Acta Psychologica 144 (2013) 344–351

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/ locate/actpsy

Body image distortions in healthy adults

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ARTICLE INFO

Article history:
Received 25 March 2013
Received in revised form 17 June 2013
Accepted 21 June 2013
Available online 9 August 2013

PsycINFO classification:
2220 Psychometrics & Statistics & Methodology: Tests & Testing
2320 Human Experimental Psychology: Sensory Perception

Keywords:
Body image
Body representation
Position sense

ABSTRACT

Distortions of body image have often been investigated in clinical disorders. Much of this literature implicitly assumes healthy adults maintain an accurate body image. We recently developed a novel, implicit, and quantitative measure of body image — the Body Image Task (BIT). Here, we report a large-scale analysis of performance on this task by healthy adults. In both an in-person and an online version of the BIT, participants were presented with an image of a head as an anchoring stimulus on a computer screen, and told to imagine that the head was part of a mirror image of themselves in a standing position. They were then instructed to judge where, relative to the head, each of several parts of their body would be located. The relative positions of each landmark can be used to construct an implicit perceptual map of bodily structure. We could thus measure the internally-stored body image, although we cannot exclude contributions from other representations. Our results show several distortions of body image. First, we found a large and systematic over-estimation of width relative to height. These distortions were similar for both males and females, and did not closely track the idiosyncrasies of individual participant's own bodies. Comparisons of individual body parts showed that participants overestimated the width of their shoulders and the length of their upper arms, relative to their height, while underestimating the lengths of their lower arms and legs. Principal components analysis showed a clear spatial structure to the distortions, suggesting spatial organisation and segmentation of the body image into upper and lower limb components that are bilaterally integrated. These results provide new insight into the body image of healthy adults, and have implications for the study and rehabilitation of clinical populations.

1. Introduction

The brain contains a number of body representations for interpreting sensory information and interacting with the environment. Head and Holmes (1911) provided the classic description of different ‘schemata’ representing the body: a ‘postural schema’ maintaining a continuously-updated representation of current body posture, and a ‘superficial schema’ mediating localisation of touch onto the body surface. There is also evidence of lexical-semantic (Schwoebel & Coslett, 2005) and topological (Pick, 1922) representations of the body, which can be selectively impaired in some cases of focal brain damage (Schwoebel & Coslett, 2005). A further representation of the body, though, is the so-called “body image”, a conscious representation that is commonly thought to rely predominantly on visual information, and represents the sizes and shapes of body parts and their arrangement to form a whole (Gallagher & Cole, 1995). The body image reflects what the body is perceived to be like (Longo, Azanon, & Haggard, 2010). Note that the use of the term “body image” need not include emotional and aesthetic elements, although metric aspects of the body are often associated with these aspects (Schilder, 1935).

There has been a range of research into how we represent the size and shape of our bodies. Scientists and artists, for example, have explored what body shape we find most attractive (e.g., Fan, Dai, Liu, & Wu, 2005; Fan, Liu, Wu, & Dai, 2004; Holliday, Longe, Thai, Hancock, & Tovee, 2011; Singh, 1993; Sorokowski, 2010). Another strand of research has investigated altered body image in clinical populations, notably individuals with eating disorders (e.g., Garner, Garfinkel, & Bonato, 1987; Molinari, 1995; Probst, Van, Vandereycken, & Goris, 1992; Slade & Russell, 1973).

Interestingly, few studies have investigated body image in the normal population, and very few of those have used quantitative measures. As a result, relatively little is known about the brain's conscious representation of the body as a physical object. Many studies of body image involved participants' adjusting the size of an image to match their actual body size (e.g., Allebeck, Hallberg, & Espmark, 1976; Bell, Kirkpatrick, & Rinn, 1986; Freeman, Thomas, Solyom, & Hunter, 1984; Glucksman & Hirsch, 1969; Probst et al., 1992; Shafran & Fairburn, 2002; Traub & Orbach, 1964). These tasks are limited in that they only provide an estimate of the explicitly perceived overall size of the body, and do not assess the various parts of the body individually. The same limitation is true for many computerised tests, such as the Body Virtual Image

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http://dx.doi.org/10.1016/j.actpsy.2013.06.012

Realty Scale (Riva & Melis, 1997). The Body Image Testing System (Schlundt & Bell, 1993), a computer-graphic technique developed by Benson, Emery, Cohen-Tovee, and Tovee (1999), and the Body Image Assessment Software (Letosa-Porta, Ferrer-Garcia, & Gutierrez-Maldonado, 2005) both allow size estimates of individual body parts, but these estimates are made on an image of the entire body. This kind of presentation presumably favours comparative judgements (e.g., is the foot larger or smaller than the face), rather than testing representation of each part individually.

