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The left side of gestures: left perceptual bias for meaningless hand gestures recognition is independent from handedness

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Abstract
The "Left Perceptual Bias" (LPB) is the effect for which the left side of a picture such as a face is used to a greater extent than its right side as shown in a wide variety of experimental tasks. This effect has been observed for faces, body parts and objects. The present work investigated the presence of a LPB in recognizing hand gestures in two experiments. The role of the side of stimuli presentation (left /right), stimuli orientation (palm/back), participants' handedness and gender were analyzed. Participants were presented with images of meaningless gestures performed by an actor with the right or left hand, from a palm or a back view. Immediately afterward, participants were shown a drawing and had to discriminate whether it represented the same gesture or not. In the first experiment, the task was administered to a sample of right-handed participants, half males. Results showed shorter response times for stimuli presented on the left side and for those shown from the palm. No gender differences were observed. The second experiment included a sample of left-handed participants and the LPB was replicated. Taken together, our results suggest an interpretation of the bias in terms of asymmetries in perceptual processing rather than the involvement of motor representations.

Keywords Left perceptual bias · Symmetry perception · Hand gestures perception · Visual perception

Introduction

A preference for processing the left side of an object has been observed for a wide variety of stimuli such as faces, objects and hands (Bourne, 2011; Hagemann, 2009). This introduction is aimed at describing existing literature on the topic, particularly focusing on the hypotheses present in the literature to explain this phenomenon. Moreover, the present study will focus on the perception of hands and gestures. Thus, the main aim of the present study is to disentangle between different hypotheses on the leftward preference for hands and gestures processing, particularly between perceptual and motor hypotheses.

The so-called "Left Perceptual Bias" (LPB) for faces, first described by Wolff (1933), was defined as the effect for which the left side of a visually presented face is used to a greater extent than its right side in a wide variety of experimental tasks such as face-matching tasks, identification of face identity, gender, age, attractiveness, and emotional expression (Bourne, 2011; Dunstan & Lindell, 2012; Gilbert & Bakan, 1973; Megreya & Havard, 2011). The bias has also been shown to be independent of the participant's age (Williams et al., 2016) and gender (Hugdahl et al., 1993). While a clear preference for the leftward stimulus has been observed in judgment tasks of simple low/mid-level visual perceptual stimuli (Charles et al., 2007; Nicholls et al., 1999), the presence of this effect in complex stimuli other than faces is less clear. In fact, a bias toward the left has been found for complex objects (i.e., Chinese characters), but only in participants familiar with those stimuli; consequently, it has been argued to be an object recognition's perceptual expertise indicator (Hsiao & Cottrell, 2009; Liu et

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al., 2018). Moreover, a recent study found a leftward preference in the judgment of attractiveness of stimuli patterns, discussing this result in favor of a generalization of the leftward bias to other non-facial stimuli relying on the integration of different features into a configuration (Rodway et al., 2019). However, a study measuring eye movements to different kinds of objects found that the majority of participants performed an initial saccade to the left when looking at faces but not at landscapes or symmetrical objects (Leonards & Scott-Samuel, 2005), suggesting that it is not simply an integration of features process, but that different configurations involve partially separate processes. Based on these premises, the leftward bias observed for a range of different types of stimuli has been interpreted differently according to the type of stimulus: in the case of low/mid-level visual perceptual stimuli, an attentional bias is believed to be in place (Nicholls et al., 1999), whereas with objects it could reflect expertise for complex visual objects (Hsiao & Cottrell, 2009). Finally, when patterns are involved it has been interpreted as the result of configural processing (Rodwat et al., 2019). In light of such different explanations, evidence of a leftward bias across stimuli and experimental paradigms causes controversies in finding a univocal explanation, giving rise to different theories.

An influential account, mainly in the domain of face processing, postulates that the described leftward preference is due to the right hemispheric dominance for this type of object. This allows stimuli presented on the left visual field to reach directly the right hemisphere where they are processed faster compared to those presented on the right visual field (Gilbert & Bakan, 1973). In agreement with this account, neuroimaging studies showed that the right hemisphere is specialized in judging human face identity and in processing facial expressions (Heilman, 2021) as well as for emotional processing (Demaree et al., 2005). Further support for this explanation comes from the fact that the right hemisphere is also generally specialized in visuospatial processing (Kinsbourne, 1970) and for the analysis of configurations, which are essential in face processing (Rhodes, 1993). This is also supported by neuroimaging studies (Yovel et al., 2008). Based on these studies, hemispheric specialization could account for leftward preferences observed for stimuli other than faces.

A partially similar account proposes that perceptual asymmetries can be explained as the result of the activation of a hemisphere in response to functions for which it is specialized, which in turn causes a bias in the attention directed to the contralateral visual space. Consequently, if the right hemisphere is activated by a task to a greater extent than the left hemisphere, attention in the hemifield on the left will be increased leading to greater importance of the left side of the item for perceptual judgment (Nicholls et al., 1999).

