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Conceptual distortions of hand structure are robust to changes in stimulus information

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A B S T R A C T

Previous studies showed stereotyped distortions in hand representations. People judge their knuckles as farther forward in the hand than they actually are. The cause of this bias remains unclear. We tested whether both visual and tactile information contribute to the bias. In Experiment 1, participants judged the location of their knuckles by pointing to the location on their palm with: (1) a metal baton (using vision and touch), (2) a metal baton while blindfolded (using touch), or (3) a laser pointer (using vision). Distal mislocalisations were found in all conditions. In Experiment 2, we investigated whether judgments are influenced by visual landmarks such as creases. Participants localized their knuckles on either a photograph of their palm or a silhouette. Distal mislocalisations were apparent in both conditions. These results show that distal biases are resistant to changes in stimulus information, suggesting that such mislocalisations reflect a conceptual mis-representation of hand structure.

1. Introduction

Hands are ubiquitous in our daily lives. It is through the hands that we experience the world around us most directly. They are especially important for goal-directed action and in learning to manipulate objects (Klatzky, Pellegrino, McCloskey, & Doherty, 1989; Reed, Grubb, & Steele, 2006). From infancy, humans use their hands for two primary functions: to acquire information and to manipulate their environments (Jones & Lederman, 2006). Hands are also a valuable source of social knowledge, providing information about other people's intentions (Woodward, 2009) as well as aiding language comprehension (Goldin-Meadow & Wagner, 2005; McNeill, 1992). We use hands to communicate before we learn language. By 11 months, infants can recognize and use pointing gestures (Carpenter, Nagell, & Tomasello, 1998), and show shifts of attention in the direction of dynamic points even earlier (Bertenthal, Boyer, & Harding, 2014; Rohlfing, Longo, & Bertenthal, 2012). A recent study which analyzed data from head cameras worn by infants found that while faces are a dominant visual input during the first year of life, hands emerge as dominant in the second year (Fausey, Jayaraman, & Smith, 2016).

With all the experience we gather through the lifespan, it seems intuitively that we really should know hands like the proverbial "back of our hand". Recent research, however, has revealed that their representations can be strikingly distorted. For example, in a study by Longo and Haggard (2010) participants were asked to judge the perceived location of landmarks (i.e. knuckles and fingertips) of their occluded left hand. By comparing the relative position of judgments of each landmark, implicit perceptual maps of hand structure were constructed and compared to actual hand structure. These maps were highly distorted in a stereotyped way across people, with the hand represented as wider than it actually is and the fingers as shorter than they actually are. Similarly, the distance between two unseen touches aligned with the medio-lateral hand axis is perceived as substantially larger than the same

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distance aligned with the proximo-distal axis (Green, 1982; Longo & Haggard, 2011). Other studies, involving explicit judgments of body part size have also revealed similar distortions (D'Amour & Harris, 2017; Linkenauger et al., 2015; Longo & Haggard, 2012).

In two recent studies, we have found that people have highly distorted conceptual knowledge of the configuration of landmarks within their hand, believing their knuckles (i.e., the metacarpophalangeal joints) to be substantially farther forward in the hand than they actually are (Longo, 2015; Margolis & Longo, 2015). Longo (2015) asked participants to lay their hand palm-up on a table (in a position in which knuckles are not visible) and to use a long baton to indicate the location on the palm directly opposite the knuckle of each finger using the other hand. Participants consistently judged their knuckles as farther forward in the hand than they actually are, showing a clear distal bias for all fingers aside from the thumb. In the study of Margolis and Longo (2015), similar distal biases were apparent when participants were asked to judge the location of their knuckles by clicking the mouse cursor on an empty silhouette, created from an image of the dorsal side of their hand, presented on a screen in front of them.

