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Where exactly am I? Self-location judgements distribute between head and torso

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ABSTRACT

I am clearly located where my body is located. But is there one particular place inside my body where I am? Recent results have provided apparently contradictory findings about this question. Here, we addressed this issue using a more direct approach than has been used in previous studies. Using a simple pointing task, we asked participants to point directly at themselves, either by manual manipulation of the pointer whilst blindfolded or by visually discerning when the pointer was in the correct position. Self-location judgements in haptic and visual modalities were highly similar, and were clearly modulated by the starting location of the pointer. Participants most frequently chose to point to one of two likely regions, the upper face or the upper torso, according to which they reached first. These results suggest that while the experienced self is not spread out homogeneously across the entire body, nor is it localised in any single point. Rather, two distinct regions, the upper face and upper torso, appear to be judged as where "I" am.

1. Introduction

If someone were to ask you where you are, what would be the most precise answer? Most people can tell by their senses and memory that they are in a particular country and city, and in a certain place, some part of a particular room, more or less distant from one or more objects, etc. But is there a more specific answer that can be given? Perhaps you would say that you are where your body is. But your body is an extended object, with distinct parts that can move independently; so is there a specific part of your body that counts you? Where *exactly* are you?

A number of recent studies have explored the idea that a particular part of the body fixes a subject's ultimate location. Using a structured interview technique, Bertossa, Besa, Ferrari, and Ferri (2008)) elicited gradually narrowing self-location judgements along each of the three spatial dimensions. They report that sighted and blind Italians and sighted Chinese participants home in on a common location, the centre of the head, as the location of the "I-that-perceives", the place for which each individual judges that "I am here" regardless of what or how they perceive. In another study, Starmans and Bloom (2012) found similar results when pre-school children and adults were asked to judge the relative distance of an object from a humanoid character. By varying the location of the object and the orientation of the character, Starmans and Bloom determined that both children and adults deem an object to be closest to a subject when it is in front of the subject's eyes, leading them to the provocative claim that "children and adults intuitively think of the self as occupying a physical location within the body, close to the eyes" (Starmans & Bloom, 2012, p. 317).

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While the results of Bertossa et al. (2008) and of Starmans and Bloom (2012) pick out the head as the referent of self-location judgements, contrasting results were found in a study by Limanowski and Hecht (2011). They asked participants to mark the location of the self within an outline of a human body and within a rectangular shape containing depictions of a human heart and brain. Responses clustered around the head and torso of the human outline and around the location of the heart and brain in the rectangular shape, though for the latter there was a preference for the location of the brain.

The methodology of these studies contrasts in many ways. Both Starmans and Bloom (2012) and Limanowski and Hecht (2011) required subjects to make judgements concerning a depiction of a humanoid (or close to humanoid) figure, rather than judgements concerning their own bodies. Although Limanowski and Hecht's method is more direct than Starmans and Bloom's, it is less direct than Bertossa and colleagues' in this latter respect. To the extent that Limanowski and Hecht's and Starmans and Bloom's studies involved self-location judgements, they were projections onto the depicted subjects in the task. Nevertheless, these studies each differ from that of Bertossa et al. (2008), in so far as each implements systematic changes in the context in which self-location judgements are made. A further limitation of Bertossa and colleagues' study is that their structured interview did not allow for the possibility of specifying multiple bodily locations across self-location judgements. Sensory systems are known to process information in body-part centred frames of reference (e.g., Graziano, Yap, & Gross, 1994; but see also Limanowski & Blankenburg, 2013), as well as hybrid reference frames involving combinations of these (e.g., Carrozzo & Lacquaniti, 1994), and idiosyncratic frames of reference for transformation between body-part centred frames (e.g., Chang & Snyder, 2010). Accordingly, in the course of a self-location judgement, participants might use a variety of strategies corresponding to the inherent diversity and flexibility of multi-sensory integration processes, thereby picking out any of a variety of bodily locations.

