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Estimation and representation of head size (people overestimate the size of their head – evidence starting from the 15th century)

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The head is a special part of our body since we do not see it directly. Four experiments were conducted to verify what healthy people know about the size of their head. As a control, we used the accuracy in estimating other people's heads (in all the experiments) and the estimation of the size of another part of the body, the hand (in Experiment 4). Results showed that people overestimate their own head size compared to its actual size when visual information is not provided (Experiments 1–4). They also overestimate their head size compared to the heads of others whether viewed directly (Experiment 1) or from memory (Experiment 2). Overestimation with respect to the actual size is reduced when visual information is provided (Experiments 1 and 4) and when proprioception is (presumably) increased by wearing a headband (Experiment 3). Overestimation with respect to actual size is not found for hands (Experiment 4). In the final study evidence emerged of head size overestimation in self-portraits as compared to portraits of others.

Is there any bias in people's estimates of the size of their own head? Are these estimates comparable to estimates of other people's heads? The head is an important part of our body in terms of physical identity, but it is special because, unlike other body parts, we cannot directly see it. We have many opportunities to see our head in photographs, but we only see it life size by means of mirrors. In this introduction we review what is known in the literature on face recognition, body image and perception of mirror images. However, none of these studies has tested what is special about people's estimation of their own head size in comparison with other people's heads.

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Mirror images and face recognition

In the literature on face recognition, the influence of visual information and in particular of what we see looking at mirror reflections has been studied (Bredard, 2003; Laeng & Rouw, 2001; Troje & Kersten, 1999) including the issue of left–right reversal in mirrors (Bianchi & Savardi, in press; Gregory, 2001; Savardi & Bianchi, 2005). The role of familiarity with the visual information provided by mirrors has been demonstrated with respect to the *ease of recognizing* faces in frontal views for one's own but not for other people's faces (Bredard, 2003; Laeng & Rouw, 2001; Troje & Kersten, 1999) and to the *better likeness* perceived in picture views of other people's faces and mirror views of one's own face (Rhodes, 1986). Moreover, Bredard (2003) found local versus global strategies for recognition of one's own versus other people's faces. To explain this finding, Bredard (2003, p. 806) suggested that because mirrors make us familiar with asymmetric facial features, people use these features to recognize themselves. Tong and Nakayama (1999) reported that people are quicker at identifying their own face than the face of a stranger when the task asked to search a target face among a set of faces. This advantage was observed independently of whether people's own face was frontal, three-quarter, or profile view, and even upright or upside down. Tong and Nakayama concluded that people possess a robust representation of their own face.

None of these studies concerning face recognition focused on the size of the head.

Visual information and body image

The role of vision has also been debated in literature on body image. Proprioception seems to play a large role in implicit body representation in some studies (Craske, Kenny, & Keith, 1984; de Vignemont, Ehrsson, & Haggard, 2005; Gandevia & Phegan, 1999; Lackner, 1988; O'Shaughnessy, 1995). Visual information however seems to be the key factor in other studies (Botvinick & Cohen, 1998; Kinsbourne, 1995; Ramachandran & Rogers-Ramachandran, 1996; Riddoch, 1941; Taylor-Clarke, Jacobsen, & Haggard, 2004).

With respect to *size*, many studies have tested special populations, such as individuals with eating disorders (e.g. Connor, Johnson, & Grogan, 2002; Holder & Keates, 2006; Story, French, Resnick, & Blum, 1995), depression and low self-esteem (e.g. Holson, Kraft, & Roysamb, 2001; Tiggemann & Wilson-Barrett, 1998), drug addiction (e.g. Wright, Grogan, & Hunter, 2000), distress and bodily changes (e.g. Rumsey & Harcourt, 2005) – for an overview see Cash and Pruzinsky (2002). Distortions in perceived body size were found in these populations. Discrepancies between actual size and individuals' estimates of their own body are thus taken as indicators of distorted body image. It is assumed that people are able to give an accurate estimation of their body size if they do not suffer from psychological disorders (data from the control group are often not discussed). However, some authors have suggested that the overestimation or underestimation of body size does not necessarily imply psychological disorders or dissatisfaction with current size. For instance, Brodie, Bagley, and Slade (1994) found that healthy University students perceived themselves as fatter than their true image. Holder and Keates (2006) noticed that the size of the drawings used in comparison tasks influenced participants: reduced drawings yield proportionately larger estimates than actual size drawings. Gleeson and Fritt (2006) have recently emphasized the need to broaden the focus of research on body image to the range of everyday experiences and understanding of the body, while not abandoning the work on pathological responses.

Rudd and Lennon (2000) suggested that body image includes a perceptual as well as an affective component and that the perceptual component refers to how we see our size, shape, weight, features, movement, and performance. In the present paper we study the estimation of *head size* in healthy people, comparing *visual* and *proprioceptive* information (we use the term proprioception in the same sense as it is used in studies of the role of visual and proprioceptive information in body image construction, e.g. by Paqueron *et al.*, 2003). In the case of heads, when asking about the role of visual information we are in fact asking about the role of perception in mirror images. From the literature on face recognition we know that mirror images are a relevant source of information about the shape and features of one's own face. Is this also true for head *size estimation*?

Mirror images and head size estimation

When asked to draw their own head the same size as it would appear *on a mirror* surface, people generally overestimate not only the size of their own head *on the surface* of a mirror, but also their actual head size (Bertamini & Parks, 2005; Lawson & Bertamini, 2006; Lawson, Bertamini, & Liu, 2007; Savardi & Bianchi, 2006). The former finding shows that people have *no knowledge* of the size of their head on the mirror surface. To understand the latter finding (overestimation of the actual size) a comparison is needed with results from experiments regarding the estimation of other people's heads or of one's own head. For example, it is necessary to test whether this overestimation is an indication of the size that observers actually *perceive* when looking at themselves in a mirror set at an ecological distance, or the size remembered from past experience.

