

The visual analysis of emotional actions

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Is the visual analysis of human actions modulated by the emotional content of those actions? This question is motivated by a consideration of the neuroanatomical connections between visual and emotional areas. Specifically, the superior temporal sulcus (STS), known to play a critical role in the visual detection of action, is extensively interconnected with the amygdala, a center for emotion processing. To the extent that amygdala activity influences STS activity, one would expect to find systematic differences in the visual detection of emotional actions. A series of psychophysical studies tested this prediction. Experiment 1 identified point-light walker movies that convincingly depicted five different emotional states: happiness, sadness, neutral, anger, and fear. In Experiment 2, participants performed a walker detection task with these movies. Detection performance was systematically modulated by the emotional content of the gaits. Participants demonstrated the greatest visual sensitivity to angry walkers. The results of Experiment 3 suggest that local velocity cues to anger may account for high false alarm rates to the presence of angry gaits. These results support the hypothesis that the visual analysis of human action depends upon emotion processes.

Human observers demonstrate impressive visual sensitivity to the actions of other people. This was first documented in the classic studies of Johansson (1973) in which he showed that the movements of a few points were sufficient to readily generate compelling percepts of human action. Such point-light displays are traditionally constructed by attaching luminous points to the main joints of a moving actor. The actor's movements are filmed so that only the moving points are visible. While such displays are highly degraded, observers are able to rapidly and accurately perceive a point-light actor's action (Johansson, 1973), intent (Runeson & Frykholm, 1983), social dominance (Montepare & Zebrowitz-McArthur,

1988), emotional state (Atkinson, Dittrich, Gemmell, & Young, 2004) and gender (Troje, 2002).

Psychophysical studies have identified two factors that define visual sensitivity to point-light displays of human action. One of these is motor experience. Visual sensitivity to human action varies as a function of the observer's own motor experience with those actions (Knoblich & Flach, 2001; Jacobs, Pinto, & Shiffrar, 2004). For example, observers demonstrate greater visual sensitivity to point-light displays of their own actions than to the actions of their friends. Because people have the most motor experience, and little visual experience, with their own actions, this heightened capacity for self-recognition indicates

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that motor processes contribute to action perception (Loula, Prasad, Harber, & Shiffrar, 2005).

A second important contributor to the recognition of human movement is visual experience. The more one sees a particular action, the greater one's visual sensitivity to point-light depictions of that action (Jacobs & Shiffrar, 2005). Indeed, sensory experience is key to the perception of the self as a social entity (Decety & Chaminade, 2003). Neurophysiological data support the importance of visual experience in action perception. Single-cell recordings in nonhuman primates and functional neuroimaging studies with humans indicate that the superior temporal sulcus (STS) is selectively responsive to human motion (Beauchamp, Lee, Haxby, & Martin, 2002; Perrett, Rolls, & Caan, 1982; Puce & Perrett, 2003). STS activity is strongly associated with the perception of point-light displays of human action but not moving objects or random motion (Bonda, Petrides, Ostry, & Evans, 1996; Grossman et al., 2000; Oram & Perrett, 1996). Importantly, STS activity is modulated by the visual experience that observers gain from watching point-light actions (Grossman, Blake, & Kim, 2004). Thus, both perceptual sensitivity and STS activity to human motion are influenced by visual experience.

The goal of the current research is to examine whether an additional factor, namely, emotional processes, also shape visual sensitivity to human action. Behavioral findings indicate that human observers can accurately recognize distinct emotions portrayed in the whole body movements of point-light actors (Atkinson et al., 2004; Clarke, Bradshaw, Field, Hampson, & Rose, 2005; Dittrich, Troscianko, Lea, & Morgan, 1996). Moreover, emotion recognition is best when point-light actors are presented as naturally interacting couples (Clarke et al., 2005). This suggests that social and emotional processes may significantly influence the visual analysis of human movement.

The potential impact of emotional processes on action perception is further suggested by several neurophysiological findings. First, STS activity appears to be heightened for potentially threatening, and thus fear-inducing, actions (Wheaton, Pipingas, Silberstein, & Puce, 2001). Furthermore, STS activity is modulated by an observed actor's intent in normal observers (Jellema & Perrett, 2003; Saxe, Xiao, Kovacs, Perrett, & Kanwisher, 2004) but not in autistic observers (Pelphrey, Morris, & McCarthy, 2005). Indeed,

significant anatomical abnormalities have been found in the STS of autistic children (Boddaert et al., 2004; Waiter, Williams, Murray, Gilchrist, Perrett, & Whiten, 2005). Finally, observation of static images of fearful whole-body expressions is associated with enhanced activity in the STS and in other action representation and preparation areas (De Gelder, Snyder, Greve, Gerard, Hadjikhani, 2004).

The hypothesis that the visual analysis of human action within the STS may be modulated by the emotional content of that action is consistent with the numerous feedback and feed-forward connections between the STS and the amygdala (Adolphs, 1999; Baron-Cohen, 1995; Brothers, 1997). For example, the amygdaloid nuclei are an important part of the limbic system (Felleman & Van Essen, 1991; Jones & Powell, 1970) and play a critical role in the assessment of the emotional content of perceptual stimuli (Adolphs, 1999; Brothers, 1997). STS projections account for a significant proportion of the visual input to the amygdala (Amaral, Behnia, & Kelly, 2003; Iwai & Yuki, 1987; Iwai, Yuki, Wantanabe, Hikosaka, Suyama, & Ishikawa, 1990). Furthermore, projections from the amygdala to the STS are considerable (Amaral et al., 2003).

