Assessing the presence of face biases by means of anorthoscopic perception

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Abstract

Anorthoscopy is a presentation mode in which an image is shown sliding behind a slit-shaped aperture, so that it is visible only part by part and never in its entirety. With the aims to assess (1) whether the processing of complex stimuli (faces) correctly occurs in anorthoscopy, and (2) whether the Own-Gender Bias (OGB: the better recognition of stimuli belonging to the same gender of the observer: faster and more accurate) and the Left-Face Bias (LFB: the preference to analyze the left half of the face) occur in such a part by part presentation, we presented female and male faces as whole stimuli (Experiment 1) and in anorthoscopy (Experiments 2 and 3), as well as female/male chimeric faces (Experiment 4), during a gender categorization task. Experiment 1 confirmed that participants correctly categorized the gender of faces, but the OGB was not found. In Experiments 2 and 3 we manipulated the direction (Experiment 2: upward/downward; Experiment 3: leftward/rightward), the speed (slow and fast) of the sliding faces, and the width of the aperture (small and large). Both tasks revealed that facial gender was correctly categorized in anorthoscopy. The OGB was found, but only for males/females in Experiments 2/3, respectively. In Experiment 4 the LFB emerged only in the tachistoscopic session, suggesting that this perceptual bias does not extend to anorthoscopy.

Keywords Anorthoscopic presentation · Gender categorization · Chimeric faces · Own-Gender Bias · Left-Face Bias

Introduction

The ability to perceive, memorize and recognize faces is crucial for survival, so much so that this skill is not exclusive to humans, but has also been confirmed in other species (Freiwald & Tsao, 2011). Several models of face perception have been proposed in the literature: starting from the well-known model proposed by Bruce and Young (1986), in which identity and emotional expression were considered as two different “modules”, Moscovitch, Winocur, and Behrmann (1997) proposed the “specific-domain hypothesis” arguing that a specific and complex cognitive function (i.e. face perception) is

grounded in a specialized cortical network, independent from other cognitive functions. Behavioural studies demonstrated how face perception involves both local and holistic processing (Searcy & Bartlett, 1996): face perception is based on both the local-based (analytic) processing of each feature of the face (Garner, 1978), and on the simultaneous and integrated (holistic) encoding of the stimulus as a whole (Sergent, 1984).

The holistic hypothesis is supported by both neuropsychological studies and experimental findings on healthy participants. It has been shown that when holistic processing is compromised, as in autism (Behrmann et al., 2006) and in prosopagnosia (Avidan, Tanzer, & Behrmann, 2011; DeGutis, Chiu, Grosso, & Cohan, 2014; Van Belle, De Graef, Verfaillie, Busigny, & Rossion, 2010), face recognition becomes difficult. For instance, in prosopagnosic patients, typical effects underlying global analysis in face perception (such as face inversion effect, composite face effect and Navon effect) do not occur (Avidan et al., 2011), suggesting that the simultaneous presentation of face parts is necessary for face processing (Boutsen & Humphreys, 2002). Notably, this dominance of holistic analysis in face processing would not be ubiquitous, in fact, there are several counterexamples in the literature about prosopagnosic patients: on the one hand, Le Grand et al. (2006) found that only one out of eight patients showed an impairment in global

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analysis (composite face task; see also Schmalzl, Palermo, & Coltheart, 2008); on the other hand, Duchaine, Yovel, and Nakayama (2007) did not find a bias for local processing of elemental features, and finally Duchaine (2000) found normal performance in global-local task.

Moreover, in the healthy population a number of perceptual effects confirmed the holistic analysis of facial stimuli, such as the face inversion effect (Thompson, 1980; Yin, 1969), the composite face effect (Young, Hellawell, & Hay, 1987), and the part-whole effect (Tanaka & Farah, 1993). In particular, when the observer is presented with an upside-down face, a “part-based” analysis of local features occurs (Farah et al., 1998; Prete, Marzoli, & Tommasi, 2015; Rossion, 2008). This is the reason why the composite effect disappears when composite faces are presented in inverted orientation (Young et al., 1987). Similarly, when a facial stimulus is presented as composed of two misaligned halves, this misalignment disrupts the holistic processing, as opposed to the aligned conditions, which promote the integration of facial features into a global face representation (Goffaux & Rossion, 2006). These findings emphasize how face processing needs both local and holistic analysis.

Besides the identity of a person, facial stimuli also convey different kinds of information, such as gender and age. As regards gender, it has been shown that it is processed by exploiting a number of different sources of information (Le Gal & Bruce, 2002), such as configural components (i.e. distance between eyes and nose; first and second-order relations; Burton, Bruce, & Dench, 1993), specific facial characteristics (i.e. nose protuberance, brow height), and other informative cues (i.e. hairstyle; O'Donnell & Bruce, 2001; Wright & Sladden, 2003). Although cultural gender-specific cues such as hairstyle and make-up help us to correctly recognize the gender of faces (O'Donnell & Bruce, 2001), several studies have shown that adults (Bruce & Young, 1998) and children (Wild et al., 2000) are also able to classify the gender of a face when these cues are hidden, highlighting that biological and anatomical cues are sufficient for gender categorization (Cellerino, Borghetti, & Sartucci, 2004).

Zhao and Hayward (2010), by using a composite face task, found that holistic processing is involved in gender discrimination. Moreover, consistent with a part-based processing, Hayward, Rhodes and Schwaninger (2008) found that participants are able to use both configural and local information during gender categorization (i.e. scrambled face parts), although it has been shown that holistic processing modulates part-based processing (Zhao & Hayward, 2010). In fact, local-based processing seems to be stronger when features of scrambled faces are in a face-like configuration, compared to the case in which local features are shown in random positions.

Different categorization tasks need different processing strategies, so that specific experimental methods have been used in past research to assess which aspects of information are diagnostic in a given task (i.e. identity, gender, age processing). For

instance, in the “bubbles technique” and in the “aperture paradigm” the visual field is restricted, and facial processing is based on partial information extracted from apertures or windows. The bubbles technique involves a number of Gaussian windows randomly positioned over an image, thus creating a “bubbles mask”, which allows to see only a subset of information at a time. The bubbles technique allowed to determine which are the “diagnostic regions” on a face (i.e. crucial regions for a correct categorization task) and the differential information required by different categorization tasks (Gosselin & Schyns, 2001).

A similar technique is represented by the aperture paradigm, also known as “anorthoscopic presentation”, proposed almost two centuries ago and long forgotten, to be revived by Irvin Rock around 50 years ago (see Rock, 1981). Anorthoscopy, which had already been used by Plateau (1829), is an unconventional method of visual presentation, that consists in the presentation of an image sliding behind a narrow slit-shaped aperture, thus revealing only one section of the image at any given moment. It was used to study the perception of shape, showing that *“the presence of an image is neither sufficient nor necessary to account for the perceived shape”* (Rock, 1981, page 110). Two anorthoscopic procedures have been most often used: the “dynamic aperture paradigm” (DAP), in which the aperture moves over a static image, and the “static aperture paradigm” (SAP), in which the image moves behind a static aperture. According to the retinal painting theory (Anstis & Atkinson, 1967; Helmholtz, 1867), in the DAP the figure would be reconstructed thanks to a temporal summation of different portions, due to the fact that each portion of the image is viewed at a different portion of space, so that the entire image can be reconstructed on the retina portion by portion. In the SAP, each part of the image is overwritten on the same portion of the retina, because all parts are presented at the same spatial location (the slit being static and often placed in the centre of the visual field). In the SAP the retinal painting theory is not sufficient to explain the perceptual processes. In fact, stimuli are reconstructed via both a temporal and a spatial summation of the different “overwritten” portions of the image on the retina: the entire image would be reconstructed as a mental representation, as faithful as possible to the original image, in a post-retinal process (Parks, 1965).

More recently, Yin, Shimojo, Moore, and Engel (2002; see also Aydin, Herzog, & Ogmen, 2007) used shape distortions to evaluate the integration process of aperture-viewed stimuli. They showed that cortical activity in the lateral occipital complex and in motor areas, involved in shape (Kourtzi & Kanwisher, 2000; Malach et al., 1995) and motion perception (Movshon, Adelson, Gizzi, & Newsome, 1985), respectively, was modified according to the distortion of shapes. In this study, the cortical activity did not change in the early visual areas, suggesting that dynamic shape integration does not involve these areas. Thus, the anorthoscopic paradigm can be deemed a useful tool to study the mental representation of complex stimuli, such as faces, a complex process that takes

place in high-level cortical regions, beyond the early visual areas. In fact, in the anorthoscopic paradigm consecutive sections of the image are progressively presented, and thus this paradigm could be potentially useful to investigate facial perception and recognition by exploiting part-based face processing. Recently, Murphy and Cook (2017) presented both upright and inverted faces, either as entire images shown for 1,000 ms or by means of a dynamic aperture paradigm. In order to test the limits of holistic processing, they asked participants to categorize age, gender, identity and emotional expression of facial stimuli. In their paradigm the facial image was covered by a black surface with a horizontal aperture (12.5% the height of the face) moving either upward or downward and leaving visible one facial strip at a time (DAP). As hypothesized, the authors found a better performance for faces in upright orientation and presented in their entirety compared to faces presented upside-down and anorthoscopically. Differently from their hypotheses, however, they also found similar detrimental effects in both entire and DAP conditions when stimuli were presented upside-down, together with a better performance in the entire than in the DAP condition for both upright and upside-down presented stimuli. The authors concluded that the classical inversion effect cannot be explained by means of holistic processing, but it also depends on a part-based analysis. It has to be highlighted that these authors used a DAP, in which the image remains static behind a moving slit, so that – according to the retinal painting theory (Anstis & Atkinson, 1967) – a temporal summation process would ensure a visual (retinal) reconstruction of the image. A temporal integration is essential for perceptual organization of a visual scene (Anaki, Boyd, & Moscovitch, 2007), and some authors suggested that the visual short-term memory (Irwin & Zelinsky, 2002) or both short-term and long-term memory (Hollingworth & Henderson, 2002) are involved in visual integration.