Plan of the experiments

In five experiments, a baseline estimation of head size made in the absence of visual information (i.e. the normal condition of perceiving one's own head) is compared to: the estimation of one's own and other people's heads when *viewed directly* (Experiment 1); the estimation made *from memory* (Experiment 2); the estimation made with *open or closed eyes* and when one's head size *proprioceptive information is increased* by wearing a headband (Experiment 3); and finally the estimation of *another part* of the body, that is the hand (Experiment 4). In the final study, we analysed the reproduction of human heads in a special sample of data: half-body *portraits and self-portraits* by famous artists (Experiment 5).

EXPERIMENT 1

In this study we asked people to estimate the *size* of their own head *when they did not see* it and *when they did see it* in a mirror. The difference score between estimated and actual size in these two conditions was compared to the estimation that people make of another person's head, at a matched distance.

We focused on three questions: (1) Is there overestimation of head size in the absence of visual information? (2) Do systematic errors persist when visual information is available? and (3) Is the error generalized to estimation of another person's head size?

Method

Participants

Seventy-two undergraduate students (aged 19–36) were divided in two groups of 36 and randomly assigned to the two experimental conditions. The subjects assigned to the second condition participated in the experiment in groups of four (see Procedure).

Procedure

Data were collected in the Psychology Department Laboratory at the University of Verona. Participants were invited to sit 40 cm from a vertical easel where A3 sheets of paper were fixed (see Figure 1). Two conditions were studied between subjects.

Condition 1 (group 1)

- *Task 1*: *Self-head estimation baseline*: In the first task, participants were asked to draw a life-size outline of their own head as accurately as possible, without any visual help. After the response was given, the sheet of paper was removed and replaced with a new blank one.
- *Task 2*: *Visually based self-head estimation*: Participants were invited to look at themselves in the mirror and then to draw their head the same size as they perceived it to be. The mirror (45 × 60 cm) was set next to the easel, at a distance of 40 cm from the participant, so that the virtual head was 80 cm away.

Condition 2 (group 2)

- *Task 1*: *Self-head estimation baseline*: The same as Condition 1.
- *Task 2*: *Visually based estimation of a different person's head*: Participants took part in the experiments in groups of four. One participant at a time was invited to sit

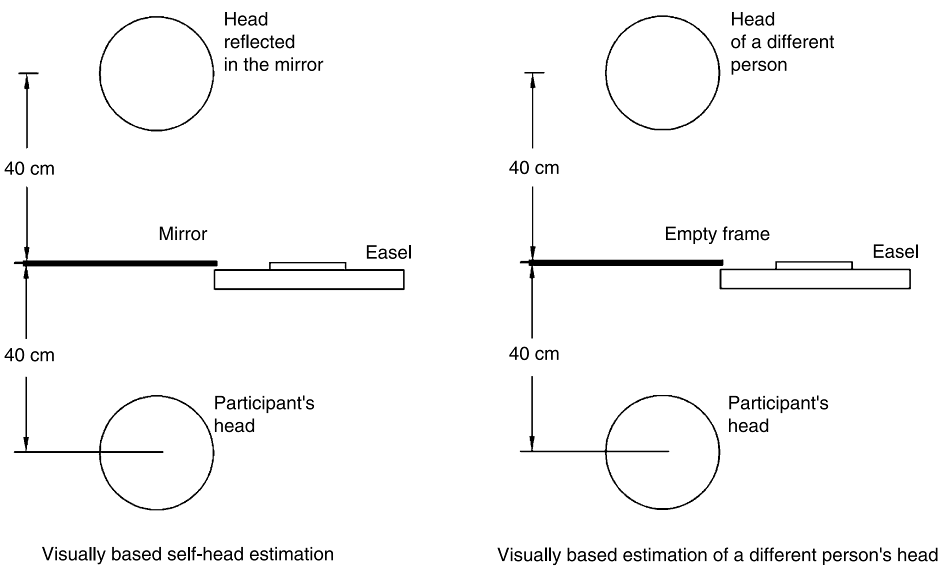

Figure 1. An illustration of the conditions in Experiment 1 for *Visually based self-head estimation* and *Visually based estimation of a different-person's head*.

40 cm from the easel where the sheet of paper was fixed. The other three participants, in turn, were used as models: they sat on a chair at 80 cm in front of the first participant. He/she looked at the other person's head through a frame (the frame of the mirror used for task 2, in Condition 1) and was asked to draw an outline of it, as accurately as possible in terms of size.

Each person was asked to estimate the head size of the three other people (in task 2) so that, in total (both tasks 1 and 2), each group produced 16 outlines.

In both conditions and in both tasks, participants were told that head size is measured from the chin to the top of the head and cheekbone to cheekbone (zygoma to zygoma). Participants were allowed to correct their drawings as many times as they wanted. They were asked to mark the final outline with a different coloured pen and to put a little mark in the points corresponding to the cheekbones. During the experiment participants were not allowed to see the drawings made by the other members of the group.

Participants' actual head size (height and width) was measured with a ruler at the end of the experiment.

Results

Measurements were taken from the drawings, corresponding to the *height* (vertical distance from top to bottom of the outline) and *width* (horizontal distance from zygoma to zygoma) of the head represented. A preliminary analysis of height and width separately showed that head size could also be evaluated in terms of the surface area, without altering the overall pattern of results. Moreover, given that the task involved drawing a life-size *outline* of the head and not estimation of its *height* and *width* (with a ruler, for instance), an analysis of the size of the drawings in terms of area is more consistent with the task. An ellipse was chosen as a close match to the shapes produced by the participants. The area of the ellipse was calculated from the values for width (w) and height (h) of the drawn heads (Area $= \pi \times w/2 \times h/2$).

Here and in the rest of the paper, the analyses were carried out on the difference scores (estimated minus actual size).

