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BRIEF REPORT

Social Bodies: Preliminary Evidence That Awareness of Embodied Emotions Is Associated With Recognition of Emotions in the Bodily Cues of Others

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We experience and express emotions via our bodies, and we are also able to infer the emotional states of others by observing their movements and postures. The ability to extract affective bodily cues in social contexts may be achieved via internal simulation, which is closely associated with experience and awareness of emotions in one's own body. Here, we hypothesized that reports of one's own bodily experiences of emotions would be associated with the ability to infer other people's emotions from their bodily signals. Healthy individuals (n = 106) participated in two tasks. An emotional gait perception task was used to test the ability to extract emotional cues from other people's body movements. Subjective bodily experience of emotions was visualized with a computerized mapping tool, which required participants to localize sensations on the body corresponding to specific emotions. Participants reported specific locations of body sensations for different emotions. Emotional gait perception accuracy was positively associated with participants' reported intensity for bodily experiences of happiness and anger and with their tendency to report body mapping patterns similar to prototypes established in a much larger sample. Results suggest that awareness of emotions in one's own body is related to our ability to perceive emotions in others. Implications for future work on the role of embodiment in social cognition and psychiatric disorders are discussed.

Keywords: embodiment, emotion recognition, biological motion, gait perception, social cognition

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"Heartwarming," "cold feet," and "boiling with anger"—our understanding of emotion is intricately tied to bodily metaphors that we use to describe and communicate our internal experiences (see Lakoff & Johnson, 1999). Emotion metaphors reflect widespread, if not universal, patterns of human bodily experiences and physiology. In line with folk knowledge, recent studies have established that different emotions are associated with discernible patterns of autonomic nervous system activity (see review by Kreibig, 2010), and that our subjective experiences of different emotions correspond to spatially distinct "maps" on the body (Hietanen et al., 2016; Nummenmaa et al., 2014). These findings suggest that embodiment and internal simulation of emotions are intricately tied to interpersonal communication.

Both impaired social functioning and disruptions to bodily awareness are central features of several psychiatric disorders (Crespi & Dinsdale, 2019; Noel et al., 2017; Pinkham et al., 2020; Torregrossa et al., 2019, 2022). Better understanding of the relationship between bodily self-disturbance and social impairments could contribute to the development of new interventions. Given the transdiagnostic relevance of social dysfunction and the presence of social difficulties in those across the psychosis and autism spectrum conditions (Aaron et al., 2015; Blain et al., 2017; Cotter et al., 2018), elucidating the role of mechanisms such as disrupted bodily awareness is particularly important and is relevant to initiatives such as the National Institute of Mental Health Research Domain Criteria (Insel et al., 2010) and the Hierarchical Taxonomy of Psychopathology (Kotov et al., 2017). In the present study, using a sample of healthy young adults, we examined associations between the perception of emotional cues in gait and participants' reports of their own bodily emotions.

Embodied emotion refers to "the perceptual, somatovisceral, and motoric reexperiencing of the relevant emotion in one's self" (Niedenthal, 2007)—a phenomenological experience where perception or recollection of emotional signals leads to simulation or reenacting of the corresponding emotional state. Thinking about an emotion activates the autonomic nervous system in a similar fashion as actively experiencing the same emotion (Levenson, 2003). Such somatomotor simulation and reenacting of emotions may allow us to plan actions, facilitate adaptive behavior, and support interpersonal interactions (Decety & Jackson, 2004; Keysers et al., 2010; Niedenthal, 2007). Further, humans often spontaneously mimic others' emotions in a variety of situations and contexts, particularly those that facilitate social and affiliative goals (Hess & Fischer, 2014).