Other evidence has supported the idea that whole face presentation is crucial for holistic processing (Farah, Tanaka, & Drain, 1995); in fact, when each part of a face is presented simultaneously but in different “boxes” (we can say in a “decomposed” presentation), the face inversion effect (FIE) does not occur. However, Richler, Gauthier, Wenger, and Palmeri (2008) showed that configural processing occurs even when face parts are separated in space, and studies about temporal integration (Anaki et al., 2007) show that holistic processing supports temporal integration of faces. Indeed, when face parts are briefly separated in time (with a variable interval between each part presentation of 0, 17, 200 and 700 ms) FIE occurs in both whole-face and piecemeal presentation. However, when intervals separating parts lasting 700 ms, FIE differs between the two conditions, demonstrating that face parts are integrated in a time-limited visual buffer and suggesting that the simultaneous presentation of face parts is not necessary for holistic processing. Finally, and in contrast

with Anaki, Boyd, and Moscovitch (2007) findings, Cheung, Richler, Phillips, and Gauthier (2011) argued that when face parts are separated in time, holistic processing cannot occur. Starting from these premises, our study is based upon previous findings, for which “*simultaneous presentation of facial information is critical for holistic processing*” (Cheung et al., 2011).

The main aim of the present study was to assess whether the static anorthoscopic paradigm could allow for the correct processing of faces, and to explore whether facial gender in particular is based on holistic processing. We also aimed at testing the so-called Own-Gender Bias (OGB; Shaw & Skolnick, 1994; Skolnick & Shaw, 1999) according to which female observers should be more accurate at identifying female faces whereas male observers should be more accurate at identifying male faces. Further studies revealed that the OGB is ascribable to hairstyle, which influences gender recognition (O'Donnell & Bruce, 2001; Wright & Sladden, 2003). Considering this evidence, we asked both female and male participants to categorize the gender of female and male faces superimposed to an oval-shaped mask, used to hide the hairstyle. Finally, we also aimed at assessing whether the anorthoscopic presentation is also characterized by another well-know bias, namely the Left-Face Bias (e.g. Li, Li, Wang, & Cao, 2018), according to which facial stimuli are mainly categorized based on their leftward half, due to the right-hemispheric superiority in face processing (e.g., Bodamer, 1947; Kanwisher, McDermott, & Chun, 1997; Rhodes, 1985).

In Experiment 1, used as a control test, we presented female and male faces in the centre of the screen and asked participants to categorize their gender. We expected that participants would correctly carry out the task and we also hypothesized that an OGB could emerge in this basic condition.

Moving from the results of this task, in Experiments 2 and 3 we presented the same stimuli during the static aperture paradigm. Specifically, facial images slid behind a static slit-shaped aperture, and thus a mental reconstruction of the moving image was needed in order to categorize the stimulus as female or male. If face analysis is based on holistic processing, we could expect a failure in gender categorization in this task (holistic analysis being prevented by presenting images part by part). Nevertheless, moving from the results by Murphy and Cook (2017), it could be also hypothesized that gender processing can occur despite the serial presentation of facial portions. Moreover, due to the fact that, except for the study by Murphy and Cook (2017), the anorthoscopic paradigm had been used only with simple stimuli such as line segments (Rock, 1981), cube or planar arrays of concentric circles (Fujita, 1990), and complex stimuli such as animals and clouds (Bisiach, Luzzatti, & Perani, 1979; Ogmen & Herzog, 2010), we also probed the optimal conditions for the anorthoscopic presentation of facial images, by

manipulating (1) the width of the aperture, (2) the stimulus speed, and (3) the motion direction of the stimuli. In Experiments 2 and 3, two groups of participants were presented with either horizontally or vertically sliding female and male faces, observed behind a wider/thinner slit, at a faster/slower speed.

Experiment 4 was mainly aimed at assessing the LFB during anorthoscopy. In this last experiment we presented chimeric faces composed of a half female face and a half male face, asking participants to carry out the same gender categorization task as in the previous tasks. We presented these stimuli entirely in the centre of the screen (whole-face session) and moving behind a vertical narrow aperture (anorthoscopic session). We expected to confirm the LFB in the tachistoscopic session and to possibly extend this evidence to the anorthoscopic presentation.

Experiment 1

Experiment 1 was carried out as a baseline condition. In this experiment, a whole-face condition was used: female and male faces were presented in their entirety for 680 ms, and observers were required to give their dichotomic gender judgments (female or male).

Materials and methods

Participants

The task was administered to 40 healthy Italian adults (20 females; mean age: 21.90 years $\pm$ 0.56) with normal or corrected-to-normal vision. All participants were volunteers, with a mean handedness score of 60.96 ($\pm$ 4.58; one left-handed), according to the Edinburgh Handedness Inventory (Oldfield, 1971). Before the task, participants gave informed consent to take part in the study, and after the end of the task they were debriefed. The procedure was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Stimuli

Stimuli consisted of photographs in frontal view of 30 female and 30 male faces selected from the Karolinska Directed Emotional Faces (Lundqvist, Flykt & Öhman, 1998) with neutral facial expressions. Photographs were chosen in order to exclude outstanding features such as glasses or peculiar make-up or beard. An oval-shaped black mask was used to hide hair and thus to prevent potential gender-diagnostic cues. The photographs were converted into gray-scale images and were presented at a resolution of 196×265 pixels.

Procedure

Participants comfortably sat in a dark room and were tested individually at a distance of 70 cm from the computer screen. Instructions were presented on the computer screen and then explained verbally by the experimenter. Two trials were presented before the beginning of the experiment to familiarize with the task (they were subsequently excluded from the analysis). During these two trials, the experimenter remained behind the participant in order to answer potential questions. In each trial a white fixation cross was presented in the centre of a black screen (Fujitsu Siemens, resolution: $1,280 \times 1,024$ pixels, refresh rate: 60 Hz) for 1,000 ms, after which a stimulus was presented in its entirety for 680 ms in the centre of the screen. After its disappearance, the screen remained black until the participant gave the response, and then the next trial started. All stimuli were presented twice for a total of 120 trials and their presentation order was randomized across and within participants.

Participants were instructed to categorize the faces as female or male by pressing two different keys on the keyboard (keys corresponding to the letters “q” and “p” on an Italian keyboard). They were informed that the response could be given only when the stimulus had disappeared (when the screen became black), and they were invited to respond as fast and accurately as possible. Participants were divided into two subgroups: 20 participants (ten females) were required to respond by using the left/right hand to categorize male/female faces, respectively, and the remaining 20 participants (ten females) were required to use the opposite association (left/right hand for female/male faces, respectively).

The entire task was administered by means of E-prime Software (Psychology Software Tools Inc, Pittsburgh, PA, USA) and it lasted about 5 min. At the end of the task, participants were asked to complete the Edinburgh Handedness Inventory (Oldfield, 1971) and then they were debriefed.

Results

Statistical analysis was conducted by means of the software Statistica 8.0.550 (StatSoft. Inc., Tulsa, OK, USA). A repeated-measures analysis of variance (ANOVA) was carried out, using Gender of face (female, male) as within-subjects factors, and Gender of participant (female, male) and Group (Group 1: left hand = male face; Group 2: left hand = female face) as between-subjects factors. Categorization accuracy was transformed into percentage and it was used as the dependent variable. Participants whose mean exceeded two standard deviations from the mean in at least one condition were excluded from the analyses (three females and one male).

Only the main effect Gender of participants was significant ($F_{(1, 32)} = 6.02$, $MSE = 0.009$, $p = 0.019$, $\eta_p^2 = 0.16$), showing

that female participants ($94\% \pm 0.8\%$) outperformed male participants ($92\% \pm 0.2\%$).

