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Visual exploration of emotional body language: a behavioural and eye-tracking study

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Abstract

Bodily postures are essential to correctly comprehend others' emotions and intentions. Nonetheless, very few studies focused on the pattern of eye movements implicated in the recognition of emotional body language (EBL), demonstrating significant differences in relation to different emotions. A yet unanswered question regards the presence of the "left-gaze bias" (i.e. the tendency to look first, to make more fixations and to spend more looking time on the left side of centrally presented stimuli) while scanning bodies. Hence, the present study aims at exploring both the presence of a left-gaze bias and the modulation of EBL visual exploration mechanisms, by investigating the fixation patterns (number of fixations and latency of the first fixation) of participants while judging the emotional intensity of static bodily postures (Angry, Happy and Neutral, without head). While results on the latency of first fixations demonstrate for the first time the presence of the left-gaze bias while scanning bodies, suggesting that it could be related to the stronger expressiveness of the left hand (from the observer's point of view), results on fixations' number only partially fulfil our hypothesis. Moreover, an opposite viewing pattern between Angry and Happy bodily postures is showed. In sum, the present results, by integrating the spatial and temporal dimension of gaze exploration patterns, shed new light on EBL visual exploration mechanisms.

Introduction

Bodily postures are crucial to correctly grasp others' emotions and intentions (e.g., Calbi et al., 2017; Proverbio et al., 2014; de Gelder, 2009; de Gelder et al., 2010). Albeit a growing body of literature about the processing of emotional body language (EBL) has appeared in the last years, very few studies focused on the pattern of eye movements implicated in the recognition of EBL.

To our knowledge, the first study aimed at investigating the gaze patterns associated with the perception of EBL was presented at a symposium only ten years ago (Fridin et al., 2009). The authors selected body postures expressing four different emotions (joy, sadness, anger and fear) and their results demonstrated significant differences among the visual exploration patterns in relation to the different emotions. Specifically, when perceiving angry and fearful body postures, participants mainly gazed at the hands and the arms, whereas for happy body postures, they focused on the head.

A few years later, Mariska Kret and colleagues (2013b) published a study on the recognition of emotions from both faces and bodies, isolated or combined together as compound stimuli. Participants' eye movements were recorded while performing three different categorization tasks. On the basis of their results, the authors concluded that angry and fearful expressions attract more attention than happy expressions, suggesting a preferential way in focusing the attentional resources to potentially dangerous stimuli. In this regard, the authors pointed out that an interesting explanation is provided by the motivated attention theory (Lang et al., 1997; Bradley et al., 2003) which considers emotion as organized by two evolutionarily old motivational systems (i.e. defensive and appetitive). Hence, angry and fearful expressions, characterized by negative valence and high arousal, can be recognized as motivationally relevant

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stimuli activating the defensive system and, for this reason, capable to increase the activity in the visual cortex (Bradley et al., 2003). Moreover, the recognition of facial and bodily expressions is enhanced when they are emotionally congruent, demonstrating how they can exert a reciprocal influence, in both directions (Kret et al., 2013b).

Although developed to explore how socially anxious individuals attend to emotional stimuli, a recent study from Kret and colleagues (2017) showed interesting results about the gazing patterns adopted while viewing different emotional bodily postures (fearful, angry or happy). Specifically, participants were asked to label the bodily expressions (with blurred face) in a three-alternative forced-choice task while their eye movements were recorded. The analyses on the proportion of time spent looking at two specific regions of interest (hands and head) revealed also that when looking at negative bodily postures, participants spent more time gazing at the hands than at the head, and this was particularly true for high socially anxious participants. The authors hypothesized that this latter result could be explained by the tendency of high socially anxious individuals to avoid eye-contact, which is compensated by enhanced attention to body-regions and particularly to the hands (Kret et al., 2017).

In this regard, it has been recently suggested that, albeit previous evidence showing that the hands and the arms are crucial elements to express and identify emotions from the body (Witkower & Tracy, 2018; Cartmill et al., 2012; Dael et al., 2012; Wallbott, 1998), the extent to which hands position or posture influence emotion recognition is still unknown (Ross & Flack, 2020). For this reason, Ross and Flack asked participants to categorize the emotion of static bodily postures (fearful, angry, happy and sad) *with either the hands, arms, or both components* deleted. Results demonstrated that the removal of the hands, but not of the arms, negatively influenced recognition accuracy for fear and anger only. These results suggest the specific and crucial role that the hands have in the expression and recognition of threat-based emotions, likely due to the strong hand motor component characterizing such emotions (Ross & Flack, 2020; de Gelder et al., 2004; Pichon et al., 2008).

Very recently, Pollux and coworkers (Pollux et al., 2019) investigated whether gaze behaviour while viewing different whole-body expressions (with visible or invisible faces) is influenced not only by the emotional cues but also by the dynamicity of the bodily postures. Their results showed that, despite subtle differences across emotions in the viewing behaviour, participants adopted a uniform strategy for both static and dynamic displays, by focusing their attention to the upper body (i.e. head, torso and arms). Surprisingly, they also revealed a *"stronger face bias in dynamic compared to static displays when faces were visible"*. These results remind us of another line of eye-movement research recently emerged to investigate which kind of visual and perceptual process (i.e., feature or configuration) contribute to visual body discrimination (e.g., Tao & Sun, 2013; Arizpe et al., 2017). Interestingly, through the investigation of the body inversion effect (e.g., Reed et al., 2003) in whole and headless bodies, Arizpe and colleagues (2017) demonstrated that, while looking at upright body postures, the density of fixations was higher on the head and torso (i.e. upper body), while looking at inverted ones, the density was higher on the pelvis area. Furthermore, although their results indicated the highly discriminative role of the head in the context of bodies visual processing, it clearly emerged that the head presence was not necessary for the body inversion effect to come. Bearing in mind that other authors reported the reduction or the extinction of the body inversion effect for headless bodies (Minnebusch et al., 2009; Brandman & Yovel, 2010; Yovel et al., 2010), further studies are needed to clarify this aspect. This, together with the evidence of a large body of literature showing a rapid and tight integration of emotional signals from faces and bodies (e.g. Kret et al., 2013a; Meeren et al., 2005; Rajhans et al., 2016; Wang et al., 2017), led us to employ in the present study only headless bodies, to investigate the eye-movements pattern strictly associated with emotional body postures and not influenced by the presence of the face/head.