Condition 1: Self-head estimation versus visual self-head estimation

A mean surface overestimation of 89.73 cm^2 (which corresponds to a 42% error relative to overall size) with respect to the real size of the head was found in task 1 ($t(35) = 5.871$, $p < .001$). This finding is consistent with previous results (Bertamini & Parks, 2005; Savardi & Bianchi, 2006). The difference ($t(35) = 6.524$, $p < .001$) between the first and second tasks (Figure 2, on the left) suggests that visual information helps. In the second task responses were close to the actual size (mean overestimation = 15.72 cm^2 which corresponds to a 8% error relative to overall size; $t(35) = 1.795$, *ns*).

Condition 2: Self-head estimation versus estimation of a different person's head

The first task (*self-head estimation*) confirmed overestimation with respect to the real size of the head ($t(35) = 8.649$, $p < .001$). The mean overestimation (59.84 cm^2, which corresponds to a 30% error) did not differ from that found with the same task in Condition 1 ($t(70) = -1.782$, *ns*), see Figure 2. A comparison with the estimation of a *different person's head* (Figure 2, on the right) showed a significant overestimation of one's own head with respect to another person's head ($F(1, 142) = 67.405$, $p < .001$). Other people's heads were underestimated by an average of 20.68 cm^2 which

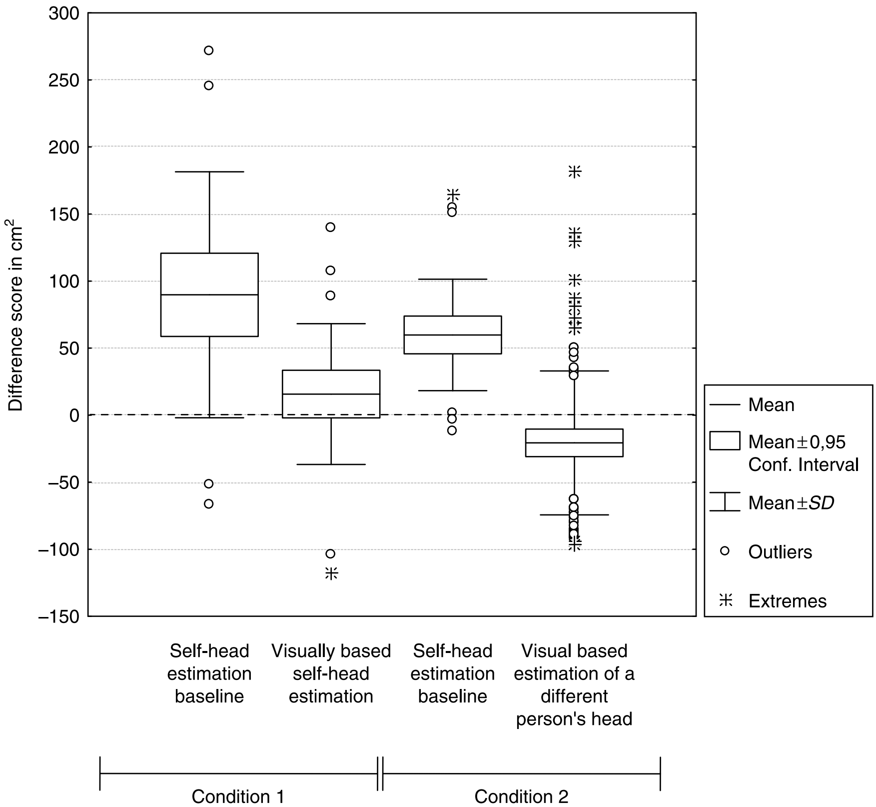

Figure 2. Difference scores (estimated minus actual size) in Experiment 1. On the left: *Self-head estimation baseline* and *Visually based self-head estimation*, in Condition 1. On the right: *Self-head estimation baseline* and *Visually based estimation of a different person's head*, in Condition 2.

corresponds to a 10% error ($t(107) = -4.003, p < .001$). Also in conditions of visibility (second task in both conditions) a difference was found between the estimation of size of one's own head with respect to the estimation of a different person's head ($t = -3.542$, $df = 142$, $p < .001$).

EXPERIMENT 2

Experiment 1 revealed that, without direct visual information, people *overestimate* the size of their own head. In contrast, when direct visual control was present the overestimation was not confirmed. However, participants drew their head bigger than other people's heads seen at the same distance. In Experiment 1 the absence of direct visual information was tested only for one's own head. Experiment 2 was designed to verify if the overestimation is confirmed when the condition of absence of visual information is used also for another person's head.

Method

Participants

Thirty-nine undergraduate students (aged 19–30) of the University of Verona took part in the experiment at the end of a 1-hour class on issues unrelated to the experiment.

Procedure

Participants were asked to sit in alternate seats, making sure that someone was sitting in front of them and someone behind them. Two sheets of A3 paper were given to each participant, one for each of the two tasks presented.

- *Task 1*: *Self-head estimation baseline*: Participants were asked to draw the outline of their head on the first A3 sheet of paper, following the same instructions given in Experiment 1. The paper with the self-head drawing was given back to the experimenter.
- *Task 2*: *Memory estimation of a different person's head*: Participants were invited to turn round and to look at the person sitting behind them for 20 seconds. They were then told to resume their initial position and draw, on the second sheet of A3 paper, the outline of the head of the person they saw. The distance between participant and model was 80 cm. Participants were not allowed to turn round again to check the accuracy of their drawing, but had to base it on memory.

Participants' head height and width were measured at the end of the experiment.

Results

Results are presented in Figure 3. As in Experiment 1, a bias towards overestimation (mean overestimation of $83.62\,\text{cm}^2$, that is 40% error relative to overall size) of one's own head with respect to the actual size was found ($t(39) = 7.680$, $p < .001$).

Interestingly, an overestimation of the actual size (mean overestimation= $49.75\,\text{cm}^2$, i.e. 24% error relative to overall size) was also found for another person's head ($t(39) = 4.760$, $p < .001$). Thus, when direct visual information is not available, a generic effect of enlargement emerges. However, even in this condition, the overestimation was bigger for one's own head than for the other person's head ($t(39) = 4.389$, $p < .001$).

