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My face through the looking-glass: The effect of mirror reversal on reflection size estimation

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ABSTRACT

People tend to grossly overestimate the size of their mirror-reflected face. Although this overestimation bias is robust, not much is known about its relationships to self-face perception. In two experiments, we investigated the overestimation bias as a function of the presentation of the own face (left–right reversed – as in a mirror – or nonreversed – as in a photograph), the identity of the seen face, and prior exposure to a real mirror. For this we developed a computerized task requiring size estimations of displayed faces. We replicated the observation that people overestimate the size of their mirror-reflected face and showed that the overestimation can be reduced following a brief mirror exposure. We also found that left–right reversal modulates the overestimation bias, depending on the perceived face's identity. These data underline the enhanced familiarity of left–right reversed self-faces and the importance of size perception for understanding mirror reflection processing.

1. Introduction

To most people, the fact that the reflection of one's own face on the surface of a mirror is physically half the size of one's actual face size (half the width and half the height, hence a quarter of one's actual face surface), is deeply counterintuitive (Gombrich, 1960; Parks, 2001). Moreover, this is true regardless of the distance between observer and mirror. During self-perception in a mirror, observer and visual target are one and the same. Hence, the mirror surface, acting like a virtual window, always stands midway between the eye of the observer and the location where his or her reflection appears to stand in the virtual space "behind" the mirror (see Fig. 1A). It follows that the projection of one's own face on the surface of the mirror is necessarily half the size of one's actual face, regardless of distance. That most people tend to overlook this fact has been shown in several recent experiments. When asked to quantify the size of their mirror reflection, participants tend to overestimate the size of their reflected face, i.e. they incorrectly estimate the size of their face's reflection as closer to the size of their physical face than to the correct size of 50% of their physical face (Bertamini & Parks, 2005; Lawson & Bertamini, 2006; Lawson, Bertamini, & Liu, 2007).

This overestimation bias has been interpreted as a combination of perceptual factors and cognitive factors. Our strong inbuilt capacity for perceiving size constancy seems to hamper our capacity to correctly perceive the size of a reflection as opposed to the actual size of the object being reflected. For instance, seeing a tree through the window provides an immediate idea of the tree's size, not the surface its projection occupies on the window plane. Accordingly, it has been proposed

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Fig. 1. Overestimation bias of the reflected face and stimuli. (a) The projection of the reflected face on the surface of a mirror is half the size of one's actual face. In front of a mirror (left panel), use stickers to delimitate the visible top and bottom of your face (middle panel). You can then measure the height of the resulting space, through which the entirety of your face can still be seen in the mirror, and compare it to the actual height of your face (right panel; for more details, see Bertamini and Parks, 2005). (b) Sample of the stimuli produced for experiments 1 and 2. The upper row shows normal-oriented stimuli (as in a photograph), the lower row shows left–right reversed stimuli (i.e. as people perceive themselves in a mirror). For each stimulus, participants were asked to respond whether the displayed face is bigger or smaller than the face they would see in a mirror. Note that all face stimuli are aligned with the participant's head at eye level.

that people interpret mirrors as windows, rather than a two-dimensional plane with images on its surface (Bertamini, Lawson, & Liu, 2008; Lawson et al., 2007). Hence, the size of the image projected on the mirror tends to be overestimated as it is automatically "regressed" (Thouless, 1931) to the size of the physical object being reflected. However, a range of experiments, while confirming the robustness of the overestimation bias, showed that the magnitude of the bias can at least be decreased by different factors, such as allowing participants to look at a real mirror while judging the size of their reflected face or asking them to estimate the size of a reflected face-sized ellipse instead of their own face (Lawson & Bertamini, 2006).

Based on these observations, Lawson and Bertamini (2006) suggested a mixed-account of the size overestimation bias. Its persistence in conditions where one's reflection could directly be seen in a real mirror strongly suggests a perceptual account (i.e. our tendency to interpret 2D planar surfaces as 3D environments), yet the fact that the bias can be modulated in specific conditions suggests an influence of cognitive factors, such as naïve beliefs and expectations about mirrors and familiarity with the standard size of the reflected object the projected size of which has to be estimated.