A further explanation that has been proposed for this effect is the scanning habits deriving from reading experience. In fact, the studies mentioned so far were conducted on participants reading from left to right and this could explain why participants attend to the left side of stimuli first (Havard, 2007). However, even though some studies on participants with right-to-left scanning habits showed no left perceptual bias (Sakhuja et al., 1996), others disconfirmed this result (Gilbert & Bakan, 1973). Thus, at least in the case of faces, the left perceptual bias is probably not primarily driven by scanning habits, as also confirmed by studies on 6-months-old babies and animals showing the bias on faces (Guo et al., 2009). In conclusion, as postulated by Megreya and Havard (2011) regarding face processing, scanning habits might interact with the left perceptual bias.

All the theories summarised above for the bias can be roughly grouped into general visual perceptual theories for the explanation of the bias. On the other hand, leftward bias has also been explained by a motor account. This is particularly true for a leftward preference observed for hands.

A preference for the left side has indeed been shown for other parts of the human body, particularly for hands. It has been observed in a task where participants had to predict movements performed with the right or left hand (Hagemann, 2009): results show that they were better able to predict the outcome of movements performed with the observed right hand. Moreover, it has been observed in a task where participants had to judge the orientation of an ambiguous silhouette, which was judged more often as right- than left-handed (Marzoli et al., 2015) and this effect was more pronounced when stimuli were presented in the right hemifield than in the left both for static (Marzoli et al., 2017a, b) and spinning figures (Lucafò et al., 2021). The authors explain this effect in terms of preference for the right hand of observed people. This has been linked to the advantage given by looking at the limb most often used by right-handers when gesturing and in potential aggressive behaviors (Marzoli et al., 2014).

This has been explained by what we can call a motor account: according to the common coding hypothesis (Hommel et al., 2001), when we perceive and perform an action there is an activation of the same motor representations, suggesting that to understand an action people map it into their own repertoire of actions. In support of this, there are also motor simulation theories stating that in order to understand actions we simulate them (Blakemore & Decety, 2001). However, the fact that left-handers, as well as right-handers, showed a bias towards the right hand both in predicting the outcome of an action (Loffing & Hagemann, 2020) and in judging the orientation of silhouettes (Marzoli et al., 2017a, b), argues in favor of the involvement of visual rather than motor processes in this asymmetry (Lucafò et al., 2021; Marzoli et al., 2017b). On the other hand, there are studies favoring the Common coding hypothesis: Constant and Mellet (2018), using the Bergen Left-Right Discrimination test (Ofte & Hugdahl, 2002), found that left-handers were faster when processing the left hand rather than the right. Also, Gardner and Potts (2010) found that left-handers show an attentional bias towards others' left side of the body while it is the opposite for right-handers. Differences in left- and right-handers were further observed in motor imagination studies (Marzoli et al., 2011, 2013). A differentiation between the two explanations of the bias may also be potentially accounted by the viewpoint of the subject. In fact, as suggested by Choisdealbha & Nuala Brady, 2011, the engagement of visuo-sensorimotor rather than only visual processes might be accounted by the view of the stimuli with an egocentric rather than an allocentric perspective. On the other hand, other authors find mixed results also by using allocentric perspectives (Cheng et al., 2020).

In sum, the presence of a leftward preference for the observed right hand is still unclear, as are its potential explanations: on the one hand, it could be due to visual perceptual processes similar to those involved in the left perceptual bias for faces, while on the other it could be due to a motor representation of the action, as suggested by the common coding hypothesis. It must be noted that the literature on gesture processing mainly focuses on meaningful gestures. Gestures are used both in the production and comprehension of speech: the importance of such gestures is highly influenced by individual differences (e.g., ethnicity, linguistic proficiency, and linguistic status of the speaker). Moreover, gestures can help in communication in case of reduced cognitive abilities (Ozer & Goksun, 2020). However, in the present study, we focused on gestures that are meaningless and lateralized: this will help us understand more basic components of gesture processing, net of meaning, and consequent semantic processing.

Our first aim was to verify the presence of a left side advantage in discriminating between hand gestures; the second aim was to clarify the reason for such a left perceptual bias. In particular, we wanted to disentangle between different explanations: on one side a lateralization of body part processing as observed in left perceptual bias for faces vs. a visuo-motor representation of the dominant hand.

We aimed at doing so by presenting our participants with a task of meaningless gesture recognition. We decided to use those stimuli as, if we detect a bias in the recognition of meaningless gestures, this bias might not be directly linked to the engram of an action. In fact, it might be true that to recognize meaningful gestures we simulate them (Blakemore & Decety, 2001), but it might also be that with meaningless actions a perceptual analysis is more likely. A potential leftward bias then could be equally interpreted as a motor and as a perceptual bias.

Since it has been shown that hands are processed with faster response times and greater accuracy in their back compared to their palm (Zapparoli et al., 2014), we included this experimental manipulation. It has been suggested that the palm/back distinction could be related to mental rotation abilities and, as mental rotation abilities have been differentiated in males and females (Boone & Hegarty, 2017; Toth & Campbell, 2019; Voyer et al., 2020), we also controlled for the role of gender on recognition of meaningless gestures and on the palm/back distinction by doubling the size of the sample. This allowed us to assess the role of sex in this ability. The literature proposes that males perform better than females in mental rotation tasks. Thus, we expected our results to go in the same direction as in the literature.