Increasingly, amygdala function is understood as an appraiser of the potential threat or danger posed by "incoming" stimuli (Amaral et al., 2003; Sato, Yoshikawa, Kochiyama, & Matsumura, 2004). Such a position is consistent with observed deficits in "emotional reactivity" (Amaral, 2003). For example, rhesus monkeys sustaining bilateral amygdaloid lesions do not react appropriately to potentially dangerous social situations (Amaral, 2003). Extensive work on rodents (LeDoux, 1995; Davis & Whalen, 2001) and some sporadic primate work (Kalin, 1993; Kluver & Bucy, 1938) further highlight the role of the amygdala (and their removal) in fear, fear conditioning and phobia development. Human data from lesion and functional imaging studies strongly confirm amygdala function in perceiving and reacting to fear (Whalen, Shin, McInerney, Fischer, Wright, & Rauch, 2001; Whalen et al., 2004). The amygdala has also been implicated in the perception of other emotions (e.g., Adolphs & Tranel, 2004; Breiter et al., 1996; Yang et al., 2002).

Broader amygdaloid activation may be associated with the processing of potential threat during conditions of reduced attention at the expense of response specificity (Anderson,

Christoff, Panitz, De Rosa, & Gabrieli, 2003). This idea ties in well with the view of the amygdala as an orchestrating factor in the organization of withdrawal-related behaviors (Adolphs, 2002; Adolphs & Tranel, 2004; Anderson, Spencer, Fulbright, & Phelps, 2000). Consistent with this, amygdala activation in response to emotional stimuli is rapid (Oya, Kawasaki, Howard, & Adolphs, 2002) and may not require conscious awareness of or attention to a stimulus (Whalen, Rauch, Etcoff, McInerney, Lee, & Jenike, 1998; Vuilleumier, Armony, Driver, & Dolan, 2001).

Taken together, neurophysiological data support the existence of tight connections between the processes underlying the visual analysis of point-light defined action and the processes involved in emotion recognition. To the extent that these connections serve functional purposes, emotional processes might shape the visual analysis of human action in profound ways. This hypothesis is tested in the psychophysical studies described below.

EXPERIMENT 1

Visual categorization of emotional gaits

To determine whether the emotional content of an action influences the visual detection of that action, it was first necessary to create a set of stimuli that reliably depicted different emotions. According to Darwinian theories of emotion (Darwin, 1872; LaBarre, 1947), certain combinations of bodily postures, gestures, and expressions are uniquely associated with each of the basic emotions. Consistent with this, observers can accurately determine an actor's emotional state from point-light displays of that individual's bodily actions (e.g., Atkinson et al., 2004). The purpose of this first experiment was to create a set of point-light walker movies that conveyed equally recognizable emotions.

Method

Participants. Eight Rutgers University – Newark undergraduate students participated in this experiment for partial credit toward a course requirement. All participants were naïve to the hypothesis under investigation, had normal or corrected to normal visual acuity. All participants provided written informed consent. Furthermore,

this and all of the studies reported here were reviewed and approved by the Rutgers University IRB.

Apparatus. All stimuli were displayed on a 14-inch Dell™ screen with a refresh rate of 60 Hz and a 1024 × 768 pixel resolution. A Dell™ Pentium computer controlled monitor output. Experimental design and control were programmed in Microsoft™ Visual Basic 6.0. Motion Builder 5.0 by Kaydara™ was used in all stages of movie processing and editing. Gaits were tracked with a ReActor motion capture system from Ascension Technology Corporation. This apparatus was used in all of the experiments reported here.

Stimuli. Stimulus construction began with the motion tracking of two professional actors inside the ReActor motion capture system. Each actor wore a specially designed suit to which a set of 30 motion sensors was attached. The sensors provided spatiotemporal measures of the actors' limb and head movements. Within the motion capture system, each actor individually walked along linear paths of 3 m for approximately 3–4 sec. The resulting sensor measurements were subsequently converted to point-light walker movies. On each trial, the walking actor expressed one of five emotional states (afraid, angry, happy, sad, or neutral) in his gait.

Point-light depictions of the motion capture data were edited into three-second movies and displayed on a computer monitor. These movies were edited so that each emotional gait was depicted from four different observer-centered orientations (walking towards the observer, away from the observer, from left to right, and from right to left). The stimuli were presented in a 15 × 15 cm window positioned in the center of the computer screen. Walkers subtended a maximum vertical height of 15 degrees of visual angle (DVA) and a maximum horizontal width of 4.2 DVA at the point of widest limb extension. Each point was bright blue and subtended a maximum diameter of 0.5 DVA. Point-light walkers became larger as they approached observers and smaller as they walked away from observers with a minimum height of 6.0 DVA. A static frame from one such movie is illustrated in Figure 1.

Procedure. Each participant viewed the resulting series of 300 point-light movies in random order. Participants were instructed to watch each

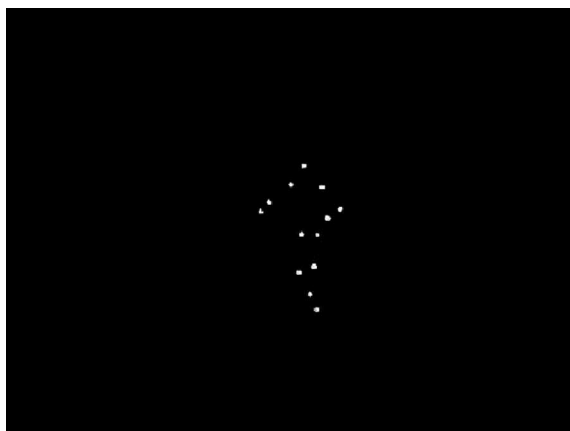


Figure 1. A sample frame from a movie used in Experiment 1 depicting an angry point-light walker.

movie and then to report, with a mouse click, which of the five possible emotional states were depicted in that action. The question was phrased as: “What emotion did you see in this display?”