The relevance of these empirical observations on mirror perception to studies of self-face recognition has remained unexplored. This is despite the fact that self-face stimuli have often been used in recent years in the cognitive neurosciences. Indeed, behavioral and neuroimaging studies aiming at understanding the brain mechanisms of self-face recognition in humans have increased recently, but yielded conflicting results (see reviews in Devue & Brédart, 2011; Gillihan & Farah, 2005; Legrand & Ruby, 2009). Part of the explanation for such divergent findings may lie in methodological variations, such as the choice of faces used as comparison to the own face. For instance, as one's own face is a highly familiar face, likely due to frequent mirror exposure (Tong & Nakayama, 1999), it is important to control for such familiarity by comparing performance of the self face with other familiar faces, such as the face of a friend, co-worker or celebrity. Another confounding factor in studies of self-face recognition is the presentation of the self-face stimulus. It is a seldom-mentioned fact that the own face, unlike other people's faces, cannot be perceived directly, and it is only since the development of quality mirrors and their democratization that humans can perceive how their own faces look like frequently and directly (more recently also via photography and other technologies). Yet mirrors provide a self-image different from the image other persons form of oneself in one important respect: it is left–right reversed. This is not a trivial point: besides the fact that numerous thinkers have pondered on the origin and nature of this peculiarity of mirrors (e.g. Gregory, 1997; Navon, 1987; Takano & Tanaka, 2007), studies have shown that people perceive their mirror-reversed face as more familiar than their "normally oriented" face, and conversely for the face of a familiar person (Mita, Dermer, & Knight, 1977; Rhodes, 1986). This was further confirmed by studies showing that humans are better at detecting asymmetrically located features for their own face, while such features are less important when judging the orientation of the face of a familiar other person (Brédart, 2003). However, previous work on self-face recognition has not studied the impact of these documented differences regarding the orientation of self-faces. Therefore, it remains to be shown how left–right orientation of one's own face can influence self-face perception, especially in comparison to other familiar faces, which are much less likely to be known in reversed orientation.

In order to better understand the principles underlying visual self-face recognition, it is therefore important to examine the reflected face overestimation bias and the effects of mirror reversal. These factors have not been controlled in most behavioral and neuroimaging studies involving self-face recognition, despite the fact that other studies have shown their importance in visual cognition. Moreover, left–right reversal and reflected face overestimations have never been investigated in the same study.

In two experiments, we conjointly explored the reversal and size factors of mirrored self-perception in a new experimental paradigm. We show that left–right reversal affects judgments of the size of one's own reflected face. Because self-recognition *per se* was irrelevant to the present task (which required fast responses in a two-alternative forced-choice and randomized design, where left–right reversal should *a priori* have no influence on performance) our results point to an implicit effect of left–right reversal in face processing that depends on whether the own or another person's face is shown.

2. Experiment 1

In experiment 1, we investigated the effect of face orientation (mirror reversed versus nonreversed) on the size overestimation bias of mirror reflections. Participants were asked to perform a size estimation task of faces shown on a computer screen, while imagining they were looking at a mirror rather than a screen. Crucially, face orientation was irrelevant to the task and participants were not informed about the presence of differently orientated stimuli.

2.1. Method

2.1.1. Participants

Sixteen healthy participants (four female and 12 male, two left-handed) took part in experiment 1 (mean age ± SD: 26.8 ± 3.2 years). All of them had normal vision and none reported a history of neurological or psychiatric disorder. Informed consent was obtained from all participants prior to their inclusion in the study. They received financial compensation for their participation.