Moreover, we administered the same experiment to a sample of left-handed participants to better understand the role of motor simulation.

In Experiment 1, we showed meaningless gestures performed by an actor, expressed by the right or left hand, with the palm or the back hand, and we asked a group of right-handed participants to recognize them when presented as a schematic drawing. We expected to find a leftward bias where gestures encoded on the left side of the actor's body were recognized with faster reaction times compared to those presented on the right side. As much controversy is present in the literature on the role of hand dominance in a leftward bias in gesture processing, Experiment 2 aimed at investigating the role of hand dominance on the leftward bias. The same paradigm for gesture recognition was administered to left-handers. If a simulation of gestures (motor hypothesis) was activated and was responsible for the asymmetry, an opposite bias should have been shown by left-handers. On the other hand, if the left bias was due to the perceptual processing, we expected to find no differences between left and right-handers.

Methods

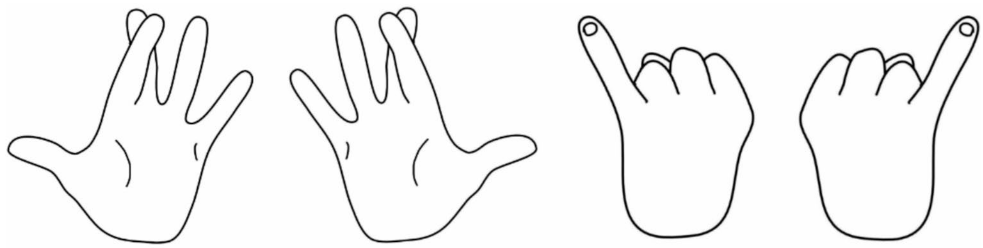
Experiment 1

Introduction

A leftward bias has been observed for different visual categories among which body parts such as faces and hands (Bourne, 2011; Hsiao & Cottrell, 2009; Hagemann, 2009). Regarding hands, studies in the literature find a better ability in predicting movements performed with the observed right hand (Hagemann, 2009) together with an attribution of right-handedness to ambiguous silhouettes (Marzoli

Fig. 1 From left to right: example of a meaningless gesture performed with the left hand in palm-view; example of the same gesture performed with the right hand; example of a meaningless gesture performed with the left hand in back view; example of the same gesture performed with the right hand

Fig. 2 The stylized version of the gestures from Fig. 1. These types of stimuli were used as recognition stimuli and appeared right after the picture



et al., 2015). However, it is not clear if this bias can be observed also when hands simply represent visual gestures, and no prediction of motion is asked to participants. Thus, in Experiment 1 we aimed at investigating the presence of a left perceptual bias in the recognition of meaningless gestures. As in the literature better performance has been reported in processing hands' back compared to their palm (Zapparoli et al., 2014), we also wanted to account for this factor. As hands shown through their palm and their back were used as stimuli, we also wanted to investigate participants' mental rotation ability. In fact, it might be that this variable influences performance in the task. In addition, as mental rotation has been shown to be different in male and female participants (Boone & Hegarty, 2017; Toth & Campbell, 2019; Voyer et al., 2020) in favour of males, we felt it was important to also control for sex differences. That is why we collected a double sample: to allow us to investigate potential sex differences.

Participants

48 right-handed participants (half females) took part in the experiment (mean age = 24; sd = 1.54, range = 19–30).

Participants were recruited from among the student population and through the personal contacts of the researchers. To determine their hand dominance, participants filled out an Italian handedness questionnaire similar to the Edinburgh Handedness Inventory (Salmaso & Longoni, 1985).

The only applied exclusion criteria other than hand dominance was that of not having neurological or psychiatric disturbances. They were tested at University of Milan-Bicocca and Libera Università Maria Ss. Assunta (LUMSA) University of Rome. The reported research protocol was approved by the ethical committee of University of Milan-Bicocca, and written informed consent was obtained from all participants.

Stimuli

Stimuli were 36 photographs of a man displaying 18 different hand gestures (Fig. 1). Each gesture was presented twice: once with the left hand and once with the right hand. Moreover, each gesture represented the hand once from a palm view and once from a back view. Thus, 72 stimuli were presented in total. Response stimuli were the same gestures represented in the pictures but represented as stylized drawings of hands (Fig. 2). Drawings were used to make sure that participants were recognizing the gesture instead of performing a perceptual matching. By presenting drawings rather than photographs, we aimed to encourage participants to engage in higher-level gestures recognition, rather than relying on visual similarity of perceptual stimuli. From now on, when referring to the stimuli we will always consider them as viewed by the participant.