Experiment 2

In Experiment 2 a static horizontally oriented slit-shaped aperture was used. We presented female and male faces moving either at a slow or at a fast speed, behind the aperture, which could be wider or thinner. In order to investigate the possible spatial effect of gender processing (for instance, if the gender categorization is more accurate when the mouth is presented before the eyes), in half of the trials the face moved downwards, and in the other half of the trials it moved upwards. The main aim of the present study was to assess whether the gender of facial stimuli could be correctly processed under conditions of horizontal anorthoscopic presentation (SAP), forcing the perceivers to integrate the different regions of a face in order to process the entire stimulus. We expected a better performance in slower than in faster speed condition, and with the larger than with the smaller slit width, due to the greater amount of information in these conditions. Moreover, observers should not show a particular tendency to prefer one direction (upward or downward) over the other. Finally, as we exploited a gender categorization task, we aimed at verifying the possible presence of the Own-Gender Bias previously found in different studies (Shaw & Skolnick, 1994), even if such a bias did not emerge in Experiment 1.

Murphy and Cook (2017) used a similar paradigm, as described above, but they obtained facial images from morph continua between two images (e.g. female-male; man-boy; Clinton-Bush, and so on) by using seven steps among the two extreme levels, whereas we used unprocessed (female or male) facial images. There are three more important differences between our task and that carried out by Murphy and Cook (2017). First, the timing of a whole face presentation in aperture viewing (portion by portion) was 6 s in their study whereas each trial in our experiment lasted 1,768 ms (in the slower condition); second, in their experiment the aperture moved over the face (DAP) whereas in our experiment the aperture stood still and the face moved behind it (SAP); third, we factored in the size of the aperture.

Materials and methods

Participants

The task was administered to 65 healthy Italian participants (33 females) with normal or corrected-to-normal vision. All participants took part in the study as volunteers and none of them had taken part in Experiment 1. The mean age of the sample was 22.37 years (± 0.47 years) and the mean handedness score was 40.70 (± 6.34), as measured by the Edinburgh

Handedness Inventory (Oldfield, 1971), including 13 left-handed participants. Before the task, participants gave informed consent to participate in the study, and after the end of the task they were debriefed. The procedure was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Stimuli and procedure

Stimuli and procedure were the same as described in Experiment 1, but – instead of being presented entirely – they were presented by means of a static aperture paradigm. The height of the horizontal aperture could be 6 pixels (2.53% of the height of the face) or 12 pixels (5.06% of the height of the face). The width of the aperture was the same as the width of the facial stimuli. As in Experiment 1, a trial started with a white fixation cross in the centre of a black screen (ACER, resolution: $1,280 \times 768$ pixels, refresh rate: 60 Hz) for 1,000 ms, after which a face was presented moving behind the aperture. The stimulus movement behind the aperture could be slower (4.04 cm/s; presentation time: 1,768 ms) or faster (7.93 cm/s; presentation time: 884 ms), and in order to exclude the “jerky vision”, image moved behind this aperture shifting of 5 pixels at time. Facial stimuli could move downward, or upward (see Fig. 1). After the disappearance of the face, the screen remained black until the participant gave the response, and then the next trial started. As in Experiment 1, participants were required to categorize faces as female or male, by pressing the keys “q” and “p”: 33 participants (Group 1, 17 females) were asked to press the key “p” with the right hand for female faces and the key “q” with the left hand for male faces, the remaining 32 participants (Group 2, 16 females) were asked to use “p” for male faces and “q” for female faces.

A total of 480 trials were administered: 30 female and 30 male faces were presented in upward and downward directions, both at a slower and at a faster speed, and through a thinner and a wider aperture. The order of stimuli was randomized within and among participants. The entire task was administered by means of E-prime Software (Psychology Software Tools Inc, Pittsburgh, PA, USA) and it lasted about 20 min. At the end of the task, participants were asked to report if they had noticed “anything strange” in the stimuli, then they were asked to complete the Edinburgh Handedness Inventory (Oldfield, 1971), finally they were debriefed.

Results

Statistical analyses were carried out by means of Statistica 8.0.550 (StatSoft. Inc, Tulsa, OK, USA). In a first step, an analysis by item was carried out by means of a series of *t*-tests used to evaluate the correct categorization rates for each stimulus. In a second step, an ANOVA was carried out on the percentage of correct responses for each condition.

Fig. 1 Schematic representation of the Static (horizontal) Aperture Paradigm used in Experiment 2, in which a face moves upwards or downwards behind a horizontal slit-shaped aperture

Recognition rates of the stimuli

The percentage of correct responses for each stimulus was calculated. The mean percentage of correct categorization was compared with the chance level (50%), by means of a single-sample *t*-test: the gender of the faces presented anorthoscopically was categorized with an accuracy higher than that expected by chance ($68\% \pm 1.8\%$, $t_{(59)} = 9.35$, $p < 0.001$). Furthermore, a series of single-sample *t*-tests, carried out on the percentage of correct categorization for each face, showed that five stimuli were categorized with an accuracy lower than that expected by chance (three female faces; $p < 0.01$ for all comparisons). Moreover, the recognition accuracy for seven more stimuli (four female faces) did not differ from the chance level. The mean accuracy for the remaining 48 stimuli for which the accuracy was higher than chance ($p < 0.01$ for all comparisons) was $73\% (\pm 0.01\%)$. A chi-square test was also used to compare the frequency of correctly categorized stimuli with the frequency of not-correctly categorized stimuli (48 vs. 12), showing that the frequency of correct categorization was significantly higher than the frequency of incorrect categorization ($\chi^2_{(1)} = 21.6$, $p < 0.001$).

Recognition rates of participants

A repeated-measures ANOVA was carried out, using Gender of face (female, male), Direction (upward, downward), Speed (slow, fast) and Width (small, large) as within-subject factors, and using Gender of participant (female, male) and Group (Group 1: left hand for male face; Group 2: left hand for female face) as between-subject factors. The percentage of correct responses was used as the dependent variable. Participants whose mean exceeded two standard deviations from the mean in at least one condition were excluded from the analyses (nine females and six males).

The main effect of Direction was significant ($F_{(1, 46)} = 11.49$, $MSE = 0.05$, $p = 0.001$, $\eta_p^2 = 0.20$): faces were better recognized when moving upward ($70\% \pm 1.90\%$) than downward ($68\% \pm 2.04\%$). The main effect of Speed ($F_{(1, 46)} = 190.72$, $MSE = 1.12$, $p < 0.001$, $\eta_p^2 = 0.80$) showed that the performance was better in the slow ($73\% \pm 1.78\%$) than in the fast condition ($66\% \pm 2.04\%$). Moreover, the main effect of Width ($F_{(1, 46)} = 274.93$, $MSE = 1.76$, $p < 0.001$, $\eta_p^2 = 0.86$) revealed that the accuracy was higher in the large ($74\% \pm 1.73\%$) than in the small condition ($65\% \pm 2.02\%$).

The interaction between Gender of participant and Gender of face was significant ($F_{(1, 46)} = 5.82$, $MSE = 0.51$, $p = 0.020$, $\eta_p^2 = 0.01$). Post hoc comparisons, carried out by means of the Duncan test, revealed that male faces were better categorized by male than by female participants ($p = 0.011$; Fig. 2), and a non-significant trend emerged for a better recognition of female than male faces by female participants ($p = 0.092$).

The significant interaction between Gender of face and Width ($F_{(1, 46)} = 65.53$, $MSE = 1.38$, $p < 0.001$, $\eta_p^2 = 0.59$) showed that only for female faces the performance was better

Fig. 2 Interaction between Gender of participant and Gender of face in Experiment 2. Error bars represent standard errors. The asterisk shows a significant comparison

in the large than in the small condition ($p < 0.001$). Moreover, when the slit was large, female faces were better categorized than male faces, whereas when the slit was small, male faces were better categorized than female faces ($p < 0.001$ for both comparisons). The interaction between Gender of face and Speed ($F_{(1, 46)} = 5.273$, $MSE = 0.09$, $p = 0.026$, $\eta_p^2 = 0.10$) showed that the performance was better in the slow than in the fast condition, both for female and male faces ($p < 0.001$ for all comparisons). The interaction between Direction and Speed was significant ($F_{(1, 46)} = 4.27$, $MSE = 0.02$, $p = 0.044$, $\eta_p^2 = 0.08$): participants' performance was better in the slow than in the fast condition, both for the downward and upward direction ($p < 0.001$ for both comparisons). In the fast condition the accuracy was higher for the upward than for the downward direction ($p = 0.001$). The interaction between Group and Direction was also significant ($F_{(1,46)} = 4.96$, $MSE = 0.02$, $p = 0.031$, $\eta_p^2 = 0.09$) and post hoc comparisons showed that Group 2 performed better than Group 1 when faces moved downward ($p = 0.038$). Moreover, the performance of Group 1 was better when faces moved upward than downward ($p < 0.001$).

The significant interaction among Gender of face, Direction and Group ($F_{(1,46)} = 8.022$, $MSE = 0.31$, $p = 0.001$, $\eta_p^2 = 0.15$) showed a better performance of Group 2 with respect to Group 1 for female faces in the downward condition ($p = 0.002$). Moreover, Group 2 better categorized female than male faces in the downward condition ($p = 0.007$) and they better categorized male faces in the upward than in the downward condition ($p = 0.025$). Also the interaction among Direction, Width and Group was significant ($F_{(1, 46)} = 5.51$, $MSE = 0.02$, $p = 0.023$, $\eta_p^2 = 0.11$). Post hoc tests showed that the performance of Group 1 in the small condition was better in the upward than in the downward direction, whereas the performance of Group 2 was better than that of Group 1 when the slit was small, and stimuli moved downward ($p = 0.039$).