Other tasks have focused on metric size estimates of individual body parts, predominantly with a moving calliper or an adjustable light beam (Gleghorn, Penner, & Schulman, 1987; Slade & Russell, 1973; Thompson & Spana, 1988). These methods of adjustment are problematic because the initial size that is shown significantly influences participants' responses, and the bias is not even across estimates that require increasing and decreasing adjustments (Ferrer-Garcia & Gutierrez-Maldonado, 2008). The Image Marking Procedure avoids these problems by asking participants to mark the perceived size of individual body parts on a sheet of paper (Askevold, 1975). However, this method does not allow assessment of the spatial organisation of the body. On the other hand, the Body Scheme Task provides information about the spatial organisation of the body but not the size of its parts (Daurat-Hmeljiak, Stambak, & Berges, 1978). In this task, participants place an image of an individual body part (e.g., the arm) relative to an anchor part (e.g., the head) shown on a piece of paper to indicate the relative positions of these parts in their own body.

Body Image Tasks divide into *depictive* methods, in which the participant compares their body to a visual image, and *metric* methods, in which the participant simply compares some spatial measure of their body to some standard (Longo & Haggard, 2012). Meta-analyses of the literature on eating disorders have suggested that depictive methods elicit both larger (Cash & Deagle, 1997) and more consistent (Smeets, Smit, Panhuysen, & Ingelby, 1997) body image distortions than metric methods. Intriguingly, Longo and Haggard (2012) found the opposite pattern for healthy participants in the case of the body image of the hand. When participants compared their hand to distorted photographs of hands (a depictive task), their responses were quite accurate; when they compared the length of each finger to the length of a line (a metric task), however, they showed large distortions. This discrepancy can be explained by contrasting explicit access to the body image representation for depictive tasks, with implicit access for metric tasks (Longo & Haggard, 2010). In a previous study, Longo and Haggard (2010) investigated implicit body representations underlying position sense by asking participants to point towards the location of several landmarks on their occluded hand. By comparing the relative judged locations of each landmark, perceptual maps of represented hand size and shape could be calculated and compared to actual hand shape. The task can be considered implicit because individual judgements refer only to the locations of body parts, although the map that finally emerges is a depiction of the whole hand. These maps revealed a highly stereotyped pattern of distortions, in which the hand was misrepresented as wide and the fingers as short. These distortions did not appear when participants made explicit judgments about whether images of their hand were presented at the correct aspect ratio or not.

We recently developed a similar approach to test the implicit perceived size of body parts and overall body configuration — the Body Image Task (BIT) (Fuentes, Pazzaglia, Longo, Scivoletto, & Haggard, 2013). In this task, participants are shown a single body part on a monitor as an anchor stimulus and are asked to judge the relative location of several other body parts by clicking on the corresponding location on the monitor. Like the map of hand position sense (Longo et al., 2010), this task is implicit in the sense that participants do not see images of their body or body parts but are instead asked to indicate the position of a number of different landmarks with respect to an anchor. This task was inspired by the Body Scheme Task of Daurat-Hmeljiak et al. (1978), described above. Importantly, however, by having participants indicate locations using a mouse click rather than by arranging an icon, the BIT allows more precise measurement of the represented metric properties of the body and allows the represented size, position, and orientation of multiple body parts to be assessed.

Thus, the BIT allows us to quantitatively study the body image without explicitly asking about body size and shape. In the present study we tested two large samples of healthy adults using the BIT as well as a template matching task providing a more explicit measure of perceived body shape.

2. Methods

2.1. Participants

Seventy-eight participants took part in the study in person (in-person group): 41 females and 37 males. Ages ranged from 18 to 72 years, with a mean of 27 years (±10 year standard deviation). A further online experiment included data from 274 participants (online group): 209 females, 63 males, and 2 who did not report their gender. Ages ranged from 18 to 51 years, with a mean of 27 years (±7 year standard deviation). No participant was part of both test groups. With this additional dataset of online participants we had an independent, large sample that we could compare to our smaller in-person sample. We were also able to increase the sample size to a level that allowed for multivariate analyses. Finally, we could assess whether an online version of the BIT is a valid method of data collection for future large-scale studies.

All participants gave informed consent: in-person participants gave written consent and online participants gave electronic consent. All experiments were approved by the local ethics committee at University College London.

2.2. Body Image Task (BIT)

2.2.1. Procedure

Participants in both versions of the experiment were given the same written instructions (see Supplementary Material). The instructions invited them to locate a named body landmark relative to an anchor part (the head) shown on the screen. Twelve body parts were tested: left shoulder, right shoulder, left elbow, right elbow, left hand, right hand, left hip, right hip, left knee, right knee, left foot, and right foot.

On each trial, participants saw the name of a body part on the top of the screen and the outline of a head in one of four positions near the top of a boxed area (see Fig. 1). The screen advanced to the next trial when participants clicked the mouse to respond. Each of the 12 body parts was judged five times in a pseudo-random order, for a total of 60 trials. Participants completed a three-trial practice before starting the experiment.

