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Motion or emotion: Infants discriminate emotional biological motion based on low-level visual information

Marissa Ogren[a,*], Brianna Kaplan[b], Yujia Peng[a], Kerri L. Johnson[a], Scott P. Johnson[a]

[a] Department of Psychology, University of California, Los Angeles, United States
[b] Department of Psychology, New York University, United States

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ABSTRACT

Infants' ability to discriminate emotional facial expressions and tones of voice is well-established, yet little is known about infant discrimination of emotional body movements. Here, we asked if 10–20-month-old infants rely on high-level emotional cues or low-level motion related cues when discriminating between emotional point-light displays (PLDs). In Study 1, infants viewed 18 pairs of angry, happy, sad, or neutral PLDs. Infants looked more at angry vs. neutral, happy vs. neutral, and neutral vs. sad. Motion analyses revealed that infants preferred the PLD with more total body movement in each pairing. Study 2, in which infants viewed inverted versions of the same pairings, yielded similar findings except for sad-neutral. Study 3 directly paired all three emotional stimuli in both orientations. The angry and happy stimuli did not significantly differ in terms of total motion, but both had more motion than the sad stimuli. Infants looked more at angry vs. sad, more at happy vs. sad, and about equally to angry vs. happy in both orientations. Again, therefore, infants preferred PLDs with more total body movement. Overall, the results indicate that a low-level motion preference may drive infants' discrimination of emotional human walking motions.

1. Introduction

Perceiving the emotions of others is a crucial component of healthy social development (Denham et al., 2003; Izard et al., 2001). Emotion perception and understanding allow us to decipher the feelings of others and gives us the opportunity to interact with them appropriately (Hesse & Cicchetti, 1982; Olson, Astington, & Harris, 1988). Emotions are often read from facial expressions and voices. However, such information regarding emotion is not available when the agent is approaching from a far distance. A successful and efficient understanding of emotion based on human body motions thus may determine the survival of an individual under extreme conditions. Even though numerous studies have shown that infants can discriminate emotions represented in faces and voices (e.g., LaBarbera, Izard, Vietze, & Parisi, 1976; Schwartz, Izard, & Ansul, 1985; Walker-Andrews & Grolnick, 1983) little is known about whether infants can discriminate emotional human body movements. The goal of the present research was to extend our knowledge of infant emotion perception beyond the facial and vocal domains to investigate whether infants can discriminate emotional human walking motions and whether they may use high-level emotional cues or low-level cues, such as total motion, to do so.

Infants begin to perceive and discriminate emotions in faces and voices within the first postnatal year. By 6 months, infants can discriminate between still images of emotional faces (LaBarbera et al., 1976; Schwartz et al., 1985), and 4-month-olds respond differently to various emotions presented during a game of peekaboo (Montague & Walker-Andrews, 2001). Five-month-olds can

* Corresponding author at: University of California, 1285 Franz Hall, Box 951563, Los Angeles, CA 90095-1563, United States.
E-mail address: Mogren@ucla.edu (M. Ogren).

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recognize when the emotional tone of a voice changes (Walker-Andrews & Grolnick, 1983) and can match the facial and vocal expressions of other infants (Vaillant-Molina, Bahrick, & Flom, 2013). In addition to perceptual discrimination, infants are capable of categorizing emotions in vocal tone by 5 months, and facial expression by 7 months (Flom & Bahrick, 2007). When the intermodal preference technique (Spelke, 1976) is used, 7-month-old infants can match emotions across face and voice (Walker, 1982), and infants as young as 3.5 months can do this when the face is that of their own mother, but not when the face is someone unfamiliar (Kahana-Kalman & Walker-Andrews, 2001; Walker-Andrews, Krogh-Jespersen, Mayhew, & Coffield, 2011). Seven-month-old infants are also capable of matching the emotions of a face and voice when the bottom third of the face is occluded (Walker-Andrews, 1986), and can categorize certain emotional expressions, such as surprise when tested against fear (Ludemann & Nelson, 1988). This evidence suggests that perception of emotions across face and voice is established early, and that young infants are capable of discriminating, categorizing, and intermodally matching such stimuli. However, little is known at present about infant perception of emotion in other domains, such as body movements.