An interesting and yet unanswered question regards the presence of the "left-gaze bias" while scanning bodies. This bias is usually expressed by more fixations/longer viewing time on the left side of centrally presented faces (from the observer's point of view; i.e. the anatomical right side). By now, it is also known that the same bias is expressed by a faster inspection of the left side of centrally presented faces (from the observer's point of view) (e.g., Guo et al., 2009, 2012; Butler et al., 2005). For instance, Guo and colleagues (2012) wrote that the anatomical right side of the observed face "is often inspected first and for longer periods". Their results demonstrated a higher probability that this side of the face (i.e. anatomical right side—left side from the observer's point of view) be inspected at the initial stage of face viewing (Guo et al., 2012). More recently, Calvo et al. (2019) pointed out that the systematic tendency to look first at the left side of a face (from the observer's point of view) reflects the natural left-gaze bias (Calvo et al., 2019). It has been argued that the left-gaze bias is due to the dominance of the right hemisphere for both facial and configural processing (e.g., Rossion et al., 2003; Anes & Short, 2009). Other authors hypothesized that this bias is the result of the interaction between the hemispheric lateralization and a directional bias of visual scanning process, consolidated during the evolution (Vaid & Singh, 1989; Chokron, 2002). Leonards & Scott-Samuel (2005) argued that the left-gaze bias could specifically take place for socially relevant stimuli, and this idea could be confirmed by studies indicating that the higher is the emotional load of both stimuli and task, the more emphasized is the polarization to the left of an observed face (e.g., Mertens et al., 1993; Thompson et al., 2009; Marzoli et al., 2014). Nonetheless, it is worth noting that more recent studies demonstrated the presence of such a bias, as a tendency to first look at the left side from the observer's point of view (i.e. first fixations of shorter latency when directed to the left), also during scenes and artworks visual exploration (e.g., Calbi et al., 2019; Foulsham et al., 2018; Ossandon et al., 2014; Dickinson & Intraub, 2009). Recently, Marzoli and colleagues hypothesized that the left-gaze bias could be observed also during bodies visual exploration, arguing that the attentional and perceptual advantage of the left visual field could have an adaptive function from a communicative point of view, during a dyadic interaction: to direct the attention to the region where normally acts the dominant hand of the other (Marzoli et al., 2014).

In the light of the above-described evidence, the principal aim of the present study was to further clarify the characteristics of EBL perception. More specifically, to explore both the presence of a left-gaze bias and the modulation of EBL visual exploration mechanisms, we investigated the fixation patterns of participants while judging the emotional intensity of bodily postures (angry, happy and neutral, without head). The choice of anger as negative emotion is due to the purpose of specifically verifying whether the left-gaze bias could be stronger when a potentially threatening action is upcoming (see Marzoli et al., 2014). We expected shorter latency of first fixations directed to the left side (from the observer's point of view) of the observed body postures than those directed to the right side. Furthermore, this result should be stronger when looking at emotional body postures in general, and in particular, at angry ones. Regarding the amount of fixations directed at different stimuli, we expected more fixations on the left side (from the observer's point of view) of bodily postures. Furthermore, and independently from the left-gaze bias, if the emotional expressiveness is the element that engages more the observers, more fixations are expected when looking at emotional body postures than at neutral ones (e.g., Nummenmaa et al., 2006), with a higher proportion of fixations directed at the hands. However, taking into account both the task requests of participants and the stronger expressiveness of emotional bodily postures due to the higher amount of postural and positional information they embed, we could also expect less fixations when looking at emotional body postures than at neutral ones. In other words, few fixations would be sufficient to evaluate the emotional intensity of clearly emotional bodily postures than that of more ambiguous neutral ones (for similar results on facial expressions, see Guo, 2012). To verify such hypotheses it is crucial to clarify which are the most effective components (e.g., trunk, arms, hands, legs, in their form and position; see also Ross & Flack, 2020) of the human body to evoke emotional and/or motor reactions in the observer.

Materials and methods

Participants

Thirty-three healthy Italian volunteers took part in the behavioural and eye-tracking study: 14 males, 19 females, mean age 25.79 (±2.65) years. Although power calculations for multilevel models are not straightforward, our sample size was established on the 30/30 rule, which recommends sampling 30 participants with 30 observations per participant (see Van der Gucht et al., 2019; Hox, 2010; Mathieu et al., 2012). Furthermore, our sample size is comparable to that of similar previous studies (e.g., Kret et al., 2013a). All participants had normal or corrected-to-normal visual acuity, full-color vision and no vision disorders that could interfere with the eye-tracking technique. Thirty-one participants had a right dominant eye (93.9%; $N = 31$), as ascertained by the ocular dominance test. The sample was composed of 28 right-handed and five ambidextrous participants, as determined by the Italian version of the Edinburgh Handedness Inventory (Oldfield, 1971). All participants provided written informed consent to participate in the study, which was approved by the local ethical committee "Comitato etico Area Vasta Emilia Nord", and was conducted in accordance with the Declaration of Helsinki (2013).

Stimuli

Stimuli were composed of emotional body postures taken from the Bochum Emotional Stimulus Set (BESST; Thoma et al., 2013). Specifically, we selected one negative (Anger) and one positive (Happiness) emotion, as well as Neutral as control condition. More precisely, among the whole sample of emotional body postures, we selected frontal bodies correctly recognized above 75% and whose expression was evaluated as natural (i.e. a score > 2.5 on a five-point Likert-type rating of the perceived naturalness (see Thoma et al., 2013). In addition, we digitally manipulated the selected pictures to remove the head from each stimulus, as well as elements that could attract the observer's attention (e.g. watches, jewellery). Each body posture was then superimposed on a grey background (RGB: 128;128;128). The final sample was composed by 55 grey-scaled stimuli, belonging to three different experimental categories: 16 Angry (seven females), 19 Happy (ten females), and 20 Neutral (11 females). Each stimulus had a dimension of 827 × 827 pixels. The stimuli were equiluminant: an ANOVA revealed no difference in picture luminance across the categories

($F_{(2,54)} = 1.25$, $p = 0.29$; Anger = 116.2 ± 2.6 cd/cm^2; Happiness = 117.4 ± 2.5 cd/cm^2; Neutral = 116.3 ± 2.6 cd/cm^2).

Eye-tracking apparatus

A remote screen-based Tobii Pro System X3-120 eye-tracker was used to record eye movements at a sampling frequency of 120 Hz (Tobii, 2016). Images were shown by means of Tobii Studio (3.4.5) on a 4K Ultra HD color LCD screen (28″; 39.3 cm × 65.7 cm) with a resolution downgraded to 1920 × 1080 pixels. The distance of 60 cm between the observer and the computer screen was the same for all trials, set using a chinrest. This distance was used to retain a constant depth of field, to reduce head movements and to ensure a fixed orientation (Duchowski, 2007).

After the classification of raw data as fixations by means of the I-VT Filter implemented in Tobii Studio, we extracted latency of participants' first fixations and a total number of fixations by means of homemade scripts (R Core Team, 2019).

