying an extra body part and another for its position, regardless of the presence or absence of a clinical condition.

Recently, it has been shown that we can embody a supernumerary body part for a long duration (Cadete & Longo, 2020), and with independent features from one's actual body parts, such as length (Cadete & Longo, 2022) and shape (Ambron & Medina, 2023; Cadete et al., 2022). In our previous study, we tested whether a sixth finger induced in incongruent postures would still be felt to be part of one's body (Cadete et al., in press). A sixth finger positioned at 0°, 90°, 135° and 180° of finger extension and finger abduction was embodied without extinguishing or even decreasing the illusion. This highlights that illusory supernumerary fingers are not constrained by posture congruency, which is remarkably different from other bodily illusions. The current study is the first to apply the sixth finger illusion to participants with AN, and we found opposing patterns of flexibility in the embodiment of extra body parts in this clinical population. As for the embodiment of a sixth finger across orientations, there was no main effect of group, with both groups embodying the extra finger in all conditions. This may be due to the sixth finger illusion being more powerful than the rubber hand illusion, with higher embodiment scores and no adaptation period, having been instantly induced with a single touch in the original illusion (Newport et al., 2016), and 20 double strokes in the continuous version of the illusion (Cadete & Longo, 2020, 2022), which lasts around 20 s. This suggests that this bodily illusion has virtually no onset timing. The vividness of the illusion may translate into a lack of variability in the reported embodiment, due to a ceiling effect across participants in experiencing a sixth finger. Even when the extra finger is induced in different orientations, incongruent with the actual hand position, the illusion does not fade away for both groups. Interestingly, the AN group does not embody less of the sixth finger when rotated from their actual hand, they feel it as strongly up to 135° and slightly less at 180°; however, they feel the sixth finger less rotated than what is being visually suggested by the experimenter, and less rotated than the control group.

To assess the perceived orientation of the sixth finger and the actual little finger, we used a set of figures to illustrate a finger in different orientation angles from the hand, and the participant indicated which one matched their experience (Figure 3). There was a significant difference between groups for the felt orientation of the sixth finger and the actual finger across conditions. The participants with AN felt the sixth finger less rotated than it was. In other words, they perceived the sixth finger closer to the hand position, or more congruent with the hand position than the control group. The control group felt the orientation of the sixth finger as more aligned with the visual stimulus induced by the experimenter, which is the visual cue that is signalling for a sixth finger oriented at 0°, 90°, 135° or 180° from the hand. The AN group perceived the sixth finger 27° less rotated than the control participants in the 180° condition, minus 17° in the 135° condition, and around minus 4° in the 90° and 0° conditions. At the same time, we may also infer that this group was more accurate in how they perceived their actual finger orientation, as they also felt their actual little finger slightly less rotated than the HC group, averaging to 4° less rotated across conditions. Our results demonstrate a consistent distinction between the AN and the HC group, in the perceived abduction degree of the illusory sixth finger. AN participants felt the sixth finger significantly less rotated than HC participants, consistently across induced orientations.

We found a striking reduced flexibility for the orientation of the extra finger in AN participants, with a constraint for being perceived more towards the actual posture of the hand. This finding shows that the increased flexibility of body perception in this clinical population, which has been identified in previous studies (Eshkevari et al., 2012, 2014), cannot be generalised to all domains or features of body perception. Specifically, the perceived orientation of the extra finger is shown to be more constrained towards the orientation of the actual finger in AN participants. Immediately, this points to distinctive types of constraints in the representation of supernumerary body parts, in which feeling an extra finger as part of one's body can be more flexible, while the perceived posture of the same finger can be more constrained. We propose two hypotheses to explain this difference.

Our first hypothesis is that AN participants rely less on visual cues to how they perceive their body, and attributing more weight to the proprioception information about their hand, hence relying more on the touch on the actual finger combined with the proprioception of the position of that hand, and less on the seen location of the sixth finger. Indeed, there is evidence that this clinical population does not experience the size–weight illusion to the same extent as HC (Case et al., 2012). In the size–weight illusion, when feeling two objects of the same weight but different size, the larger one is perceived to be heavier; however, participants with AN are less sensitive to this illusion, which is suggested to be a result of a deficit in the integration of visual and proprioceptive signals. If there is indeed a deficit in the integration of the signals of these two modalities, it could explain the constraint for the sixth finger orientation, where the seen location of the sixth finger is not well integrated with the proprioception of the actual finger. To resolve the conflict, proprioception may be weighted more heavily during multisensory integration of the extra finger, although the visual cue still induces the rotated orientation of that finger, just consistently less than in HC participants.

Another possibility to explain this constraint specific to the AN group is that the extra finger in AN participants is constrained in its position due to being represented as a duplication of the existing finger with a lower degree of independence from the existing fingers. A sixth finger that is represented independently from the existing fingers can be located in a different place from the actual fingers. In previous experiments, it has been shown that the sixth finger is represented independently, with its own size (Cadete & Longo, 2022), shape (Cadete et al., 2022) and posture (Cadete et al., in press). In this study, we also demonstrate a flexibility to represent the posture of the supernumerary finger in HCs, and further show a distinct pattern in the perception of rotated sixth fingers in AN individuals. It could be that in AN participants, the supernumerary finger is also represented with some independence, however, to a less extent than in HC participants. If it was purely felt as a duplication, it would not be felt rotated, unless the actual finger was also rotated. Our results show that AN participants do feel the sixth finger more rotated than in the 0° condition and more rotated than the actual little finger, near the orientation induced, however less rotated than HC controls, an effect consistent for all orientation conditions. Even though the sixth finger is being represented independently from the actual finger, felt in a rotated position from the hand, it seems it is relying more on the spatial representation of the actual fingers, resulting in perceiving the finger much less rotated than the control participants. The same result could be explained by a higher reliance on the long-term body image of the fingers, however, it would not explain why the embodiment of a sixth finger is flexible in AN participants, but not its position.