Procedure

After a practice trial, participants were administered an experimental paradigm consisting of 72 trials, repeated four times each. In each trial, participants saw a fixation cross for 200 ms; afterward, they saw the man displaying a hand gesture for 500 ms. Then the stylized drawing of a hand appeared, and they had to answer whether the gesture was the same as in the picture or different pressing, respectively, the "B" or the "N" key with their dominant hand. Those keys were chosen as they are close to one another: this allowed participants to use only their dominant hand to respond. "B" represented the correct response for half of the participants, while for the other half the correct response was denoted by "N". Participants were instructed to respond as fast as they could and a timeout for the response screen was set at 2500 ms. In half of the trials, the drawing represented the same gesture as the one presented in the picture and in the other half a different gesture was presented. Order of presentation was counterbalanced. For a visual representation of the experimental paradigm, see Fig. 3.

Aside from the experimental paradigm, participants also performed a mental rotation task. The task was based on Shepard & Mezler stimuli and retrieved from Inquisit test library (Ganis & Kievit, 2015). Within this task, participants are exposed to images of two 3D cube objects and are asked to decide whether the cube objects are the same or the mirror version of each other. 12 cube objects are presented and can be rotated by 0, 50, 100, or 150 degrees. Thus, the task consists of 12 cube objects presented in 4 rotation angles for 2 categories (same vs. mirror images).

Statistical analyses

The effect of the side of the presentation of stimuli on response times was tested using a linear mixed model using R (R Core Team, 2016), the nlme package (Pinheiro et al., 2017), the emmeans package (Lenth, 2019) and the sjstats package (Lüdecke & Lüdecke, 2019). The experimental factor side of presentation (left vs. right), hand view (back vs. palm), their interaction, and the experimental factor sex (female, male) were entered as fixed factors in a linear mixed model predicting response times. When referring to left or right in the analyses we always refer to the side of the stimulus when viewed by the participant. Moreover, scores in the test of mental rotation were entered as a covariate. To combine accuracy and reaction times on the mental rotation task, the Inverse Efficiency Score was considered (Townsend & Ashby, 1978). The Inverse Efficiency Score is a score that combines reaction times and accuracy by dividing RTs by accuracy. This was done after checking that RTs and accuracy did not yield different results when considered separately (Bruyer & Brysbaert, 2011). Random coefficients were both single participants and the single items presented. To reduce skewness and Kurtosis of our response times, their logarithm was considered. Marginal pseudo-R2 was calculated for fixed effects, using the MuMIn package (Barton, 2018). This is because mixed-effect models have two different types of explained variance (R2): the first represents the variance explained by the fixed effects (i.e. marginal R2) and the second represents the variance explained by both fixed and random factors (i.e. conditional R2). Marginal pseudo-R2 was calculated through a hierarchically