EXPERIMENT 3

In Experiment 2 we found an overestimation of the head when *memory* of size is involved. This could be a possible explanation also for the overestimation of one's own head. However, overestimation was bigger for one's as compared to another person's head. In Experiment 3, we focused on the proprioceptive component of estimation of this body part, by considering whether the overestimation changes when the estimation is made while having an elastic band around the head, and when the estimation is made with eyes closed. The rationale for the use of the elastic band is to create a *condition of increased proprioception* of the outer limits of one's own head.

Method

Participants

Twenty-nine undergraduate students (aged 19–27) participated as group 1. Thirty-three undergraduate students (aged 19–26) participated as group 2.

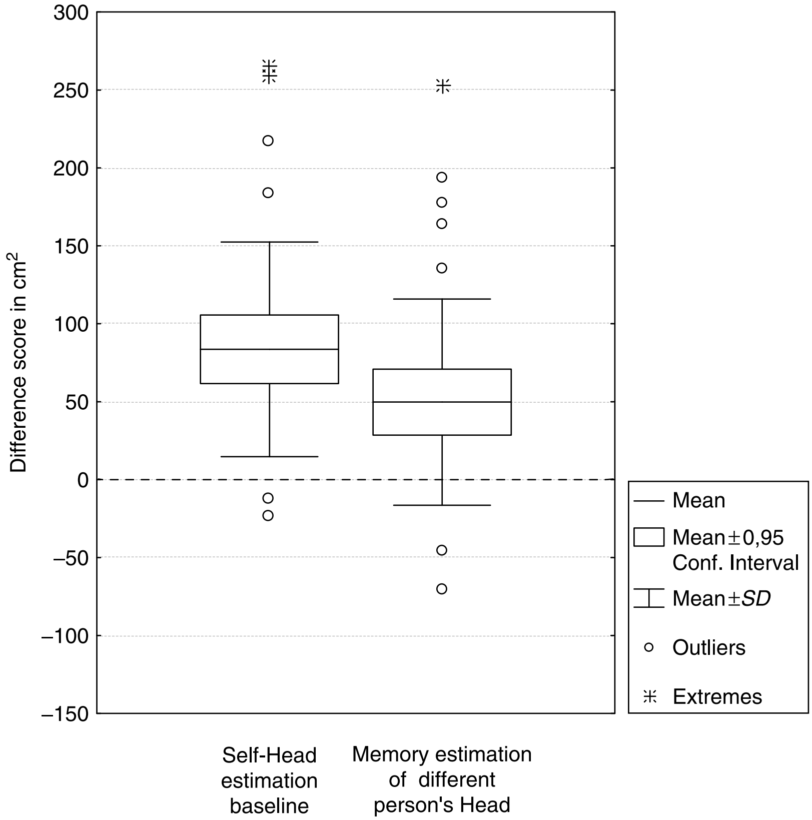

Figure 3. Difference scores (estimated minus actual size) in the two memory tasks of Experiment 2: *Self-head estimation baseline* versus *Memory estimation of a different person's head*. In both cases the estimation was made without seeing the target head.

Procedure

Data were collected in a classroom at the University of Macerata. For both groups, two tasks were studied within subjects.

Condition 1 (group 1)

- *Task 1*: *Self-head estimation baseline*: The same task used in Experiments 1 and 2.
- *Task 2*: *Self-head estimation – increased proprioception*: Participants were invited to put an elastic headband around their head, from the top of the head to the chin, and to draw what they perceived to be the size of their own head on an A3 sheet of paper.

Condition 2 (group 2)

- *Task 1*: *Self-head estimation baseline*: The same task used in Condition 1.
- *Task 2*: *Closed eyes self-head estimation*: Participants were invited to close their eyes and to focus on the size of their head. They were allowed to open their eyes

when they were ready to draw the outline. They could make corrections to the initial drawing, but they still had to base their correction on the size perceived with closed eyes.

Participants' head height and width were measured at the end of the experiment.

Results

Condition 1

The results confirmed overestimation (mean overestimation = 59.69 cm^2 which corresponds to a 31% error relative to overall size) in the first task ($t(29) = 6.834$, $p < .001$) (see Figure 4, on the left). This estimation was bigger than that made when participants had increased awareness of the proprioceptive information about their head size ($t(29) = 6.336$, $p < .001$). In the latter case, estimated size was not different from actual head size (mean overestimation = 5.647, i.e. 3% error, $t(29) = 0.901$, *ns*) and not different from that made in the presence of visual information from the mirror in Experiment 1 ($t(64) = -.902$, *ns*).