2.1.2. Materials and procedure

Color pictures of each participant were taken using a digital camera (BenQ C1220, 12MP, Taiwan) a few days prior to the experimental session. For the picture, participants were asked to insert their head through a hole cut in a green cloth in order to get a uniform background color and were asked to keep a neutral facial expression. Uniform lighting was obtained with a front facing neon lighting. Pictures were then digitally formatted with a gray background and matched luminance for background and face. For each participant a set of 25 images ranging from 30% to 150% (in steps of 5%) of the actual head size (obtained for each participant by measuring the length from the chin to the top of head with a ruler: mean 23 cm ± 2 cm) was created. A further set was created by using the same 25 pictures and left–right reversing them (Fig. 1B). We selected this range of sizes on the basis of pilot experiments in order to obtain a comparable amount of images judged as being "bigger" or "smaller" than the participant's mirror-reflected face would be.

Participants sat on a chair in a dark room with their eyes at a distance of ~80 cm from a vertically adjusted monitor (HP, 23 inches, 1200×1920 pixels resolution, LCD, USA). Chair height and chin-rest were adjusted individually so that the subject's eyes were at mid-screen height and aligned vertically with the eyes of the stimuli (which remained constant throughout the experiment, regardless of size or orientation). Prior to each stimulus presentation, a white fixation cross (on a black background) was displayed for 500 ms. This was followed by a 180-ms long presentation of one of the 50 stimuli. A black screen was then immediately displayed until the participant responded. In each of five experimental blocks, each image appeared twice in normal orientation, and twice in mirror-reversed orientation ($25 \times 2 \times 2 = 100$ presentations per block). Thus, each stimulus was presented 10 times leading to a total of 500 stimulus trials. All images within one block were presented in random order. A training period of ten trials preceded the experiment.

Half of the participants began the task after receiving the following oral instructions: "*Imagine that the screen in front of you is a mirror. You will be shown briefly an image of your face, in different sizes. Your task is to indicate as fast as possible, for each picture, whether you think it is smaller or bigger than if it were your mirror reflection*."

The other half of the participants was given the same instructions, but instead of starting the task they were first placed in front of a real mirror to the left of the screen and at the same distance from where the stimuli would appear on the screen during the experiment (mirror exposure condition). Like the screen monitor, the mirror was vertically oriented, but had an overall larger size. Participants were then explicitly told to examine the size of their reflection. Thus, by this procedure, the correct answer for the size-estimation task to follow was revealed to half our participants before the experiment. After about 20 s of mirror exposure, the mirror was removed, the participant placed in front of the screen, and the practice trials started, followed by the five experimental blocks. Participants responded with their right hand on a response-pad, using the index finger for "smaller" and the middle-finger for "bigger".

Trials for which the reaction time exceeded the mean plus 3 standard deviations were discarded from the analysis (0.9% loss). Inspection of the data for the most extreme ranges of stimuli (30–40% and 140–150%) revealed no response errors (i.e. "bigger" for the smaller stimuli or "smaller" for the larger stimuli). To determine the point of subjective ambiguity in estimating the size of own face reflection, we analyzed the variable image size as a function of the proportion of "bigger" responses (size over-estimations). The point of subjective ambiguity is the value on the size axis for which the subject would say in equal proportions that the image presented was "smaller" or "bigger". To obtain this value, we fitted a sigmoid psychometric function to the data points using the least-squares regression (Matlab 7.6, MathWorks, Natick, MA, USA; see Lopez, Bachofner, Mercier, & Blanke, 2009 for a similar approach). For statistical analysis, this value was determined independently for reversed and non-reversed pictures and for each participant, and then entered in a repeated measures ANOVA, with one within factor (Orientation: mirror reversed; nonreversed) and one between factor (Mirror Exposure: exposure; no exposure).