Speed, Width, Gender of participant and Group significantly interacted ($F_{(1, 46)} = 5.13$, $MSE = 0.01$, $p = 0.028$, $\eta_p^2 = 0.10$) and post hoc comparisons confirmed that the performance was better in the large than in the small condition, as well as in the slow than in the fast condition, in all groups (female and male participants in both Group 1 and Group 2). Moreover, in the fast and large conditions, male participants in Group 2 outperformed male participants in Group 1 ($p = 0.033$).

Finally, the interaction among Gender of face, Direction, Speed and Width was significant ($F_{(1, 46)} = 15.09$, $MSE = 0.09$, $p < 0.001$, $\eta_p^2 = 0.24$): female faces were better recognized in the large than in the small condition in both the slow and the fast presentation and in both the downward and the upward direction. Moreover, female faces were better recognized in the slow than in the fast presentation, except for the downward small condition. For female faces in the fast and small

condition the performance was better in the downward than in the upward condition, whereas for male faces the performance was better in the upward than in the downward condition ($p < 0.018$ for all comparisons), except when the presentation was slow and the slit was small.

Discussion

The present study confirmed that anorthoscopic presentation allows participants to correctly process the gender of facial stimuli, as already found by Murphy and Cook (2017). We found that recognition accuracy was higher than chance, confirming that such a part by part presentation does not prevent facial gender processing.

Moreover, the results also confirmed the better performance when more information is available, corresponding to a larger width of the slit and to a lower speed of the faces. The interaction between the gender of the participants and the gender of the stimuli revealed the expected OGB, at least in male participants (a trend towards a better performance with female faces by female participants was also evident, but it did not reach the significance), even if such a bias was not found in Experiment 1. We can suppose that the OGB emerges when the difficulty of the task increases, as in the anorthoscopic presentation, although it is not evident in the entire presentation of faces due to a ceiling effect in this basic condition in both female and male participants.

An interesting result of the present Experiment concerns the difference we found between the two groups of participants: in Group 1 participants used the right hand to categorize female faces and the left hand to categorize male faces, whereas in Group 2 participants used the reversed association. The use of one hand to categorize a specific gender forced the observers to create a mental representation related to spatial localization of keys.

According to several studies, a cultural explanation has been suggested for perceptual asymmetries such as in mental representation (Morikawa & McBeath, 1992), according to the evidence that Arabic speakers show an opposite pattern compared to Western speakers in the spatial agency bias (imagination: Maass, Suitner, Favaretto, & Cignacchi, 2009; mental representation: Maass & Russo, 2003; advertisements of sports and shoes: Suitner & Maass, 2016; social behaviour: Maass, Suitner, & Nadhmi, 2014).

This representation in one case was the same as that hypothesized by the Spatial Agency Bias (SAB: male in the left and female in the right hemispace), according to which observers represent the left group as more powerful or "agentic" than the right group. Similarly, upper position in the visual field has been hypothesized to reflect the power of a group (Paladino, Mazzurega, & Bonfiglioli, 2017; Schubert & Maass, 2011). In fact, at least in Western cultures, in which people write from left to right

and from top to bottom, people explore the visual scene from the upper-left to the bottom-right. Moreover, people with a leading role tend to be positioned in the upper-left space showing that the upper side is a cue of power and leadership (Paladino et al., 2017; Schubert & Maass, 2011). In accordance with the SAB, we found that in the group in which the left key was associated to male faces, the performance was better when stimuli moved in the upper direction, whereas in the group in which the left key was associated to female faces, the performance was better when stimuli moved to the bottom. This evidence contrasts with the results found by Murphy and Cook (2017), who did not find differences between the two motion directions. We can conclude that these differences could reflect the paradigms used, a static aperture paradigm in the present study and a dynamic aperture paradigm in the study by Murphy and Cook (2017), as well as the fact that only a gender categorization was required in the present experiment.

Another interesting evidence of this study concerns the interaction between the gender of the stimuli and the width of the aperture: female faces were better recognized than male faces when a larger aperture was used, but male faces were better recognized when a thinner aperture was used. This result is in line with Cellerino, Borghetti, and Sartucci (2004), who showed that the amount of information needed to categorize facial gender is lower for male than for female faces.

Experiment 3

Experiment 3 was aimed at investigating the possibility that gender categorization in anorthoscopic presentation is influenced by the slit orientation: in Experiment 3 we used the same paradigm as that used in Experiment 2, but we exploited a vertical slit-shaped aperture, starting from the evidences that face recognition benefits most from horizontal than from vertical information (Dakin & Watt, 2009). Different to Experiment 2, in which the participants saw sequentially either eyes and mouth of the facial stimulus in the upward direction, or first the mouth and then the eyes in the downward direction, in the present Experiment participants saw all the features of a vertical slice of the stimulus at a time (the left before the right or vice versa), similarly to the procedure adopted by Murphy, Gray and Cook in a study published very recently (2020). According to the left-to-right writing (and reading) direction in Western culture (Chatterjee, Southwood, & Basilico, 1999), we expected a better performance when the face moved from left to the right than in the opposite direction (according to the visuo-motor component of language; Suitner & Maass, 2016). Finally, we expected to confirm the Own-Gender Bias as found in Experiment 2.

Materials and methods

Participants

The task was administered to 60 healthy Italian adults (30 females; mean age: 24.42 ± 0.67 years) with normal or corrected-to-normal vision. All participants were volunteers, with a mean handedness score of $64.72 (\pm 3.24)$; one left-handed), according to the Edinburgh Handedness Inventory (Oldfield, 1971). Before the task, participants gave informed consent to take part in the study, and after the end of the task they were debriefed. The procedure was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Stimuli and procedure

Stimuli and procedure were the same as those described in Experiment 2, with one difference: the slit was rotated 90° , and stimuli slid leftward or rightward (instead of upward or downward). Specifically, in each trial a white fixation cross was presented in the centre of a black screen (SONY, resolution: $1,280 \times 768$ pixels, refresh rate: 50 Hz) for 1,000 ms, after which a stimulus was presented. The height of the aperture was the same as the stimuli, namely 265 pixels. The width of the aperture could be either 12 pixels, corresponding to 6.52% of the stimulus width, or 6 pixels, corresponding to 3.26% of the stimulus width. The stimulus moving behind the aperture could be slower (3.89 cm/s; 1,360 ms) or faster (7.60 cm/s; 680 ms), and in order to exclude the “jerky vision”, image moved behind this aperture shifting of 5 pixels at time. The facial image could move leftward or it could move rightward (see Fig. 3). After the end of the anorthoscopic presentation, the screen remained black until the participant gave the response, and then the next trial started.

Participants were divided into two subgroups: 30 participants (15 females) were required to respond by using the left/right hand to indicate male/female faces, respectively; the other 30 participants (15 females) were required to respond by using the left/right hand to indicate female/male faces, respectively.

Results

Statistical analyses were the same as those described in Experiment 2.

Recognition rates of the stimuli

The percentage of correct responses for each face was calculated. The mean percentage was compared with the chance level (50%), by means of a single-sample *t*-test. The result confirmed that the gender of faces presented in anorthoscopic

Fig. 3 Schematic representation of the Static (vertical) Aperture Paradigm used in Experiment 3, in which a face moves leftwards or rightwards behind a vertical slit-shaped aperture

presentation was correctly categorized ($77\% \pm 1.87\%$, $t_{(59)} = 14.50$, $p < 0.001$). Furthermore, single-sample t -tests were used to compare the proportion of correct categorization of each face with the chance level (50%). Results showed that three stimuli were incorrectly categorized (three male faces judged as female; $p < 0.01$ for all comparisons), and that the categorization rate of two female faces and one male face did not differ from chance ($p = 0.864$, $p = 0.079$ and $p = 0.28$, respectively). The remaining 54 stimuli were correctly categorized, the accuracy being higher than chance for each stimulus ($p < 0.01$ for all comparisons), with a mean accuracy of $81\% (\pm 0.01\%)$. A chi-square test showed that the frequency of correct categorization was significantly higher than the frequency of incorrect categorization (54 vs. 16; $\chi^2_{(1)} = 38.4$, $p < 0.001$).

Furthermore, a statistical comparison between the accuracy found in Experiments 2 and 3 was performed by means of an independent-samples t -test. The result showed that the performance was better in the vertical than in the horizontal slit-shaped aperture paradigm ($t_{(123)} = 5.975$; $p < 0.001$).

