RUNNING HEAD: Emotion from Hands

Spatial Relations Between Hands Shape Visual Perception of Emotion

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Abstract

Body posture provides a rich source of information about the emotional states of other people. Recent research has shown that people can recognise emotions even from isolated images of body parts, especially from hands. In perception of emotion from faces, research has emphasised the importance of relational information about the global spatial relations between different parts of the face. The role of holistic processing in perception of emotion from bodies is unknown. One potential signature of holistic processing in emotional perception of bodies is the finding the recognition of emotions is higher when both hands are shown compared to just one hand. This could indicate that the spatial relationship between the hands carries information about emotions over and above that present in each hand individually. Alternatively, it could reflect the fact that when two hands are present there is simply twice as much total information. This study therefore compared emotion recognition when participants were shown: (1) both hands in their actual configuration, (2) both hands in a distorted configuration, or (3) one hand. Performance was substantially above chance in all conditions, replicating the finding that emotion can be recognised from isolated hand images. Critically, performance was higher when both hands were shown in their actual configuration compared to the other two conditions. These results provide evidence for holistic processing in the perception of emotion from body parts.

Our body is an important channel for communicating with other people and expressing emotions. A vast literature in experimental psychology and cognitive neuroscience has focused on facial expressions of emotion. However, it has long been known that bodily displays of emotion are also important for communication, both in humans and many other animals (Bell, 1847; Darwin, 1872). In the last two decades, there has been a resurgence of interest in how we perceive the emotional states of others from their bodily posture (de Gelder et al., 2015). We are easily able to recognise a range of emotions from bodily cues, and in some cases it appears to be the body rather than the face that differentiates between intense emotions (Aviezer et al., 2012).

Most studies investigating perception of bodily displays of emotion have shown the entire body (e.g., Atkinson et al., 2004; Coulson, 2004; Dael et al., 2012; de Gelder & Van den Stock, 2011; de Meijer, 1989; Wallbott, 1998). A few studies, however, have shown that individual body parts may also carry information about emotion. Grosbras and Paus (2006), for example, showed that anger can be perceived from isolated hand movements. Pollick and colleagues (2001) showed that emotions can be recognised from point-light displays of arm movements. In another study, Ross and Flack (2020) showed that removing arms and hands from images of actors displaying emotional expressions reduced the accuracy with which they could be classified. We recently showed that people can classify emotions even when images of only isolated body parts are shown (Blythe et al., 2023). Participants saw images of isolated hands, arms, heads (without faces), and torsos. While performance for isolated parts was lower than for whole bodies, it was above chance levels for all body parts tested. Interestingly, performance was significantly higher for hands than for other parts (arms, heads, and torsos). This result suggests that hands may play a particularly important role in communicating emotion.

In face perception, a large body of research has emphasised the importance of the global spatial relationships between different features in recognising individuals and their emotional expressions, what has been variably termed “configural” or “holistic” processing (Piepers & Robbins, 2012). For example, emotion recognition is impaired when the top and bottom halves of a composite face image are misaligned (Calder et al., 2000). The local information available in the image is unaffected by such misalignment, but the overall spatial relationship between parts is. Other research, however, has indicated that specific parts of the face, such as the eyes and mouth, are especially important for communicating emotion, with different features being particularly important for different emotions (Smith et al., 2005; Wegrzyn et al., 2017). Together, these results suggest that facial emotion is processed using a combination of local processing of individual features and more holistic processing of the entire face.

The role of local and global holistic processing in perception of emotion from bodily postures remains unclear. The finding that emotion can be recognised from isolated body parts (Blythe et al., 2023) indicates that perception of local features is sufficient for some degree of emotion perception. But in that study classification performance was substantially higher for whole bodies than for isolated parts. This whole-body advantage could be because whole bodies retain holistic information about the overall configuration of the body. Alternatively, however, it is also true that the whole bodies contain more total information since they depict many different isolated body parts. In a recent series of studies, Poyo Solanas and colleagues (2020a, 2020b) used pose-estimation software to determine which postural and kinematic features of bodies carry information used to perceive emotion. They argue that emotion is carried largely by what they call ‘midlevel’ features, such as limb angles and symmetry. Such midlevel features may be above the level of what is carried by a single isolated body part, but also do not reflect integration across the body as a whole.