Bodily awareness and experience of emotion may also affect our ability to perceive emotions expressed in the bodies of others. Embodied emotion and social cognition are linked via activation of the "shared network" in the brain that supports internal simulation. The "shared-network" hypothesis suggests that the neural networks recruited during one's own emotional experiences are also involved in processing the emotional experiences of others (Singer, 2006). Thus, our ability to infer the emotional states of others may stem from our capacity for internally simulating and recreating the mental and bodily states of others. For instance, observing prototypical emotional expressions activates the facial muscles associated with those emotions (Hofree et al., 2014). Conversely, blocking facial movements (Oberman et al., 2007) or deactivating the somatosensory cortex with transcranial magnetic stimulation (Pourtois et al., 2004) impairs emotion perception. An individual's current emotional state can be accurately "read out" from the activity of their somatosensory cortical activity (Saarimäki et al., 2016), and manipulations of bodily arousal have been shown to influence individuals' processing of emotional stimuli (Kever et al., 2015). Finally, *emotional contagion* is also reflected in increased interpersonal synchrony in brain activation in the limbic and paralimbic emotion circuits, likely facilitating interpersonal alignment and communication (Smirnov et al., 2019). These findings suggest that one's experience of bodily sensations triggered by emotions might be associated with emotion recognition accuracy, yet this hypothesis currently lacks direct empirical support. In the present study, we examined this by testing whether participants' reported intensity of bodily emotions was associated with their ability to accurately perceive emotional cues in gait.

While the simulation hypothesis and studies concerning embodied emotion show support for the link between emotion recognition and one's experience of emotion in the body. We could also expect these two domains may share similarities due to common sociocultural representations of emotional states. For instance, when someone recognizes a face as happy or angry, they may be relying as much on knowledge of emotion prototypes and cues rather than just simulation in recognizing and identifying said emotion as happy or angry (Lindquist et al., 2015). Research shows that individuals with difficulties identifying and describing their feelings also have difficulties correctly identifying emotional information from film clips (Aaron et al., 2018), are less accurate at emotion perception (Prkachin et al., 2009), and score lower on self-report measures of empathy (Aaron et al., 2015). Furthermore, studies on self-reported patterns of bodily activation associated with various emotions suggest that similar representations of emotions are identified when prompted with emotional words, facial expressions, and emotional film clips, while participants are also able to accurately recognize and label the body maps of emotions produced by other individuals (Nummenmaa et al., 2014). This, taken with broader research indicating that emotion recognition abilities correlate across stimuli using different modalities of expression—for example, faces, voices, and bodies (Bänziger et al., 2009)—suggests that shared representations of emotions may cut across how individuals report experiencing emotions in their own bodies and recognizing the emotions of others. In the present study, we examined this by testing whether the similarity between participants' reported experiences of bodily emotions and normative prototypes for those emotions was associated with their ability to accurately perceive emotional cues in gait.

Efficient and accurate recognition of embodied emotional cues is particularly important for successful social interaction. Although a vast majority of emotion recognition research has focused on facial expressions, emotions can be communicated through a variety of other channels—including bodily cues (de Gelder, 2006). In fact, bodily cues of emotion may supersede facial expressions when faces and bodies convey conflicting information (Meeren et al., 2005). Furthermore, when the target is at a distance or faces are not discernable (e.g., because of face mask use), gait or body movements can provide particularly valuable cues to the emotional states of others (Atkinson et al., 2007). Rapid and accurate perception of other people's emotional states allows us to adapt our own behavior (Campbell et al., 2010) to prepare for impending social interactions.

Past research suggests that social cognitive abilities are related to our internal experiences and representations of emotional states, both of which are also related to our perception of internal bodily signals (Aaron et al., 2018; Murphy et al., 2019; Parrinello et al., 2022; Schaan et al., 2019). Nonetheless, no studies—to our knowledge—have directly examined associations of recognition of full-body emotion cues with experience and subjective awareness of emotion-associated bodily sensations. In the present study, we directly tested whether reports of one's own bodily emotions would be associated with accuracy for perceiving other people's emotions from body movements (i.e., gait patterns), focusing on the specific emotions of happiness and anger. See Figure 1, for a schematic representation of key study constructs and hypotheses. Specifically, we hypothesized that participants' accuracy in recognizing happy and angry cues from gait would positively correlate with (a) participants' reported intensity of bodily sensations for happiness and anger, as well as (b) the degree to which participants' reported bodily sensations for happiness and anger matched prototypical reports from a large normative sample.