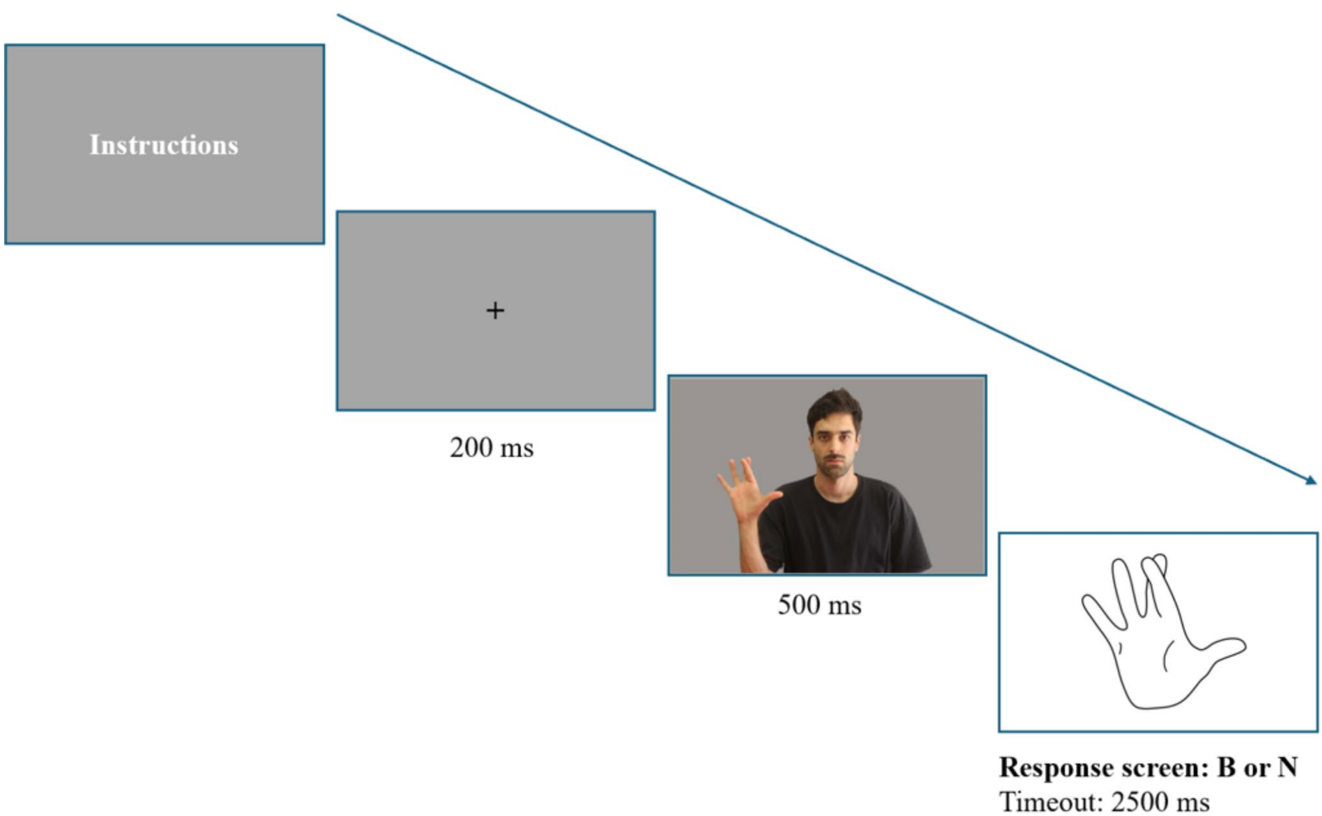


Fig. 3 Graphical representation of the experimental procedure

nested procedure starting from a model without fixed effects containing all the random intercepts and adding fixed terms one at a time (following the procedure used by Di Sarno, Costantini, Richetin, Preti & Perugini, 2022). Based on this procedure, the effect size of each term is defined as the change in marginal R2 between a nested model and the previous.

Results

Results indicated that there is a significant main effect of side of presentation of stimuli on response times ($F_{(1,1677)}=56.54$, $p<0.0001$, $R^2=0.004$, SE = 0.007, estimate = 0.03, 95% CI = lower: 0.013, upper: 0.04). Post-hoc tests revealed significantly lower response times for stimuli presented on the left side (mean = 805.25, sd = 309.37, median = 729.78) compared to those presented on the right side (mean = 837.75, sd = 321.96, median = 756.94) (t=-7.534, $p<0.0001$). Also the hand view factor resulted in a significant main effect ($F_{(1,1677)}=5.27$, $p=0.02$, $R^2=0.0004$, SE = 0.007, estimate = -0.023, 95% CI = lower: -0.037, upper: -0.009). Post-hoc tests revealed significantly lower response times for hands seen through their palm (mean = 815.96, sd = 310.06, median = 739.51) compared to those of hands seen through their back (mean = 827.04, sd = 322.02, median = 764.26). Interestingly, a significant interaction was observed between side of presentation of the stimulus and hand view ($F_{(1,1677)}=5.14$, $p=0.02$, $R^2=0.0004$, SE = 0.01, estimate = 0.023, 95% CI = lower: 0.003, upper: 0.043). Figure 4 shows a graphical representation of the interaction. The difference between palm and back view is not significant when hands are presented on the right side of the observer (t = 0.019, $p=0.98$) while this difference is significant when they are presented on its left side (t = 3.221, $p=0.001$).

Mean accuracy for the mental rotation task was 0.74 (sd = 0.165), mean reaction time was 2718.23 ms (sd = 858.52). Their combination through Inverse Efficiency Score led to a mean IES of 3859.11 msec (sd = 1683.11). However, the effect of the covariate relative to mental rotation was not significant ($F_{(1,45)}=1.76$, $p=0.19$, $R^2=0.01$, SE = 0.00001, estimate = 0.00023, 95% CI = lower: -0.00001, upper: 0.00058). Even the main effect of sex is not significant even though it shows a trend towards significance ($F_{(1,45)}=3.65$, $p=0.06$, $R^2=0{,}02$, SE = 0.047, estimate = -0.088, 95% CI = lower: -0.183, upper: 0.006). Mean response times for males were 779.72, sd = 284.67, median = 715.49; mean response times for females were 863.28, sd = 339.65, median = 777.88. Eventually, mean dominance handedness score was 26.46 (sd = 60.45).

Discussion

Experiment 1 had two aims: the first one was that of investigating the presence of a left perceptual bias in recognizing meaningless hand gestures and if there are differences in hand orientation. Results of experiment 1 confirmed the presence of a left perceptual bias: gestures presented on the