Results and discussion

The data were analyzed initially as the percentage of movies correctly categorized across each emotion. Subsequently, the inter-observer agreement for each individual stimulus was also computed. A one-sample 2-tailed *t*-test indicated that overall emotion recognition performance in this task ($M = 81\%$, $SD = 15\%$) was significantly above chance, $t(39) = 33.68$, $p < .01$. The overall mean probability of correct emotion recognition closely replicated previous findings (Atkinson et al., 2004; Dittrich et al., 1996). This finding supports the proposal that the way in which people move conveys dynamic cues to their emotional state and that the human visual system is sensitive to these cues. Thus, while substantial research has examined the perception of emotion from facial expression (e.g., Ekman, Friesen, & Ancoli, 1980), bodily movement appears to be another rich source of information to emotional state.

A primary goal of this study was to create point-light movies that reliably conveyed particular emotions through human movement. To that end, three point-light movies for each of the five emotional categories (afraid, angry, happy, neutral, and sad) were selected. Each movie was selected on the basis of the level of inter-participant agreement. Specifically, for each movie, participants agreed at least 83% of the time that the same emotion was depicted. These

fifteen movies constituted the core stimuli in the following two experiments.

EXPERIMENT 2

Is action detection emotion dependent?

Having created a set of point-light stimuli that reliably conveyed five different emotions, we could then examine whether the visual analysis of human action is modulated by emotional processes. Neural processes in the STS are involved in the visual detection of masked point-light displays of human action (e.g., Grossman et al., 2004). If the visual analysis of human action in the STS is itself affected by emotion processes in the amygdala, then action detection should vary with emotion. Furthermore, to the extent that the amygdala contributes to the appraisal of threatening stimuli (e.g., Amaral et al., 2003; Sato et al., 2004), then observers should be especially adept at detecting angry, and thus threatening, point-light walkers. Conversely, if the visual analysis of human action is completed before emotional processes are evoked, then action detection should not vary with emotion. Experiment 2 tested these predictions.

Method

Participants. Thirteen Rutgers University – Newark undergraduate students participated in this experiment for partial credit toward a course requirement. All participants were naïve to the hypothesis under investigation and had normal or corrected to normal visual acuity. All participants provided written informed consent.

Stimuli. The stimulus set, constructed in Experiment 1, consisted of three different instances of a point-light walker expressing five different emotional states: angry, sad, fearful, happy, and neutral. Each emotional stimulus was presented so that the point-light-defined person walked in one of four possible directions: directly towards the observer, directly away from the observer, in the picture plane walking from right to left, and in the picture plane walking from left to right. This created a total of 60 stimuli (3 instances \times 5 emotions \times 4 directions). The stimuli were presented in a 15 \times 15 cm window positioned in the center of the desktop computer screen.

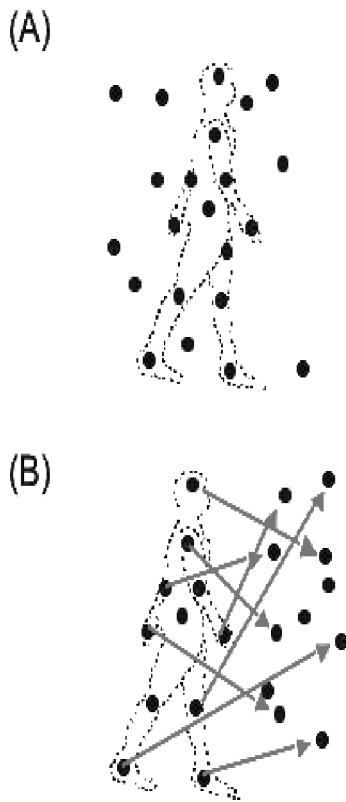


Figure 2. Diagrams depicting the stimuli from Experiment 2. (A) A static frame of a point-light walker in a mask. Note that the outline of the walker was never presented during the experimental or practice trials. (B) In the target present trials, a coherent point-light walker was present in the mask. In the target-absent trials, diagrammed here, the points defining the walker were scrambled.

Following a classic psychophysical detection procedure (Bertenthal & Pinto, 1994), each point-light walker appeared within a mask constructed from positionally scrambled versions of the points defining that very walker (see Figure 2). That is, each display consisted of 13 points that defined the walker and 13 points that defined the mask. Since the mask was constructed from the point-light walker, the velocities of the points defining the walker and mask were identical. As a result, walker detection required a global analysis of the points defining the walker (Bertenthal & Pinto, 1994).

The mask for each walker movie was individually constructed so that the velocities of the points defining the mask and the points defining the walker were equated across stimuli. Each mask point was placed no farther than one-point radius from the walker point being masked. Close juxtaposition between walking points and mask points renders walker detection difficult. The

starting positions of the masking points were calculated from the positions of the points defining the first frame of the walker. Thus, the amount of scrambling never exceeded the walker's original co-ordinate space. The mask points had the same color, luminance, densities, and velocities as the walker points. Only the global organization of the points defining the walker differentiated those points from the points defining the mask.

In half of the trials, a coherent point-light walker was present in the mask. These were "walker present" trials. In the remaining trials, the points defining the walker were positionally scrambled in the same manner as the mask, thereby making the walker unidentifiable. These "walker absent" trials were otherwise identical to the "walker present" trials. Each subject viewed a total of 240 trials (60 "target-present" and 60 "target-absent" trials in each of two blocks).

Procedure. Participants sat facing the computer screen at a specified distance of 57 cm. They were informed that they would see a sequence of brief point-light movies and were requested to report, by pressing one of two buttons on a mouse, whenever or not they saw a walking point-light person within a cloud of moving points. No mention of emotion or direction was included in the instructions. Participants were informed that only responses made during the three-second duration of each movie were recorded.

Two practice trials were administered before the experimental trials. Practice trials were identical to the experimental trials with the exception that the point-light walker was computer generated and always emotionally neutral. Once participants were comfortably able to report the presence or absence of the point-light walker within the three-second response window, the experimental session was initiated. Following a within-subjects design, each subject saw 120 displays in each of two blocks. No performance feedback was given. Trial order was randomized across walker presence/absence, walker direction, walker emotion, and participant. Participants completed each block of trials in approximately 12 minutes.