In this study, the sixth finger illusion was shown to be a powerful illusion, which elicits high embodiment levels in both groups, even when induced in orientations which are incongruent with the hand position, which is visually available to the participant. In a previous study, healthy participants embodied a sixth finger in all four abduction and extension orientations: 0°, 90°, 135° and 180° (Cadete et al., in press). In this study, we replicate these results, however in this study, the more rotated, the less did the sixth finger feel part of one's body, whereas in our previous study, it was similarly embodied in all abduction and extension rotations. Ambron and Medina (2023) have somewhat contrasting results to both our studies: they also found that a sixth finger abducted at 90° from the hand was embodied, however the illusion extinguished at 120° and 180°. Still, the three studies show that the supernumerary finger was embodied at 90°, while our two studies show it was embodied up to 180° of abduction in HC and AN participants and up to 180° of abduction and extension in healthy participants. This is patently contrasting to the rubber hand illusion (Costantini & Haggard, 2007; Tsakiris & Haggard, 2005), or the invisible hand illusion (Guterstam et al., 2013), in which the illusion of having a rubber hand vanishes when positioned at 90° from the hand-centred frame (Cadete et al., in press; Makin et al., 2008). An extra body part may allow for extra flexibility compared to hand illusions, due to its independence: we can represent our actual finger in one position at the same time as an extra finger in another. The same is not possible in the rubber or invisible hand illusions, as they imply a replacement of the hand, for which, it must be congruent with the actual hand position. We argued before (Cadete et al., in press) for a strong independence hypothesis, wherein the supernumerary finger is independent from the short-term representation of the existing fingers, such as its current position, but also from their long-term representation, such as its shape and range abilities. This hypothesis explains why we can feel a sixth finger abducted up to 180°, whereas our actual fingers do not have that ability.

This study has several limitations that should be acknowledged. First, because the research was conducted in a clinical population, access to a large sample was restricted. Second, the study did not include a group of individuals with AN in recovery. As a result, direct comparisons were limited to acutely ill patients and healthy controls, which prevents us from determining whether the observed alterations – such as reduced flexibility in the perceived orientation of the sixth finger – reflect enduring features of the disorder or transient effects related to acute illness factors, such as starvation or cognitive changes. Third, we did not assess general cognitive flexibility, for instance through set-shifting tasks, in either group. This is relevant because previous studies have consistently reported persistent inefficiencies in cognitive flexibility in AN, particularly in set-shifting and central coherence (Brockmeyer et al., 2022; Dann et al., 2023; Fuglset, 2019). Such executive function differences could plausibly shape participants' performance in body illusion tasks, for example by influencing their ability to shift between real and illusory body representations or by reinforcing a rigid representation of finger posture despite contradictory sensory information. Future research should therefore aim to include larger clinical samples, where possible, participants in recovery, and standardised measures of cognitive flexibility to clarify the role of these factors in shaping body representation malleability in AN.

Overall, we showed that both groups embodied the sixth finger in all orientations, with remarkably significant changes across orientations in the HC group, and only significantly changing between 0° and 180° in the AN group. Critically, we found a significant difference between groups in the perceived orientation of the sixth finger, and actual little finger. Participants with AN feel the sixth finger less rotated than HC participants in all conditions, for both the sixth finger and the actual finger. This shows a constraint in AN for the position of the extra body part. We attribute this constraint to a different way of integrating visuo-proprioceptive signals by individuals with AN (Risso et al., 2019, 2020). Another possibility is that the sixth finger in participants with AN has

less independence from the actual finger, being more constrained to the position of their actual finger, as the representation of the extra body part is being processed partly as a duplication of the existing finger, and partly independently, as it is still felt rotated. Both proposals would allow for AN participants to still embody the sixth finger with great flexibility, and yet have reduced flexibility for its orientation position from the actual hand.

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Ethical Considerations

The ethics committee of the Istituto Auxologico Italiano approved the study (reference number: 2023_04_18_07), and the study was conducted in accordance with the latest Declaration of Helsinki guidelines. All participants were volunteers who gave informed written consent before participating in this study.

Consent to Participate

All participants provided written informed consent prior to participating.

Author Contributions

Conceptualisation: FB, DC, AS, VV, EA, EV, GC, LM, MRL; Data curation: FB, DC; Formal Analysis: FB, DC; Methodology: FB, DC, AS, MRL; Supervision: AS, MRL; Writing – original draft: FB, DC; Writing – review and editing: AS, MRL.

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Data Availability Statement

This set of raw data is accessible under request in Zenodo because includes sensitive information: https://zenodo.org/records/10246063. Please write your request at: f.brusa@uxologico.it. The analysis scripts and visual stimuli are available in the OSF link: https://osf.io/dt43m/.

Supplemental Material

The Supplemental Material is available at: qjep.sagepub.com.

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