One piece of evidence from our recent study (Blythe et al., 2023) is relevant to this issue. In Experiment 3, Blythe and colleagues compared performance at classifying emotions when both hands were visible compared to when only one hand was. While performance was above chance in both cases, accuracy was significantly reduced when only one hand was shown. One possibility is that in the two hand condition there is simply twice as much total information about the emotion being expressed. On this interpretation, the relevant information is contained locally within each hand. Alternately, it may be that the spatial relationship between the two hands carries additional information that is not available from either hand considered individually.

In the present study, we investigated the role of relational information in the perception of emotion from isolated hands. If the increased performance at classifying emotion from two hands compared to one hand is based on assessment of the spatial relationship between the two hands, this advantage should be reduced if the hands are moved relative to each other. In contrast, if the advantage for two hands is simply due to the local information available in each hand, changing their relative position should not affect performance.

Method

Participants

Fifty-six individuals (37 women, 19 men) between 20 and 74 years of age (*M*: 32.1 years, *SD*: 8.9) participated in this online study implemented in the Gorilla Experiment

Builder (https://gorilla.sc/) (Anwyl-Irvine et al., 2020). Fifty participants were right-handed and six left-handed by self-report. Participants were physically located in the UK and had normal, or corrected-to-normal, vision. Participants were recruited through the social networks of the researchers (N=52) and through the Prolific webpage (N=4). All procedures were approved by the School of Psychological Sciences Research Ethics Committee at Birkbeck. The data was collected in 2023.

Sample size was determined according to the same criteria used in Experiment 3 of our previous paper using this paradigm (Blythe et al., 2023). Specifically, we conducted an a priori power analysis to have power of 0.95 to detect a medium effect size (Cohen's d = 0.5) with alpha of 0.05, using G*Power 3.1 (Faul et al., 2007).

An additional sample of 20 participants (9 women, 11 men) between 22 and 69 years of age (M: 37.6 years, SD: 13.8) were recruited from Prolific to provide naturalness ratings on the stimuli.

Stimuli

Stimuli were similar to those we used in our previous study (Blythe et al., 2023) and included front-facing images of 12 actors (9 female) modelling body postures displaying six emotions (happy, surprised, afraid, sad, disgusted, and angry). Images were selected from the Bochum Emotional Stimulus Set (BESST), an open-source resource featuring static images of 85 Caucasian actors portraying different emotions (Thoma et al., 2013). We used images from 12 BESST actors, eight of which we had used in Experiment 3 of our previous study (actors 5, 8, 10, 13, 23, 39, 58, and 85) plus an additional four (actors 17, 29, 45, and 81).

As in our previous study, the hands were isolated from the full-body BESST images using the GNU Image Manipulation Program (GIMP). In the *Both Hands* condition, both hands were visible. In the *One Hand* condition, only the actor's right hand was shown. Finally, in the *Two Hands Distorted* condition, the spatial relationship of the two hands was altered, while preserving the distance between them. A custom MATLAB (Mathworks, Natick, MA) script created a bounding rectangle around each hand, selected and translated the left hand so that the centre of its bounding rectangle was in a random direction between 0-360° from the right hand, while preserving the distance between the centres of the two bounding rectangles. In five cases, the script produced images in which the two hands were partly on top of each other. In these cases, the hands were manually shifted in GIMP to be as close as possible without overlapping. Examples of these images are shown in Figure 1.

Figure 1: Examples of stimuli from one actor.

Procedures

Procedures were similar to Experiment 3 of our previous study (Blythe et al., 2023) except that the two hand distorted condition was used instead of the left hand condition. Stimuli were presented online using the Gorilla platform. Participants completed the experiment using their own tablet or computer (mobile phones were not permitted). Exact stimulus sizes and viewing distance therefore varied for each participant according to screen size.