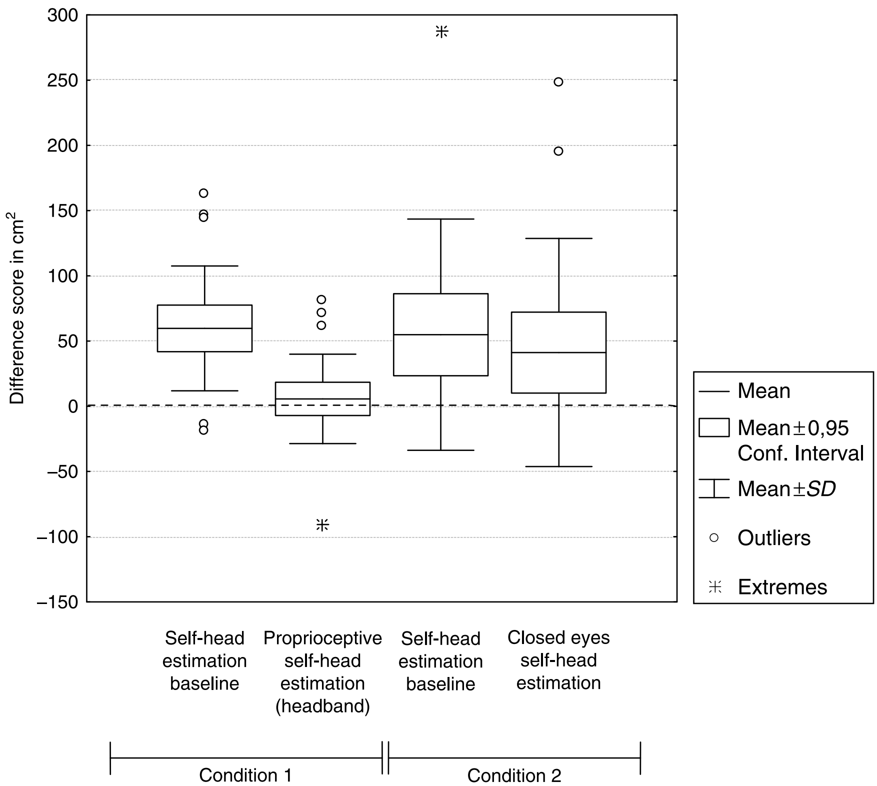

Figure 4. Difference scores (estimated minus actual size) in Experiment 3. On the left, Condition 1: *Self-head estimation baseline* and *self-head estimation – increased proprioception*. On the right: Condition 2: *Self-head estimation baseline*, where participants draw the outline of their head with open eyes, and *closed eyes self-head estimation*.

Condition 2

The comparison between the difference scores in the two tasks revealed that the overestimation was not influenced ($t(32) = 1.729$, *ns*) by making the drawing with open (mean overestimation = 53.67 cm^2, i.e. 25% error relative to actual size) or closed eyes (mean overestimation = 41.16 cm^2, i.e. 19% error) (see Figure 4, on the right).

EXPERIMENT 4

In this experiment we introduced a different way of collecting estimates, to test the influence of the task used in all previous experiments (draw an outline) on our findings. The new technique involved an experimenter standing next to the participant and using a tape. The length of the tape was adjusted until the participant was satisfied with the match between the length of the tape and the height of the head. In addition to comparing self- and other-estimations, we tested the presence and absence of direct visual information, and we asked estimates for the head and the right hand. The hand was chosen for convenience as a part of the body that is easy to test but is also of a size relatively similar to the head (albeit a bit smaller).

Method

Participants

Sixty-four undergraduate students (aged 18–56) were randomly assigned to the two experimental conditions: vision and memory. Since a model was required for each participant, people were tested in pairs, taking turns to be the participant or the model (see Procedure). The model was always the same sex as the participant.

Procedure

Data were collected in the Visual Perception laboratory at the University of Liverpool.

Condition 1 (group 1): vision condition

Participants stood 100 cm in front of a doorway (Figure 5). From the doorway we hung either a mirror, for the *self-head estimation*, or an empty frame of the same size, for the *different person's head estimation*. In the latter case, the model was standing 100 cm on the other side of the doorway, so that their head was visible within the frame approximately in the same position as the virtual head of the participant would appear in the mirror. The order of self-head and different-person's-head estimation were balanced across the participants.

The experimenter standing next to the participant adjusted the length of a tape measure carefully following the instructions of the participant and holding the tape face down so that the actual measurement was not visible to either of them. Only after the participant decided that the length was a correct match for the height of the head did the experimenter turn the tape measure right side up and record the estimate on a datasheet.

Condition 2 (group 2): memory condition

Everything was the same as for the vision condition except that participants simply had to estimate from memory. For the self-head estimation, the task was the same used

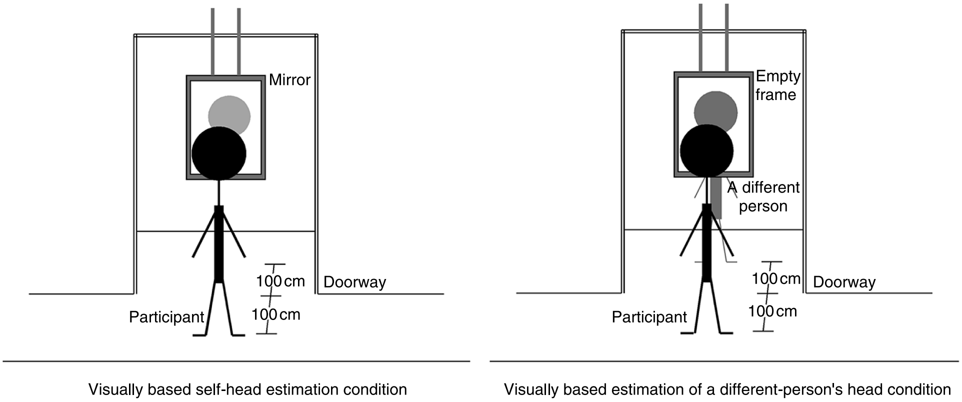

Figure 5. An illustration of the *self-head estimation* condition and the *different person's head estimation* condition in Experiment 4. Participants stood in front of a door and either a mirror or an empty frame of the same size was hung above the door.

in Experiments 1–3. For the different-person's-estimation, the model was introduced to the participant (at the same distance of Condition 1) but was then asked to wait outside the room during the estimation.

After estimating their own or other people's heads, participants were asked to estimate hands. The participant's or model's left hand was raised with the palm facing outwards and the elbow bent. Estimations were asked in the same two conditions of *vision* and *memory*, for both one's own and another person's hand.

Results

As estimations of heads and hands are not directly comparable, we report the analyses separately (see Figure 6).

Head

Overall the mean was 23.2 cm for self estimates and 22.4 for other people's estimates. The errors from actual size were 18 and 13%, respectively. All difference score means were significantly greater than zero ($2.98 < t < 6.87$). More importantly, there was a difference between self-estimation and estimation of other people's heads in both the memory task ($t(31) = 2.06$, $p < .05$) and the vision task ($t(31) = 2.07$, $p < .05$).