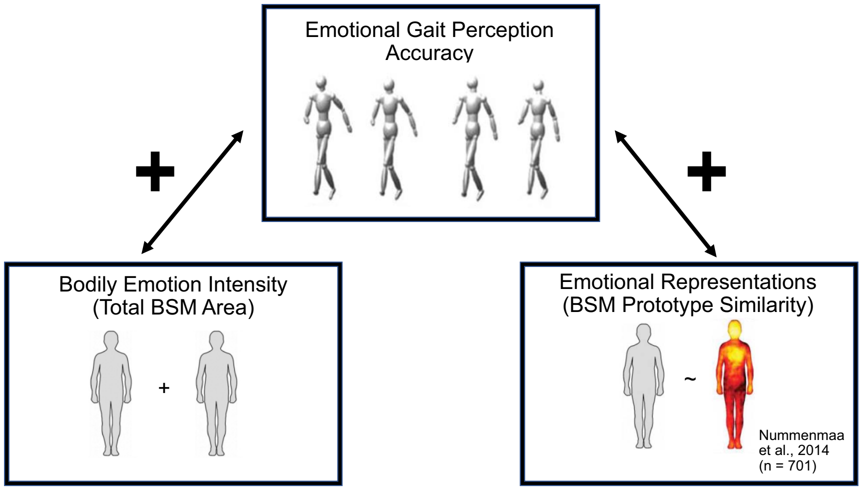
Method

Participants

One hundred six healthy college students (75 women) were recruited using the Vanderbilt University Psychological Research Subject pool. The mean age was 19.7 years ($SD = 1.3$). Our sample size was informed by a previous study of emotional gait perception that used the same task, which had 42 participants (Peterman et al., 2014). We initially planned to recruit 84 participants (twice the original sample), given the expected reduced range of gait perception performance in a healthy undergraduate sample. After concluding study recruitment, however, we collected data from 106 participants. Post hoc sensitivity power analysis suggests that this sample size would give us 80% power to detect an effect size of $r = .269$ or 88% power to detect a correlation of $r = .300$.

The exclusion criteria were as follows: diagnosed psychiatric or neurological disorders, history of head injury, substance use within 6 months, and current psychotropic or pain

Figure 1
Conceptual Diagram of Key Study Constructs and Variables



Note. Constructs measured in the present study included (1) accuracy on an emotional gait perception task, (2a) bodily emotion intensity as measured using participants' total BSM area for happy and angry emotions, and (2b) awareness of emotional representations as measured by the similarity between participants' BSMs with prototypes for happy and angry emotions. We hypothesized that greater accuracy on the gait perception task would be associated with greater total BSM area and greater BSM prototype similarity. BSM = bodily sensation map. See the online article for the color version of this figure.

medication. Participants were prescreened for these criteria when signing up for the study online. The protocol was approved by the Vanderbilt University Institutional Review Board. Participants gave written informed consent and received course credit for their participation. After obtaining written consent, participants were given instructions for the Emotional Gait Task and the Embody Task.

Emotional Gait Task (Peterman et al., 2014)

Polygonal "walking" avatar stimuli were created with motion morphing, which permits parametric adjustment of emotional "signal" in the stimulus (see Roether et al., 2009 for standardization of the emotional gait stimuli). To show a full perspective of the gait, each avatar was angled to the participant's left side (see Supplemental Figure S1).

"Happy" and "angry" stimuli at three levels of intensity were used in the present study: a 50% (attenuated) happy or angry gait walker, a 100% (prototypical) happy or angry gait walker, and a 150% (exaggerated) happy or angry gait walker. Aspects of movement that defined the emotional content of each polygonal avatar walker included the flexion of the head and arms (head tilted forward for the angry gait and tilted backward for the happy gait) and the postural positioning of the torso (pitched forward for anger and leaned back for happy; Peterman et al., 2014). Additional details for and sample animations from the task and stimuli can be found online: https://jov.arvojournals.org/article.aspx?articleid=2204009#87985549.

For each trial, a gait stimulus was presented for 1 s, after which participants pressed one of two keys corresponding to "happy" or "angry" to indicate their decision. There was no time limit for the response. Accuracy was recorded. There were 192 trials, which followed 10 practice trials. The order of presentation for stimuli was randomized.