Each trial started with a fixation cross for 200 ms, followed by stimulus presentation. Stimuli were presented on a white background above six rectangular grey buttons with the six emotion labels. Participants were instructed to judge which of the six emotions the person in the image appeared to be displaying. Stimuli remained on the screen until participants made their response by clicking the mouse cursor on one of the six boxes. The order of the six emotion labels was constant across trials for each participant, but two different orders were used across participants.

For each of the three conditions, participants saw images depicting each of the six emotions for four of the twelve actors. This resulted in 24 trials per condition, and 72 trials in total. The 72 trials were presented in random order. Different actors were used for each condition to ensure that participants could not base responses on memory for having already seen the same image in a different condition. The assignment of actors to the three conditions was counterbalanced across participants according to a Latin square. Thus, there were six counterbalance groups in total.

Transparency and Openness

We report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study. The study's design and analysis were not preregistered. Stimuli, raw data, and analysis scripts are available on the Open Science Framework website: https://osf.io/mp78r/

Results

Figure 2 shows classification accuracy for the three conditions. Consistent with the results of our previous study (Blythe et al., 2023), performance was substantially above chance level (i.e., 16.7%) in all three conditions, as tested using one-sample t-tests with Holm-Bonferroni correction for multiple comparisons. Accuracy was on average 50.0% (*SD*: 13.4%) in the both hands condition, $t(55) = 18.56$, $p < .0001$, Cohen's $d = 2.481$; 42.9% (*SD*: 11.0%) in the one hand condition, $t(55) = 17.82$, $p < .0001$, Cohen's $d = 2.381$; and 45.8% (*SD*: 11.8%) in the two hands distorted condition, $t(55) = 18.44$), $p < .0001$, Cohen's $d = 2.464$.