Recognition rates of participants

Categorization accuracy was transformed in percentage and it was used as the dependent variable in a repeated-measures ANOVA, in which Gender of face (female, male), Direction of motion (leftward, rightward), Speed (slow, fast) and Width (small, large) were used as within-subject factors, and in which Gender of participant (female, male) was used as a between-subjects factor. Participants whose mean recognition rates exceeded two standard deviations from the mean in at least one condition were excluded from the analyses (three females and seven males). In a preliminary ANOVA, also Group (Group 1: left hand = male face; Group 2: left hand = female face) was considered as a between-subject factor, but it was not significant as main effect ($F_{(1, 46)} = 2.39$, $MSE = 0.08$,

$p = 0.129$). Only one five-way interaction including Group was significant (including Gender of face, Direction, Speed, Group and Gender of participant: $F_{(1, 46)} = 5.19$, $MSE = 0.02$, $p = 0.027$), but post hoc tests did not show group differences. Thus, in order to reduce the number of variables, Group was excluded from further analyses.

The significant main effect of Gender of face ($F_{(1, 48)} = 16.22$, $MSE = 1.49$, $p < 0.001$, $\eta_p^2 = 0.25$) revealed a better performance for female faces ($84\% \pm 1.42\%$) than for male faces ($75\% \pm 1.76\%$). The main effect of Speed ($F_{(1, 48)} = 21.68$, $MSE = 0.09$, $p < 0.001$, $\eta_p^2 = 0.31$) confirmed a better performance with the slow ($81\% \pm 1.55\%$) than with the fast ($79\% \pm 1.73\%$) presentation, as well as the significant main effect of Width ($F_{(1, 48)} = 137.27$, $MSE = 0.87$, $p < 0.001$, $\eta_p^2 = 0.74$) confirmed that the accuracy was higher in the large ($83\% \pm 10.7\%$) than the small ($77\% \pm 9.86\%$) condition.

The interaction between Gender of participant and Gender of face was significant ($F_{(1, 48)} = 4.22$, $MSE = 0.39$, $p = 0.045$, $\eta_p^2 = 0.08$; Fig. 4). Post hoc comparisons, carried out by means of the Duncan test, showed an Own-Gender Bias only

Fig. 4 Interaction between Gender of participant and Gender of face in Experiment 3. Error bars represent standard errors. Asterisks show significant comparisons

for female participants: female participants recognized better female than male faces ($p < 0.001$). Moreover, the performance of females was worse compared to that of males in the categorization of male faces ($p = 0.035$).

The interaction between Gender of face and Direction was significant ($F_{(1, 48)} = 7.85$, $MSE = 0.08$, $p = 0.007$, $\eta_p^2 = 0.14$; Fig. 5). Post hoc comparisons revealed that the accuracy was better for female than for male faces in both directions ($p < 0.001$). Moreover, male faces were better recognized in the rightward than in the leftward condition ($p = 0.022$).

The interaction between Gender of face and Speed was significant ($F_{(1, 48)} = 22.71$, $MSE = 0.11$, $p < 0.001$, $\eta_p^2 = 0.32$). Post hoc comparisons showed that female faces were better recognized than male faces in both conditions (for both comparisons: $p < 0.001$). Moreover, male faces were better recognized in slow than in fast condition ($p < 0.001$).

Finally, the interaction among Gender of participant, Direction, Speed and Width reached statistical significance ($F_{(1, 48)} = 4.20$, $MSE = 0.02$, $p = 0.046$, $\eta_p^2 = 0.08$). Post hoc comparisons showed that in all cases the performance was better in the large than in the small condition, and that no difference emerged between female and male participants in each combination of the different conditions. Similarly, there was no difference between leftward and rightward motion, with the exception of female participants' accuracy, which was higher in the rightward than in the leftward condition when stimuli moved slowly with the thinner slit ($p = 0.016$). Finally, the performance was better in the slow than in the fast condition for male participants in the small and leftward condition, and for female participants both in the small rightward condition and in the large leftward condition ($p < 0.035$ for all comparisons).

Fig. 5 Interaction between Direction and Gender of face in Experiment 3. Error bars represent standard errors. Asterisks show significant comparisons

Discussion

The present study confirmed that of Experiment 2, showing that anorthoscopic presentation does not prevent participants from correctly categorizing the gender of faces, extending the result to the presentation behind a vertical slit-shaped aperture. This evidence confirms that anorthoscopic viewing, despite its fragment-like nature, allows participants to process a complex class of stimuli, such as human faces.

Moreover, the present results also confirm a female face advantage previously shown in different studies (e.g. Herlitz & Lovén, 2013), gender categorization being better for female than for male faces (with both motion directions and with both speeds). This evidence is in accordance with the results by Ramsey, Langlois, and Marti (2005), who explained the advantage for female faces by referring to a perceptual bias based on the fact that female faces are less variable and perceptually more similar to one another than male faces.

The present results also confirm the Own-Gender Bias, but this pattern was found only in female observers, confirming previous evidence (Herlitz & Lovén, 2013). As in Experiment 2, it has to be highlighted that a trend towards an OGB is present in both female and male participants, even if in the present task it reached the significance only for females. Several studies showed a general face recognition advantage in females (Bowles et al., 2009; Connellan, Baron-Cohen, Wheelwright, Batki, & Ahluwalia, 2000; Hall, 1978; Sommer, Hildebrandt, Kunina-Habenicht, Schacht, & Wilhelm, 2013), as well as a faster face processing in females than in males (Bowles et al., 2009; Godard & Fiori, 2010), and it has been proposed that this effect is related to a greater attention towards social stimuli in females (Baron-Cohen, 2002). However, there are many studies supporting the idea that this advantage is specific for female faces (Lewin & Herlitz, 2002; Lovén, Herlitz, & Rehnman, 2011), confirming a female OGB.

Other evidence revealed a male bias during categorization tasks (Armann & Bülthoff, 2012; Wild et al., 2000), explained as possibly due to a perceptual or cognitive bias, resulting in a default “male” response, when distinctively female hairstyles are absent (Intons-Peterson, 1988), and there are doubts about the gender.

In Experiments 2 and 3 the OGB was found, and it was significant only for females in Experiment 2 and only for males in Experiment 3. Nevertheless, it has to be highlighted that a trend towards the OGB was found in all tasks (in particular, for males in Experiment 2 and for females in Experiment 3).

As expected, and as found in Experiment 2, the results also revealed a better performance when more information was available (larger aperture) and when it was available for a longer time (slower motion). These results are in line with the fact that the serial presentation of portions of the image,

due to the anorthoscopic paradigm, makes the visual processing more difficult. However, only when male faces were presented, the performance increased during the slower condition with respect to the faster condition. We can speculate that this is true for male faces due to the fact that the categorization rates for female faces were higher in all conditions due to the female face advantage.

Finally, the evidence according to which male faces were better categorized when presented from the left to the right side of space can be viewed as a further confirmation of the Spatial Agency Bias (SAB; Chatterjee, 2002), according to which spatial imagery and gender categorization are linked to stereotypic beliefs. Even if more studies are needed to validate this speculation, the present results seem to support a stereotypical interpretation, with stimuli coming from the left more often recognized as male.

Comparisons among tasks

Because in all described experiments we found a Gender effect, and in order to isolate the effect of anorthoscopic presentation and clarify the findings of the different tasks presented, two different ANOVAs were carried out in order to compare the effect of anorthoscopy versus whole face presentation, for horizontal and vertical SAP, respectively. ANOVAs were carried out by using Paradigm (anorthoscopic and whole-face) and Gender of participant (female and male) as between-subject factors, and Gender of face (female and male) as within-subject factor, and by using the percentage of correct gender categorization as the dependent variable.

Results

Horizontal SAP versus whole-face

The effect of Paradigm was significant ($F_{(1, 82)} = 948.49$, $MSE = 2.416$, $p < 0.001$, $\eta_p^2 = 0.92$), revealing that the accuracy was better in the whole-face than in the anorthoscopic procedure ($p < 0.001$).

The interaction between Gender of participant and Paradigm was significant ($F_{(1, 82)} = 4.22$, $MSE = 0.014$, $p = 0.045$, $\eta_p^2 = 0.06$). Post hoc comparisons, carried out by means of the Duncan test, showed that female participants ($95\% \pm 0.86\%$) outperformed male participants ($92\% \pm 1.16\%$; $p = 0.040$) only in the whole-face procedure, and that accuracy was better in the whole-face than in the anorthoscopic procedure for both female and male participants ($p < 0.001$ for both comparisons).

The interaction among Gender of participant, Gender of face and Paradigm was significant ($F_{(1, 82)} = 6.36$, $MSE = 0.04$, $p = 0.001$, $\eta_p^2 = 0.07$). Post hoc comparisons revealed that the accuracy was better in the whole-face than in the anorthoscopic procedure in all conditions ($p < 0.001$ for all

comparisons). Moreover, an Own-Gender Bias emerged only for male participants in the anorthoscopic procedure ($p < 0.001$), even if a trend suggesting an OGB was also found for female participants with the same paradigm ($p = 0.078$).