Participants who did the BIT in person also had a front-view photograph taken while they stood with their arms outstretched at their sides. For body parts that were hidden from view by clothing (e.g., the hips), stickers were placed on participants' clothing to indicate locations.

2.2.2. Analysis

For each participant, we calculated the average reported position of each body part. Responses that clearly confounded the left and right sides of the body or were beyond two standard deviations of the participant's mean for the given body part were excluded from analysis. On average, 2% of trials per participant were excluded.

For our first analysis, average reported body part positions were transformed into a common space by expressing them as a proportion of judged height using the two-point registration procedure in which two landmarks are selected to have coordinates (0,0) and (0,1), respectively, with all other points scaled accordingly (Bookstein, 1991). The point midway between the location of the two feet was defined as

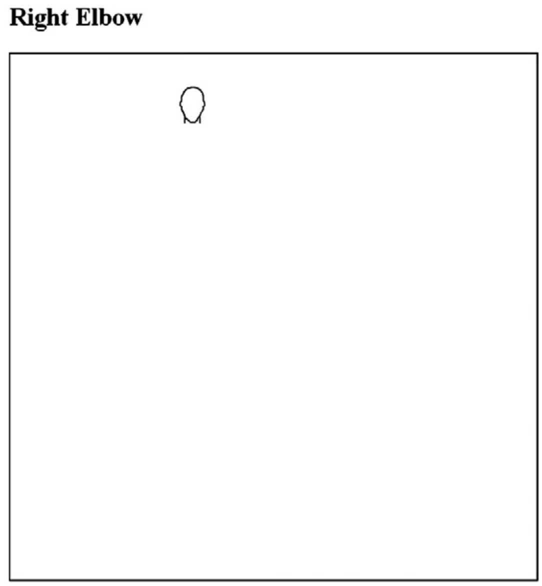

Fig. 1. Example trial of Body Image Task.

(0,0) and the point midway between the eyes was taken as (0,1). This unit distance was used to normalise each map into a common space without altering the relative proportions of different body parts. This allowed for comparisons of the relative lengths of different body parts across participants, as well as between the body image and actual body form. Examples of the body image based on this common space are shown in Fig. 2.

The following body part lengths were then calculated by measuring distances between pairs of points:

- Head to left shoulder
- Head to right shoulder
- Shoulder width (left shoulder to right shoulder)
- Upper arm length (shoulder to elbow), left and right
- Lower arm length (elbow to hand), left and right
- Torso length (shoulder to hip), left and right
- Hip width (left hip to right hip)
- Upper leg length (hip to knee), left and right
- Lower leg length (knee to foot), left and right

We then compared perceived body part lengths to true lengths within the in-person test group. We expressed the percentage overestimation of each length as the difference between the perceived length and the participant's true body part length, as a percentage of the true length. We performed 14 two-tailed t-tests (corrected for multiple comparisons), one for each length, to test for differences from zero. For each body part we also ran a correlation between perceived and true length to test for self-specificity.

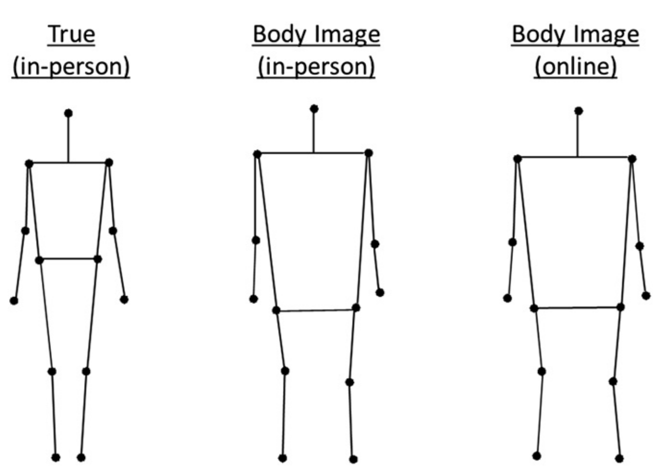

Fig. 2. Average responses. The average true arrangement of body parts compared to the average compiled responses of perceived body part positions.

For the online test group, we did not measure participants' true body part lengths. We therefore expressed body part lengths as the difference between the perceived length and the average true length of the in-person test group, as a proportion of the in-person group's average true length. We again performed 14 two-tailed t-tests, one for each length, to test for differences from zero.