An investigation of how infants perceive emotional body movements is important because body expressions are common in infants' visual environments and may influence perception of emotion more broadly. When adults were shown facial expressions on bodies presenting differing emotional states, for example, body expression had a significant impact on how the facial expressions were categorized, even when the adults were asked specifically to categorize the expression of the face (Meeren, van Heijnsbergen, & de Gelder, 2005; Van den Stock, Righart, & de Gelder, 2007). Mondloch, Horner, and Mian (2013) investigated the possibility of a similar influence in children. Six-year-olds accurately identified the emotions of faces and body expressions in isolation, but their ability to identify the emotion of facial expressions was disrupted when presented with a different body expression. These results with adults and children have been extended to dynamic displays of emotion across face and body (Nelson & Mondloch, 2017). Additionally, ERP data from 8-month-old infants indicates differentiated neural responses when emotional facial expressions are paired with matching vs. mismatching body expressions (Rajhans, Jessen, Missana, & Grossmann, 2016).

Everyday social interactions involve emotions conveyed in both face and body and it has been theorized that the development of emotion perception in faces and bodies follow similar trajectories (Bhatt, Hock, White, Jubran, & Galati, 2016). Despite the importance of body expressions for emotion perception among children and adults, much remains unknown regarding infant perception of emotion in body movements independent of facial expressions (Zieber, Kangas, Hock, & Bhatt, 2014; Zieber, Kangas, Hock, & Bhatt, 2014).

In particular, it is unclear whether the development of infant perception of emotional body movements can be attributed to an understanding of emotion based on a holistic perception of body motion or, instead, to perception of low-level visual information (e.g., speed, trajectories, total motion). Different emotional body movements have different velocities (Johnson, McKay, & Pollick, 2011); thus addressing the role of low-level visual information in infant perception of emotional stimuli is crucial. An informative kind of stimulus for assessing the perception of body movements is *biological motion*, the motion patterns that are specific to animate entities. Perception of biological motion has been frequently tested using point-light displays (PLDs). In such experiments, reflective markers are placed on the joints of an actor and the actor's movements are recorded. When played back, the video recordings show the reflective markers as white dots against a black background (Johansson, 1973, 1976). An advantage to assessing body movements using PLDs is that the physical features of the actor (e.g., body size, biological sex, hair color) are entirely removed, leaving only information about the movement of joints. Despite the limited visual information, adults spontaneously and readily perceive human body movements in PLDs (Johansson, 1973).

Adults glean important social information from PLDs. Adults perceive biological sex and gender (Kozlowski & Cutting, 1977; Mather & Murdoch, 1994; Troje, 2002), intentions (Blakemore & Decety, 2001), identity (Cutting & Kozlowski, 1977; Loula, Prasad, Harber, & Shiffrar, 2005; Troje, Westhoff, & Lavrov, 2005), distinct actions (Dittrich, 1993; Norman, Payton, Long, & Hawkes, 2004), and emotions (Atkinson, Dittrich, Gemmell, & Young, 2004; Atkinson, Tunstall, & Dittrich, 2007; Johnson et al., 2011) from human PLDs. Although adults do holistically process such social stimuli, they can also still discriminate emotional stimuli when they are inverted (Atkinson et al., 2007), indicating that even adults use some low-level stimulus features when discriminating PLDs. Given the amount of social and emotional information adults perceive in PLDs, investigating infant perception of emotion in PLDs is important to understand the developmental underpinnings of such social-perceptual skills.