In Experiment 3 of Longo (2015), similar biases were also found when participants were asked to judge the location of the knuckles of the experimenter's hand, suggesting that the distortion reflects conceptual knowledge about the configuration of hands in general, rather than self-specific representation of one's own hand. These results show that healthy participants can demonstrate behavior similar to this observed in disorders characterized by distorted body representations such as autotopagnosia, a condition resulting from damage to the left parietal cortex, in which patients are impaired in judgments about the configuration and location of body parts (Buxbaum & Coslett, 2001; Sirigu, Grafman, Bressler, & Sunderland, 1991). Autotopagnosic patients are generally impaired when asked to point to parts of their own body, and are also impaired when asked to point to parts of other people's bodies or mannequins (Gerstmann, 1942; Ogden, 1985; Sirigu et al., 1991). Autotopagnosia is generally thought to reflect damage to a representation called the *body structural description*, which mediates knowledge of the spatial layout of bodies (Corradi-Dell'Acqua et al., 2008; Longo, Azañón, & Haggard, 2010; Schwoebel & Coslett, 2005). The distal biases we recently described (Longo, 2015; Margolis & Longo, 2015), thus, suggest that even in healthy people the body structural description does not provide a fully veridical representation of body configuration, but is systematically distorted in stereotyped ways across people.

Another example of systematic distortions becomes apparent when healthy people are asked to draw a face. A study by Carbon and Wirth (2014) showed that in all drawings the eyes are positioned much higher in the head than they really are. The authors explained this bias by suggesting that people do not take into account the convexity of the forehead. Similarly, Longo (2015) suggested that distal bias in knuckles localization reflects "intuitive anatomy", a naïve belief about the hand structure.

Could these distortions instead reflect a more basic perceptual bias resulting from specific sensory cues present while participants perform the task? One potential interpretation of this effect is that participants, in giving their judgments, were visually influenced by the crease at the base of the fingers on the palmar hand surface, which is substantially farther forward in the hand than the knuckle. However, while responses in Longo (2015) were clearly distal to the actual location of the knuckle, they were also clearly proximal to the crease, suggesting that participants had not simply confused the crease for the knuckle. Furthermore, in Experiment 2 of the study of Longo (2015) similar distal biases were found when participants were blindfolded, suggesting that the bias is not a purely visual bias in the direction of the crease.

Hands are common in our visual experience of the world, but are ubiquitous in touch, in which the hands form a 'fovea' for tactile perception (Mancini et al., 2013). In the study by Longo (2015) participants showed distal biases in knuckles localization on the palm even when blindfolded, providing some indication that immediate vision may not be required to elicit this effect. However, it is not possible to assess how similar in magnitude the biases are considering that the comparison of visual-tactile and tactile-only judgments was between experiments. Therefore, it remains unclear what kind of sensory information affects these distal biases, and how and to what extent visual and tactile cues might affect them. The present study aimed to systematically investigate whether information from different modalities contributes to these biases and whether they are affected by visual cues such as the crease. Experiment 1 used the paradigm of Longo (2015) to investigate the contribution of vision and touch to knuckle mislocalization. Participants judged the location of their knuckles (the metacarpophalangeal joints) by pointing on their palm in three conditions: (1) using a baton on the skin providing both visual and tactile cues (*VisuoTactile* condition), (2) using a laser pointer resulting in only visual cues (*Visual* condition), or (3) using that baton while blindfolded resulting in just tactile cues (*Tactile* condition). Experiment 2 used the paradigm of Margolis and Longo (2015) to directly assess the potential role of the creases at the base of the fingers as a visual cue in producing the bias. Participants localized their knuckles by clicking the mouse cursor on either a photograph of their palm or on a blank white silhouette of the palm, in which visual cues such as the crease were removed.

2. Experiment 1

Experiment 1 tested whether both visual and tactile information contribute to the distorted representation of hand structure we recently described (Longo, 2015). Participants were asked to localize their knuckles by indicating the location on their palm directly opposite to each knuckle. In the *VisuoTactile* condition, participants used a long baton to make their judgments and could see where they were pointing, providing both visual and tactile information about their response. In the *Tactile* condition, participants used the same baton, but were blindfolded, and thus forced to rely on tactile information to make their judgments. In the *Visual* condition, participants used a laser pointer to indicate their response, resulting in similar visual cues to the VisuoTactile condition, though tactile information was not present on the palm. If the distal biases in knuckle localization are driven by visual signals, then they should emerge in the VisuoTactile and Visual conditions, but not in the Tactile condition. If the biases are driven by tactile signals, then they should appear in the VisuoTactile and Tactile conditions, but not in the Visual condition. By contrast, if the biases reflect genuine misconceptions about hand structure, they should appear in all three conditions, irrespective of which sensory cues are available.