Hand

Overall the mean was 17.2 cm for self estimates and 16.9 for other people's estimates. The errors from actual size were 5 and 4%, respectively. There was a strong tendency for an overall underestimation of hand size ($-3.05 < t < -1.27$), and a difference between self-estimation and estimation of other people's hands in the memory task ($t(31) = 2.35$, $p < .05$) but not in the vision task ($t(31) = -0.39$, *ns*).

A SURVEY OF CLASSIC PORTRAITS

So far we have presented data from experiments in which people are explicitly asked to estimate size, or draw an accurate outline. If the overestimation found in self-head

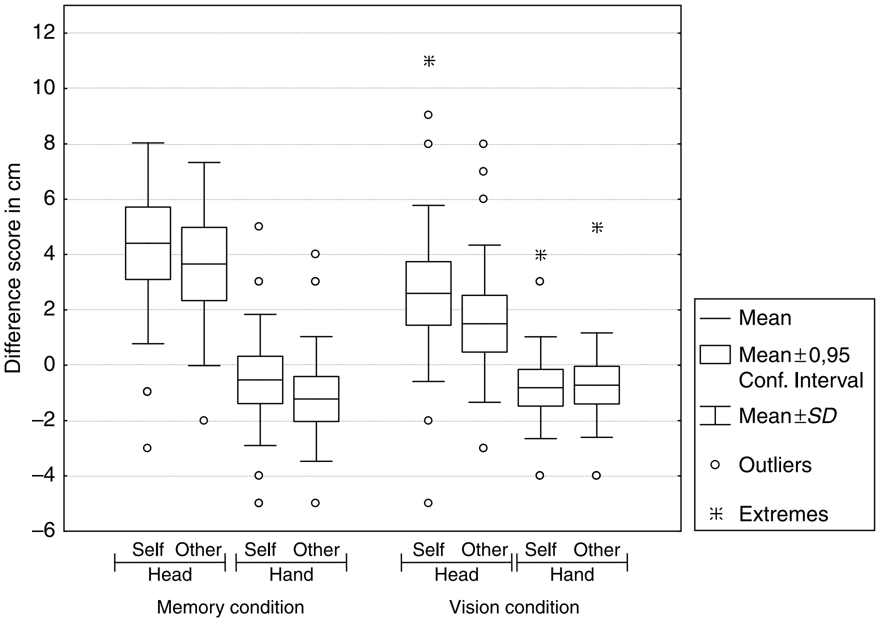

Figure 6. Difference scores (estimated minus actual size), for head estimation and hand estimation. For each group, the vision and the memory conditions are presented, and the self-estimation scores are compared to the different person estimation scores.

drawing tasks is a general phenomenon, other supporting evidence might be available. We decided to analyse self-portraits from famous painters, as this was found productive in previous work (Bertamini, Latto, & Spooner, 2003).

In the history of art, there is not a single set of rules that artists must follow when painting self-portraits. It is certain, however, that painters used mirrors (Boatto, 1997; Caroli, 1998). Indeed, it is not rare to find self-portraits showing painters turning their heads aside to look at themselves in a mirror while painting. Similarly, it is not infrequent to find self-portraits showing coat or shirt buttons in the reversed mirror position, or showing the painter holding the brush in the opposite hand they actually used to paint. For instance, van Gogh paints with his right hand in the portrait by Gauguin (Vincent at the Easel, 1888), but with the left in his self-portrait (*Self-portrait in front of the easel*, 1888), and in another painting (*Self-portrait with bandaged ear*, 1889) his overcoat is buttoned the wrong way.

We compared the size of the depicted head in two samples: self-portraits and portraits. Will there be a size difference in the paintings, depending on whether the subject is the painter's own head as opposed to a different person's head?

Method

Procedure

Using reproductions in art catalogues, 115 self-portraits and 124 portraits were analysed (the list of the analysed paintings and a few examples of them are available at the web page: www.liv.ac.uk/vp/projects/portraits.html). They were all half-body realistic portraits (period: 15th–20th century), showing subjects not wearing hats or any kind of hair-dressing that might make the identification of the outline of the head imprecise. We tried to use paintings by artists who had painted both self-portraits and portraits. One-hundred-and-nineteen (50%), out of the 239 paintings analysed were paired according to painter (i.e. we have both portraits and self-portraits by the same painter).

An estimation of the size of the head on the canvas was calculated, by measuring the head's height and width and then using the information about the size of the canvas from the catalogues. The size of the canvas and the (approximate) year of the painting were also recorded for analysis.

Results

In the 21st century we are used to pictorial representations in which scale is arbitrary. Most of the time we print photographs on paper only a few centimetres high, for convenience. However, portraits historically tended to be painted with proportions not dissimilar to that of the human body. In terms of height, the overall average we found was 22.2 cm with a *SD* of 5.3 cm. Whatever the reasons, the small variability in scale is convenient for our analysis.

The average head size (i.e. the area of the ellipse as used in Experiments 1–3) was 309 cm^2 for self-portraits and 224 cm^2 for portraits.

Not surprisingly head size was correlated with canvas size ($r = .451$), and perhaps more unexpectedly head size increased slightly with the point in time when the head was painted ($r = .308$) – see Figure 7. We performed an ANCOVA to compare head area in self-portraits to head area in portraits (type of painting) and we included as factor the orientation of the head (three-quarter view or full view). We also included both the size of the canvas and the year as covariates. Orientation was not significant ($F(1, 230) = 1.33$, *ns*) but the type of painting was significant ($F(1, 230) = 5.62$, $p < .05$), supporting the hypothesis that painters make their own head larger than the