Vertical SAP versus whole-face

The effect of Paradigm was significant ($F_{(1, 82)} = 243.52$, $MSE = 0.781$, $p < 0.001$, $\eta_p^2 = 0.75$): the accuracy was higher in the whole-face than in the anorthoscopic procedure ($p < 0.001$). The significant main effect of Gender of face ($F_{(1, 82)} = 9.97$, $MSE = 0.07$, $p < 0.001$, $\eta_p^2 = 0.10$) revealed a better performance for female faces ($88\% \pm 0.9\%$) than for male faces ($83\% \pm 1.3\%$). The significant interaction between Gender of face and Paradigm ($F_{(1, 82)} = 10.57$, $MSE = 0.080$, $p = 0.001$, $\eta_p^2 = 0.11$) showed that female faces ($84\% \pm 1.2\%$) were better categorized than male faces ($75\% \pm 1.3\%$) in anorthoscopic procedure ($p < 0.001$). Finally, the accuracy was better in the whole-face than in the anorthoscopic procedure for both female and male faces ($p < 0.001$ for both comparisons).

The interaction among Gender of participant, Gender of face and Paradigm was significant ($F_{(1, 82)} = 4.70$, $MSE = 0.03$, $p = 0.033$, $\eta_p^2 = 0.05$). Post hoc comparisons showed that the accuracy was better in the whole-face than in the anorthoscopic procedure in all conditions ($p < 0.001$ for all comparisons). Finally, an Own-Gender Bias emerged for male ($p = 0.017$) and female ($p < 0.001$) participants in anorthoscopic procedure.

Discussion

In order to clarify the anorthoscopic findings of Experiments 2 and 3, two different ANOVAs were carried out to compare anorthoscopic (horizontal and vertical slit), to a whole-face paradigm. The effect of Paradigm was significant in both horizontal and vertical paradigm demonstrate a greater impairment of performance in anorthoscopic procedure compared to whole-face control task. These findings suggested that anorthoscopic presentation alters gender processing, although it does not prevent holistic processing of facial stimuli. We can speculate that earlier stages of perception are altered by anorthoscopic procedure, consequently, the input of the high-level processes (output of the first stages) would be modified and, in turn categorization result affected. Moreover, our findings suggest the presence of the OGB only in the anorthoscopic condition, that is, when the difficulty of the task was enhanced. In fact, no gender bias was found in whole-face task, it is possible that the easiness of the task hidden the effect (OGB), whereas, under anorthoscopic circumstances, given the difficulty of the task, participants could use irrelevant information or different strategies to make their decision about gender.

Experiment 4

Many neuropsychological, neuroimaging and behavioral studies have confirmed the right-hemispheric superiority in face recognition manifesting itself as a perceptual and behavioral bias in paying more attention to the left side of an observed face (Bodamer, 1947; Kanwisher et al., 1997; Rhodes, 1985). This Left-Face Bias (LFB) is evident for the perception of many facial features, such as gender, emotion, ethnicity and attractiveness (Burt & Perrett, 1997; Butler et al., 2005; Christman & Hackworth, 1993; for a review see Voyer, Voyer, & Tramonte, 2012). However, other studies did not show perceptual or attentional asymmetry towards one side in the recognition of faces (Mason & Macrae, 2004). In order to investigate the possible presence of an LFB during anorthoscopic presentation, in this latter task we exploited a peculiar category of facial stimuli, namely chimeric faces (Levy, Heller, Banich, & Burton, 1983), which are created by combining two hemifaces (left and right) from two different faces. Each chimeric face is composed juxtaposing two parts (left and right hemiface), which can differ in gender, age, emotion or identity. Presenting a chimeric face for a short time (tachistoscopic) under central fixation, the information coming from the two halves is primarily processed by the contralateral hemispheres, so that the more specialized hemisphere in a given task drives the first response (Levy, Trevarthen, & Sperry, 1972). Several tachistoscopic paradigms using chimeric face stimuli showed an LFB (Heller & Levy, 1981; Milner & Dunne, 1977; Schwartz & Smith, 1980), and Gilbert and Bakan (1973) demonstrated that the left hemiface advantage persists in a free-viewing paradigm.

Several studies using chimeric faces have shown that holistic processing, namely FIE, does not occur when faces are presented in upside-down orientation (Parente & Tommasi, 2008; Prete et al., 2015). Conversely, Butler and Harvey (2005) found a left face bias also when faces were flipped, and the authors explained their findings suggesting that participants paid more attention on a particular feature conveying gender cues, although configural processing is disrupted by inversion. In Experiment 4 we sought to assess the interaction between holistic processing and its hemispheric effect manipulated by combining aperture and chimeric faces paradigms (a left face effect revealing a right hemisphere superiority in this task). If anorthoscopic procedure alters holistic processing in face perception, spatial and temporal integration of faces parts would not occur and, consequently, if the first (low-level) stage of processing is altered, then mental representation (high-level process) would be also altered, and LFB would not occur. In line with this hypothesis, Le Grand, Mondloch, Maurer and Brent (2004) suggested that holistic processing occurs in the first stage of perceptual face encoding and representation of each part is successively extracted; however, this latter component is not a mere piecemeal registration of the facial parts

(Anaki et al., 2007), but it is a reconstruction of the stimulus carried out by exploiting information stored in a time-limited visual buffer. If the LFB occurs, we can explain it according to a left hemiface bias (Parente & Tommasi, 2008; Prete et al., 2015; Prete, Malatesta, & Tommasi, 2017), which refers to the attentional bias toward the left hemiface which is extended to the representational space (attentional bias toward the left hemisphere: pseudoneglect; i.e. imagery, memory; McGeorge, Beschin, Colnaghi, Rusconi, & Della Sala, 2007). In both explanations (pseudoneglect and LFB), in fact, the right hemisphere superiority occurs (Heilman & Van Den Abell, 1980; Mesulam, 1981; Parente & Tommasi, 2008; Prete et al., 2015).

Due to the fact that we can hypothesize that when participants view an image sliding behind a narrow window, they reconstruct the image, and provide their response upon this representation, it is possible that the left face bias advantage persists in anorthoscopic viewing. In Experiment 4 we tested these hypotheses by presenting chimeric female/male and male/female faces during anorthoscopy by using a vertical static aperture paradigm. In order to obtain a control condition, the same chimeric stimuli were also presented in their entirety in a tachistoscopic session.

Starting from the results of the previous studies (Experiments 2 and 3), we aimed at establishing which of different alternatives about spatial bias is more suitable: (1) According to the SAB model, we would expect more “male” responses when chimeric faces flow rightward than leftward, and we would expect more “female” responses when chimeric faces flow leftward than rightward. (2) If a stimulus exploration occurs (Elkind & Weiss, 1967), then we would expect participants’ responses to be congruent to the left hemifaces when the image flows leftward with respect to rightward (the left most portion of the stimulus being presented first and the direction of motion being thus congruent with normal scene exploration). (3) If a perceptual asymmetry occurs (LFB), participants would pay more attention to the left than the right hemiface (regardless direction of motion). Finally, (4) according to Girgus, Gellman, and Hochberg (1980), participants anticipate what they think they will see, and then they match the present stimulus with the anticipated input. In this view, if the judgments are based on this procedure, gender recognition could be based on the first hemiface presented, regardless the direction of motion. As a consequence, a primacy effect would occur, because the observer could hypothesize that if the first half of the stimulus is male, then also the remaining portion of the face should be male

Materials and methods

Participants

Fifty healthy Italian adults (25 females) with normal or corrected-to-normal vision took part in the study as volunteers (mean age: 25.54 ± 0.69 years). The mean handedness score

of the sample was 60.09 (± 4.94 ; two left-handed), according to the Edinburgh Handedness Inventory (Oldfield, 1971). Participants signed informed consent prior the beginning of the study, and after the end of the task they were debriefed.

Stimuli

The photographs of nine female and nine male faces in frontal view with a neutral facial expression were extracted from the Karolinska Directed Emotional Faces (Lundqvist et al., 1998), selected from the item correctly categorized in Experiment 3 (vertical slit). Stimuli were converted to grey-scale images and they were covered by the black oval-shaped mask used in the previous Experiments. In order to create chimeric faces, each stimulus was divided into two hemifaces (a left and a right hemiface) with a vertical cut. Each half face (female or male) was then juxtaposed to another half face of the opposite gender (see Fig. 6), obtaining 81 left-female/right-male stimuli and 81 left-male/right-female stimuli, for a final set of 162 stimuli.

Procedure

Participants comfortably sat in a dark room, at a distance of about 70 cm from the computer screen (ACER, resolution: 1,280 $\times$ 768 pixels, refresh rate: 60 Hz), and they were tested individually. Before the experimental sessions, participants were invited to read the instructions, in which it was specified that they had to carry out a gender-categorization task, in two consecutive sessions: in the first session (anorthoscopic

Fig. 6 Schematic representation of chimeric stimuli preparation: (A) female face; (B) male face; (C) female and male faces enclosed in a standard black oval-shaped mask; (D) each face image divided into two hemifaces; (E) each hemiface combined with the hemiface of the opposite gender to constitute a chimeric female/male face

session) facial stimuli were presented as moving behind an aperture, in the second session (tachistoscopic session) stimuli were presented entirely and rapidly. Participants were then asked to complete two trials of the first session, used to familiarize with the task. During these trials the experimenter remained behind the participant in order to answer potential questions. Participants were then instructed to keep their gaze on the central fixation cross for the entire duration of the task and to categorize each stimulus as female or male, by pressing two different keys (“RED” for female and “BLU” for male) with their right hand (corresponding to the keys “b” and “n”), taking care of being as fast as possible. Different to the previous Experiments, we decided to ask participants to use only one hand to provide the responses (in order to help participants to keep their gaze on the fixation cross for the whole task and to reduce the number of factors in the statistical analysis). Participants were invited to respond only when the entire stimulus disappeared (when the screen became black). At the end of the first session (anorthoscopic presentation) participants were asked whether they had noticed “something strange in faces”, and then the second session (tachistoscopic presentation) started. Finally, participants were asked to complete the Edinburgh Handedness Inventory (Oldfield, 1971).