Each trial started with the presentation of a white fixation point in an otherwise black field for one second. Then, a randomly selected point-light movie appeared for three seconds. As soon as the participant responded, the next fixation window appeared followed by another point-light movie.

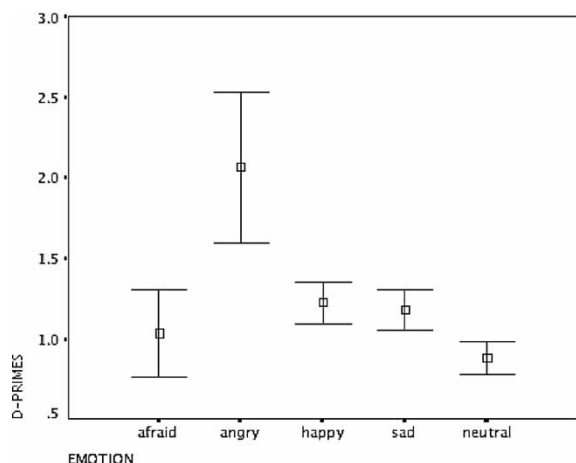


Figure 3. Average detection performance from Experiment 2 broken down by emotion, collapsed across all subjects, presented as a sensitivity measure in *d*-primes. There is a significant main effect of emotion of detection performance. The error bars represent the standard error.

In those cases when a participant did not respond within the three-second window, the subsequent trial started at the completion of the previous one. At the conclusion of the experiment, all participants were thoroughly debriefed about the purpose and the design of the study.

Results

The results were analyzed for response accuracy, bias, and latency. *D*-primes served as the measure of detection sensitivity and were calculated for each subject by subtracting the standardized rate of false alarms (trials in which an absent walker was incorrectly “detected”) from the standardized rate of hits (trials in which a present walker was correctly detected; McMillan & Creelman, 1991). Larger *d*-primes indicate greater separations in the probability distributions of hits and correct rejections and thus indicate greater sensitivity to the presence of the walker. Figure 3 summarizes the *d*-prime measures for each emotion collapsed across subjects.

A 5-level (walker emotion) Repeated Measures ANOVA indicated a significant effect of emotion on detection performance, $F(4, 48) = 3.17, p < .05$. Paired two-tailed *t*-tests of the *d*-prime means across emotions suggest that detection performance with angry walkers was significantly greater than detection of neutral walkers, $t(12) = 2.83, p < .05$. Detection performance with emotionally neutral gaits did not

significantly differ from the other gaits (all $ps > .05$).

The data were also analyzed with respect to gait direction. Two global directions were considered: horizontal gaits were from left to right or right to left relative to the observer and vertical gaits towards and away from the observer. No significant main effect of gait direction was found, $F(1, 120) = 0.03, p = .87$. The interaction between emotion and gait direction was not significant, $F(4, 120) = 1.14, p = .34$. Furthermore, a 5-level (emotions) Repeated Measures ANOVA indicated no main effect of reaction time on detection performance, $F(4, 48) = 0.586, p = .67$. Thus, enhanced detection of angry walkers cannot be attributed to a speed–accuracy tradeoff.

A second type of data analysis involved calculating the *decision criterion*, *c*, associated with each stimulus type (McMillan & Creelman, 1991; Stanislaw & Todorov, 1999). This measure, defined as a function of the negative standardized average of false alarms and hits for each subject per category, reflects the response bias (Stanislaw & Todorov, 1999). This criterion, in other words, is the systematic point where observers “draw the line” between reporting whether or not they see a target. Consistent with the pattern of response criteria depicted in Figure 4, a 5-level Repeated Measures ANOVA revealed a significant main effect of emotion $F(4, 48) = 22.18, p < .001$. Paired two-tailed *t*-tests comparing each emotional gait with the neutral gaits suggest that observers were significantly more inclined to false alarm, that is,

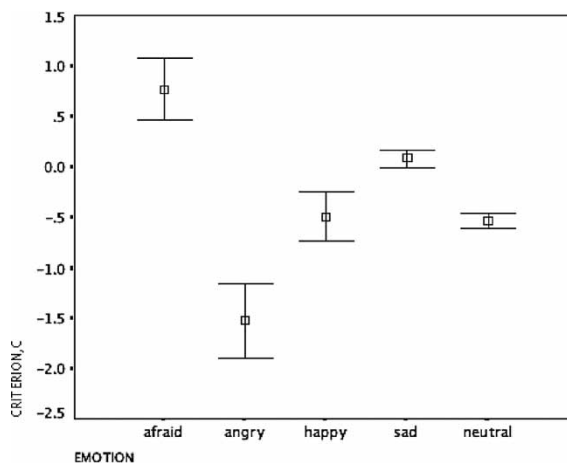


Figure 4. Response bias, from Experiment 2, depicted as the average decision criterion, broken down by emotion, collapsed across all subjects. Observers most frequently detect an absent walker when that walker conveys anger. The error bars represent the standard error.

to report that an absent walker was actually present, with angry walkers than with neutral walkers, $t(12) = -2.90$, $p < .05$, or with any other walker (all $ps < .01$).

Discussion

The results of this experiment suggest that emotion contributes to the visual detection of human motion. Specifically, observers were best able to detect angry walkers. The detection of point-light walkers in masks is thought to involve processes in the STS (Grossman et al., 2004). The finding that walker detection is emotion dependent is consistent with the hypothesis that emotional processes constrain perceptual processes during the visual analysis of human motion. This seems to be especially true for the visual detection of angry people. Significant interconnections between the STS and the amygdala (Wheaton et al., 2001) may be the basis for this behavior. If so, then the current results suggest that amygdala activity contributes to action perception by modulating activity in the STS.