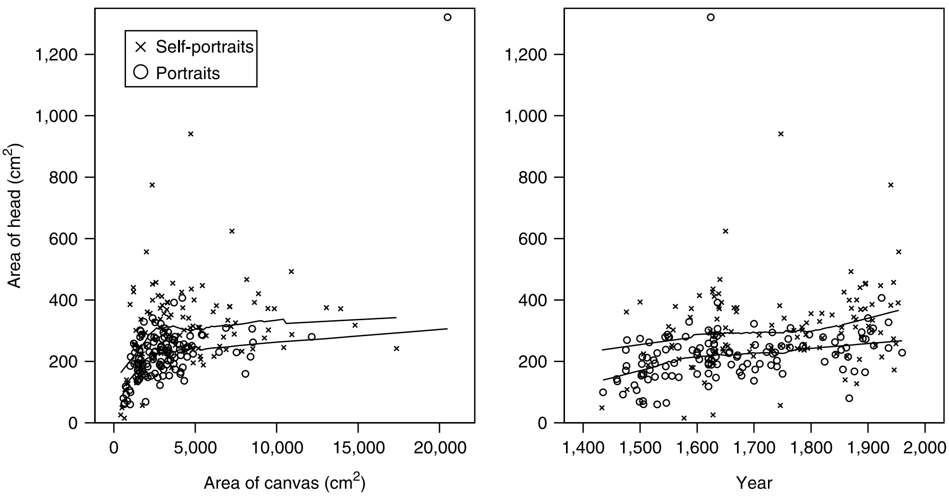

Figure 7. Scatter plots showing the relationship between head size and canvas size (on the left), and between head size and the year when the head was painted (on the right). Crosses are self-portraits and circles are portraits. To illustrate the trends, given the considerable amount of overlap, we used loess curves. The curve for self-portraits is consistently above the one for portraits.

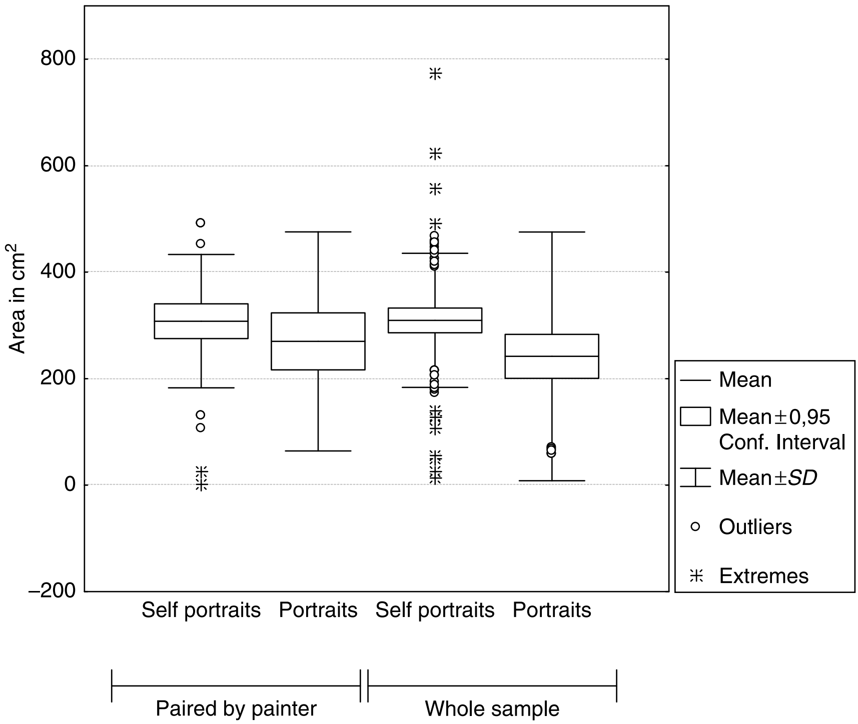

Figure 8. Area of the painted head in the samples analysed of self-portraits ($N = 115$) and portraits ($N = 125$).

heads of other people. Because year was controlled for the effect appears to hold across the centuries.

A comparison between the area of the heads in the self portraits and portraits is shown in Figure 8.This overestimation was also found when the comparison was within the subset of 119 portraits and self-portraits paired by painter ($t = 2.668$, $df = 29$, $p < .05$) – see Figure 8, on the left.

Note that most portraits were commissioned and therefore it is possible that the painter had a vested interest in flattering the patron. If painting larger heads were a conscious strategy, one might expect a trend towards larger heads in the case of portraits. We suggest that the difference found is not the result of a conscious decision but a more subtle effect that influences everybody, not specifically painters.

FINAL DISCUSSION

The perception of our own body relies on touch, proprioception and also on visual information (Craske *et al.*, 1984; de Vignemont *et al.*, 2005; Gandevia & Peghan, 1999; Lackner, 1988; Taylor-Clarke *et al.*, 2004; Thomas, Press, & Haggard, 2006). Cross-modal links integrate these representations to produce the coherent conscious experience of body events (e.g. Haggard, Newman, Blundell, & Allison, 2000; Sathian, Zangaladze, Hoffman, & Grafton, 1997).

The question of people's mental map of their own body in terms of *position*, *shape*, and *size* has been addressed by neuropsychological research on body schema (see, for a review, Denes, 1989; Reed & Farah, 1995) and by psychological literature on body image (see Introduction). The experiments presented here contribute to the description of the perceived *size* of body parts in healthy adults by focusing on the case of the *head*. The question of how somatic and visual information contribute to body image is particularly intriguing with respect to this part of the body because it is not directly visible. To summarize, what have we found?

The effect of visual information on estimation of own head size

Results from Experiments 1 to 4 revealed consistent overestimation with respect to the actual size *when visual information was absent*. This overestimation was *reduced when visual information* was available.

The effect of vision in improving accuracy is consistent with the data showing reduction of over-grasp – with over-grasping considered as an indication of the uncertainty about size estimation and position of the target object – when visual information is provided (see, for instance, Edwards, Wing, Stevens, & Humphreys, 2005; Kudoh, Hattori, Numata, & Maruyama, 1997; Wing, Turton, & Fraser, 1986). The comparison between size estimation of the head with and without visual help revealed a larger overestimation of the head *without visual help*, as compared to when participants were looking at themselves in mirrors (two different distances of the mirror were considered in Experiments 1 and 4). The overestimation, therefore, does not originate from how people see images in mirrors. We discuss two other possible factors: Memory and Proprioception.