In the anorthoscopic session, the procedure was the same as that described in Experiment 3 (vertical aperture paradigm). Chimeric faces were presented as moving (speed of motion 7.60 cm/s; duration of stimulus motion 683 ms, and in order to exclude the “jerky vision”, image moved behind this aperture shifting of 5 pixels at time) either rightward or leftward behind a narrow vertical aperture (width: 12 pixels, corresponding to 6.52% of the width of the face). The height of the aperture was the same as the stimuli, namely 265 pixels. After the end of the stimulus presentation, the screen remained black until the participant gave the response, and then the next trial started. Each of the 162 stimuli was repeated four times and the task was thus composed of 648 trials, with a pause inserted halfway through the task. Presentation order of the stimuli was randomized within sessions and among participants. At the end of the anorthoscopic session, participants were informed that they could take a break, and then new written instructions were presented for the second session.

In the tachistoscopic session participant were instructed that the presentation of the stimuli would be very rapid. Each trial started with a central fixation cross in the centre of a black screen for 1,000 ms, followed by a chimeric face presented in its entirety for 150 ms. Then the screen became black until the participant gave the response, after which the next trial started. The tachistoscopic task was composed of 162 trials in a randomized order, and it always followed the anorthoscopic session.

The whole Experiment, composed of the two sessions, lasted about 25 min and it was administered using E-Prime software (Psychology Software Tools, Inc, Pittsburgh, PA,

USA). The experimental procedure was conducted in accordance with the guidelines of the Declaration of Helsinki.

Results

Data analysis

A Laterality Index (LI) was calculated by dividing the number of responses based on the left half-face for the total number of stimuli in a condition. LI was comprised between 0 and 1, where LI = 0 means a right hemiface bias (gender categorization solely based on the gender of the right half-face), and LI = 1 means a left hemiface bias (gender categorization solely based on the gender of the left half-face). LI = 0.5 represents the absence of a lateral bias in gender categorization.

The LI was used as the dependent variable for both the anorthoscopic and the tachistoscopic sessions. For each session, three different analyses were carried out. The first analysis was aimed at verifying the overall Left-Face Bias: LI was calculated for all participants and all conditions and the mean LI was compared with the chance level (50%), by means of a single-sample *t*-test. The second analysis was aimed at further investigating the possible LFB in each condition separately, by means of a series of *t*-tests. Finally, the third analysis was carried out in order to control for the possible interaction among the variables, by means of a repeated-measures ANOVA. For the anorthoscopic condition Gender of left hemiface (female, male) and Direction (leftward, rightward) were used as within-subject factors, and Gender of participant (female, male) was used as between-subject factor. For the tachistoscopic condition Gender of left hemiface (female, male) was used as within-subject factors and Gender of participant (female, male) was used as between-subject factor. In all of the analyses, the LI was used as the dependent variable.

Finally, in order to verify a possible “primacy effect”, namely the bias according to which participants would base their judgements on the first hemiface presented (regardless of its gender), only for the anorthoscopic condition a Primacy Index (PI) was calculated. PI was obtained by dividing the number of responses based on the first hemiface for the total number of stimuli in a condition. PI was comprised between 0 and 1, where PI = 0 means a “recency bias” (gender categorization based on the last hemiface presented), and PI = 1 means a “primacy bias” (gender categorization based on the first hemiface presented), with PI = 0.5 representing the absence of a bias. Finally, a single-sample *t*-test was used to compare the PI with the chance level.

Tachistoscopic condition

In the tachistoscopic condition the overall single-sample *t*-test was significant, confirming the Left-Face Bias ($t_{(48)} = 5.47, p < 0.001$).

Participants whose mean recognition rates exceeded two standard deviations from the grand mean in at least one condition were excluded from the analyses (two females). Single-sample *t*-tests were carried out on the LI for each condition: the result revealed a significant LFB for male/female faces ($t_{(48)} = 7.69, p < 0.001$), and an almost significant LFB for female/male faces ($t_{(48)} = 1.98, p = 0.052$). Moreover, the LFB occurred in both female participants ($t_{(23)} = 6.333, p < 0.001$) and male participants ($t_{(25)} = 2.19, p = 0.038$).

In the ANOVA, the main effect of Gender of participant was significant ($F_{(1, 46)} = 8.26, MSE = 0.40, p = 0.006, \eta_p^2 = 0.15$): the LFB was higher for female participants (0.66 ± 0.05) than for male participants (0.57 ± 0.04). Gender of face was significant ($F_{(1, 46)} = 20.45, MSE = 0.48, p < 0.001, \eta_p^2 = 0.31$), showing that the LFB was greater when the left hemiface was male (male/female faces: 0.70 ± 0.03) than female (female/male faces: 0.55 ± 0.03). The interaction between Gender of face and Gender of participant was not significant ($F_{(1, 46)} = 0.329, p = 0.569$).

Anorthoscopic condition

In the anorthoscopic condition no significant results were found. In particular, as regards the LI, the single-sample *t*-test against the chance level was not significant, showing that there was no bias for either the left or the right hemiface ($t_{(49)} = -0.17, p = 0.867$).

Participants whose mean LI exceeded two standard deviations in at least one condition were excluded from the analyses (one male participant). None of the single-sample *t*-tests reached statistical significance: female left hemiface ($t_{(49)} = 1.59, p = 0.118$), male left hemiface ($t_{(49)} = -1.69, p = 0.097$), rightward condition ($t_{(49)} = 1.51, p = 0.137$), leftward condition ($t_{(49)} = -1.59, p = 0.117$), female participants ($t_{(25)} = -0.20, p = 0.839$) and male participants ($t_{(24)} = -0.04, p = 0.964$). Finally, no significant results emerged in the ANOVA.

As regards the Primacy Index, the single-sample *t*-test against the chance level was not significant, revealing that there was no bias for either the first or the second hemiface presented ($t_{(49)} = -1.76, p = 0.083$).

Comparison among anorthoscopic and tachistoscopic tasks

In order to investigate the possible difference between anorthoscopic and tachistoscopic presentation we collapsed the leftward and rightward conditions of the anorthoscopic session and performed an explorative ANOVA (because the condition are unbalanced) using Gender of left hemiface (female, male) and Session (anorthoscopic, tachistoscopic) as within-subjects factors, and Gender of participant (female, male) as between-subjects factor. The LI was used as the dependent variable.

As regards main effects, Session was significant ($F_{(1, 42)} = 31.637$, $MSE = 0.85$, $p < 0.001$, $\eta_p^2 = 0.43$): in the tachistoscopic session (0.63 ± 0.03) the LI was higher than in the anorthoscopic session (0.50 ± 0.01). Moreover, the effect of Gender of participant was significant ($F_{(1, 42)} = 7.480$, $MSE = 0.20$, $p = 0.009$, $\eta_p^2 = 0.15$): the LI was higher for female (0.60 ± 0.04) than for male participants (0.53 ± 0.03). Also the main effect of Gender of face was significant ($F_{(1, 42)} = 5.218$, $MSE = 0.10$, $p = 0.027$, $\eta_p^2 = 0.11$), showing that the LI was higher for male/female faces (0.59 ± 0.02) than for female/male faces (0.54 ± 0.02).

The interaction between Session and Gender of participant was significant ($F_{(1, 42)} = 8.139$, $MSE = 0.22$, $p = 0.006$, $\eta_p^2 = 0.16$). Post hoc comparisons, carried out by means of Duncan tests, showed that the LI was higher in the tachistoscopic session than in the anorthoscopic session for female participants ($p < 0.001$) and the difference was almost significant also for male participants ($p = 0.056$). Moreover, the LI was higher for female than male participants only in the tachistoscopic session ($p < 0.001$).

Finally, the significant interaction between Session and Gender of face ($F_{(1, 42)} = 17.399$, $MSE = 0.22$, $p < 0.001$, $\eta_p^2 = 0.29$) showed that the LI was higher in the tachistoscopic session than in the anorthoscopic session for both female/male ($p = 0.010$) and male/female faces ($p < 0.001$), and that only in the tachistoscopic session the LI was higher when the left face was male than female ($p < 0.001$). Finally, the LI was higher in female than male participants only in the tachistoscopic session ($p < 0.001$) when male/female chimeric faces were presented ($p < 0.001$).