Procedure

Upon arrival in the laboratory, participants signed the informed consent form and after the assessment of visual acuity and both manual and ocular dominance, their potential attentional asymmetry was evaluated by means of a line bisection task Manning et al. 1990. Participants' emotion recognition and empathic abilities (Interpersonal Reactivity Index—IRI, Davis, 1983; Albiero et al., 2006; Toronto Alexithymia Scale—TAS-20, Bagby et al., 1994; Bressi et al., 1996), social desiderability (MC-SDS, Crowne & Marlowe, 1960), as well as their level of anxiety as a permanent trait (STAI-Y2, Spielberger, 1983; Pedrabissi & Santinello, 1989), their level of social phobia (Social Phobia Inventory – I-SPIN, Gori et al., 2013; Connor et al., 2000) and the sensitivity of their behavioural activation and inhibition systems (BIS/BAS, Carver & White, 1994; Leone et al., 2002) were assessed by means of several questionnaires administered via Google Forms before or after completion of the experimental task (see Tab. 1 in Supplementary Materials). To be more specific, the two latter questionnaires were selected because they measure approach/avoidance tendencies and social phobia, respectively. Bearing in mind our hypothesis as well the results of previous studies (e.g. Kret et al., 2017), these are the aspects that in our opinion might play a more crucial role in the way participants visually explored bodily postures of different emotions. The experimental session consisted of an eye-tracking task and a behavioural task that were carried out simultaneously, followed by a second repetition of the behavioural task.

After the evaluation of the correct position of the participant in front of the Tobii by means of the "track status meter", a calibration procedure required participants to follow (without moving their head) a red bouncing ball, which paused at nine unpredictable positions on the screen, in a 3 × 3 configuration.

At the beginning of each trial, a black fixation cross on a grey background was displayed for 200 ms. The fixation cross was randomly presented on the right or left side of the screen, to avoid a location-related bias of the first fixation (Tatler, 2007; Guo & Shaw, 2015). When the fixation cross disappeared, one experimental stimulus was shown for two seconds. Participants were asked to freely visually explore the image, after which they had to verbally answer the question, "How would you judge the emotional intensity of the person?" on a VAS scale (0–100 = not at all intense–very intense), without time limits but as accurately as quickly as possible (see Fig. 1). Participants answers were recorded by an experimenter on an Excel sheet. Each stimulus was randomly presented twice, for a total of 110 trials. The experiment lasted about 10 min. At the end of the eye-tracking recording session, participants were shown the stimuli one more time in a different randomized order (each stimulus was presented twice, for a total of 110 trials) and they were asked to rate the valence of the depicted body posture (i.e.

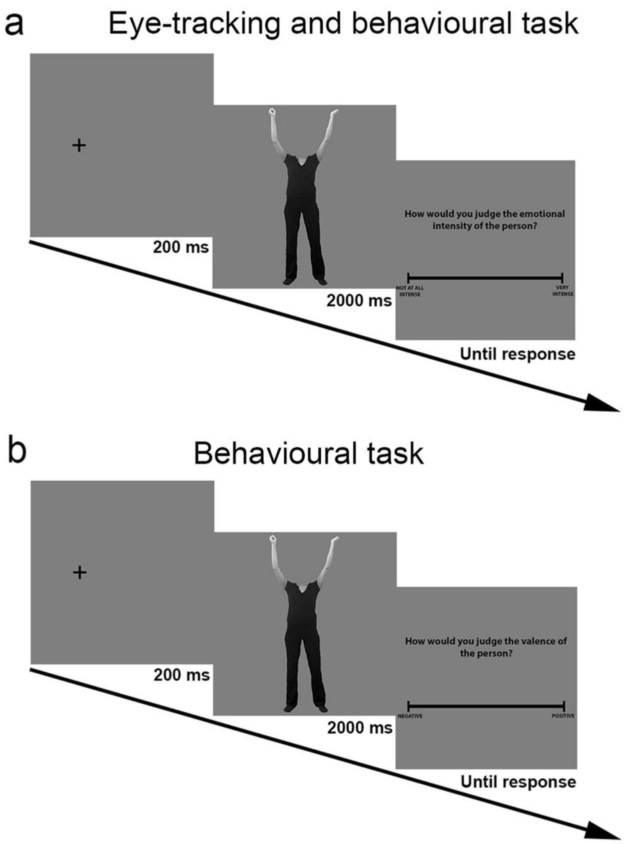

Fig. 1 Experimental paradigm: **a** Eye-tracking and behavioural task. **b** Behavioural task

"How would you judge the valence of the person?") on a VAS scale (0–100 = negative–positive) by using the mouse, without time limits but as accurately as quickly as possible. Stimuli delivery and response recording was controlled using E-prime 2.0 software.

The eye-tracking experimental task was preceded by a training session that included nine trials comprehending nine images (three per each condition) not pertaining to the experiment. To maintain light-controlled conditions, the experiment was conducted in a semi dark room.

To evaluate the perceived implicit movement of the bodily postures, other fifteen participants (5 male, 10 female; mean age 26.2 (± 3.2) years) were subsequently asked to freely visually explore the 55 grey-scaled stimuli proposed in the main experiment, randomly presented twice, for a total of 110 trials, after which they had to answer the question, "How would you judge the implicit movement of the bodily posture?" on a VAS scale (0–100 = static–dynamic), without time limits but as accurately as quickly as possible. Stimuli delivery and response recording was controlled using E-prime 2.0 software.

Eye data analyses

To investigate whether there were a lateralization bias and a modulation of visual exploration patterns by the different emotional conditions, each image was divided into two identical and symmetrical Areas of Interest-AOIs, covering the whole-body posture: Left and Right AOI (see Fig. 5a in Supplementary Materials as an example). The latency of the first fixation, as well as the mean number of fixations directed at each AOI, were analysed by means of a linear mixed-effects analysis, respectively.

For each parameter, the model was obtained by means of a hierarchical approach. We started with a simple model and added parameters if their inclusion improved model fit. Likelihood ratio tests, Akaike Information Criterion (AIC) and Bayesan Information Criterion (BIC) were used to establish whether the inclusion of fixed, random and interaction effects would significantly improve model fit. We entered each visual parameter as a dependent variable and AOI (2 levels: Left, Right), Condition (3 levels: Anger, Happiness, Neutral), Actor's gender (2 levels: Male, Female) and Participants' gender (2 levels: Male, Female) as independent fixed variables. We entered by participants intercept for the effect of AOI and, only for the model performed on first fixations' latency, Condition slope as random effects.

To further explore the modulation of a participant's visual exploration patterns by the three different experimental conditions, we evaluated the heatmaps. To produce the heatmaps we used a kernel density estimation: the kernel bandwidth was set at 100 pixels, applied to each image across participants to create a density visual scale. In such a way, we took into account the variability of the actors' bodily postures. It clearly emerged that, although the stimuli were headless bodies, for Happy body postures the density of fixations was higher around the head's putative region (Head), whereas for both Neutral and Angry body postures it was higher around the hands (see Fig. 6 in Supplementary Materials). Consequently, we drew three new AOIs (i.e. Head, Left-Hand, and Right-Hand) of identical dimension (see Fig. 5b in Supplementary Materials as an example). Then, following the hierarchical approach as described above, we performed a linear mixed effect analysis on the proportion of fixations directed at each AOIs within the total number of fixations directed at the whole stimulus. We entered AOI (3 levels: Head, Left-Hand and Right-Hand), Condition (3 levels: Anger, Happiness, Neutral), Actor's gender (2 levels: Male, Female) and Participants' gender (2 levels: Male, Female) as independent fixed variables. We entered by participants intercept for both the effect of AOI and Condition as random effects.