We performed an additional analysis to further assess differences between perceived and true body shape. First, to eliminate differences in posture, the arm and leg coordinates for perceived (all participants) and true (in-person participants only) part positions were rotated such that the elbows and hands were straight below the shoulders (same x), and similarly the knees and feet were straight below the hips. For each in-person participant, Procrustes superposition was then used to optimally rotate, translate, and uniformly scale their perceived and true bodies to minimise the distance between parts (Bookstein, 1991; Rohlf & Slice, 1990). In addition, the average in-person perceived body was compared to the average in-person true body with Procrustes superposition. For the online dataset, each perceived body was compared to the average true in-person body, and the average perceived online body was also compared to the average true in-person body. Principle component analysis (PCA) was performed on the residual distances between perceived and true body parts for the in-person dataset and between perceived and average true parts for the online dataset. This analysis provided a quantitative way of investigating which body parts were perceived as most distorted, and how many separate components of the distortion might exist.

2.3. Template selection task

2.3.1. Procedure

In this task, participants identified which of a range of body shapes corresponded most closely to the perceived shape of their own body. Based on the true dimensions of 18 participants not included in this dataset (8 males, 10 females, mean age 27 years ± 5 year standard deviation), a figure with a representative hip width/height ratio of 0.177 was created. A dot marked the location of each body part identified in the BIT on this figure. The width of the figure was altered to create 13 templates with widths ranging from 40% to 160% of the original, average width, in increments of 10%. This procedure provided a set of average body templates with different aspect ratios.

After completion of the BIT, participants performed the template selection task, based on these width-altered templates. Participants in both versions of the experiment where given the same written instructions (see Supplementary Material), inviting them to identify the template best corresponding to their own body shape. Nine trials were performed, each with the templates in a different random order.

2.3.2. Analysis

For each participant, the hip width/height ratio of each template selected was averaged across the nine trials. For the in-person group, we tested for a correlation between the averaged template ratios and participants' true hip width/height ratios. For both the in-person and online groups, we also tested for correlations between average template ratios and perceived hip width/height ratios.

3. Results

Fig. 2 shows the average true body shape of in-person participants, as well as the average body image of the in-person and online groups.

Qualitatively, distortions in body image are already evident on the group level, and the in-person and online groups appear similar.

3.1. Body image distortions

We first assessed distortions in individual body part lengths in the in-person group. The normalised perceived length of 14 body parts was calculated (see Section 2). Each length was then expressed as the difference between the perceived length and the participant's true body part length, as a proportion of the true length. Two-tailed t-tests revealed that the length of 13 of 14 body parts was distorted from true size (all $p < 0.01$ after adjustment for multiple comparisons, see Table 1). The lower left leg was the only body part for which a hypothesis of no distortion could not be rejected. Fig. 3 shows that, relative to height, in-person participants overestimated the distance from their head to both shoulders, the length of their upper arms, and the length and width of their torso, while they underestimated the length of their lower arms and their legs. Dividing the group based on gender, a 14 part × 2 gender repeated measures ANOVA revealed no effect of gender ($F(1,76) = 2.02$, $p = 0.16$) and no interaction between part and gender ($F(13,988) = 1.26$, $p = 0.23$).

We next investigated whether these extensive distortions were evident in the larger online group of participants. Because we did not have the true measurements of online participants, we assumed that they had the same overall body proportions as the in-person group. That is, we expressed their normalised perceived lengths as the difference between the perceived length and the average true length from the in-person group, as a proportion of the average true length. Again we found distortions in perceived body part length in all parts except the left lower leg (two-tailed t-tests, all $p < 0.01$ corrected for 14 comparisons, except lower left leg). These distortions were in the same directions (i.e., under- vs. overestimation) as the in-person group, whose body images were compared to their own individual true body measurements (see Fig. 3). As with the in-person group, we found no gender differences in the online group; a 14 part × 2 gender repeated measures ANOVA revealed no effect of gender ($F(1,270) = 0.15$, $p = 0.43$) and no interaction between part and gender ($F(13,3484) = 0.11$, $p = 0.16$).

We next assessed body image distortions by comparing perceived and true bodies with a more synthetic analysis of the entire body configuration, using Procrustes superposition. We first eliminated individual differences in limb posture (see Section 2). Then the average in-person perceived body was compared to the average in-person true body by rotating, translating, and uniformly scaling the shapes to minimise the distance between the 13 parts. This revealed a disproportionate error in the placement of the hips relative to other body parts (see Fig. 4). This suggests that the instructions for hip location may not have been understood: participants appeared to confuse their hips with their waist, suggesting a semantic confusion not of direct relevance to our interest in body image. We therefore repeated the Procrustes superposition without the hips, and found similar distortions in body image as with our previous part-based analysis: the body is perceived to be wider, upper arms are longer, and lower arms and legs are shorter. This appears to be true for both the in-person group and the online group (see Fig. 4).

Table 1
Results of two-tailed t-tests assessing distortions in body part lengths. In person group: difference between the perceived length and the participant's true body part length, as a proportion of the true length, compared to 0. Online group: difference between the perceived length and the participant's true body part length, as a proportion of the in-person group's average true length, compared to 0. Negative t-values indicate underestimates.