2.2. Results and discussion

The average estimated reflection size across conditions was 90.1% (SD: 20.5%), thus larger than the physically correct mirror reflection size of 50%. Overestimation was less pronounced in the mirror exposure conditions (76.8%; SD: 19.0%) compared to when subjects were not allowed to see their face in a mirror before the task (103.4%; SD: 12.6%; Fig. 2A). This difference was significant (main effect of Mirror Exposure; $F(1, 14) = 10.86$, $p < .01$, $\eta_p^2 = .43$). We also found that mirror reversal significantly decreased overestimation (mirror reversed: 89%; SD: 20.2%; nonreversed: 91.2%; SD: 21.3%; $F(1, 14) = 16.16$, $p < .01$, $\eta_p^2 = .53$; Fig. 2B). The interaction term did not reach significance ($F(1, 14) = 4.35$, $p = .09$). Size estimations for all conditions were significantly different from the correct answer of 50% (T-tests for single means, all $p < .01$). However, size estimations in the Mirror Exposure condition were significantly different from 100% (mirror reversed: $t_7 = -3.61$, $p < .01$; nonreversed: $t_7 = -3.29$, $p = .01$), showing that the overestimation bias in this condition was not imputable to a general tendency to estimate the actual size of one's face. In the no exposure condition, size estimations were not different from 100% (mirror reversed: $t_7 = 0.41$, $p = .68$; nonreversed: $t_7 = 1.08$, $p < .31$). Post experiment debriefing revealed that participants were not aware of the aims of the experiment. Only one participant realized that there were two sets of pictures with different orientations.

Results of experiment 1 are in line with previous observations that people grossly overestimate the size of their own reflection (Lawson & Bertamini, 2006). Despite different estimating methods and experimental conditions, the overestimation magnitude that we obtained is similar to previously published data, i.e. closer to the size of the physical face (100%) than to the correct mirror reflection size (50%). Our finding that direct exposure to an actual mirror reduced the overestimation bias (from 103.4% to 76.8%), although without eliminating it, is also comparable with data by Lawson and Bertamini (2006) where mirror exposure reduced overestimation from 106% to 85%. Thus, in the present and previous work, exposure to a

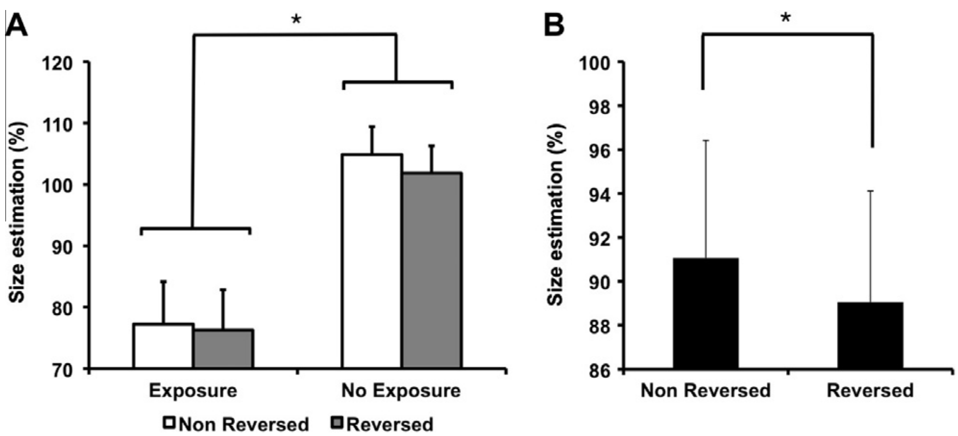

Fig. 2. Mirror exposure and left–right reversal modulate overestimation. (a) When participants were exposed to a mirror before performing size estimations (mirror exposure), overestimation of the mirror-reflection was strongly reduced. (b) Left–right reversed faces were subjectively estimated as smaller than nonreversed ones. Error bars represent standard errors.

mirror did not permit participants to estimate reflected size correctly, but decreased the overestimation bias. This suggests that participants in the Mirror Exposure condition did not use a strategy of visually comparing the respective face sizes as seen in the mirror (during the mirror exposure procedure) with the size on the computer screen in order to perform the size estimation task. This is also unlikely because the mirror and computer screen were not the same size, and the faces were displayed too shortly to reasonably allow participants to examine, for instance, the distance between the displayed face and the edge of the screen. Moreover, no such strategy could explain the pattern of our results in terms of face reversal. Indeed, we found that the overestimation bias can be modulated by the orientation of the image. In the mirror reversed condition, the reflection size of one's own face was estimated slightly, but significantly more accurately (i.e. less strongly overestimated). This effect persisted even in the mirror exposure condition, revealing its robustness.