An alternative interpretation of these results is that task performance is enhanced with angry walkers simply because anger is expressed with high velocity movements, which are easy to detect. Clearly, different emotions are associated with characteristic patterns of movement (Darwin, 1872; Pollick, Paterson, Bruderlin, & Sanford, 2001). For example, sad people tend to move slowly. To control against the possibility that angry gaits were better detected because they have high-velocity components, the mask for each walker stimulus was constructed from the same point velocities that defined that walker. As a result, the velocities of the points defining the mask were identical to the velocities of the points defining the walker (whether scrambled or not). Thus, any potential velocity differences between the mask and walker points were eliminated both across and within stimuli.

It is interesting to note that gait direction did not significantly impact walker detection in this study. To the extent that amygdala activation is associated with the appraisal of “incoming” stimuli (Amaral et al., 2003; Sato et al., 2004), one would expect to find enhanced detection of people approaching observers. The point-light walkers in these studies were displayed on a desktop computer screen. Since these point-light walkers were necessarily small, they were consis-

tent with normally sized individuals viewed from a distance of approximately 25 meters. Previous research suggests that different processes may be involved in the perception of distant and nearby people (Jacobs et al., 2004). Thus, the absence of a main effect of gait direction in this experiment may be associated with the perception of distant walkers. We are currently developing studies with life-sized point-light walkers to investigate this possibility.

A final issue concerns the response criteria. Why are observers more likely to report the presence of a walker whenever the stimulus depicts “angry” motion? One possibility is that the velocity information present in the mask is sufficient for observers to perceive anger. From a functional perspective, the perception of angry local motion cues may be sufficient to bias perceptual decisions in walker-detection tasks since failing to detect an angry person is a potentially costly error. This possibility is examined in the next experiment.

EXPERIMENT 3

Emotion perception from local velocity?

The previous results indicate that observers were most sensitive to angry walkers. They additionally indicate that observers were also most likely to false alarm to angry walkers. When observers commit a false alarm, they report the presence of a point-light walker on trials in which no walker was present. Such false alarms were most prevalent on walker-absent trials in which the point-light display was constructed from an angry gait. Why did this response bias occur and what might it mean?

One possibility relates to the proposal that the amygdala is critical for modulating vigilance under cases of uncertainty. Uncertainty and vigilance are central concepts in psychophysical tasks used to measure detection thresholds since observers must remain alert to the possible presence of a randomly occurring target. Indeed, it has been proposed that the amygdala modulates vigilance levels precisely by altering sensory thresholds (Whalen, 1998). The response characteristics of the amygdala have led some to conclude that the amygdala is involved in the analysis of biologically relevant stimuli for the purpose of guiding approach-avoidance behavior

(Davies & Whalen, 2001). Since the approach of an angry person, especially an unknown individual, is a significantly threatening stimulus, it might prompt the planning of flight or avoidance behaviors via the amygdala. For obvious functional reasons, an organism cannot wait until an angry stranger is actually upon them before planning avoidance behavior. Therefore, subtle sensory cues to potential threat may be sufficient to trigger this system. Consistent with this, observation of the white portions of a fearful person's eyes is wholly sufficient to trigger amygdala activity (Whalen et al., 2004).

Along the same lines, we wondered whether the velocities of the scrambled points defining the "angry" masks might be sufficient for the perception of anger. If so, this might explain why participants have a tendency to report the presence of a walker in walker-absent stimuli that were constructed from angry gaits. Specifically, the perception of angry motion in the mask might have triggered an assessment of potential threat that caused observers to shift their decision criteria. To address this question, participants performed an emotion-recognition task with masked displays that did not contain a point-light walker. If emotion perception requires the presence of a whole person or whole limbs, then emotion recognition should be at chance in this task. Conversely, to the extent that the local velocity cues in a mask are sufficient for emotion perception, then emotion recognition should be above chance.

Methods

Eleven Rutgers University – Newark undergraduate students participated in this experiment for partial credit toward a course requirement. All participants were naïve to the hypothesis under investigation and had normal or corrected to normal visual acuity. All participants provided written informed consent.

The masks from the point-light walker stimuli of Experiment 2 were used here. The procedure followed that employed in Experiment 1. On each trial, participants viewed a mask of randomly positioned points. On all trials, no walker was present in the mask. Recall that each mask was created by scrambling the starting locations of the points defining a walker. Thus, each mask was constructed from one of the five emotional gaits. Participants were instructed to watch each mask

and to report, with a mouse click, which of the five emotions (neutral, happy, sad, angry, or afraid) best described that stimulus.

Results

Since this was a five alternative forced-choice task, chance performance is 20% correct. A one-sample 2-tailed *t*-test indicated that overall emotion recognition performance in this task ($M = 64\%$, $SD = 25\%$) was significantly above chance, $t(54) = 13.30$, $p < .01$. The means and standard deviations of emotion recognition accuracy to the five emotion-based masks were: angry ($M = 0.74$, $SD = 0.18$), afraid ($M = 0.38$, $SD = 0.19$), happy ($M = 0.87$, $SD = 0.08$), sad ($M = 0.47$, $SD = 0.18$), and neutral ($M = 0.74$, $SD = 0.19$). A 5-level (emotions) repeated measures ANOVA indicated a significant main effect of emotion on recognition performance, $F(4, 10) = 16.59$, $p < .01$. Paired two-tailed *t*-tests indicated that recognition rates of the afraid and sad emotions masks were significantly poorer than emotion recognition for any of the other three masks (all $ps < .01$).

Discussion

The results of this experiment indicate that observers are able to extract cues to emotion from the point-light masks. Because masks were made of points in motion that were randomly positioned and hence lacked a coherent global structure, they were analyzed locally (Bertenthal & Pinto, 1994). Thus, we conclude that significant emotion cues were carried by the local velocity signals. This is consistent with previous findings that visual perception of emotion from motion does not require the presence of a coherent body (Pollick et al., 2001). Furthermore, these results support the hypothesis that both local (Experiment 3) and global (Experiment 2) motion processes are involved in the visual detection of human motion (Thornton, Pinto, & Shiffrar, 1998).