Prior research has demonstrated that infants are sensitive to biological motion shortly after birth (Bidet-Ildei, Kitromilides, Orliaguet, Pavlova, & Gentaz, 2014; Simion, Regolin, & Bulf, 2008), and by 3–5 months infants recognize the human form in PLDs (Bertenthal, Proffitt, & Cutting, 1984; Bertenthal, Proffitt, & Kramer, 1987). Developments in biological motion perception also align with development in other aspects of social cognition, such as interpreting gaze direction (Yoon & Johnson, 2009), and overlapping neural regions respond to both biological motion and social perception (Pelphrey, Morris, Michelich, Allison, & McCarthy, 2005), suggesting that infant perception of social cues in biological motion may be characteristic of normative development. ERP studies have shown that infants distinguish between emotional states of PLDs (Missana & Grossmann, 2015; Missana, Atkinson, & Grossmann, 2015) when stimuli were overt, stereotypical displays of each emotion (e.g., crouching in fear). It remains unknown whether infants can distinguish the emotions of stimuli that are more typical in infants' social environments, such as walking motions. Walking motions, a subset of possible biological motions, may be more difficult to discriminate due to similarities in the overall movement patterns, but are more ecologically valid as emotional information is likely more commonly displayed in daily life through walking motions than overt emotional body movements.

1.1. The present research

The goal of the present research was to investigate the possibility that infants can discriminate PLDs of emotional human walk motions in a preferential looking paradigm. In three studies, we presented infants with side-by-side pairings of angry, happy, sad, and neutral walking PLDs and recorded their eye movements. Proportion of total attention to each walk motion was used as the dependent variable in all analyses. Dependent sample t-tests were used to determine whether, across all infants, there was a significant preference for one walk motion over another, which would indicate that the infants discriminated between them. (Infants must recognize that two stimuli are different in order to consistently prefer one over the other.)

Prior research with non-PLD stimuli indicated that 6.5-month-old infants discriminate happy and neutral body movements (Zieber et al., 2014a), and so we hypothesized that infants in the present study may discriminate emotional walking PLDs. We identified two competing theories for how they might do so: (1) If infants detected discrete emotional body movements *holistically* (as one entity, rather than multiple separate parts), they should consistently discriminate PLDs (preferentially attend to one PLD over the other) for each pair of emotional walkers when upright, but fail to do so in an inverted orientation. Adults process biological motion stimuli holistically, as processing is disrupted when presented in an inverted orientation (Dittrich, 1993; Pavlova & Sokolov, 2000). Infants demonstrate holistic processing of faces by 3 months of age (Turati, Di Giorgio, Bardi, & Simion, 2010). This supports our hypothesis that infant emotional-based processing of biological motion may involve holistic processing. Alternatively, (2) Infants may not process the stimuli holistically, and that low-level stimulus features, such as total motion may instead drive discrimination of emotional biological motion. In this case, infants' pattern of preferential looking to the emotional PLD walkers should not be disrupted in the inverted orientation. To test these possibilities, Experiment 1 began by assessing infant looking to pairs of PLDs that were distinct in emotion and total motion, an example of a low-level perceptual cue that may be particularly salient to infants (Tsang et al., 2018). In Experiment 2, we tested the effects of inversion (which may disrupt infant processing of holistic information but not low-level cues) on the same emotional stimulus pairs. In Experiment 3, we tested discrimination in PLDs with distinct emotional valences but similar total motion.

2. Study 1

Using a within-subjects design, we presented infants with PLD walkers representing angry, happy, and sad emotions, each individually paired side-by-side with a neutral PLD walker. Consistent looking to one PLD more than the other for a given emotion pairing would provide evidence for infants' discrimination of the two emotional PLDs.

2.1. Method

2.1.1. Participants

A sample of 26 healthy, full-term infants (11 male) ranging from 11.11 to 17.56 months (M_{age} = 14.66, SD_{age} = 2.04) participated in the study. A power analysis using the effect size from Study 1 in Zieber et al. (2014a), setting alpha = .05 and power = .8 determined a necessary total sample size of 21 infants to detect infant discrimination of emotional body movements. An additional six infants were excluded from the final dataset due to excessive fussiness (N = 4), failure to complete calibration (N = 1), or experimenter error (N = 1). Twenty-one infants had at least one parent who had completed four years of college; four parents did not report their education level. The ethnic/racial background of participants was as follows: Caucasian (N = 16), Multiracial (N = 5), Hispanic/Latino (N = 2), Unreported (N = 2), Asian (N = 1). Infants were recruited from lists of birth records provided by [Los Angeles County]. Parents provided written informed consent in accordance with the [University of California, Los Angeles] Institutional Review Board #10-000619, titled G07-09-054-03H, and the study was conducted in accordance with the ethical standards of the American Psychological Association. Parents were provided with a small gift (e.g., a T-shirt or toy) for participating.