Since the heatmaps (see above) provide a powerful visualization of an averaged spatial scan-path, but entirely lack any information regarding the time, we divided the fixations density of each AOI into 20-time slices (i.e. 100 ms) to plot the fixations' frequency in each AOI over time (see also Coco, 2009). To further investigate any temporal difference among conditions, the latency of first fixations in each AOI was analysed by means of a linear mixed-effects analysis following the hierarchical approach (see above). We entered AOI (3 levels: Head, Left-Hand and Right-Hand), Condition (3 levels: Anger, Happiness, Neutral), Actor's gender (2 levels: Male, Female) and Participants' gender (2 levels: Male, Female) as independent fixed variables. We entered by participants and AOI interaction intercept for the effect of Condition, and by AOI and stimuli interaction intercept as random effects. For an extensive formulation of the models and more details about their terms, please see Supplementary Table 2.

As a final note, we did not employ a data-driven approach because the nature of our stimuli did not allow us to compare the different experimental conditions (see as an example the data-driven approach implemented in iMap4; Lao et al., 2017). On the contrary, by using the AOI approach, we were able to select the same region of interests across stimuli despite the different spatial configuration peculiar of each emotional condition.

Tukey's test was used for post-hoc comparisons among means. In case of violation of sphericity, degree of freedoms and *p* values were Greenhouse–Geisser corrected ($\varepsilon \leq 0.75$).

Behavioural analyses

Behavioural data were analysed by means of a linear mixed-effects analysis. We entered Arousal and Valence scores as dependent variable and Condition (3 levels: Anger, Happiness, Neutral) as an independent fixed variable, respectively. We entered by participants intercept for the effect of Condition as a random effect. For each parameter, the model was obtained by means of a hierarchical approach. Tukey's test was used for post-hoc comparisons among means. In case of violation of sphericity, degree of freedoms and p values were Greenhouse–Geisser corrected ($\varepsilon \leq 0.75$).

About the analysis of the implicit movement ratings, we performed an ANOVA with Condition as within-factor (3 levels: Anger, Happiness, Neutral). Tukey's test was used for post-hoc comparisons among means. In case of violation of sphericity, degree of freedoms and p values were Greenhouse–Geisser corrected ($\varepsilon \leq 0.75$). Normality checks were carried out on the residuals, which were approximately normally distributed ($W = 0.93$, $p > 0.05$).

Correlations

To better qualify our results, we performed several Kendal correlations. Specifically, we correlated the total scores of BIS/BAS and I-SPIN questionnaire with each visual parameter (i.e. latency of first fixation and mean number of fixations) for each experimental condition (3 emotions * 2 AOIs). Furthermore, to investigate the relation between behavioral ratings and eye movements, we correlated, for each emotional condition (Anger, Happiness, Neutral), the mean rating with each visual parameter (latency of the first fixation and mean number of fixations) related to different AOIs (Left and Right). In addition, we correlated, for each emotional condition (Anger, Happiness, Neutral), the mean rating with each visual parameter (latency of the first fixation and mean number of fixations) regardless of the AOIs. Bonferroni corrections were applied. For details on significant results and related figures, please see Supplementary Materials.

For all analyses, we used R (R Core Team, 2019) and lme4 (Bates et al., 2014), ez (Lawrence, 2013) and lsmeans (Lenth, 2016). For data visualization we used ggplot2 (Wickham, 2016).

Eye-tracking results

Latency of first fixation—left and right AOI

The model explained 21% of the variance in latency taking into account the random effects ($R^2_m = 0.05$; $R^2_c = 0.21$). The model revealed a main effect of AOI ($F_{(1,32)} = 13.05$, $p < 0.001$), with latency of first fixations directed at Left AOI on average being 162 ms shorter than latency of first fixations directed at Right AOI ($t = -4.7$, $p < 0.0001$; Left: $M = 444$ ms, 95% CIs = [433.4, 454.6]; Right: $M = 611$ ms, CIs = [597.7, 624.3]). The model also revealed a significant main effect of Condition ($F_{(1.72,55)} = 7.9$, $p < 0.01$). Post-hoc tests showed that latency of first fixations directed at Angry body postures were shorter than that directed at Neutral body postures ($t = -4.2$; $p < 0.0001$), while there was no difference between Happy body postures and both Angry and Neutral body postures (Anger: $M = 504$ ms, CIs = [489.9, 518.1]; Neutral: $M = 548.4$ ms, CIs = [533.7, 563.1]; Happiness: $M = 528.3$ ms, CIs = [512.2, 544.4]). The model also revealed a near to significant "AOI by Condition" interaction ($F_{(1.6,52.5)} = 3.3$, $p = 0.055$). Post-hoc tests showed that, for each emotional condition, latency of first fixations directed at Left AOI on average was shorter than latency of first fixations directed at Right AOI (Anger-Left: $M = 426.1$ ms, CIs = [408.8, 443.3]; Anger-Right: $M = 579.4$ ms, CIs = [558.4, 600.4]; Happiness-Left: $M = 457$ ms, CIs = [435.8, 478.2]; Happiness-Right: $M = 594.6$ ms, CIs = [571.1, 618.1]; Neutral-Left: $M = 446.5$ ms, CIs = [430, 463]; Neutral-Right: $M = 451.4$ ms, CIs = [427.9, 474.9]) (all Ps < 0.02). By comparing the emotional conditions, post-hoc tests only revealed that latency of first fixations directed at Angry body postures was 75 ms shorter than latency of first fixations directed at Neutral body postures on the Right AOI ($t = -4.6$; $p < 0.001$) (see Fig. 2a).

Number of fixations—left and right AOI

The model explained 85.4% of the variance in number of fixations taking into account the random effects ($R^2_m = 0.06$; $R^2_c = 0.85$). The model revealed a significant main effect of Condition ($F_{(1.7,54.8)} = 3.5$, $p < 0.05$) but post-hoc tests did not show significant differences. The model also revealed a significant "AOI by Condition" interaction ($F_{(1.9,60.8)} = 20.4$, $p < 0.0001$). By comparing the emotional conditions, post-hoc tests revealed that, on the Left AOI, total number of fixations directed at Neutral body postures was higher than that directed at both emotional body postures (Anger vs. Neutral: $t = -0.6$; $p < 0.01$; Happiness vs. Neutral: $t = -1.1$; $p < 0.0001$; Anger-Left: $M = 5.3$, *CIs* = 4.9–5.7; Neutral-Left: $M = 5.9$, CIs = [5.3, 6.5]; Happiness-Left: $M = 4.8$, CIs = [4.2, 5.4]), while on the Right AOI, total number of fixations directed at Neutral body posture was lower than that directed at Happy body postures ($t = -0.6$; $p < 0.01$; Happiness-Right: $M = 6.1$, CIs = [5.5, 6.7]; Neutral-Right: $M = 5.5$, CIs = [4.9, 6.1]). Furthermore, post-hoc tests showed that, when looking at Happy body postures, participants made more fixations at the Right than at the Left AOI ($t = 1.3$; $p = 0.05$) (see Fig. 2b).