The results of the current study indicate that cues to emotion were available in the scrambled point-light masks. This places an important constraint on the interpretation of decision criterion results from Experiment 2. Participants in Experiment 2 may have perceived the presence of angry motion in the mask before they were able to segregate the mask points from the walker

points and subsequently report the presence or absence of an angry walker. This possibility is consistent with the finding that the perception of anger in point-light displays resists stimulus perturbations more than the perception of other emotions (Clarke et al., 2005). To the extent that amygdala function underlies threat detection (Amaral et al., 2003; Sato et al., 2004), one might expect to find a systematic bias or *over*-detection of walkers in displays containing angry motion, even when that motion is inherently local in nature, since failing to detect an angry person can be a very costly mistake. Furthermore, such a reliance on local cues is consistent with the proposal that amygdala activity during threat analysis is associated with decreases in response specificity (Anderson et al., 2003). Thus, the results of Experiments 2 and 3 converge to support the hypothesis that biases in perceptual decisions may reflect real-world constraints on the perception of and responses to emotional people in action.

GENERAL DISCUSSION

The neurological structures related to visual analysis of human movement (e.g., STS) and those related to emotion (e.g., the amygdala) are highly interconnected (Adolphs, 1999; Baron-Cohen, 1995; Brothers, 1997; Heberlein, Adolphs, Tranel, & Damasio, 2004; Puce & Perrett, 2003). These interconnections could serve at least two information-processing circuits. First, visual analyses of human action could be completed in the STS and passed on to the amygdala for subsequent emotional analysis. According to this model, action detection should be independent of emotional processes since detection processes would be completed before emotional analyses were initiated. A second possibility is that action analyses in the STS are conducted in interactive collaboration with emotional processes in the amygdala. From this perspective, action detection should be emotion dependent. Given the role of the amygdala in threat detection (e.g., Anderson et al., 2003), any interdependence of action detection and emotional processes should be most evident with threatening actions. The goal of the current series of psychophysical studies was to examine these possibilities through tests of the visual detection of emotional actions.

In Experiment 1, participants viewed short point-light movies of walking actors portraying

different emotions and reported each emotion. Participants were significantly above chance in their ability to identify the emotions conveyed in these gaits. This indicates that emotions are detectable from very primitive motion cues. An interesting implication from this result is that there may be a fundamental body-motion-based emotional vocabulary similar in universal properties to those arising from facial expressions (e.g., Ekman, 1972). From the collection of stimuli in Experiment 1, we selected those in which the walker's emotion was most consistently recognized. This subset of movies was then used in a walker-detection task conducted in Experiment 2.

In Experiment 2, point-light walkers were presented, or not, within masks of identically moving points. While watching each movie, participants reported whether or not a walker was present within the mask. Although participants were not informed of or asked to judge the emotional quality of the walkers, their ability to detect the walkers was significantly modulated by walker emotion. Participants demonstrated the greatest visual sensitivity to angry walkers. The angry displays were additionally associated with a significant response bias as participants most frequently "detected" the presence of an absent walker in these displays. To investigate the origins of this bias, participants in Experiment 3 viewed point-light masks, constructed from the emotional walkers but not actually containing them, and judged the emotion conveyed by each mask. The results of this study indicate that significant emotion information is conveyed in the masks themselves. If observers were biased by the presence of angry motion cues available in the mask, this might explain why false-alarm rates were highest with angry movies.

The combined results of these studies suggest that emotional bodily expression can affect the visual detection of human action. Such a dependence of emotion on action detection is consistent with the substantial interconnections between higher order visual areas and the limbic system. Furthermore, this dependence may reflect the existence of an integrated processing circuit between the STS and amygdala. It is widely hypothesized that the amygdala is involved in the perception of threat (e.g., Anderson et al., 2003). Angry people are certainly threatening. Enhanced detection of threatening actions may represent an important condition under which emotional processes impact perceptual analyses. Furthermore, biased perceptual decisions during

the analysis of angry motion in masks may reflect the relatively greater importance of detecting impending threats. Thus, while previous studies have indicated that visual sensitivity to human motion is defined by visual and motor experience (e.g., Loula et al., 2005), the current studies indicate that emotional processes also define when and how we perceive the actions of other people.

The current findings can also be understood in relationship to the perception of human action by observers with autism. The core characteristic of autism is a significant impairment in social interactions (Schultz, 2005). This impairment appears to be associated with abnormalities in the amygdala (e.g., Baron-Cohen et al., 1999) and the STS (e.g., Boddaert et al., 2004; Waiter et al., 2005) among other areas. These two neural abnormalities are in turn associated with behavioral deficits in social processing (e.g., Adolphs, Tranel, & Damasio, 1998) and the detection of point-light people (Blake, Turner, Smoski, Pozdol, & Stone, 2003). When considered with these previous findings, the current results suggest that, to the extent that observers with autism can detect point-light defined human actions, their detection rates should be unaffected by the emotional content of those actions.