Body measurement	In-person (n = 78)		Online (n = 274)	
	t-Stat	p-Value	t-Stat	p-Value
Head to left shoulder	5.06	<0.01	11.60	<0.01
Head to right shoulder	4.20	<0.01	8.32	<0.01
Shoulder width	9.55	<0.01	16.57	<0.01
Left upper arm	9.90	<0.01	19.17	<0.01
Right upper arm	−5.48	<0.01	−9.14	<0.01
Left lower arm	−8.86	<0.01	−14.40	<0.01
Right lower arm	9.43	<0.01	17.83	<0.01
Left torso length	24.24	<0.01	50.21	<0.01
Right torso length	24.94	<0.01	46.48	<0.01
Hip width	8.91	<0.01	19.79	<0.01
Left upper leg	−16.73	<0.01	−37.31	<0.01
Right upper leg	−17.36	<0.01	−29.44	<0.01
Left lower leg	−0.39	0.69	−1.78	0.08
Right lower leg	−5.29	<0.01	−7.01	<0.01

3.2. Principle component analysis (PCA)

In order to assess if variations in body image are comparable to those in true body shape, we applied PCA to the distortion vector lengths produced by Procrustes superposition for each body part. The distortion vector lengths are the distances between the true and perceived body part positions after the Procrustes superposition. They give a quantitative measure of error in perceiving each individual body part. For each in-person participant, Procrustes superposition was used to compare perceived and true body shape. Because Procrustes superposition between perceived and true averages revealed disproportionate errors for the hips (see Fig. 3), the hips were not included in this analysis, leaving 11 body parts. PCA on the residual distances between perceived and true body parts revealed that 76% of total variance was accounted for by three components, which were grouped into identifiable anatomical zones. The first component, which we labelled *arms*, loaded on the left and right shoulders, left and right elbows, and left and right hands. It explained 51% of the variance. The second component, labelled *legs*, loaded on the left and right knees and left and right feet, and explained 14% of the variance. The third component, labelled *head*, loaded only on head position, and explained 11% of the variance. For online participants, we had no measure of true individual body shape, so we compared each perceived body to the average true in-person body. Remarkably similar components were revealed by PCA on this different set of residual distances: *arms* (left and right shoulders, left and right elbows, and left and right hands, 53%), *legs* (left and right knees and left and right feet, 13%), and the *head* (10%) again accounted for the same total variance, 76%. The pattern of components provide clear evidence of left–right symmetrical integration of the body image, since homologous body parts for the left and right sides contribute to the same component for both upper and lower limbs. In contrast, they provide little evidence for vertical integration of the body image, because the upper and lower limb distortions contributed to distinct components.

3.3. Template selection task

Despite the distortions on the BIT, when presented with a series of body templates with differing hip width/height ratios, in-person participants performed well at selecting the templates that most closely matched their true body dimensions. A paired t-test revealed no significant difference between participants' true hip width/height ratios and their average template hip width/height ratios ($p = 0.16$), although they tended to choose templates with aspect ratios lower than their true hip width/height ratio. Because true measurements of online participants were unavailable, we could not perform a comparable analysis with this group.

3.4. Self-specificity

Finally, we assessed whether participants responded in a self-specific way by testing if individual differences in true body shape were mirrored in participants' judgements. First we compared perceived lengths and true lengths, relative to respective height, for body parts not involving the hips. We found no correlations between perceived and true lengths for any body part (all $p > 0.05$). We also