Proportion of fixations—head and hands AOIs

The model explained 78.5% of the variance in proportion of fixations taking into account the random effects ($R^2_m = 0.41$;

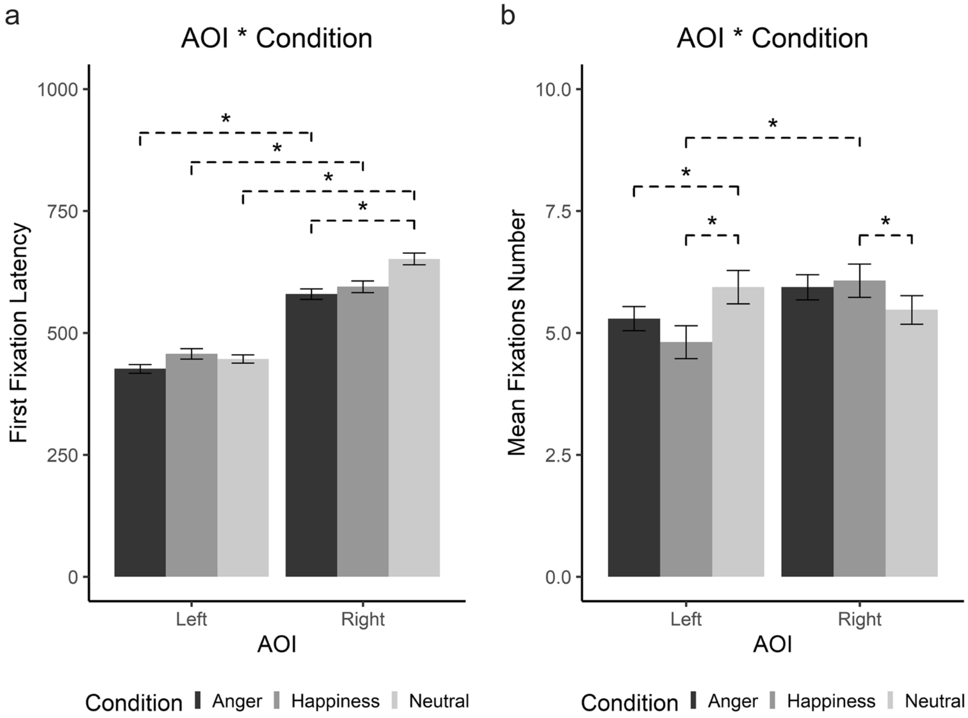

Fig. 2 **a** First Fixation latency: significant AOI * Condition Interaction; **b** Mean Fixations number: significant AOI * Condition Interaction. Error bars represent standard errors of the means-SE. *$p < 0.05$

$R^2_c = 0.78$). The model revealed a significant main effect of Condition ($F_{(1.5,44.9)} = 16.2$, $p < 0.0001$). Post-hoc tests showed that emotional body postures attracted a higher proportion of fixations than Neutral body postures (Anger vs. Neutral: $t = 4.3$; $p < 0.001$; Happiness vs. Neutral: $t = 5.3$; $p < 0.0001$; Anger: $M = 12.6\%$, CIs = [10.4%, 14.7%]; Neutral: $M = 8.3\%$, CIs = [6.7%, 9.9%]; Happiness: $M = 13.6\%$, CIs = [11.4%, 15.7%]). The model also revealed a significant “AOI by Condition” interaction ($F_{(2.5,75.2)} = 112.8$, $p < 0.0001$). By comparing the emotional conditions, post-hoc tests revealed that, on the Head’s putative region, a higher proportion of fixations was directed at Happy body postures than both Angry and Neutral body postures (Anger vs. Happiness: $t = -20.8$, $p < 0.0001$; Happiness vs. Neutral: $t = 20.7$, $p < 0.0001$; Anger: $M = 3.1\%$, CIs = [1.7%, 4.5%]; Neutral: $M = 3.2\%$, CIs = [1.8%, 4.6%]; Happiness: $M = 24\%$, CIs = [20.1%, 27.9%]), while on both Left and Right Hand, a higher proportion of fixations was directed at Angry body postures than both Happy and Neutral body postures (Anger-Left Hand vs. Happy-Left Hand: $t = 6.5$, $p < 0.0001$; Anger-Left Hand vs. Neutral-Left Hand: $t = 3.6$, $p = 0.01$; Anger-Right Hand vs. Happy-Right Hand: $t = 6.3$, $p < 0.0001$; Anger-Right Hand vs. Neutral-Right Hand: $t = 5.8$, $p < 0.0001$; Anger-Left Hand: $M = 17.2\%$, CIs = [13.5%, 20.9%]; Neutral-Left Hand: $M = 12.2\%$, CIs = [9.4%, 14.9%]; Happiness-Left Hand: $M = 8.1\%$, CIs = [6.1%, 10.1%]; Anger-Right Hand: $M = 17.6\%$, CIs = [13.9%, 21.3%]; Neutral-Right Hand: $M = 9.4\%$, CIs = [7%, 11.7%]; Happiness-Right Hand: $M = 8.7\%$, CIs = [6.3%, 11%]). Furthermore, post-hoc tests showed that, when looking at both Angry and Neutral body postures, participants made more fixations at the Hands than at the Head’s putative region (Anger-Head vs. Anger-Left Hand: $t = -7.5$; $p < 0.0001$; Anger-Head vs. Anger-Right Hand: $t = -7.7$; $p < 0.0001$; Neutral-Head vs. Neutral-Left Hand: $t = -4.8$; $p = 0.0001$; Neutral-Head vs. Neutral-Right Hand: $t = -3.3$; $p < 0.05$), while when looking at Happy body postures participants made more fixations at the Head’s putative region than at both the Hands (Happiness-Head vs. Happiness-Left Hand: $t = 8.5$; $p < 0.0001$; Happiness-Head vs. Happiness-Right Hand: $t = 8.1$; $p < 0.0001$) (see Fig. 3a).