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REFERENCES

- Adolphs, R. (1999). Social cognition and the human brain. *Trends in Cognitive Science*, 3, 469–479.
- Adolphs, R., & Tranel, D. (2004). Impaired judgments of sadness but not happiness following bilateral amygdala damage. *Journal of Cognitive Neuroscience*, 16, 453–462.
- Adolphs, R., Tranel, D., & Damasio, A. R. (1998). The human amygdala in social judgment. *Nature*, 393, 470–474.
- Amaral, D. G. (2003). The amygdala, social behavior, and danger detection. *Annual New York Academy of Science*, 1000, 337–347.
- Amaral, D. G., Behniea, H., & Kelly, J. L. (2003). Topographic organization of projections from the amygdala to the visual cortex in the macaque monkey. *Neuroscience*, 118, 1099–1120.
- Anderson, A. K., Spencer, D. D., Fulbright, R. K., & Phelps, E. A. (2000). Contribution of the anteromedial temporal lobes to the evaluation of facial emotion. *Neuropsychology*, 14, 526–536.
- Anderson, A. K., Christoff, K., Panitz, D., De Rosa, E., & Gabrieli, J. D. (2003). Neural correlates of the automatic processing of threat facial signals. *Journal of Neuroscience*, 23, 5627–5633.
- Atkinson, A. P., Dittrich, W. H., Gemmell, A. J., & Young, A. W. (2004). Emotion perception from dynamic and static body expressions in point-light and full-light displays. *Perception*, 33, 717–746.
- Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind*. Cambridge, MA: Bradford, MIT Press.
- Baron-Cohen, S., Ring, H. A., Wheelwright, S., Bullmore, E. T., Brammer, M. J., Simmons, A., & Williams, S. C. (1999). Social intelligence in the normal and autistic brain: An fMRI study. *European Journal of Neuroscience*, 11, 1891–1898.
- Beauchamp, M. S., Lee, K. E., Haxby, J. V., & Martin, A. (2002). Parallel visual motion processing streams for manipulable objects and human movements. *Neuron*, 34, 149–159.
- Bertenthal, B. I., & Pinto, J. (1994). Global processing of biological motions. *Psychological Science*, 5, 221–225.
- Blake, R., Turner, L. M., Smoski, M. J., Pozdol, S. L., & Stone, W. L. (2003). Visual recognition of biological motion is impaired in children with autism. *Psychological Science*, 14, 151–157.
- Boddaert, N., Chabane, N., Gervais, H., Good, C. D., Bourgeois, M., Plumet, M. H., Barthelemy, C., Moureh, M. C., Artiges, E., Samson, Y., Brunelle, F., Frackowiak, R. S., & Zilbovicius, M. (2004). Superior temporal sulcus anatomical abnormalities in childhood autism: A voxel-based morphometry MRI study. *Neuroimage*, 23, 364–369.
- Bonda, E., Petrides, M., Ostry, D., & Evans, A. (1996). Specific involvement of human parietal systems and the amygdala in the perception of biological motion. *Journal of Neuroscience*, 16, 3737–3744.
- Breiter, H. C., Etcoff, N. L., Whalen, P. J., Kennedy, W. A., Rauch, S. L., Buckner, R. L., et al. (1996). Response and habituation of the human amygdala during visual processing of facial expression. *Neuron*, 17, 875–887.
- Brothers, L. (1997). *Friday's footprint: How society shapes the human mind*. London: Oxford University Press.
- Clarke, T. J., Bradshaw, M. F., Field, D. T., Hampson, S. E., & Rose, D. (2005). The perception of emotion from body movement in point-light displays of interpersonal dialogue. *Perception*, 34, 1171–1180.
- Davis, M., & Whalen, P. J. (2001). The amygdala: Vigilance and emotion. *Molecular Psychiatry*, 6, 13–34.
- Darwin, C. (1872). *On the origins of the species* (6th ed.). London: John Murray.
- Decety, J., & Chaminade, T. (2003). When the self represents the other: A new cognitive neuroscience view on psychological identification. *Consciousness and Cognition*, 12, 577–596.
- De Gelder, B., Snyder, J., Greve, D., Gerard, G., & Hadjikhani, N. (2004). Fear fosters flight: A mechanism for fear contagion when perceiving emotion expressed by a whole body. *Proceedings of the National Academy of Science USA*, 101(47), 16701–16706.