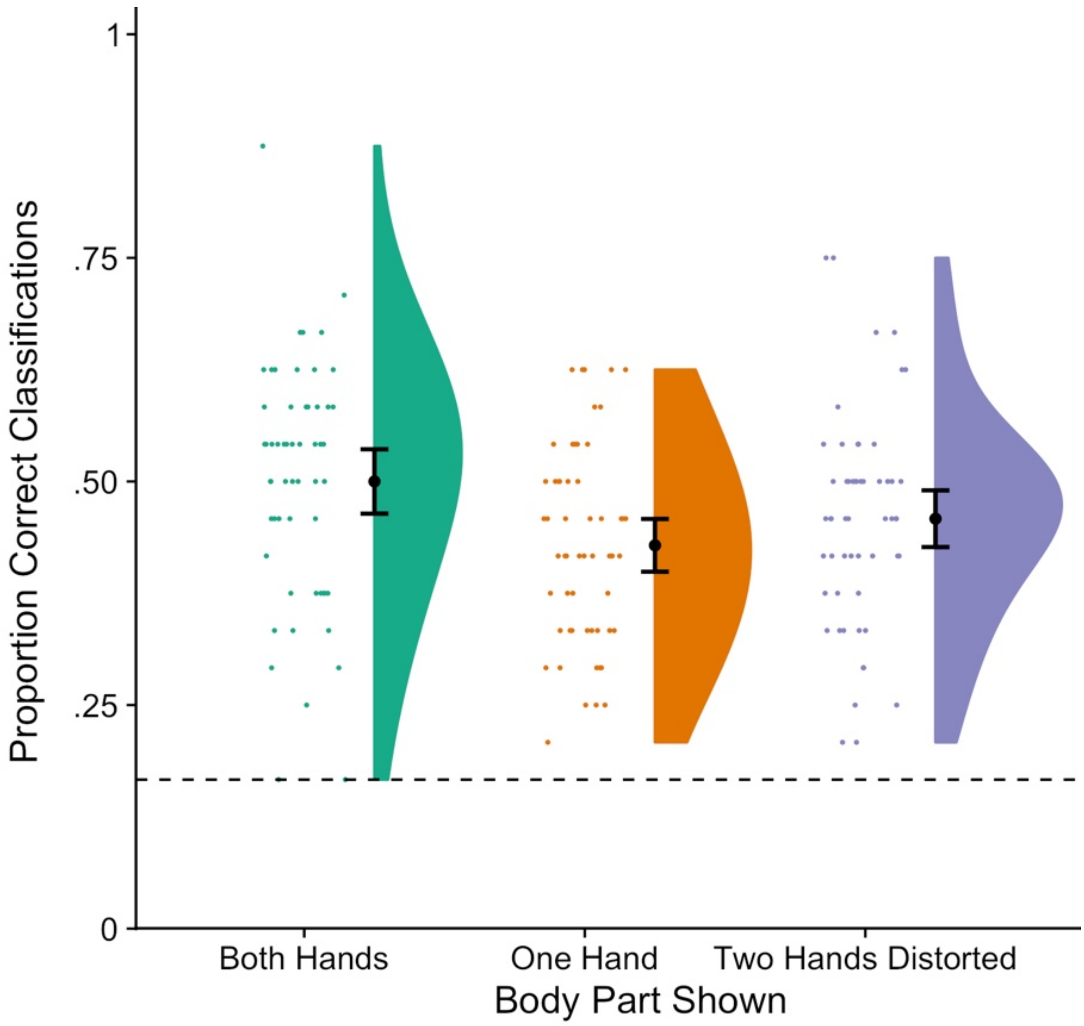

Figure 2: Classification accuracy for each of the stimulus types, shown using raincloud plots (Allen et al., 2021). Points show data from individual participants, while curves show the probability density function. The dashed horizontal line indicates chance performance (i.e., 1/6 = 0.167). Black circles indicate the mean and error bars the 95% confidence interval. Classification was significantly above chance for all three conditions, and was significantly higher for both hands condition than the two other conditions.

A repeated-measures ANOVA showed that classification accuracy differed significantly across the three conditions, $F(2, 110) = 9.47$, $p < .001$, $\eta_p^2 = .147$. Post-hoc t-tests with Holm-Bonferroni correction were used to compare the different conditions. Consistent with our previous study, performance was higher for the both hands stimuli than the one hand stimuli, $t(55) = 4.38$, $p < .0001$, Cohen's $d_z = 0.586$. Critically, performance was also higher for both hands stimuli than for two hands distorted stimuli, $t(55) = 2.61$, $p = .012$, Cohen's d_z = 0.349. There was no significant difference in performance between the one hand and two hands distorted conditions, $t(55) = 1.73$, $p = .089$, Cohen's d_z = 0.232.

Figure 3 shows confusion matrices for the three conditions. To quantify the similarity of the overall pattern of confusions, we used representational similarity analysis (RSA) (Kriegeskorte et al., 2008), in the same way as in our previous study using this paradigm. For each participant and each pair of conditions, we calculated the Pearson correlation between the 30 off-diagonal elements (i.e., the errors).

One-sample t-tests comparing the mean Fisher-transformed correlations to 0 provided evidence for similarity in the patterns of confusions between both hands and one hand stimuli (*M*: .314), $t(55) = 11.46$, $p < .0001$, $d = 1.532$, both hands and two hands distorted stimuli (*M*: .344), $t(55) = 11.81$, $p < .0001$, $d = 1.579$, and one hand and two hands distorted stimuli (*M*: .342), $t(55) = 12.16$, $p < .0001$, $d = 1.625$. A repeated-measures ANOVA showed no significant difference between the correlations between pairs of conditions, $F(2, 110) = 0.45$, $p = .641$, $\eta_p^2 = .008$. This suggests that while the spatial relation between the two hands may provide information useful for determining the emotion displayed, it does not change the more abstract relations between the different emotions.