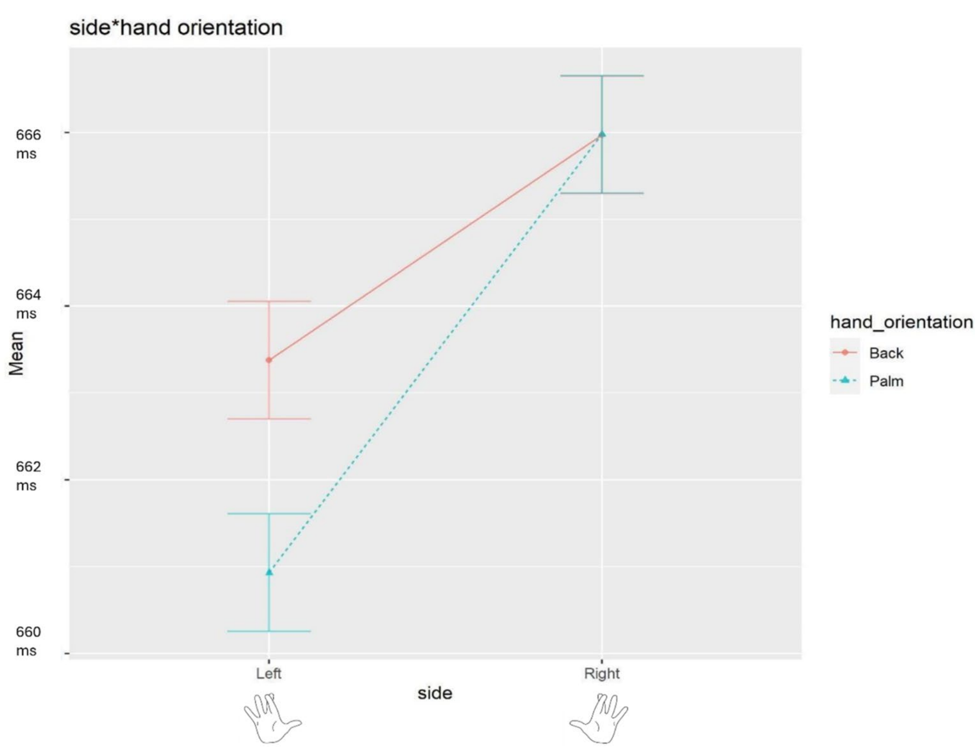


Fig. 4 Graphical representation of the side of presentation of stimuli (left and right) in interaction with hand orientation (palm and back). When using left we mean the left side of the observed stimuli and not the left hand of the man presented in the picture

left side were processed faster than those presented on the right side. Moreover, faster reaction times were observed when hands were seen through their palm, and this happened only when hands were seen on the left side of the observer.

The second aim of the present study was that of controlling for the potential role of sex in this observed effect. Results do not reveal any effect of sex in our task. This might be due to the fact that mental rotation does not significantly affect the presented task, as shown by the fact that the covariate relative to this task was not significant. If this is the case, even if sex differences in mental rotation tasks are true, they do not impact the task.

In summary, with experiment 1 we confirmed a left perceptual bias for meaningless gestures and that gestures seen through their palm are recognized faster than those seen through their back. Moreover, we made sure that sex differences did not account for this result. In experiment 2 we wanted to disentangle different possible explanations for this bias. This bias might be accounted as a perceptual bias, as reported for faces or as a motor bias caused by motor simulation of gesture for its comprehension. Thus, in experiment 2 we tested a group of left-handers with the same experiment.

Experiment 2

Introduction

As stated in the general introduction, different hypotheses have been proposed to explain the leftward bias observed for hands. The two main groups of explanations we will focus on are the visual perceptual and the motor one. According to a visual perceptual account, a leftward bias in processing hands might be explained by a preferential perceptual processing of the left side of the observed stimulus. This, in turn, might be caused by right hemispheric dominance (Gilbert & Bakan, 1973; Nicholls et al., 1999) or by an evolutionary preference for the most commonly acting part of the observed body (Marzoli et al., 2014). On the other hand, leftward preference for the observed left gesture might be explained by a motor simulation account stating that either when we perceive or perform an action there is an activation of the same motor representations, suggesting that to understand an action people match it with their own repertoire of actions (Hommel et al., 2001). Experiment 2 is aimed at disentangling between these two explanations by administering the same procedure as in experiment 1 to a sample of left-handed participants and comparing their results with those of right-handers. If the visual perceptual account is the preferential explanation for the bias, we would expect left-handed participants to show the same results as the right-handed ones. On the other hand, if the motor explanation is true, we would expect left-handers to show opposite results compared to right-handers. Indeed, the motor simulation theory assumes that the observer takes the perspective of the observed person to simulate the action. Thus, if the participant is left-handed, he/she should pay more attention to the observed right side.

Participants

24 left-handed participants (half females) took part in the experiment (mean age = 24.04; sd = 3.07, range = 19–30). Participants were recruited from among the student population and through the personal contacts of the researchers. To determine their left-hand dominance, participants filled out an Italian handedness questionnaire similar to the Edinburgh Handedness Inventory (Salmaso & Longoni, 1985).

The only applied exclusion criteria other than left handness was that of not having neurological or psychiatric disturbances.

As in the first experiment no significant effects of sex were found, we did not test a double sample again and thus we did not investigate for sex differences. However, the sample of the present experiment was still balanced across sexes. They were tested at University of Milan-Bicocca and Libera Università Maria Ss. Assunta (LUMSA) University of Rome. The reported research protocol was approved by the ethical committee of University of Milan-Bicocca, and written informed consent was obtained from all participants. To determine their hand dominance, participants filled out the Italian version of the Edinburgh Handedness Inventory (Salmaso & Longoni, 1985).

Stimuli and procedure were the same as in Experiment 1 (2.1).