- Dittrich, W. H., Troscianko, T., Lea, S. E., & Morgan, D. (1996). Perception of emotion from dynamic point-light displays represented in dance. *Perception, 25*, 727–738.
- Ekman, P. (1972). Universals and cultural differences in facial expressions of emotion. In J. Cole (Ed.), *Nebraska symposium on motivation* (Vol. 19, pp. 207–283). Lincoln, NE: University of Nebraska Press.
- Ekman, P., Friesen, W. V., & Ancoli, S. (1980). Facial signs of emotional experience. *Journal of Personality and Social Psychology, 39*, 1125–1134.
- Felleman, D. J., & Van Essen, D. C. (1991). Distributed hierarchical processing in the primate cerebral cortex. *Cerebral Cortex, 1*, 1–47.
- Grossman, E., Donnelly, M., Price, R., Pickens, D., Morgan, V., Neighbor, G., et al. (2000). Brain areas involved in perception of biological motion. *Journal of Cognitive Neuroscience, 12*, 711–720.
- Grossman, E. D., Blake, R., & Kim, C.-Y. (2004). Learning to see biological motion: Brain activity parallels behavior. *Journal of Cognitive Neuroscience, 16*, 1669–1679.
- Heberlein, A. S., Adolphs, R., Tranel, D., & Damasio, H. (2004). Cortical regions for judgments of emotions and personality traits from point-light walkers. *Journal of Cognitive Neuroscience, 16*, 1143–1158.
- Iwai, E., & Yukie, M. (1987). Amygdalofugal and amygdalopetal connections with modality-specific visual cortical areas in macaques (*Macaca fuscata*, *M. mulatta*, and *M. fascicularis*). *Journal of Comparative Neurology, 261*, 362–387.
- Iwai, E., Yukie, M., Watanabe, J., Hikosaka, K., Suyama, H., & Ishikawa, S. (1990). A role of amygdala in visual perception and cognition in macaque monkeys (*Macaca fuscata* and *Macaca mulatta*). *Tohoku Journal of Experimental Medicine, 161*(Suppl.), 95–120.
- Jacobs, A., Pinto, J., & Shiffrar, M. (2004). Experience, context, and the visual perception of human movement. *Journal of Experimental Psychology: Human Perception & Performance, 30*, 822–835.
- Jacobs, A., & Shiffrar, M. (2005). Walking perception by walking observers. *Journal of Experimental Psychology: Human Perception & Performance, 31*, 157–169.
- Jellema, T., & Perrett, D. I. (2003). Perceptual history influences neural responses to face and body postures. *Journal of Cognitive Neuroscience, 15*, 961–971.
- Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception & Psychophysics, 14*, 201–211.
- Jones, E. G., & Powell, T. P. (1970). An anatomical study of converging sensory pathways within the cerebral cortex of the monkey. *Brain, 93*, 793–820.
- Kalin, N. H. (1993). The neurobiology of fear. *Scientific American, 268*, 94–101.
- Kluver, H., & Bucy, P. C. (1938). An analysis of certain effects of bilateral temporal lobectomy in the rhesus monkey, with special reference to “psychic blindness”. *Journal of Psychology, 5*, 33–54.
- Knoblich, G., & Flach, R. (2001). Predicting the effects of actions: Interactions of perception and action. *Psychological Science, 12*, 467–47.
- LaBarre, W. (1947). The cultural basis of emotions and gestures. *Journal of Personality, 16*, 1968.
- LeDoux, J. E. (1995). Emotion: Clues from the brain. *Annual Review of Psychology, 46*, 209–235.
- Loula, F., Prasad, S., Harber, K., & Shiffrar, M. (2005). Recognizing people from their movement. *Journal of Experimental Psychology: Human Perception and Performance, 31*, 210–220.
- McMillan, N., & Creelman, C. (1991). *Detection theory: A user's guide*. Cambridge, UK: Cambridge University Press.
- Montepare, J. M., & Zebrowitz-McArthur, L. A. (1988). Impressions of people created by age-related qualities of their gaits. *Journal of Personality and Social Psychology, 55*, 547–556.
- Oram, M. W., & Perrett, D. I. (1996). Integration of form and motion in the anterior superior polysensory area (STPa) of the macaque monkey. *Journal of Neurophysiology, 76*, 109–129.
- Oya, H., Kawasaki, H., Howard, M. A., III, & Adolphs, R. (2002). Electrophysiological responses in the human amygdala discriminate emotion categories of complex visual stimuli. *Journal of Neuroscience, 22*, 9502–9512.
- Pelphrey, K. A., Morris, J. P., & McCarthy, G. (2005). Neural basis of eye gaze processing deficits in autism. *Brain, 128*, 1038–48.
- Pollick, F. E., Paterson, H. M., Bruderlin, A., & Sanford, A. J. (2001). Perceiving affect from arm movement. *Cognition, 82B*, 51–61.
- Puce, A., & Perrett, D. (2003). Electrophysiology and brain imaging of biological motion. *Philosophical Transactions of the Royal Society B: Biological Sciences, 358*, 435–445.
- Rolls, E. T., Perrett, D. I., & Caan, A. W. (1982). Neuronal responses related to visual recognition. *Brain, 105*, 611–646.
- Runeson, S., & Frykholm, S. (1983). Kinematic specification of dynamics as an informational basis for person-and-action perception: Expectation, gender recognition and deceptive intention. *Journal of Experimental Psychology: General, 112*, 585–615.
- Sato, W., Yoshikawa, S., Kochiyama, T., & Matsumura, M. (2004). The amygdala processes the emotional significance of facial expressions: An fMRI investigation using the interaction between expression and face direction. *Neuroimage, 22*, 1006–1013.
- Saxe, R., Xiao, D. K., Kovacs, G., Perrett, D. I., & Kanwisher, N. (2004). A region of right posterior superior temporal sulcus responds to observed intentional actions. *Neuropsychologia, 42*, 1435–1446.
- Schultz, R. (2005). Developmental deficits in social perception in autism: The role of the amygdala and fusiform face area. *International Journal of Developmental Neuroscience, 23*, 125–141.
- Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods, Instruments and Computers, 31*, 137–149.

- Thornton, I., Pinto, J., & Shiffrar, M. (1998). The visual perception of human locomotion. *Cognitive Neuropsychology*, *15*, 535–552.
- Troje, N. F. (2002). Decomposing biological motion: A framework for analysis and synthesis of human gait patterns. *Journal of Vision*, *2*, 371–387.
- Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2001). Effects of attention and emotion on face processing in the human brain: An event-related fMRI study. *Neuron*, *30*, 829–841.
- Waiter, G. D., Williams, J. H., Murray, A. D., Gilchrist, A., Perrett, D. I., & Whiten, A. (2005). Structural white matter deficits in high-functioning individuals with autistic spectrum disorder: A voxel-based investigation. *Neuroimage*, *24*, 455–461.
- Whalen, P. J. (1998). Fear, vigilance, and ambiguity: Initial neuroimaging studies of the human amygdala. *Current Directions in Psychological Science*, *7*, 177–188.
- Whalen, P. J., Kagan, J., Cook, R. G., Davis, F. C., Kim, H., Polis, S., et al. (2004). Human amygdala responsivity to masked fearful eye whites. *Science*, *306*, 2061.
- Whalen, P. J., Rauch, S. L., Etcoff, N. L., McInerney, S. C., Lee, M. B., & Jenike, M. A. (1998). Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge. *Journal of Neuroscience*, *18*, 411–418.
- Whalen, P. J., Shin, L. M., McInerney, S. C., Fischer, H., Wright, C. I., & Rauch, S. L. (2001). A functional MRI study of human amygdala responses to facial expressions of fear versus anger. *Emotion*, *1*, 70–83.
- Wheaton, K. J., Pipingas, A., Silberstein, R. B., & Puce, A. (2001). Human neural responses elicited to observing the actions of others. *Visual Neuroscience*, *18*, 401–406.
- Yang, T. T., Menon, V., Eliez, S., Blasey, C., White, C. D., Reid, A. J., et al. (2002). Amygdalar activation associated with positive and negative facial expressions. *Neuroreport*, *13*, 1737–1741.