Body Mapping of Emotions Task (Embody; Nummenmaa et al., 2014)

For each trial, an emotion word and two human body outlines were presented on the computer screen. Participants were asked to imagine what they feel in their bodies when they experience the emotion. Subsequently, their task was to use the mouse to color the bodily regions they felt becoming activated (on the left body outline) or deactivated (on the right body) while feeling the emotion. Mapping was conducted separately for 14 emotions, but for the present study, only happiness and anger were used to match the stimuli used in our emotional gait perception task. See Supplemental Figure S2, for a schematic diagram of the procedure. Additional details of the task can be found online: https://version.aalto.fi/gitlab/eglerean/embody, https://emotion.utu.fi/softwaredata/.

Body mapping responses were processed as described previously to yield subjectwise bodily sensation maps (BSMs) for statistical analyses (Nummenmaa et al., 2014, 2018). Group-level maps were generated using a one-sample *t*-test procedure on the subjectwise BSMs, employing a threshold of $p < .05$ with false discovery rate (FDR) correction for multiple comparisons.

Statistical Analyses

Descriptive Statistics and Validation of Task Performance

We computed descriptive statistics for accuracy on the gait perception task to summarize performance and compare results to previous research. Whole-sample BSMs were also generated to compare our participants' maps for anger and happiness to those from previous studies.

Test of Current Hypotheses

To examine associations between participants' gait perception accuracy and their body maps, we first averaged the total unthresholded shaded areas across angry and happy maps to create a "total BSM area" variable. Next, vectors representing each participant's happy and angry BSM data were compared to prototype BSM vectors—generated based on the average BSMs from a previous sample of 701 participants (Nummenmaa et al., 2014); for each participant, values of happy and angry "prototype similarity" were computed as the Spearman rank-order correlations between the participant's individual BSM vector and the prototype vector. Finally, participants' prototype similarity variables were Fischer *z*-transformed and averaged across happy and angry emotions, forming a single "BSM prototype similarity" variable for each participant.

After computing participant-level variables, Spearman rank correlations were calculated to assess group-level associations between gait perception accuracy and (a) total BSM area as well as (b) BSM prototype similarity. Last, to visualize differences between participants with low versus high levels of gait perception accuracy, we used a median split to sort participants into bottom-half and top-half groups for overall gait perception accuracy, and then generated separate happy and angry BSMs for each of these groups. Following the procedure for the whole sample maps, these maps were thresholded at $p < .05$, with FDR correction.

Results

Descriptive Statistics and Validation of Task Performance

Mean gait perception accuracy was computed for each participant as percentage of stimuli correctly classified as angry or happy. The total mean accuracy was 89.2% ($SD = 6.4$) across all three levels of intensities for the two emotions, suggesting participants were generally well able to distinguish between happy and angry gait stimuli. This level of accuracy was similar to what has been observed in previous research using the stimuli (e.g., 80% in Roether et al., 2009).

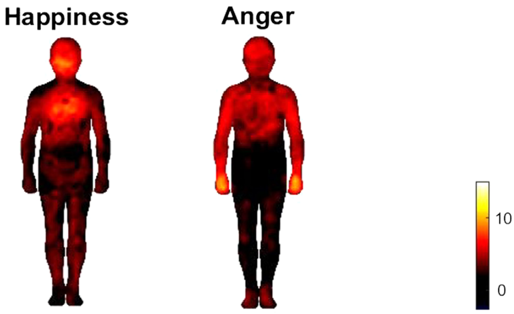
BSMs for anger and happiness for the entire sample are shown in Figure 2. Current results replicate bodily maps of emotions generated in prior studies (see Hietanen et al., 2016; Nummenmaa et al., 2014). Both emotions were associated with reports of bodily activation but not deactivation. Both emotions showed strong reported activation in the chest and head, with anger also showing strong activation in the hands and happiness also showing diffuse activation throughout the lower body.

Test of Current Hypotheses

Next, we correlated total gait perception accuracy with total BSM area. There was a positive correlation ($r = .278$, $p = .004$), indicating that greater gait perception accuracy was associated with greater reported intensity of one's own bodily emotions (Figure 3). Gait perception accuracy was

Figure 2

Topographical Maps of Emotion Sensations for Anger and Happiness in the Body



Note. The body maps show regions where subjects reported increased activation (warm colors) when feeling each emotion. The data are thresholded at $p < .05$, FDR. The color bar represents t statistics. FDR = false discovery rate. See the online article for the color version of this figure.

also correlated with participants' BSM prototype similarity scores ($r = .219$, $p = .028$).