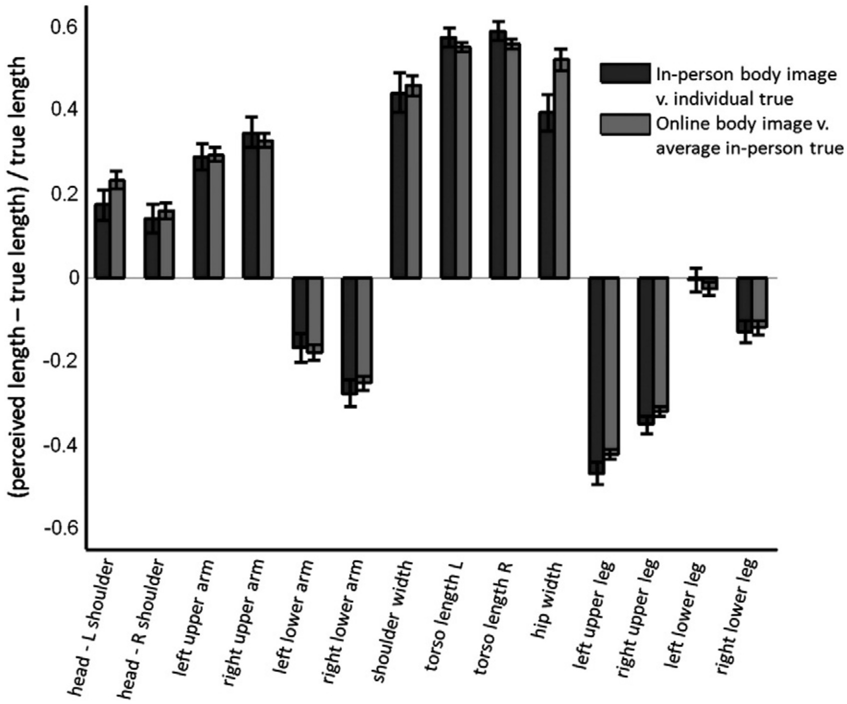

Fig. 3. Distortions in perceived body part lengths. On average, participants in both groups overestimated the distance between their head and shoulders, their upper arm length, torso length, shoulder width, and hip width. They underestimated their lower arm length, upper leg length, and right lower leg length. For participants in the in-person group, perceived lengths are compared to each individual's true length. For participants in the online group, for which we did not have true body measurements, perceived lengths are compared to the average true length of participants in the in-person group. All values are different than zero ($p < 0.01$, corrected for multiple comparisons) except for both groups' estimates of the left lower leg. Error bars represent standard error.

calculated the length between parts after Procrustes superposition, and again we found no correlation between perceived and true lengths for any parts (all $p > 0.05$). This suggests that participants may have used a template of a prototypical person when responding rather than an accurate image of their own body.

4. Discussion

We used the BIT to implicitly assess the body image in two large samples of healthy adults. The BIT asks participants to identify the position of one body part relative to another body part (here the

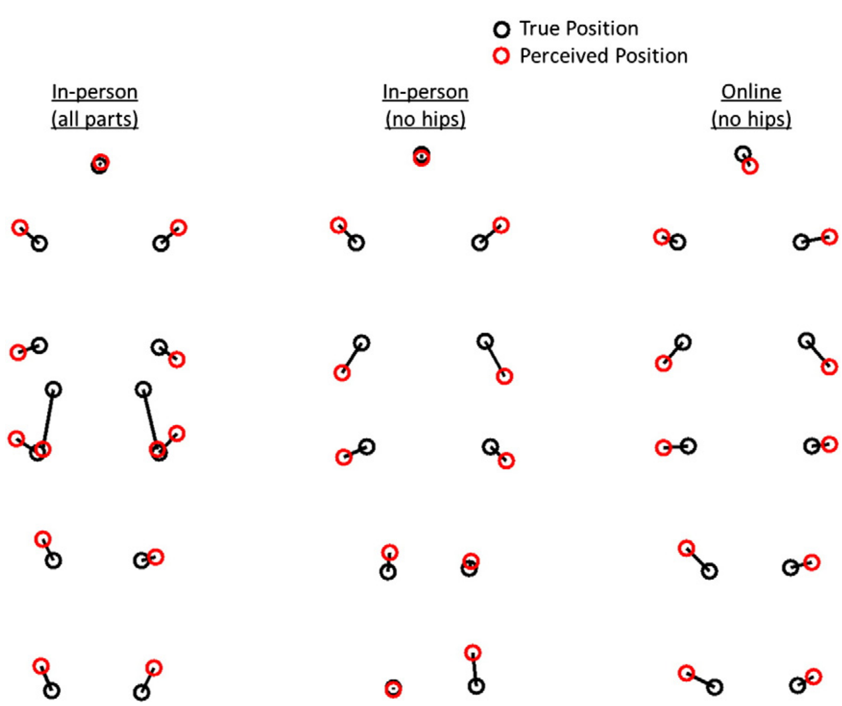

Fig. 4. Average figures after Procrustes superposition. When all parts are included in the Procrustes superposition, the hips are revealed to be disproportionately offset. Errors are more evenly distributed when the hips are not included. For participants in the in-person group, perceived positions were compared to each individual's true body configurations. For participants in the online group, perceived configurations were compared to the average true body configuration of the in-person group.

head), based on an image of one's own body as if seen in a canonical view. Our results reveal a number of insights into the body image. First, we found that participants greatly overestimated the width of their shoulders and the length of their upper arms, relative to their height, while underestimating the lengths of their lower arms and legs. These distortions were similar for both males and females. Principal components analysis showed a clear spatial structure to the distortions, hinting at the primary segmentation of the body image. Finally, we showed that the body image does not closely track the idiosyncrasies of each participant's own bodily shape.

The BIT was originally inspired by Daurat-Hmeljiak et al.'s "Body Scheme Task". In their task, participants place nine tiles of body part images (neck, left and right torso, arm, hand, and leg) on a sheet with an image of a head (Daurat-Hmeljiak et al., 1978). The BIT provides additional information (12 body parts versus the original 9). Importantly, the BIT also allows a quantitative analysis of body part size, as well as location. Each part is identified as a point, and size can be inferred from the distance between appropriate points. In the original Daurat-Hmeljiak test, pictures of body parts are placed relative to an anchor, and body part size is not examined. Previous uses of this test were largely confined to qualitative comments about the lack of alignment and integration between judgements of different body parts (Daurat-Hmeljiak et al., 1978). Moreover, as identification of body part location in the BIT only involves a point rather than placing an image, remembering previously reported locations is relatively difficult. This makes it possible to average multiple repetitions per part, providing more accurate estimates.