Latency of first fixations—head and hands AOIs

The plot of the fixations’ frequency in each AOI over time showed a different time pattern among conditions (see Fig. 4). The model explained 30% of the variance in latency taking into account the random effects ($R^2_m = 0.14$; $R^2_c = 0.3$). The model revealed a main effect of AOI ($F_{(1,32)} = 59.62$, $p < 0.0001$), with latency of first fixations directed at Left-Hand AOI on average being shorter than mean latency of first fixations directed at both Right-Hand and Head AOIs (Head vs. Left Hand: $t = 5.6$; $p < 0.0001$; Left Hand vs. Right Hand: $t = -5.45$; $p < 0.0001$; Head: $M = 796.6$ ms, CIs = [767.2, 826]; Left Hand: $M = 697.9$ ms, CIs = [680.3, 715.5]; Right Hand: $M = 928.1$ ms, CIs = [908.3, 947.9]). There was no difference between Right-Hand and Head AOIs. The model also revealed a significant main effect of Condition ($F_{(1.63,52.27)} = 16.84$, $p < 0.0001$). Post-hoc tests showed that

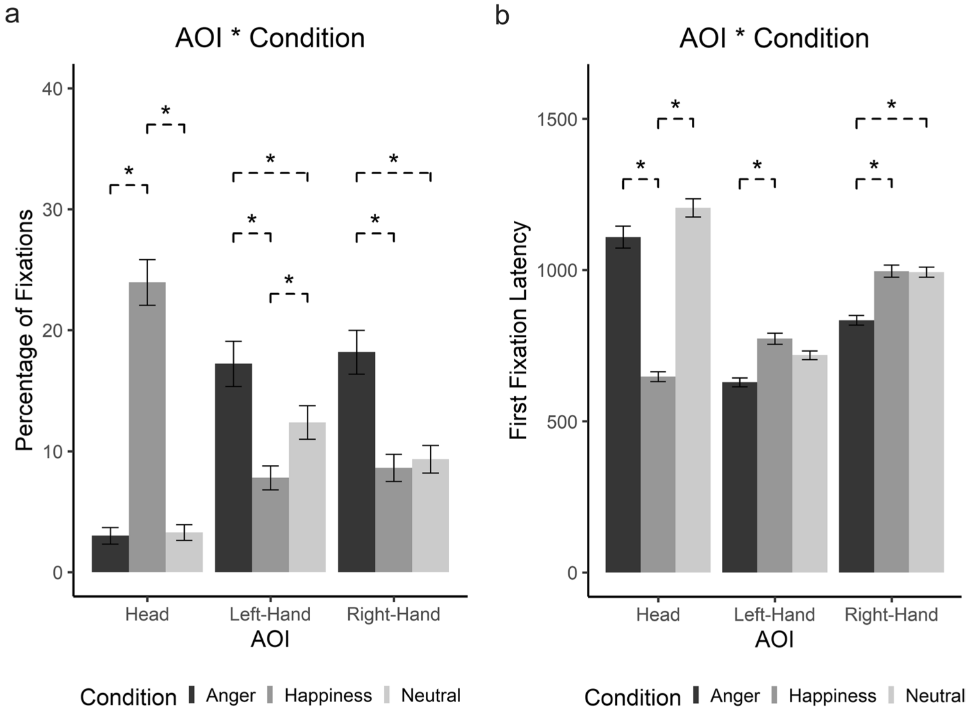

Fig. 3 **a** Percentage of fixations: significant AOI * Condition Interaction; **b** First Fixation latency: significant AOI * Condition Interaction. Only significant differences among conditions in each AOI are shown. Error bars represent SE. *$p < 0.05$

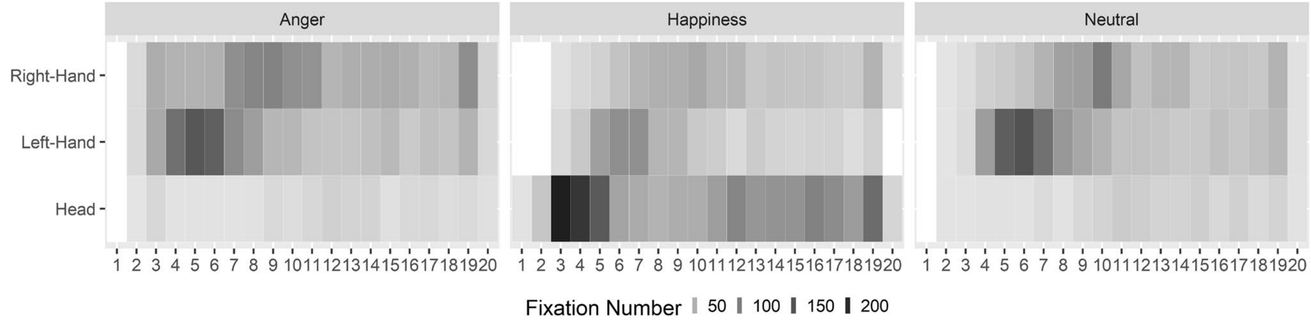

Fig. 4 Fixations' frequency in each AOI over time: fixations density was divided into 20-time slices (i.e. 100 ms)

latency of first fixations directed at both Angry and Happy body postures were shorter than that directed at Neutral body postures (Anger vs. Neutral: $t = -5$; $p < 0.0001$; Happiness vs. Neutral: $t = -5.9$; $p < 0.0001$), while there was no difference between Happy body postures and Angry body postures (Anger: $M = 771.8$ ms, CIs = [750.2, 793.4]; Neutral: $M = 894.5$ ms, CIs = [872.3, 916.6]; Happiness: $M = 763.1$ ms, CIs = [741.1, 785]). The model also revealed a significant "AOI by Condition" interaction ($F_{(1.86,59.37)} = 5.98$, $p = 0.005$). By comparing the emotional conditions, post-hoc tests revealed that, on the Head's putative region, latency of first fixations directed at Happy body postures on average was shorter than latency of first fixations directed at both Angry and Neutral body postures (Anger vs. Happiness: $t = 7.4$, $p < 0.0001$; Happiness vs. Neutral: $t = -10.9$, $p < 0.0001$; Anger-Head: $M = 1108.4$ ms, CIs = [1037, 1179.7]; Neutral-Head: $M = 1205.3$ ms, CIs = [1145.5, 1265.1]; Happiness-Head: $M = 647.9$ ms, CIs = [615.7, 680]), while on both Left and Right-hand, fixations of shorter latency were directed at Angry body postures than at Happy body postures. Furthermore, on the Right-hand only, fixations of shorter latency were directed at Angry body postures than at Neutral body postures (Anger-Left Hand vs. Happiness-Left Hand: $t = -3.3$, $p < 0.05$; Anger-Right Hand vs. Happiness-Right Hand: $t = -4.1$, $p < 0.05$; Anger-Right Hand vs. Neutral-Right Hand: $t = -4.3$, $p < 0.05$; Anger-Left Hand: $M = 629.4$ ms, CIs = [600.8, 658]; Happiness-Left Hand: $M = 772.5$ ms, CIs = [736.2, 808.8]; Anger-Right Hand: $M = 833.5$ ms, CIs = [802.7, 864.3]; Neutral-Right Hand: $M = 992.6$ ms, CIs = [959.7, 1025.5]; Happiness-Right Hand: $M = 995.8$ ms, CIs = [956.8, 1034.8]). Furthermore, post-hoc tests showed that, for Angry body postures, latency of first fixations directed at the Hands on average was shorter than latency of first fixations directed at the Head's putative region, while for Neutral body postures, this was true only for Left Hand (Anger-Head vs. Anger-Left Hand: $t = 6.8$; $p < 0.0001$; Anger-Head vs. Anger-Right Hand: $t = 3.9$; $p < 0.05$; Neutral-Head vs. Neutral-Left Hand: $t = 7.2$; $p < 0.0001$). Conversely, when looking at Happy body postures, latency of first fixations directed at the Head's putative region was shorter than latency of first fixations directed at Right Hand (Happiness-Head vs. Happiness-Right Hand: $t = -6.9$; $p < 0.0001$). By comparing the latency of first fixations directed at the Hands, participants looked more rapidly at the Left Hand than at the Right Hand in each condition (Anger-Left Hand vs. Anger-Right Hand: $t = -3.6$; $p < 0.05$; Happiness-Left Hand vs. Happiness-Right Hand: $t = -3.9$; $p < 0.05$; Neutral-Left Hand vs. Neutral-Right Hand: $t = -4.6$; $p < 0.001$) (see Fig. 3b).