Statistical analyses

The effect of the side of the presentation of stimuli on response times was tested using a linear mixed model using R, as in Experiment 1. The experimental factor side of presentation (left vs. right), hand view (back vs. palm), and their interaction were entered as fixed factors in a linear mixed model predicting reaction times. Random coefficients were both single participants and the single items presented.

Results

Results indicated that there is a significant main effect of side of presentation on response times ($F_{(1,837)} = 42.64$, $p < 0.0001$, $R^2 = 0.006$, SE = 0.01, estimate = 0.039, 95% CI = lower: 0.018, upper: 0.059).

Post-hoc tests revealed significantly lower response times for stimuli presented on the left side (mean = 840.05, sd = 328.81, median = 754.33) compared to those presented on the right side (mean = 877.77, sd = 342.55, median = 783.84) (t=-7.531, $p < 0.0001$). No main effect of hand view was observed ($F_{(1,837)} = 2.80$, $p = 0.09$, $R^2 = 0{,}0004$, SE = 0.01, estimate = -0.021, 95% CI = lower: -0.041, upper: -0.001) nor interaction between side of presentation and hand view ($F_{(1,837)} = 1.57$, $p = 0.2105$, $R^2 = 0.0002$, SE = 0.015, estimate = 0.018, 95% CI = lower: -0.01, upper: 0.047). Mean dominance handedness score was −48.40 (sd = 40.19). In addition, we also estimated the proportion of right and left-handers showing lower response times for stimuli seen on their left compared to those seen on their right side. This was meant to explore our results beyond the statistical significance of the comparison for the left and right side. We wanted to see whether we could observe qualitative differences in the proportion of participants showing leftward bias for right- and left-handers. For right-handers, 90% of participant showed a leftward bias while for left-handers 88% of participants showed a leftward bias.

Discussion

Experiment 2 was aimed at disentangling between different potential explanations for the leftward bias observed in processing hand gestures. Left-handers showed the same leftward bias as right-handers. These results go in the direction of a perceptual explanation of the bias rather than a motor one. This is because if a motor explanation was true, left-handers would simulate the observed gesture using the left hand preferentially. This would have led to a preference for the observed left hand, falling on the observer's right side.

General discussion

The present work aimed at investigating the presence of a leftward bias in the recognition of meaningless hand gestures and whether this bias might be better explained in terms of a perceptual process or as the consequence of a motor simulation. To do so we conducted two separate experiments: the first experiment was administered to a sample of right-handed young adults who were asked to recognize meaningless hand gestures performed by an actor with either his left or right hand, on a palm- or back-view. A bias towards the recognition of the observed right hand, falling on the observer's left side, was found as well as a preference for hands seen through their palm; moreover, the advantage of seeing hands from their palm was stronger when hands were presented on the observer's left side. Moreover, no effects of mental rotation nor sex were observed to influence the results. In the second experiment, we administered the same experimental paradigm to left-handed participants. This was meant to investigate whether the observed bias had a perceptual or motor nature. As a matter of fact, if the bias observed in the first experiment is linked to a motor simulation of the observed gestures (Hommel et al., 2001), we would have expected left-handers to show a bias in the opposite direction compared to right-handers. On the other hand, if the bias has a perceptual origin, we would have expected left-handers to show the same bias as right-handers. A preference for the observed right hand falling leftward was indeed observed in left-handers.

The finding of a leftward bias for gestures in right-handers is coherent with results obtained on different tasks involving hand processing such as prediction of movements (Hagemann, 2009) or judging the orientation of an ambiguous silhouette (Marzoli et al., 2015, 2017a, b; Lucafò et al., 2021). A left perceptual bias has been consistently observed for face identity recognition (e.g., Coolican et al., 2008; Guo et al., 2012) and the fact that we observe it for hand gestures might reflect a similar mechanism in the processing of faces and hands. This explanation is in line with neuroimaging studies showing a specificity in the neural response to hands, similarly to what has been observed for faces (Bracci et al., 2010; Santo et al., 2017; Conson et al., 2020). This assumption can be further corroborated by the observation of an inversion effect in judgment about the handedness of observed bodies (Marzoli et al., 2017a, b), implying a configural processing of bodies similar to faces. Such evidence points in the direction of an implication of similar mechanisms for leftward preference for faces and gestures. It is also true that a leftward preference has been observed in recognition tasks concerning other types of stimuli than faces or body parts (Rodway et al., 2019; Liu et al., 2018) but not much research on the topic is present. Moreover, studies finding a leftward preference in recognition tasks on complex visual stimuli other than faces or hands highlight the possibility that the bias is present when configural processing (Rodway et al., 2019) or expertise (Liu et al., 2018) are required. Thus, if it is true that hands and faces are special stimuli that are processed configurally and subjected to expertise, these results are not in contrast with the potential specificity of the bias for faces or hands.