Memory of visual information

In Experiments 2 and 4, after visual information was removed, people tended to overestimate the size of other people's heads both with respect to the actual size of the head and to the estimation they made when seeing it. This memory effect found for *the other's heads* might also be one of the mechanisms causing the overestimation of *one's own head* if one assumes that familiarity with mirror images of oneself make these available in memory. This oversized memory of head might contribute to body representation in terms of size just as it has been proved that memory of mirror images contribute to recognition of one's face (Bredard, 2003; Rhodes, 1986; Troje & Kersten, 1999, discussed in the Introduction). An enlargement effect in memory is, therefore, a possible partial explanation for the overestimation found in the absence of visual information. However, even from memory, overestimation was greater for one's own head than for another person's head (Experiments 2 and 4).

Proprioceptive information

One aspect specific to self-estimation which could account for the difference between self-estimation and estimation of another person's head is the presence of proprioceptive information. The role of proprioception on healthy people's body representations and, more precisely, on the *perceived size of body parts* has been demonstrated with respect to body size in general and to specific parts of the body (Craske *et al.*, 1984; de Vignemont *et al.*, 2005; Lackner, 1988). Our findings suggest that there is a bias towards enlargement of heads with normal proprioceptive information, independently of having open or closed eyes. When a headband was used to increase the proprioceptive information on one's head size, the overestimation disappeared (Experiment 3). However, we cannot exclude the possibility that the headband drew attention to the head and also gave the sensation of head compression, and that this sensation of compression contributed to the disappearence of the overestimation. On the other hand, the headband used was not particularly tight.

The hypothesis of an *uncertain* proprioceptive outline of the head in normal proprioceptive conditions is only apparently contrary to the findings of Edwards *et al.* (2005) that *over-grasp is reduced* for face-parts (mouth and nose) as compared to other parts of the body (thumb and wrist). In agreement with previous research (Kudoh *et al.*, 1997; Wing *et al.*, 1986) suggesting that the increase in over-grasp reflects uncertainty about the location and size of the stimulus, the authors interpret their results as indicating that there is *reduced stimulus uncertainty* for grasp responses to face-parts. However, the same authors rejected the possible hypothesis that people have, in general (i.e. beyond grasp responses) better stored knowledge of size for face-parts than for hand-parts, since they found that judgements about size (without vision) were not more accurate for face-parts than for thumb and wrist. Looking at the means reported in the paper, overestimations of the actual size were present (mean overestimation of 2.4 mm for face-parts and 3.2 for hand parts). Given that they also found estimates to be more accurate for smaller body parts (mean overestimation of small parts 0.7 mm; of large parts 5.00 mm) the level of overestimation for head-parts does not disagree with our results for the whole head.

The key question that we are left with *concerns enlargement*. If normal proprioception about the size of the head is not reliable and, therefore, estimation is difficult, especially when it is based solely on memory, why is the estimation biased?

Other examples of bias towards *enlargement* of body size exist in the literature. For instance, de Vignemont *et al.* (2005) found that the distortion in the perceived size of body parts induced by experimental manipulation of proprioception in healthy subjects (via tendon vibration) produced the illusory expansion of the body part affected by the manipulation, but not illusory shrinking. In the neuroscience literature some cases of bodily extension are described, notably by means of implements and additions to body parts (Berlucchi & Aglioti, 1997; Maravita & Iriki, 2004). Furthermore, when a body part is anaesthetized and receives no afferent input, it feels bigger (de Vignemont *et al.*, 2005; Gandevia & Peghan, 1999; Paqueron *et al.*, 2003). In psychiatric pathologies, macrosomatognosia is much more frequent than microsomatagnosia and usually applies to single body parts (Leker, Karni, & River, 1996; Mauguiere & Courjon, 1978). The fact that size distortions of body parts are more often enlargements than the opposite is of particular interest for our results. However, in our experiments the enlargement effect was found for head but was not confirmed when other parts of the body were considered.[1]

[1] *Participants did not overestimate their hand size when priproprioceptive information and memory of visual information was available in Experiment 4. Perhaps people overestimate most of their body parts, and hands are the exception, or perhaps they underestimate most of their body parts and the head is the exception. Informal observations (N = 14) revealed that, when visual information was not provided, underestimation emerged for feet (20% for height and 7% for width). This result was confirmed also when participants were wearing socks (a similar condition to that of wearing a headband) or were looking at their feet. Therefore for three body parts (the head, the hands, and the feet) which are large in Penfield's homunculus (Penfield & Rasmussen, 1957) size is overestimated only in the case of the head.*

Affective factors

So far we have focused on the perceptual and not the attitudinal or affective component that is said to contribute to body image (e.g. Rudd & Lennon, 2000). However, we cannot rule out that the differences found between self-estimation and other-estimation reflects a bias concerning the affective component. Most people possess unconscious favourable associations regarding themselves. Perhaps the most famous example of this is the positive association regarding the letters in one's name, the so-called name letter effect (Nuttin, 1985). It has been proposed that these associations are the markers of implicit egotism (Pelham, Carvallo, & Jones, 2005). It has also been argued that self-serving biases and positive illusions are useful for maintaining mental health and that their absence is linked to depression (e.g. Jansen, Smeets, Martijn, & Nederkoorn, 2006). Moreover, unlike reported self-esteem, people's implicit positive self-esteem seems to be an important aspect of cognition which is similar across cultures (Yamaguchi *et al.*, 2007).

A possible explanation, therefore, is that an increase in size is associated with a positive valence, and that the overestimation is caused by an implicit self-serving bias. However, we are not aware of any specific evidence that larger heads are in themselves related to self-esteem or have general positive associations. One can, however, reason by analogy with stature. It is known that tall men are found more attractive and have more reproductive success (Pawlowski, Dunbar, & Lipowicz, 2000). Further analysis based on the assessment of individual differences may eventually confirm whether this affective component, as opposed or in addition to the perceptual component, plays a role in the overestimation found in our research.

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