This effect of mirror reversal is compatible with the higher visual familiarity with the mirror-reversed face and previous studies showing that the frequent use of mirrors in everyday life increases familiarity with one's mirror reversed face as compared to non-reversed pictures of one's own face (Mita et al., 1977; Rhodes, 1986). In addition to this higher familiarity, we further suggest that left–right reversal of one's own face may also decrease the tendency to perceive planar projections in mirrors as 3D objects and allows to better access the projected size rather than physical size of one's own face. Conversely, less familiarity with one's nonreversed face may increase the tendency to perceive it as a spatially distant object, and thus hinder access to its projected size.

In experiment 2 we explored the mirror reversal effect in a different group of participants and tested whether it is self-face specific. For this we compared mirror face size estimation of the observer's own face with that of another highly familiar face, that of a close friend. Because the face of a friend is highly overlearned in the non-reversed orientation, but arguably seldom observed as mirror-reversed, we predicted that the magnitude of overestimation for the self-face and other-face should depend differently on mirror reversal.

3. Experiment 2

3.1. Method

3.1.1. Participants

Fifteen healthy participants (six female and nine male, two left-handed) took part in experiment 2 (mean age ± SD: 20.7 ± 1.0 years). All participants had normal vision and none reported a history of neurological or psychiatric disorder. They were tested in sets of two (one set of three), each participant knowing the other person for four to 15 years (mean ± SD: 3.6 ± 4.3 years). The sets were equally distributed across gender. We tested two male–female pairs, two female–female pairs and four male-male pairs (with two male participants paired with a single third male, who performed the experiment only once). Hence, each participant could be presented with stimuli of their own face (Self condition) and stimuli of a person familiar to them (Other condition). Informed consent was obtained from all participants prior to their inclusion in the study. They received financial compensation for their participation.

3.1.2. Materials and procedure

Stimulus acquisition was the same as in experiment 1. Each image presented in the Other condition was scaled with respect to the participant's own head size (i.e. pictures in the Self and Other condition were all matched for size, 100% corresponding to the head size of the participant). In absolute terms, the average magnitude of this normalization process was 1.2 cm ± 1.0 SD in height (mean head length: 21.6 cm ± 1.73 SD; maximum difference found in a pair: 2.5 cm; minimal difference: 0 cm).

The experimental setup was identical to that in experiment 1 except for the following. In study 1, each size was presented an equal number of times. In order to avoid extreme contrasts between subsequent image sizes and to obtain more trials for calculating the relevant range of the psychometric function (thereby also testing whether the reversal effect persists despite methodological variations), we adapted the image size distribution. Each block comprised one presentation of the sizes 30%, 40%, 140%, and 150%, two presentations of the sizes 50% and 130%, three presentations of the sizes 60% and 120% and four presentations for the sizes 65%, 70% , ... 110%, 115% (only this range comprised pictures scaled in steps of 5%).

One person of each pair started with the Self condition and was given the same instructions as in experiment 1. The other participant of the pair started with the Other condition and was given the same instructions, with the following addition: "(...) *However, the face you will be shown is not your face, it is* [friend's name]'s face. *So you will have to react as if you were looking at a mirror and saw the face of your friend instead of your own face. Please perform the task as if you were looking at your own face in a mirror.*"

Each condition included four blocks of 116 trials each (total: 464 trials for each condition, 928 for both). After the first condition had been performed, the experimenter explained the second condition. The repeated measures ANOVA included the two within-subjects variables Identity (self; other) and Orientation (mirror reversed; nonreversed).