Discussion

The most important finding of Experiment 4 was the absence of a Left-Face Bias, Primacy or Spatial Bias in the anorthoscopic condition. In this Experiment we presented the same stimuli both in anorthoscopic and tachistoscopic conditions in order to have the tachistoscopic condition acting as a baseline. The results confirmed an LFB in the tachistoscopic condition, supporting previous evidence (e.g. Voyer et al., 2012). The crucial difference between the anorthoscopic and the tachistoscopic presentation is that in the anorthoscopic paradigm participants have to analyse the entire visual image presented part by part, preventing the possibility that participants' attention is directly focused on the left hemiface. The serial, but complete, presentation of the chimeric stimuli in this condition allows us to infer about the mental representation of face and gender. Starting from the well-known attentional bias toward the left hemispace (pseudoneglect), which extends to representational space (i.e. imagery, memory; McGeorge et al., 2007), we could have expected that a mental representation of faces presented in anorthoscopy would have suffered from such a left representational bias. Our results

seem to suggest that such a representational bias does not exist for faces, or at least for facial gender. These findings contrast with previous evidence (Grega, Sackeim, Sanchez, Cohen, & Hough, 1988) showing a recency effect and an LFB, regardless of the direction of the chimeric faces motion. Primacy and recency effects are well-documented in the field of memory recall (Kelly & Risko, 2019; Greene, 1986) and it has been suggested that these effects could be concomitant (Miller & Campbell, 1959). However, our results showed that participants judgments were based neither on the first hemiface they had seen, nor on the last hemiface presented, thus excluding both the primacy and the recency effect.

In the tachistoscopic session, we found that the gender categorization is mainly based on the male than the female hemiface when located in left side of the space (male/female chimeric stimuli). These findings are in contrast with Parente and Tommasi (2008), who found an LFB for female faces, but they are consistent with previous evidence showing that less information is needed to recognize a male face than a female face (Cellerino et al., 2004), and that an evolutionary framework exists according to which males should be recognized faster to enhance the probability of survival (a gender stereotype according to which males are more aggressive than females; Cicone & Ruble, 1978). The tachistoscopic condition also revealed a gender difference, according to which female participants showed a stronger left bias than male participants. As highlighted previously, a number of studies showed a face recognition advantage and a faster face processing in females than in males (Bowles et al., 2009; Connellan et al., 2000; Godard & Fiori, 2010; Hall, 1978; Sommer et al., 2013), suggesting that this difference could be related to the greater attention towards social stimuli in females (Baron-Cohen, 2002). We can speculate that the female advantage in face processing, taken together with the well-established LFB in face perception and the right-hemispheric specialization in facial analysis, is the reason of the gender difference we found only in tachistoscopic presentation.

General discussion

The first aim of the present study was to assess the effect of the anorthoscopic presentation on the processing of one of the most common stimuli we perceive every day, human faces. The aperture viewing paradigm prevents the possibility to recognize faces even when observers can decide where they look (James, Huh, & Kim, 2010). However, our results are inconsistent with Haig's findings and they are consistent with the evidence suggesting that the features integration mechanism operates continuously in order to guarantee an efficient face processing. We showed that this paradigm does not prevent participants from correctly processing facial stimuli, at least as regards their gender, similar to Murphy et al. (2020).

As expected, Experiments 2 and 3 confirmed that performance improves when more information is available (larger aperture) and when it is available for a longer time (slower movement).

Holistic processing supports the idea that the visual system processes faces as an integrated perceptual whole, consisting of several features which are not separable from one another. If we assume that anorthoscopic presentation prevents holistic face processing, we should expect a performance not differing from the chance level. The present results revealed that the static aperture paradigm does not prevent participants to correctly categorize the gender of faces, possibly allowing a holistic processing despite the restricted amount of information available at any given time. An alternative explanation could be that gender categorization can exploit featural information, such as the analysis of the eyes and mouth (Brown & Perrett, 1993; Schyns, Bonnar, & Gosselin, 2002). According to this view, the anorthoscopic presentation could have facilitated a part-based analysis, allowing participants to serially focus on a specific portion of the facial image at a time.

As a number of studies confirmed the OGB (Skolnick & Shaw, 1994; Skolnick & Shaw, 1999; Prete, Fabri, Foschi, & Tommasi, 2016) mainly in females (Herlitz & Lovén, 2013; Lewin & Herlitz 2002), we also expected to obtain sex differences favouring female participants in gender categorization: females outperform males on face recognition tasks (Herlitz & Lovén, 2013), an evidence also confirmed by both neuroimaging works (Furl, Garrido, Dolan, Driver, & Duchaine, 2011; Tahmasebi et al., 2012) and studies on infants (Leeb & Rejskind, 2004). Some studies showed a variable pattern for male observers: for instance, Rehnman and Herlitz (2006) found an OGB only in male participants, whereas other studies indicated an advantage for female faces over male faces with male observers (Cross, Cross, & Daly, 1971; Ge et al., 2008). These findings are consistent with the results of Experiment 3, in which we found an OGB only in male participants. It has to be noticed, however, that a trend towards an OGB was present in both anorthoscopic tasks (Experiments 2 and 3), even if in each of them only one category reached statistical significance (females in Experiment 2 and males in Experiment 3). We also exploited chimeric faces as a tool to investigate the presence of side biases in facial representations. Due to the fact that in the anorthoscopic paradigm the stimulus is not presented in its entirety but it has to be mentally reconstructed in order for the participant to provide a response, we used this paradigm in order to evaluate the presence of the well-known Left-Face Bias in the domain of visual representation. In Experiment 4 we confirmed the expected LFB during tachistoscopic presentation of chimeric faces, but no bias was found when the same stimuli were presented in the anorthoscopic condition. This result shows that the perceptual LFB cannot be extended to the visual reconstruction of faces.

It has to be highlighted that all mental images involve both temporal and spatial components, and that in Western culture visual events or sentences depicting them are preferred when evolving from the left to the right side of space, with the subject performing action on the left side and the object undergoing action on the right side of space (Chatterjee et al., 1999). This means that individuals and objects are preferentially located according to our stereotypic belief related to agency (Maass, Pagani, & Berta, 2007). In this frame, our results are in line with the Spatial Agency Bias (SAB), suggesting that mental representations involve gender categorization: Experiment 2 showed that when the left key was associated to male faces the performance was better when stimuli moved from the bottom to the top, and the upper position in the visual field has been hypothesized to reflect the power of a group (Paladino et al., 2017; Schubert & Maass, 2011), so that we could speculate an implicit association between male stimuli and high power. On the other hand, when the left key was associated to female faces, the performance was better when stimuli moved from the top to the bottom (i.e. female faces associated to low power and agency according to the SAB). Accordingly, Experiment 3 showed that male faces were better categorized when presented from the left to the right side of the space and we can consider also this evidence in accordance with the stronger agency attributed to males with respect to females, as suggested by the SAB, concluding that spatial imagery and gender categorization are linked to stereotypic beliefs (SAB; Chatterjee, 2002; Maass et al., 2007).

Finally, in both Experiment 2 and Experiment 3 participants referred having noticed “something strange” in the stimuli. When asked informally to comment at the end of the experiment, many of the participants referred having perceived stimuli made of a half female and a half male face (as in chimeric faces). In this regard, we can speculate that this impression could be related to visual compression, suggesting that when an object moves behind a narrow slit an apparent compression occurs along the axis of motion (Anstis & Atkinson, 1967). It is possible that the spatial compression on the moving faces led to a kind of distortion of the percept, and to the following misrepresentation of the stimuli.

In the present study, we tested the observers’ ability to categorize female and male faces viewed while moving behind a static aperture, showing the image one section at a time.

In order to evaluate the possibility to generalize the present results to different aspects of face processing (beyond the gender categorization used here), future works could explore, by means of the anorthoscopic paradigm, (1) whether prosopagnosic patients (Avidan et al., 2011; DeGutis et al., 2014) and autistic patients (Behrmann et al., 2006), showing an impairment of holistic processing, are able to process identity (supported by high spatial frequency analysis/local processing) and emotional information (supported by low spatial frequency analysis/holistic analysis; Goffaux & Rossion,

2006); (2) whether a dissociation between emotion and identity recognition occurs; (3) whether the low-level perceptual abilities and the high-level ones, including imaginative and mental representation, are altered in prosopagnosic patients, according to the results found with neglect patients (Bisiach & Luzzatti, 1978); and (4) whether all of these findings can be generalized to different facial features (e.g., ethnicity, age, etc.) and to different stimulus categories (objects, scenes, bodies, etc.).

We can conclude that anorthoscopic viewing, in which the perception is partial and restricted, is a fruitful method to assess the capability to integrate different portions of objects over time and space, also in the case of complex stimuli such as human faces.

Faces have to be detected also in complex or cluttered visual scenes, and also when a small part of the face is visible due to occlusion. In all of these situations we can recognize the gender of a face, even when informative cues, such as hairstyle, are not visible (Bruce & Young, 1998). Understanding how we scan and perceive faces in such conditions and whether our judgments about gender, age or ethnicity are reliable, might be of crucial importance in perceptual psychology but also in forensic and eye-witness contexts (Wright & Sladden, 2003).

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