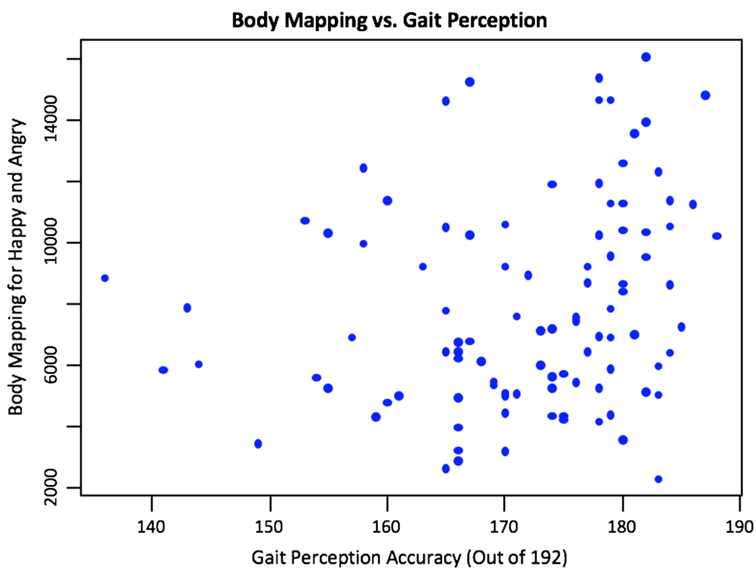
Finally, we generated separate BSMs for low- versus high-accuracy performers on the gait perception task ($n_{\text{low}} = 53$, $n_{\text{high}} = 53$) to visualize how body mapping was associated with gait perception accuracy. In general, participants in the high-accuracy group showed greater amounts of shading for both emotions compared to those in the low-accuracy group (Figure 4).

Discussion

The ability to recognize emotions from gait-related cues was positively associated with participants' reported intensity of bodily emotion sensations, as well as with their similarity to prototype patterns for these bodily sensations. This provides support for the view that embodiment of emotional states and having well-defined representations of these embodied states, may constitute an important mechanism supporting visual recognition of emotional cues in gait. Past research suggests that embodied emotion is an important mechanism for facilitating social cognition (Keysers et al., 2010; Niedenthal, 2007). The

Figure 3

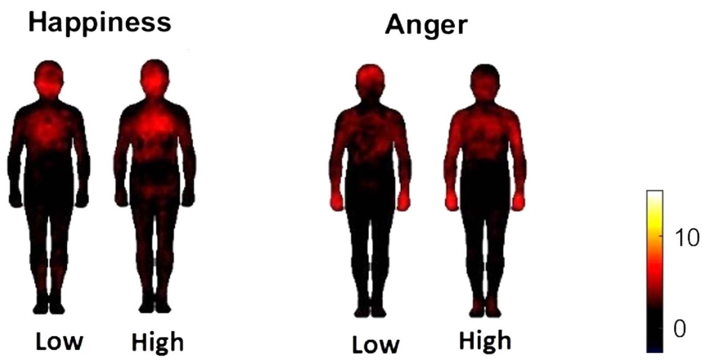
Association of Gait Perception Accuracy and Body Sensation Mapping for Happy and Angry Emotions



Note. The x-axis represents participants' total gait perception accuracy out of 192 trials, whereas the y-axis represents participants' total BSM area for happy and angry emotions. There was a positive correlation between gait perception accuracy and total BSM area ($r = .278$, $p = .004$). BSM = bodily sensation map. See the online article for the color version of this figure.

Figure 4

Body Mapping Split by Bottom-Half Versus Top-Half Gait Perception Accuracy



Note. The body maps show regions where subjects reported increased activation (warm colors) when feeling each *emotion*. Maps are split by participants in the bottom versus top half of overall gait perception accuracy. The data are thresholded at $p < .05$, FDR. The color bar represents t statistics. FDR = false discovery rate. See the online article for the color version of this figure.

present results support these findings by showing that individual differences in the tendency to experience emotions in the body translate to individual differences in emotion recognition abilities.