Behavioural results

Arousal

The model explained 78.7% of the variance in rating scores taking into account the random effects ($R^2_m = 0.62$; $R^2_c = 0.78$). The model revealed a main effect of Condition ($F_{(1.9,60.5)} = 240.2, p < 0.0001$). Post-hoc tests showed that all the differences were significant, with the emotional intensity scores attributed to Happy body postures being the highest and followed by the scores attributed to Angry and Neutral body postures (Anger vs. Happiness: $t = -2.4$; $p = 0.05$; Anger vs. Neutral: $t = 14.9$; $p < 0.0001$; Happiness vs. Neutral: $t = 17.3$; $p < 0.0001$: Happiness: $M = 66.8$, CIs = [65.6, 68]; Anger: $M = 58.8$, CIs = [57.4, 60.2]; Neutral: $M = 9.1$, CIs = [8.3, 9.9]) (See Fig. 7a in Supplementary Materials).

Valence

The model explained 58.2% of the variance in rating scores taking into account the random effects ($R^2_m = 0.46$; $R^2_c = 0.58$). The model revealed a main effect of Condition ($F_{(1.65,52.8)} = 164.4$, $p < 0.0001$). Post-hoc tests showed that all the differences were significant, with the valence scores attributed to Happy body postures being the highest and followed by the scores attributed to Neutral and Angry body postures (Anger vs. Happiness: $t = -18.2$; $p < 0.0001$; Anger vs. Neutral: $t = -7.2$; $p < 0.0001$; Happiness vs. Neutral: $t = 11$; $p < 0.0001$: Happiness: $M = 23.3$, CIs = [22.1, 24.5]; Neutral: $M = -2$, CIs = [−2.4, 1.6]; Anger: $M = -18.6$, CIs = [−19.8, −17.4]) (See Fig. 7b in Supplementary Materials).

Implicit movement

The ANOVA showed that mean scores differed significantly among Conditions ($F_{(1.4, 20.3)} = 69.1$, $p < 0.0001$). Post-hoc tests using the Tukey correction revealed that scores attributed to Happy body postures were the highest, followed by the scores attributed to Angry and Neutral body postures (Anger vs. Happy: $t = -22.6$; $p < 0.001$; Anger vs. Neutral: $t = 34.6$; $p < 0.0001$; Happy vs. Neutral: $t = 57.2$; $p < 0.0001$: Happiness: $M = 65.9$, SE = 1.1; Neutral: $M = 8.7$, SE = 0.5; Anger: $M = 43.3$, SE = 0.1) (see Fig. 8 in Supplementary Materials).

Discussion

The aim of the present study was to investigate the characteristics of EBL visual perception. Specifically, we aimed at assessing the presence of both a left-gaze bias and of a modulation on EBL gaze exploration patterns. To this purpose, eye-movements were recorded while participants judged the emotional intensity of neutral and emotional (angry and happy) static bodily postures (without the head), and the analyses were performed on the pattern of eye-movements recorded during stimuli visual exploration.

To investigate whether there were a lateralization bias and a modulation of visual exploration patterns by the different emotional conditions, we analysed the latency of the first fixation, as well as the mean number of fixations, directed at Left and Right AOIs (from the observer's point of view). Results on first fixation' latency showed the presence of a significant, but nonspecific, left-gaze bias: for all conditions, participants looked first at the Left than at the Right AOI (see Fig. 2a). Furthermore, the latency of the first fixation was shorter for Angry than Neutral body postures.

Contrary to our expectations on the left-gaze bias, results on the mean fixations number revealed an opposite pattern between Left and Right AOI: when looking at the Left AOI, participants made less fixations at emotional bodily postures, whereas when looking at the Right AOI, they made less fixations at Neutral than at Happy bodily postures. Specifically, it emerged the significant difference between Left and Right AOI for happy bodily postures only: participants made more fixations at the Right than at the Left AOI (see Fig. 2b). Since the participants rated Happy stimuli as being the most intense ones, we could hypothesize that the difference between Left and Right AOI could be related to the emotional intensity of each bodily posture. We think that the implicit dynamic nature of our stimuli had a crucial role in this evaluation. Given their characteristics (e.g., higher expansiveness due to arms and hands out and up; for a recent review on the bodily expression of distinctive emotions, see Witkower & Tracy, 2018), happy bodily postures displayed a greater amount of implicit movement and, as a consequence, of embedded motor information, which may have fostered the perception of an higher displayed intensity for these stimuli. This interpretation was fostered by the results of an additional behavioural experiment during which we asked participants to judge the implicit movement of each bodily posture. Happy stimuli received the highest scores, followed by Angry and Neutral ones (see Supplementary Fig. 8).

The evaluation of the heatmaps (Fig. 6 in Supplementary Materials) led us to focus on specific regions of interest, namely the Head's putative region (all the stimuli were indeed headless) and both Hands, revealing that, when considering gaze data directed at these specific bodily parts, emotional bodily postures attracted a higher proportion of fixations than Neutral body postures. Hence, this result is in line with the hypothesis that the expressiveness and the intensity of emotional bodily postures lead participants to make more fixations (higher attentional engagement to emotional visual stimuli; e.g., Nummenmaa et al. 2006).