Our method of testing influences on self-location attempts to avoid both the indirectness of projected self-location judgements whilst leaving open the possibility of specifying various bodily locations. We take inspiration from investigations of the geometry of binocular depth perception in vision, first developed by Wells and Hering in the 18th and 19th centuries, respectively (for review, see Ono, 1981). The basic idea was that if binocular vision is used to perceive distance of a seen object, there must be some specific point inside the observer from which distance was calculated. This point has variously been termed the 'egocentre', the 'cyclopean eye', and the 'binoculus' (Howard & Templeton, 1966; Mitson, Ono, & Barbeito, 1976). In its simplest form, this test involves rotating a rod horizontally until its near end was judged to be pointing directly at oneself. By conducting the task at a series of radial directions and extending the line of the rod in each judgement to pass through the observer, an examiner could determine the participant's 'egocentre' as the point of their intersection, which may be close to or far from the interocular axis depending on specific aspects of the task (Howard & Templeton, 1966; Mitson et al., 1976).

The aim of the present study was to systematically probe possible influences on self-location judgements by means of a generalisation of the original 'egocentre' task. Rather than identifying the location of the origin of the visual–spatial reference frame, we sought to use an analogous paradigm to probe participants' intuitions about where they – themselves – were located inside their body. Using a simple pointing apparatus that rotated in the sagittal plane, we asked participants to point directly at themselves, either by manual manipulation of the pointer whilst blindfolded or by visually discerning when the pointer was in the correct position. By varying the direction of the pointer's rotation and the elevation of the point of rotation in both the visual and haptic conditions, we were able to test whether self-location judgements are invariant over a variety of task contexts, or whether certain aspects of a task might systematically influence judgements.

2. Methods

2.1. Participants

Ten individuals (six females) between 24 and 48 years of age participated. All participants were right-handed as assessed by the Edinburgh Inventory (Oldfield, 1971), *M*: 92.20, range: 81.81–100. All procedures were approved by the local ethics committee.

2.2. Procedure

The experimental setup is shown in Fig. 1. Participants stood in front of a table in front of a vertical pole to which was attached a metal pointer which rotated freely in the participant's sagittal plane. The participant's task on each trial was to position the pointer so that it was "pointing directly at you". The position of the participant's body remained constant between trials. Participants were told that the task was not a test of the ability to judge the direction perpendicular to the pole.

There were two main experimental conditions. In the *Haptic* condition, participants were blindfolded and held the pointer in their right hand and used it to point at themselves. In the *Visual* condition, participants watched as the experimenter moved the pointer at an approximately constant velocity and indicated verbally when the experimenter should stop. If the experimenter over- or under-shot the desired location, the participant could provide further directions or restart the trial. When the participant was satisfied with their response, the experimenter pressed a key and a webcam resting on a

Fig. 1. The experimental apparatus and setup. In the *Haptic* condition (shown here), the blindfolded participant held the pointer and rotated it until they felt that it was pointed "directly at them". In the *Visual* condition, the experimenter rotated the pointer and the participant indicated verbally when it was pointing at them. In both conditions, photographs were captured with a webcam for offline coding.

tripod took a photo of the response as a JPEG file (1600 × 1200 pixels) under control of a custom MATLAB script (Mathworks, Natick, MA). The visual and haptic conditions were administered in sequential blocks, the order of which was counterbalanced across participants.

Within each of the two blocks, there were eight mini-blocks in which the pointer was attached to the pole at different heights and the trials in each mini-blocks were split between two directions of rotation. The purpose of both these manipulations was to add diversity to the task and probe possible influences on the participant's judgements. The heights were at intervals of 1/12 of the participant's height; the chin was used as a landmark and there was one point of elevation above and two below, for a total of four heights. There were two mini-blocks with the pointer at each height, administered in random order. Within each mini-block there were six trials, three with the pointer starting pointing straight up (*Top* condition) and three with the pointer starting pointing straight down (*Bottom* condition), presented in random order. Thus, there were a total of 96 trials.