3.2. Results and discussion

The data of experiment 2 reveal that the effect of mirror reversal on face size overestimation depends on the identity of the face whose reflection's size is being estimated. Whereas mirror reversed own faces were on average estimated as smaller

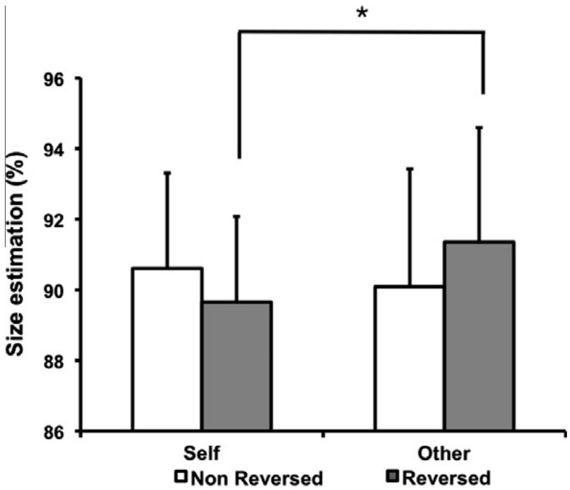

Fig. 3. Facial identity affects overestimation. Identity of the perceived face differentially influenced size estimation as a function of face orientation. Left–right reversal decreased the overestimation bias for self-faces, whereas it increased overestimation for another familiar person's face. Error bars represent standard error.

than the non mirror-reversed faces (as in experiment 1), the opposite effect was found for friends' faces, pointing to an influence of familiarity on reflection size estimation. Similar to experiment 1, the average estimated reflection size across conditions was larger than the actual mirror reflection size (90.4%; SD: 11.2%). As predicted, we found that mirror size estimation depends differently on left–right reversal for the own versus other's face. The significant interaction between Identity and Orientation ($F(1, 14) = 4.63$, $p < .05$, $\eta_p^2 = .25$) was caused by a significant difference between the value for Self mirror reversed (89.65%; SD: 9.4%) and Other mirror reversed images (91.35%; SD: 12.6%; Fisher least significant difference test; $p = .035$; all other $p > .1$; Fig. 3). There were no significant differences depending on Identity (Self: 90.1%; SD: 9.8%; Other: 90.7%; SD: 12.5%; $p = .8$) or Orientation (Nonreversed: 90.1%; SD: 10.7%; Mirror reversed: 90.36%; SD: 11.5%; $p = .8$). The decrease in size estimation for mirror reversed self faces (as found in experiment 1) was found in nine out of 15 participants in experiment 2, but failed to reach significance. The opposite, non-significant, effect was found in the Other condition (in nine out of 15 subjects). Size estimations for all conditions were significantly different from the correct answer of 50% (all $p < .01$) and also from 100% (all $p < .05$). Post experimental debriefing confirmed that participants were unaware of the aims of the study and only three participants noticed that the stimuli were either non-reversed or mirror-reversed.

Behavioral evidence has shown that left–right reversal differentially influences the perceived familiarity of one's own face and that of another person's face (Brady, Campbell, & Flaherty, 2005; Brédart, 2003; Mita et al., 1977; Rhodes, 1986). Whereas mirror reversed self faces are perceived as more familiar than non mirror-reversed ones, the opposite is true for other (familiar) persons' faces. Our data extend these findings by showing that these self-other differences with respect to face stimuli are also present for mirror size estimation. The observed effect cannot be accounted for by differences in the size of the faces of our participants: test face sizes were tailored for each participant by matching the size of the other face to that of the self face. In addition, size differences were minimal and counterbalanced within pairs, and were irrelevant to the reversal effect under study. We interpret the interaction between orientation and identity as the result of a differential impact of reversal on facial familiarity: whereas one's own face is frequently perceived as left–right reversed through reflections and as nonreversed through pictures or videos, faces of familiar persons are arguably much rarely seen in reversed orientation.