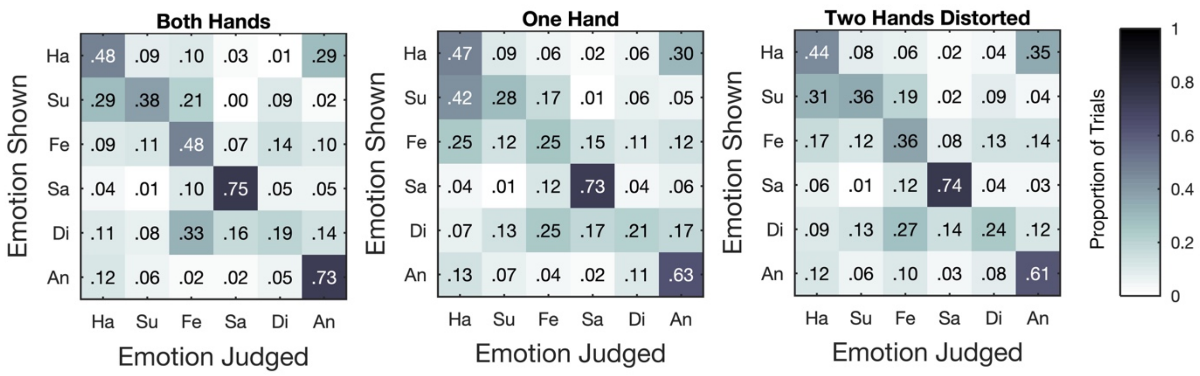

Figure 3: Confusion matrices for each body part condition. Every cell shows the proportion of trials in which each emotion judgment (x axis) was made for each of the displayed emotions (y axis), averaged across all 56 participants. Ha = happy, Su = surprised, Fe = fear/afraid, Sa = sad, Di = disgusted, An = angry.

We next investigated whether accuracy for the distorted hands may relate to the posture depicted appearing unnatural or biomechanically impossible. A new group of 20 participants rated each of the 'both hands' and 'two hands distorted' images using a 0-100 slider with endpoints labelled 'very unnatural' and 'very natural'. Overall, the both hands stimuli were rated as more natural (*M:* 55.9, *SD:* 11.8) than the distorted stimuli (*M:* 45.1, *SD:* 11.1), $t(19) = 3.53$, $p < .005$, $d_z = 0.789$. We then divided the stimuli within each category into high and low naturalness based on a median split of the ratings and calculated accuracy from the original sample of participants for each type of stimulus. For the distorted stimuli, the more highly natural stimuli were categorized correctly more often than less natural stimuli (54.6% vs. 38.7%), $t(55) = 4.75$, $p < .0001$, $d_z = 0.635$. Notably, however, the same pattern was found for the undistorted stimuli (54.1% vs. 46.1%), $t(55) = 2.33$, $p < .05$, $d_z = 0.312$.

Finally, we investigated whether the effects of spatial location are specific to some emotions. We conducted a repeated measures ANOVA including both the emotion expressed (by the shown stimulus) and the body part condition in order to investigate the interaction between these two factors. As Mauchley's test indicated the sphericity assumption was violated, the Greenhouse-Geisser correction was applied. Critically, there was a significant interaction between emotion and body part condition, $F(7.29, 401.16) = 2.68$, $p < .01$, $\eta_p^2 = .046$. To explore this interaction, we conducted separate one-way ANOVAs (looking for the effect of body part condition) for each emotion separately. There were significant effects of body part condition for stimuli showing fear, $F(2, 110) = 14.39$, $p < .001$, $\eta_p^2 = .207$, and anger, $F(2, 110) = 3.09$, $p < .05$, $\eta_p^2 = .053$. There were no significant effects of body part for any of the other four emotions (all *p*'s > .09).

Discussion

The present results provide evidence for holistic or configural processing in the perception of emotion from body parts. We replicated the finding of Blythe and colleagues (2023) that emotion can be recognised from isolated hands and also that this ability is reduced when only one hand is shown compared to two hands. The key novel result of this study is that this two-hand advantage depends on the spatial relationship between the two hands. When both hands were shown but their spatial relationship was altered, performance was similar to when only one hand was shown. These results indicate that the information carried by the hands is based not only on the configuration of each hand considered individually, but also by the spatial relationship between the two hands.