2.3. Coding

Bright yellow stickers were placed on the participant's acromion (shoulder bone), the chin, and (where needed) the elbow to facilitate coding. Offline, each photograph was annotated to include a coloured line extending in the direction the pointer was pointing. Each response was coded as falling into one of five bodily regions, depending on where it intersected the body: the *Lower Torso* (below the elbow), the *Upper Torso* (between the elbow and acromion), the *Neck* (between acromion and chin), the *Lower Face* (between chin and tip of nose), and the *Upper Face* (above the tip of the nose). These regions were chosen according to visually salient boundaries to facilitate coding. Fortunately, these correspond roughly to nameable body parts; head and torso are split into two roughly equal regions, with a region between them, the neck, bounded by chin and shoulder.

Because of unanticipated occasional delays between when the experimenter pressed the button and when the webcam image was taken, on some trials the participant had already started to move the pointer away from their response before the image was taken. A total of 20.7% of trials were therefore excluded from analysis. Because of the unusually large number of excluded trials, we conducted an analysis of variance (ANOVA) on the proportion of excluded trials, including *response modality* (haptic, visual), *start location* (bottom, top), and *height* (1, 2, 3, 4) as factors. Critically, there were no significant main effects or interactions (all p's > .05), suggesting that the delays had not systematically affected some conditions more than others.

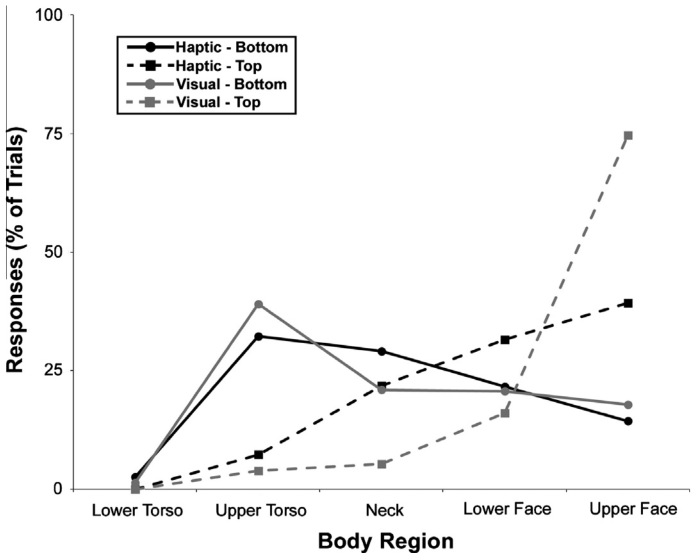

Fig. 2. The percentage of trials in which participants pointed towards each of the five regions of interest. Overall, there were two clear modal responses: the upper torso and the upper face.

3. Results

Fig. 2 shows the distribution of responses across the five regions in each of the four conditions. Responses were analysed using a repeated-measures Analysis of Variance (ANOVA), with factors *region* (lower torso, upper torso, neck, lower face, upper face), *response modality* (haptic, visual), *start location* (bottom, top), and *height* (1, 2, 3, 4). There were no significant main effects or interactions involving height. Therefore, to simplify the reported analyses, that factor was dropped. There was a significant main effect of region, $F(4,36) = 9.70$, $p < .0001$, indicating that responses were not randomly distributed across the five regions. Across conditions, there was a clearly bimodal distribution of responses, with points towards the upper torso and (especially) the upper face predominating.

This effect of region was modulated by significant interactions of start location and region, $F(4,36) = 24.00$, $p < .0001$, response modality and region, $F(4,36) = 4.56$, $p < .005$, and a three-way interaction, $F(4,36) = 3.35$, $p < .02$. The interaction of start location and region showed a clear bias towards points on the upper face when the pointer started pointing straight up (Top condition) and a clear bias towards the upper torso when the pointer started pointing straight down (Bottom condition). Indeed, Bonferroni corrected *t*-tests revealed significantly more responses to the upper face in the top than the bottom condition in the visual condition, $t(9) = 5.45$, $p < .002$, and a similar trend for the haptic condition, $t(9) = 2.83$, $p = .079$. Similarly, there were significantly more responses to the upper torso in the bottom than the top condition in both the haptic, $t(9) = 4.13$, $p < .02$, and visual, $t(9) = 3.81$, $p < .02$, modalities. The three way interaction appears to be driven by a more focused bimodality in the visual than the haptic modality, with haptic responses occurring more frequently in the neck and lower face regions between the two peaks. This suggests that the difference between modalities likely reflects reduced precision in the haptic modality, rather than any qualitative difference between haptic and visual self-location judgements.