4. General discussion

We conducted two experiments to investigate the size overestimation bias of mirror reflected faces using a new method. We (1) replicated the observation that people massively overestimate the size of their mirror-reflected face and (2) showed that the magnitude of overestimation can be reduced following a brief mirror exposure. We also (3) found that mirror left–right reversal modulates the overestimation bias and that (4) this depends on the face's identity. In what follows, we discuss these results with respect to own face perception and the special role of the own face among visual objects.

In previous work, size estimation of participants' reflected face was tested through a variety of methods including direct questioning, drawing the outline of one's imagined reflection on a mock mirror, matching paper ellipses of different sizes to the estimated size of one's reflection, verbal estimations expressed in centimeters, or direct measurements on a real mirror (Bertamini & Parks, 2005; Lawson & Bertamini, 2006). Here we developed a procedure that allowed us to quantify psychophysically the magnitude of mirror size estimation. In order to test the subjective estimation of the size of the face reflection we asked our participants to imagine that a computer screen in front of them was a mirror and collected repeated measures.

We believe that what was lost in this rather artificial setting was compensated by the quantitative possibilities it offered, i.e. varying the range of presented sizes and altering the familiarity of the displayed faces by modifying their orientation and/or identity.

The present setup revealed magnitudes that are in the same range as previous data using other approaches, suggesting that the present setting is a valid method to investigate mirror perception and cognition. Concerning the effects of prior mirror exposure, our paradigm also allowed to replicate the finding that exposure to a real mirror reduces the magnitude of mirror size overestimation (Lawson & Bertamini, 2006). Moreover, all participants were incredulous when they were shown, after our experiments, the correct size for their own face reflection (Gombrich, 1960; Parks, 2001). These results support Lawson and Bertamini's (2006; see also Lawson et al., 2007) mixed account of the overestimation bias in terms of mainly perceptual factors and additional factors influencing (although not eliminating) the bias. These authors proposed that the bias is due to perceptual size constancy for objects (i.e. just as distant objects are perceived as larger than their retinal size, the size of objects as they appear on reflecting surfaces is overestimated; Lawson et al., 2007). However, this strong overestimation bias can itself be modulated by direct interaction with a mirror or familiarity with the standard size of the reflected object (Lawson & Bertamini, 2006).

A new modulating factor that we report here for the first time is the left–right orientation of the reflected face. Despite the fact that participants were not informed about the variation of orientation of the displayed faces, we found that they judged their mirror reversed face, i.e. the face as seen regularly in mirrors, as smaller (thus closer to the correct size) than the non mirror-reversed one. This effect persisted even when the size overestimation was generally reduced when participants where exposed to their reflection in a real mirror prior to the experiment. These findings show that the magnitude of the size overestimation bias of mirror reflections decreases after mirror image interactions (Lawson & Bertamini, 2006), but also that the effect of mirror-reversal is not abolished by this interaction and likely arises due to different mechanisms. The role of mirror-reversal for highly familiar faces has previously been addressed (Brady, Campbell, & Flaherty, 2004; Brady et al., 2005; Brédart, 2003; Mita et al., 1977; Rhodes, 1986; Smith, Grabowecky, & Suzuki, 2008) in explicit tasks requiring face recognition, judgments of orientation and judgments of "likeliness" of mirror reversed versus normally oriented faces. These studies, however, remained at the explicit level and only studied a limited number of trials. Our data demonstrate implicit effects of left–right mirror reversal by asking participants to estimate the size of mirror reflections across a large number of trials rather than explicitly judging the familiarity or identity of faces. Experiment 1 showed that size estimation is influenced by mirror reversal of one's own face, and experiment 2 that mirror reversal differentially affects size estimation for self and other faces.