Research on emotional face perception has provided evidence for the involvement of both holistic processing (Calder et al., 2000) and more local processing of individual face features (Smith et al., 2005; Wegrzyn et al., 2017). Our results suggest that the same is true of emotional body perception. In our previous study (Blythe et al., 2023) and the present study we showed that people can classify emotions from isolated body parts such as hands, even when only a single hand is shown. This indicates that local information from a single body part is sufficient to allow at least some degree of perception of emotion. At the same time, the results of the present study show that the spatial relationship between the two hands carries additional information about the emotion displayed, over and above the local information present in the two hands considered individually. Together, these results suggest that both local and holistic processing are involved in the visual perception of emotion from body parts, mirroring research on facial perception of emotion.

Looking at the effect of body part condition per emotion, the effects were significant for emotions anger and fear. We believe, however, that these comparisons between emotions need to be interpreted cautiously given that we did not design the study with the goal of comparing between emotions and had very few trials per emotion (four trials) to be able to make these comparisons.

Our follow-up analysis showed that distorted stimuli are on average perceived to be less natural, and that participants are less accurate at recognising emotions from the stimuli that are perceived to be less natural. While these results indicate that our distortions affected how participants perceived whether the postures were possible or natural, we believe this would be the case for any manipulations of configural position. Moreover, the direction of causation is uncertain. It may be that participants are less able to recognise emotions from distorted hand postures because they appear unnatural. But it could equally be that distorted hand postures are judged as unnatural exactly because they do not appear to coherently express a single emotion. It is also possible that there is something special about the normal left/right relation between the hands in the horizontal axis. In this study, distortions were induced using a random angular displacement. But it may be interesting in future research to manipulate this more systematically.

Recent research has suggested that perception of emotion from bodies relies on midlevel features, above the level of individual body parts, but below the level of the entire body (de Gelder & Poyo Solanas, 2021). The present results showing that the spatial relationships between the two hands provides relevant information for perceiving emotion are consistent with this interpretation.

One limitation of our study is that the actors in our stimuli were Caucasian individuals from Germany, while the participants were all based in the UK. There is some evidence that the expression and perception of emotion differs across cultures (Kleinsmith et al., 2006; Matsumoto & Hwang, 2013). At the same time, recent results have also shown striking cross-cultural similarities in reports of which body parts emotions seem to be felt (Volynets et al., 2020). It will be interesting in future research to investigate whether the perception of emotion from hands varies across cultures. Another potential limitation is the use of remote, online testing. While this has the advantage of allowing a more diverse and representative sample than with in person testing in a university lab, it also makes it harder to ensure comparable testing conditions. Overall, performance in this study was substantially above chance, as in our previous study (Blythe et al., 2023) which was also performed online. However, it is also worth noting that accuracy with full body stimuli in our previous study was somewhat lower (64.7% vs. 85.8%) than found in the original validation study for the BESST stimulus set (Thoma et al., 2013).

A broader literature has demonstrated the important communicative functions of the hands (Goldin-Meadow, 1999; Kendon, 1994). For example, the hand gestures that accompany speech are known to increase the comprehension of observers (Berger & Popelka, 1971; Graham & Argyle, 1975; Riseborough, 1981) and learning outcomes in classroom settings (Cook et al., 2013; Valenzeno et al., 2003). Similarly, hand movements enhance word learning in toddlers (Mumford & Kita, 2014; Wakefield et al., 2018) and orient attention in pre-verbal infants (Bertenthal et al., 2014; Rohlfing et al., 2012). Indeed, hands appear to be a major focus of young children's gaze in the second year of life (Fausey et al., 2016). Our finding that the hands convey emotional information complements this body of research showing that the hand is a fundamental feature of human communication (Longo, 2025).

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Vanda Meged: Investigation, Formal analysis, Methodology, Writing – review & editing

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