A potential concern about the preceding analysis is that the very small number of responses towards the lower torso – rather than the peaks at the upper torso and upper face – may be driving the effects of region. To address this possibility, we re-ran the ANOVA excluding the lower torso (resulting in just four different regions). Critically, all the effects reported above remained significant in this analysis. Specifically, there was an effect of region, $F(3,27) = 2.90$, $p = .53$, which was modulated by significant interactions of response modality and region, $F(3,37) = 4.59$, $p < .02$, start location and region, $F(3,37) = 24.25$, $p < .001$, and a three-way interaction, $F(3,27) = 3.38$, $p < .05$. Thus, this analysis demonstrates that the effects reported above are not being driven by the absence of responses towards the lower torso region.

4. Discussion

So which part of the body counts as you? Our results suggest that no single body part is judged as the unique seat of the self. Beyond a certain spatial resolution, self-location judgements are ambiguous between at least two locations, though when forced to judge this ambiguity can be resolved according to contextual factors. When asked to point directly at themselves, in both haptic and visual modalities, our participants' judgements were clearly affected by the starting location of the pointer. Participants most frequently chose to point to one of two likely parts of the body according to which they reached first, upper face or upper torso. Critically, our participants cannot be accused of merely giving lazy responses; in that case, responses would have clustered around the lower rather than upper torso in the downward starting direction. Indeed, their responses were far from random. Each of the two regions of response has a high degree of functional salience which explains their status as natural candidates for self-location judgements.

Both eyes are housed in the upper part of the head, as are the ears and the vestibular labyrinth. Sherrington considered the latter to be supreme in a hierarchy of proprioceptive receptors, in that it "maintains not merely a limb in flexion or extension, but a posture of the whole animal in regard to gravitation" (Sherrington, 1907, p. 480). The functional salience of the head in both perceptual representation and the maintenance of posture is consistent with Starmans and Bloom's interpretation of their results as reflecting an "intuitive or phenomenological sense of where in our bodies we reside" and the tendency of Bertossa et al.'s participants to locate the "I-that-perceives" in the head.

In the morphological structure of the body, the torso is, so to speak, the great continent of the body, relative to which all other body parts are mere peninsulas. Where the torso goes, the body follows. As the only non-peninsular body part, the torso is apt to stabilize sensory manifolds in the construction of a consistent multimodal egocentric spatial representation (Grush, 2000). It has been hypothesised that body displacement illusions induced by visuotactile stroking involve an extension or displacement of the receptive fields of trunk-centred visuo-tactile neurons in the parietal cortex towards the location of visual stimuli (Blanke, 2012). Moreover, deficits in the reorientation of spatial attention can be alleviated in neglect patients (Karnath, Schenkel, & Fischer, 1991) or induced in healthy participants (Grubb & Reed, 2002) by rotating the torso to the right or left, respectively. Thus although Limanowski & Hecht attribute torso-specifying judgements to the importance of the heart in their participants' concept of selfhood, such judgements might also be interpreted as a consequence of the implicit functions the torso might play (given its structural situation) in spatial representation, spatial attention and self-representation.

Howard and Templeton (1966) once hypothesised that the locations of the visual and haptic 'egocentres' might differ. The present study demonstrates that participants are disposed to pick out one of two distinct regions of the body in self-location judgements according to which comes first, but they do not make qualitatively different self-location judgements in haptic and visual modalities. To the extent that such self-location judgements tell us anything about our concept of the self as a spatial entity, they tell us that the concept is inherently ambiguous. When forced to locate ourselves in our bodies, we may pick one of at least two functionally salient locations (our upper head or torso) according to a range of contextual factors, including which we pay attention to first.

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