The fact that we observed shorter response times for hands seen through their palm rather than their back is partially in contrast with literature showing faster reaction times in processing back-view stimuli. However, the tasks where this effect is observed are different from the task we administered in the present experiment requiring a left-right judgment (Constant & Mellet, 2018) and motor imagery (Zapparoli et al., 2014) and their different origin might imply different processing mechanisms. Both those types of tasks might have required a motor simulation. On the other hand, when a task requires visual rather than motor processes the opposite bias is observed: in tasks on judgment of ambiguous silhouettes (Marzoli et al., 2015, 2017a, b) stimuli are more frequently interpreted as front rather than back facing. The authors interpret this as the result of the fact that approaching humans are likely to convey a potential threat more than receding ones and for that reason are processed preferentially (Schouten et al., 2010). The results of the present experiment could be due to the same principle: it might be that palm gestures are more frequently threatening compared to back-view gestures and that is the reason why they are processed faster.

The fact that the facilitation of gestures seen through their palm is enhanced when stimuli are presented on the left compared to right side of participants could be then interpreted as a result of easier processing of both types of stimuli (right hands and palm view/front-facing gestures).

The results discussed so far go in the direction of a visual rather than a motor bias towards the left in hand gestures processing and this explanation is further sustained by the fact that left-handers show the same bias as right-handers. The literature concerning hand processing in left-handers compared to right-handers is mixed: there are studies finding handedness differences in tasks such as left-right judgment (Constant & Mellet, 2018) or in action imagination (Marzoli et al., 2011, 2013) while others do not find differences between right and left-handed participants (Marzoli et al., 2015, 2017a, b). Again, we argue that those results are not in contrast with one another if we consider the nature of the administered tasks: when tasks imply visual rather than motor processes, their results point in the direction of the same bias for left and right-handers while tasks concerning motor processes reveal a difference in the bias for left and right-handers.

However, it still remains to be understood what is the origin of the bias. A common explanation for the bias is hemispheric dominance. In light of the current results, the observed leftward bias is unlikely to occur as a result of hemispheric dominance. This is because neither hand processing nor hand gesture processing seem to be localized on the right hemisphere (Bracci et al., 2010; Santo et al., 2017; Villarreal et al., 2008) and thus could not explain a bias towards the observed left side but would be more in line with an opposite bias. Moreover, we find the same effect on right and left-handers. We know that left-handers can show different lateralization of a very well known lateralized function as language (Khedr et al., 2002). It is not clear yet whether an opposite lateralization in left- compared to right-handers occurs also for other cognitive functions (Karlsson et al., 2019). In the case of chimeric faces, a bias towards the left has been found for both right and left-handers; however, a recent metanalysis showed a reduced effect for left-handers and attributed this to the possibility of an opposite lateralization of function in those left-handers who do not show the bias (Karlsson et al., 2019). In our case, however, we found a very similar proportion of participants with both handednesses showing lower response times for gestures seen on their left compared to right side, so we are not inclined to attribute the observed bias to hemispheric specialization.

Our results are also difficult to be interpreted as an attentional asymmetry as in Nicholls' attentional hypothesis (Nicholls et al., 1999) the bias is still indirectly caused by hemispheric lateralization of function.

On the other hand, the present findings are in line with the explanation given by Marzoli and colleagues (2014) who postulate that there might be an evolutionary advantage in preferentially processing the observed right hand. This is because the large majority of the population is right-handed (Papadatou-Pastou et al., 2020) and thus the right side of the observed body is likely to be more informative than the left. For the same reason, it could be that palm gestures are more frequent and thus more informative than back ones, even though we do not observe this effect in left-handers. The latter result, however, might be due to the smaller numerosity of the left-handers' sample.

Eventually, differences in the lateralization of different types of gestures have been observed in right-handers who perform different types of gestures with different hands (Helmich et al., 2022). On the contrary, left handers have shown less lateralization for different types of gestures. Thus, the fact that we do not observe handedness differences in the bias might be due to a basic component common to left- and right-handers or, rather, it might be the consequence of differential processing of gestures in right- and left-handers, leading to the same phenomenon. Eventually, it might be that the presented results are influenced by the left-to-right scanning habits of our participants; thus, future research on right-to-left reading populations is needed to clarify this point.

A further consideration must be made: it might be that a leftward bias is specifically observed for stimuli that can involve motion perception as happens for facial expressions and gestures communication. It might be that the bias is more specific for motion perception than for general visual perception. We know from the face literature that processing static and dynamic faces imply at least partially separate mechanisms (O'Toole et al., 2002) and even different movements (e.g., dynamic facial expressions vs. rigid head movements) seem to imply separate mechanisms (Gobbo et al., 2024). Thus, future research might explore potential differences between left perceptual bias on static vs. dynamic hand gestures. Future research could verify this speculation.

In conclusion, in the present experiment, we observed a leftward preference for meaningless hand gestures both for right-handed males and females. Right-handers also showed a preference for palm-view hand gestures compared to back-view and this effect was more pronounced on the observed left side. Moreover, left-handers showed the same leftward preference as right-handers indicating that the observed bias is more likely to have a visual rather than a motor origin.

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Data availability The data that support the findings of this study are openly available in the OSF at the following link: https://osf.io/y7zge/?view_only=a642aff9df5d47a89879adb070c17e70.

Declarations

Competing interests The authors have no relevant financial or non-financial interests to disclose.

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