A further methodological issue concerns the choice of landmarks for BIT. We found that judgements about the hips were particularly problematic. The perceived position of the hips was strongly biased downward relative to their true location. In a previous study, an experimenter clarified the position of each body part by demonstrating them on her own body before the task began (Fuentes et al., 2013). Here, however, in order to keep instructions consistent across groups, both the online and the in-person group only received written descriptions of the body parts to be identified in the task. Because the hips are not clearly identifiable (i.e., not a joint or end of a limb), we believe that this may have led to confusion, with the semantic referent of 'hip' being poorly understood. Future studies using the BIT should either include a demonstration of the parts to be identified, or should only include parts that are consistently and clearly named, such as joints. An interesting possible area for future research might be cross-cultural differences in the BIT linked to variations across languages in the referents and scope of body part names (Majid, 2010).

4.1. The body image is distorted

Other studies have previously explored the perception of body part size, largely focusing on body width. Using the calliper adjustment technique, Slade and Russell (1973) found that a group of control females accurately estimated the width of their bodies. Gleghorn et al. (1987) also tested a control group of females with the moving calliper technique, as well as the Image Marking Procedure (IMP), and found slight overestimations of waist and hip width but underestimations of shoulder width. Molinari (1995), however, used the IMP and found that a group of 20 controls on average overestimated the width of their abdomen and pelvis by 30%. Another study used an adjustable light beam to estimate cheek, waist, hip, and thigh widths in a group of 159 healthy females; the results revealed an average global width overestimation of 21% (Thompson & Spana, 1988). Inconsistencies in previous results may in part be due to biases in methods of adjustment. Here our estimates of size were indirectly acquired from estimates of individual body part positions. Our results reveal that healthy adults overestimate their shoulder-width-to-height ratio by over 40%. This drastic distortion in overall body size was only revealed in the implicit BIT; participants accurately selected templates that matched their body size. The magnitude of this distortion emphasises the dissociation between implicit and explicit tests of body image. Finally, our estimates of width distortion are consistent with those reported in a study that used the BIT with spinal cord injury patients and matched controls (Fuentes et al., 2013). Interestingly, they recall a tendency to overestimate hand width relative to finger length in research on the hand image (Longo & Haggard, 2010).

We found no differences in errors of perceived body part length or overall body size between males and females. Most studies that have previously assessed body image focused on females, and some have linked width overestimation to cultural factors related to gender. Our results suggest that similar systematic distortions in body image occur in both genders.

What might be the basis of the widened, shrunken body image identified in implicit tests? The receptive field organisation of somatosensory neurons provides one possible explanation. Many previous studies suggest that the conscious body image involves the posterior parietal cortex (Buxbaum & Coslett, 2001; Corradi-Dell'Acqua, Hesse, Rumiati, & Fink, 2008; Corradi-Dell'Acqua, Tomasino, & Fink, 2009; Felician et al., 2009; Pick, 1922). However, this area receives a strong input from primary somatosensory areas. Therefore, the 'superficial schema' or skin representation in the primary somatosensory cortex may partly contribute to the body image. Distortions of the internal representations of the hand were shown to parallel the anisotropic, elongated receptive field shape found in SI neurons: the hand is implicitly perceived as wider and the fingers as shorter than their true shape (Longo et al., 2010). Anaesthetising body parts also results in acute increases in perceived size, and particularly in increased width (Gandevia & Phegan, 1999; Paqueron et al., 2003). Our results also reveal that the body image is on average broader and shorter than the physical body. Thus, we have replicated at the level of the entire body an anisotropic distortion previously reported for individual body parts. We suggest that the internal representation tapped by our implicit test of body image may have a partly somatosensory basis, even though the task itself is fundamentally visual (Fuentes et al., 2013; Longo & Haggard, 2012). This view contrasts with the traditional argument made from other, explicit tests of body image tests, which have emphasised visual factors (Gallagher & Cole, 1995).

4.2. The body image is spatially organised

Our principal component analysis showed a clear spatio-anatomic organisation of errors in judging the position of body landmarks. We found strongest coherent variability in judgements of arm landmarks, followed by judgements of leg landmarks. Focal attention to the upper body may be more common in everyday life than attention to the lower body, both during one's own sensorimotor action and also during social interactions with others. The coherent integration of representation for the upper body may reflect this familiarity and attention. However, this explanation cannot readily explain why the *arm* component shows greater variability than the *leg* component, as suggested by the percentage of variance explained in our principal component analysis. In a previous application of the BIT, we investigated whether sensorimotor loss confined to the legs following spinal cord injury would alter the body image of the legs only, or of both the arms and legs. That study failed to find a clear difference in body image measures for the patients' affected legs and their unaffected arms. In contrast, the present study did reveal a clear distinction between upper and lower limbs, based on coherence of error patterns, rather than on a specific pathology.