Our key findings may be interpreted in the context of interoceptive awareness. Interoception refers to the bodily signals that arise from an individual's physiological states, influencing cognition and behavior. "Interoceptive awareness" is one's ability to consciously intuit and interpret this bodily information (Cameron, 2001). Greater interoceptive awareness is associated with improved emotion reappraisal success (Füstös et al., 2013), ease of intuitive decision making (Dunn et al., 2010), and the strength of neural response to emotional stimuli (Pollatos et al., 2005). Importantly, prior work suggests that human observers can reliably infer how an individual feels in their body based on their facial expressions (Nummenmaa et al., 2014) and that greater interoceptive accuracy is associated with the report of more intense emotions after certain induction paradigms (Parrinello et al., 2022). Our findings may represent a specific case of these relationships, with greater awareness of bodily emotional information facilitating better perception of embodied emotional cues or vice versa.

Our results also indirectly support the "shared-network" hypothesis, which suggests that brain regions recruited during one's own emotional experiences are also highly involved in processing the emotional experiences of others (Singer, 2006). Thus, the strength of internal affective state representations would be related to representations of emotional states in others. If awareness of embodied emotion facilitates accurate perception of other people's emotions (and vice versa), this could have practical clinical applications. For example, clinicians may be able to improve social cognitive skills of clients by training their ability to detect and interpret their own experiences of emotions in the body. Meditation and mindfulness-based therapies already show promise for improving interoception and bodily awareness (Khalsa et al., 2008), as well as changing function of the neural network associated with interoceptive awareness (Farb et al., 2013; Hölzel et al., 2008; and Lazar et al., 2005). Such interventions may be particularly useful for people with known deficits in bodily awareness, emotion recognition, and difficulties with verbalizing emotions—such as those with autism, schizophrenia, alexithymia, or personality disorders (Aaron et al., 2015; Crespi & Dinsdale, 2019; Noel et al., 2017; Pinkham et al., 2020; Torregrossa et al., 2019).

Limitations

Despite its novelty and relevance, the present study has several limitations that are worth noting. First, the current research design cannot directly differentiate broad versus specific mechanisms linking performance on the gait and Embody tasks, and thus future work should better control for potential confounding variables such as general cognitive and perceptual abilities. Another potential limitation was the use of a generic body outline for the Embody task; in the future, participants could be allowed to select from several male, female, and sex/gender-neutral outline options (of various body types) when completing the task, which may help with generalizability, inclusivity, and task engagement. Finally, as with many studies in the psychology literature, the generalizability of our findings may be limited due to the characteristics of our sample (i.e., undergraduate students). Along these lines, future work could implement less strict exclusion criteria (e.g., including participants with substance use and diagnosed mental illness), which might capture a broader range of gait perception accuracy and bodily experiences of emotions.

Future Directions

First, the study was limited by our use of only two emotions in the gait perception task. While we selected emotions (anger and happiness) with known physiological arousal and BSMs corresponding to these categories as proof of concept, generalizability may be limited. Future studies should use a wider range of emotions (e.g., adding sadness and fear). Additionally, future research could incorporate additional indicators of bodily emotion—for example, asking participants to identify emotional cues from postures or gestures.

It is worth noting that there was no objective, independent measure of bodily activation (e.g., heart rate, temperature, and blood pressure). Thus, it remains unclear whether the relation between gait perception and experience of embodied emotion is due to individual differences in actual bodily activation (e.g., intensity of arousal), subjective awareness of emotional experience including interoception, familiarity with sociocultural norms for emotional representations, or a combination of these and other factors. Future studies could address this limitation using a combination of emotion induction, psychophysiological measurements during body mapping, and interoceptive assessments. Then it will be possible to test if internal simulation is necessary for perceiving emotions in the bodies of others.

Conclusion

Our results suggest that the perception of emotional cues in the bodies of others is related to experiences of emotions in one's own body, including reported intensity of bodily emotions and similarities between one's bodily emotions and established bodily emotion prototypes. These findings contribute to a growing body of work on the central importance of bodily experience to emotion recognition and social cognition. Future work should address this important topic further by incorporating experimental designs, physiological methodologies, and transdiagnostic patient populations.

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