The effect of mirror-reversal cannot solely be accounted for by mechanisms related to size constancy (Lawson & Bertamini, 2006; Lawson et al., 2007), as changes in left–right orientation or self versus other face kept the size of the visual object constant. Accordingly, we argue that in addition to mechanisms related to size constancy, the overestimation bias of one's face reflection also depends on mechanisms related to visual specular familiarity. The own face and how we perceive it visually is not like any other object. In addition to being a highly overlearned and familiar configural visual object (Tong & Nakayama, 1999), it is a rich source of multimodal inputs. From a very early age, humans are able to match visual information to sensorimotor processes related to the face (Meltzoff & Moore, 1977). Recent experiments have shown that the perception of tactile stimuli on one's face can be modulated by concurrent visual touches delivered to a picture of one's own face (e.g. Serino, Giovagnoli, & Làdavas, 2009; Serino, Pizzoferrato, & Làdavas, 2008), and conversely that visual self-recognition can be modulated by the level of congruency of seen and felt tactile facial inputs (Paladino, Mazzurega, Pavani, & Schubert, 2010; Sforza, Bufalari, Haggard, & Aglioti, 2010; Tsakiris, 2009). Likewise, increased proprioceptive awareness of one's own head and inwardly focusing on one's own breathing were associated, respectively, with improved size estimation of one's own head (Bianchi, Savardi, & Bertamini, 2008) and faster discrimination of mirror reversed self faces (Smith et al., 2008). It is thus likely that visual self-face perception is closely associated to processes of bodily self-consciousness such as self-location, self-identification, and the first-person perspective (Blanke & Metzinger, 2009). Such processes might actually be differently engaged as a function of the orientation of the perceived face. In this respect, it is interesting to note that individuals with mirror-touch synesthesia – a condition where observing a touch applied to another person induces a tactile sensation on one's own body – can be segregated in a "specular" group (those who feel touch on the contralateral side than the observed model, as if looking at a mirror) and a less frequent "anatomical" group (those who feel touch on the ipsilateral side than the observed model, as if they were in the model's shoes) (Banissy, Cohen Kadosh, Maus, Walsh, & Ward, 2009; Banissy & Ward, 2007). These authors argued that this "specular bias" is likely related to "the fact that one's own head is only ever seen from a mirror-reflected perspective" (Banissy et al., 2009, p. 266). The present results further predict that these synaesthetes may yield different behavioral and phenomenological results were they to observe their own face being touched while displayed in reversed or non-reversed orientation. More generally, we believe that mirror reversal is an important factor to take into account in studies using self-face stimuli, as non-trivial differences in visual processing, affective evaluation and multisensory integration might emerge according to whether the faces displayed were mirror-reversed or not. Thus, our results are of relevance to the methodology and interpretation of the numerous studies using self-faces to investigate self-consciousness, social cognition and the self.

To summarize, the present work highlights the importance of taking into account how faces are presented in studies of mirror cognition and research using self-face stimuli (i.e., did experimenters use a reversed or a nonreversed picture?). Where previous work already noted the difference in familiarity between left–right reversed and nonreversed faces, we report here a much subtler influence of left–right reversal, namely its modulating effect on the overestimation bias of mirror reflections. We suggest that this finding underlines the fact that perceiving one's own face in the mirror involves not only visual processes, but also processes related to multisensory and sensorimotor signals that reinforce along the years our familiarity with our own left–right reversed face. Our findings also draw attention on the methodological and theoretical importance of left–right reversal in self-face processing. Studies failing to control for this orientation factor might create confounds based on the assumed familiarity of the displayed face to its owner. Indeed, our findings suggest that non-reversed familiar faces of friends or celebrities might actually be *more* familiar than non-reversed self-faces, thereby mitigating their reliability as a control for familiarity.

In conclusion, seeing parts of one's own body in the mirror, such as the face, trunk, or the hands, may differ in important ways from the perception of non-bodily objects and the bodies of others. The comparative study of such different visual objects may not only allow us to gain insight about human mirror perception and the self, but also about spatial perception of visual stimuli on planar and reflecting surfaces.

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