PCA of distortion vectors showed strong correlations between the left and right sides of the body. Since this result was found for both upper and lower limbs, we suggest that strong integration across the two sides of the body is a general feature of the body image. This bilateral integration could arise for several reasons. On the one hand, integration could reflect strong transcallosal integration of representations of the two sides of the body. Alternatively, it could simply reflect knowledge that bodies are generally symmetric. Indeed, evolutionary biologists have emphasised that the symmetry of others' bodies is an important visual cue for social behaviour (Brown et al., 2005). More importantly, perhaps, strong bilateral integration rules out some possible accounts of the neural basis of the body image. For example, our results do not appear consistent with the view that each cerebral hemisphere houses an independent "hemi-image" of the contralateral side of the body. Interestingly, this bilateral integration of the body image contrasts sharply with other putative body representations, such as the superficial schema and the proprioceptive body schema — these are thought to be largely contralateral. For example, the proprioceptively-perceived position of the hand in space appears to be computed independently for each hand (Jola, Davis, & Haggard, 2011), although there are important differences between individuals in the degree of independence. Based on this comparison, we suggest that the degree of bilateral integration versus intermanual difference may be an important marker for distinguishing body image type representations from body-schema type representations (as in Jola et al., 2011).

4.3. Body image and bodily self

Interestingly, we did not find strong evidence for self-specificity in reported body image. Despite being instructed to imagine an image of themselves, participants' perceived body part sizes did not correlate with their true sizes. Our data did not allow us to reject the hypothesis that people have no access at all to information about the metric properties of their body parts and the configuration of their own body, but rather our data suggest that people make judgements with respect to a prototypical person. Given that visual information is thought to greatly contribute to body image, and given that our visual exposure to other bodies greatly outweighs our visual exposure to our own, this may reflect a bias in one's own body image due to visual experience of others' bodies. Alternatively, the lack of self-specificity may be a peculiarity of the BIT's focus on body landmark position, and body part length and configuration. The body image may include several other self-specific features that are not tested by the BIT, such as distinguishing skin marks and hair length. Nevertheless, it is interesting to note that spatial metric properties of one's own body parts appear to be poorly represented within one's own body image. This may reflect the absence of any specific physiological receptor directly specifying body part size (Gandevia & Phegan, 1999). This result also points to a possible mechanism for social construction of one's own body image based on the observed bodies of others. Our experience of our own body may reflect a generalization from viewing other people's bodies, in a sensorimotor form of Mead's (1934, p. 154) classic theory that understanding of the self follows from understanding the "generalized other". Finally, it suggests that potential therapies for body image distortions could usefully focus on learning the true size of one's own body parts.

While we found no evidence for self-specificity, the BIT has previously been used to demonstrate group differences in body image. The BIT, for example, revealed body image differences between controls and paraplegic and tetraplegic spinal cord injury patients (Fuentes et al., 2013). The BIT was also sensitive to changes in body image induced by experimental manipulations of embodiment such as the rubber hand illusion (Perez-Marcos et al., in review). This demonstrates that the BIT is at least partly sensitive to changes in representation of one's own body, and can be used to assess pre- and post-intervention changes in body image. The precise weighting of one's own experience and observation of others' bodies in the body image would be a fruitful area for future research.

4.4. Conclusion

We report the first large-scale dataset and systematic analysis of a novel, implicit and quantitative measure of body image — the Body Image Task (BIT). Using this task, we show that the body image can be measured as a set of spatial metric descriptors of body parts and relations between body parts. We found striking distortions in the body image, with a large and systematic over-estimation of width relative to height. Body image did not closely track the physical features of one's own body. Finally, we found systematic spatial organisation and segmentation of the body image into upper and lower limb components that are bilaterally integrated.

We have shown that the BIT can reveal implicit distortions in body image. Future studies could use this task to investigate patterns in body image distortions in larger datasets; for example, exploring the effects of age on the body image. This task can also be used to quantify and assess body image in clinical populations. The BIT has already been used to compare body image distortions in paraplegic and tetraplegic patients (Fuentes et al., 2013). Future studies could assess the effects of surgical interventions that alter body shape and body-part size in patients (Cimmino et al., 2013). In patients with eating disorders, it would be interesting to use the BIT to measure how patients think they are shaped, how they want to be shaped, and compare both to their true body dimensions.

Acknowledgements

This work was supported by EU FP7 Integrated Project VERE, grant no. 257695, Work Package 1. PH was also supported by a Leverhulme Trust Major Research Fellowship and by an ESRC Professorial Fellowship.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.actpsy.2013.06.012.

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