Furthermore, remarkable differences emerged among the three conditions. First, when looking at Happy bodily postures, participants made more fixations to the Head's putative region; second, when looking at Angry and Neutral bodily postures, they made more fixations to the Hands; third, when participants visually explored Angry bodily postures, the Hands received a higher number of fixations than in the other two conditions (Fig. 3a). Taking into account the timing, it emerged that the latency of first fixations directed at the Left Hand was shorter than the latency of first fixations directed at both the Right-Hand and the Head's putative region, thus confirming the presence of a significant left-gaze bias. When looking at Happy bodily postures, participants made faster fixations to the Head's putative region than to the Right-Hand, while when looking at Angry and Neutral bodily postures, they made faster fixations to both the Hands. Furthermore, participants made faster fixations to these latter AOIs when exploring Angry bodily postures than Neutral (only on the Right-Hand) or Happy bodily postures (on both the Hands) (Fig. 3b).

Although the essential role that the hands and the face have in the expression and recognition of threat- and happy-based emotions it is already well established (e.g., Witkower & Tracy, 2018; Ross & Flack, 2020; Pichon et al., 2008; de Gelder et al., 2004), only few studies investigated this topic at the eye-movements level (Fridin et al., 2009; Kret et al., 2017. See also the more recent study by Pollux et al., 2019). Both these previous investigations (Kret et al., 2017; Fridin et al., 2009) are completely in agreement with our results, showing an opposite viewing pattern between fearful/angry and happy bodily postures (i.e. more attention to the hands for negative bodily postures, and to the head for happy bodily postures). A similar conclusion was also drawn by Azarian et al. (2016). They investigated whether threatening averted body postures cued participants' attention in a gaze-cueing paradigm. Results showed eye movements of shorter latencies when there was congruence between the target position and the bodily posture's direction, but only for threatening ones (vs. neutral and happy), thus revealing that both angry and fearful bodily postures cause reflexive shifts of attention in the observers. Although previous studies on emotional cueing with faces and averted gaze reported conflicting results, the authors speculated that threat-related bodily expressions "…are more salient cues of danger than face cues, especially when there is an expression of anger".

The fact that participants focus their attention to the hands when looking threatening bodily expressions, is well established as an adaptive function from both a communicative and motor point of view (see also Marzoli et al., 2014). In particular, it may be assumed that especially to decode such threat-based emotions from the body, the hands are the most informative elements by virtue of the strong motor information they embed. Hence, likely through a visuo-motor resonance mechanism, participants specifically looked at the hands to grasp that kind of information, essential to correctly comprehend and decode the emotion (e.g., Gallese, 2003; Gallese et al., 2004; Montgomery et al., 2007). The look at the hands during the observation of angry bodily expressions is also in line with the notion that when we visually scan a scene, the brain creates a priority map based on the more salient stimuli. The recent identified direct projections from the amygdala, a key structure for processing fearful and threatening visual information, to the oculomotor system, can modulate the direction of the gaze on the hands, the stimuli that in this context carry more emotional, and possibly dangerous, information (Gerbella et al., 2014).

On the contrary, the focus of the participants on the putative region of the Head when looking at Happy bodily postures is in line with the human, and non-human primates, well-established tendency to look at the face, and specifically at the eyes, during positive and affiliative interactions (i.e. approach; see Nikitin & Freund, 2019; Kret et al., 2017; McFarland et al., 2013). This predisposition may be underpinned by a network of interconnected cortical regions comprising the frontal oculomotor region, the temporal sectors encoding the emotional content of facial stimuli ("the dorsal stream for faces"; Bernstein & Yovel, 2015), and a sector of the anterior cingulate cortex recently demonstrated to be active during the production and the perception of smile/laughter expression ("mirror mechanism" for laughter; Caruana et al., 2017, 2018). In this context, the temporal and the anterior cingulate cortex can convey visual and emotional information to the frontal oculomotor territories for creating an affiliative interaction based on the fixation of the other's face.

Regarding the hereby demonstrated "left-gaze bias" while scanning bodies (i.e. the tendency to direct visual attention to the left side of the stimuli, from the observer's point of view; e.g., Butler et al., 2005; Guo et al., 2009), our results suggest that it could be related to and explained by the higher expressiveness of the hands. This could be particularly true for Angry bodily postures, characterized by a strong hand motor component. About this latter result, to clarify the nature and the meaning of this bias, a goal for future studies will be to investigate its presence also in left-handed people and with dynamic emotional and neutral bodily postures. Furthermore, since visual parameters can be influenced by the task (e.g., Mills et al., 2011; Borji & Itti, 2014), future studies should investigate whether different experimental questions (e.g., valence rating instead of intensity) or a passive observation of stimuli would lead to different results. This point is crucial to clarify not only the nature of the complex phenomenon of the left-gaze bias but also the characteristics of emotional body language visual processing and its underlying mechanisms.

Taken together, the present results, by integrating the spatial and temporal dimension of gaze exploration patterns, shed new light on EBL visual exploration mechanisms, clearly revealing a significant modulation by the different emotional conditions and demonstrating, for the first time, a "left-gaze bias" during EBL processing. Furthermore, considering new evidence in human–robot interaction research field, the present results could provide decisive information for the development of robots capable to recognize people's affective states and motor intentions to correctly respond and interact with each other (e.g. McColl et al., 2017).

Constraints on generality and limits

This study has potential limitations. First of all, our sample of participants was composed by Western (all Italians) people only. Consequently, the studies cited in the Introduction to justify the authors' aims and hypotheses, focused only on Western observers. Considering previous studies revealing a cultural fixations bias for faces, with more central fixation pattern in East-Asian compared to Western participants (e.g., Blais et al., 2008; Caldara et al., 2010; Miellet et al., 2013), we can not exclude that cultural diversity may exist also for body visual processing in general, and for a left-gaze bias in particular. An additional limitation is related to the nature of the bodily postures themselves. Since the happy bodily postures, differently from neutral and angry ones, are characterized by upward-extended arms and hands, we can not exclude that anger and happy stimuli may differ in very low-level features which may alter patterns of eye movements. Future studies are needed to focus on a subset of stimuli in which the visual properties of happy and angry stimuli are more comparable and to test whether the pattern of eye movements is different from the one reported in the present study. Another aspect to be considered as a potential constrain on generality is the poor ecological validity of our stimuli. Although headless bodies were chosen to investigate the eye-movements pattern strictly associated with emotional body postures and not influenced by the presence of the face/head, we could expect a different visual processing of the figures as a function of head presence.

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Author contributions MC, NL, and FS designed the experiment. MC and NL performed data acquisition and analyses. MC, NL, FS, MU and VG interpreted the results. MC, and NL wrote the manuscript. All authors have contributed to, seen and approved the manuscript.

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Data and code availability The datasets analysed during the current study are available from the corresponding author on reasonable request.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval All procedures performed in this study involving human participants were in accordance with the ethical standards of the local ethical committee "Comitato etico Area Vasta Emilia Nord" and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Consent to participate Informed consent was obtained from all individual participants included in the study.

Consent to publish Not applicable.

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