2.1.2. Materials and apparatus

Stimuli consisted of 36 PLDs (18 neutral, 6 angry, 6 happy, 6 sad) from adults who were recruited for the purpose of recording their walk motions. We used a Vicon MX 3D motion-capture system to record body motions of 76 undergraduates by attaching reflective markers to their head, shoulders, elbows, wrists, hips, knees, and ankles as they walked on a treadmill. The undergraduate participants were first asked to walk on the treadmill at a self-selected pace while their walking motion was recorded (the "neutral" walk). Next, they were asked to read a brief, simple emotional scenario for one of five emotions (happiness, anger, sadness, pride, or shame) and were asked to imagine themselves in that situation. The scenarios were based on common emotional situations (e.g., receiving a gift or having someone cut in front of you in line). This process elicits emotional states from participants such that emotional PLDs created using this method are reliably identified by adults (Johnson et al., 2011). Participants were immediately asked to walk on the treadmill at a pace of their choosing while walking motion was recorded. They then stepped off the treadmill and repeated this process (one at a time) for the four emotions that had not yet been recorded. Spatial coordinates from the first 10 s of each recording were transformed into PLDs using custom software. PLDs were then spatially normalized for lateral position and height to equate each walker's size to 12.9 cm × 7.1 cm (12.2° × 6.7° visual angle at the infant's 60 cm viewing distance) and to center all displays between the actor's hips. Final videos showed 13 white markers for each walker from a frontal view (as if they were walking toward the viewer).

To validate the emotions represented by each stimulus, we presented the first 5 s of each clip to 91 adult participants on Amazon's Mechanical Turk. Participants were instructed to watch each 5 s PLD clip, and indicate whether the emotion displayed was anger, happiness, neutral, pride, sadness, or shame. We then selected the most accurately identified PLDs: 18 for neutral, and 6 each for anger, happiness, and sadness. Because participants selected from six different possible options, chance levels of selection were 16.7%. For our final stimuli, adults' correct responses were as follows: Anger = 45.8%, Happiness = 41.8%, Sadness = 55.1%,

Table 1
Adult ratings of emotional biological motion stimuli (by percentage).

Depicted Emotion	Adult Response					
	Angry	Ashamed	Happy	Neutral	Proud	Sad
Angry	45.8	3.1	23.7	14.3	12.7	.4
Happy	15.8	3.5	41.8	11.2	26.8	.9
Neutral	5.9	10.0	13.3	46.1	14.5	10.2
Sad	2.4	21.8	4.0	10.1	6.6	55.1

Neutral = 46.1%. Additional information regarding adult ratings of the PLDs is reported in Table 1. Because the percentage of correct responses was substantially above chance and the selected emotions were infrequently confused with one another by the adults, we concluded that they represented the intended emotions when presented in pairs.

The experiment was programmed with Experiment Builder, the software associated with the eye tracker (SR Research EyeLink 1000) used to collect information about infants' looking time to the stimuli. Two PLDs were shown next to each other on every trial (see Fig. 1). For our primary analyses of interest, infants' point of gaze was coded with respect to two "areas of interest" (AOIs), each fully encompassing an individual PLD walker. The dependent variable for all analyses was calculated as the proportion of total dwell time that was focused within a given AOI. One PLD was always neutral, and the other was one of the three remaining emotional walk motions (angry, happy, or sad). Stimulus presentation was separated into three blocks, with six 10 s trials in each block. Two unique examples of each emotional walk motion were presented per block in a randomized order. Side of PLD presentation (left or right) was also randomized, with the constraint that no more than three neutral PLDs were presented on the same side on subsequent trials. Each infant viewed every PLD once and only once across the 18 trials.

2.1.3. Procedure

Each infant sat on a caregiver's lap approximately 60 cm from the computer monitor. An EyeLink 1000 eye tracker (SR Research, Ottawa, ON) was used to record each infant's eye movements, as eye tracking data is more accurate and specific than looking time recorded by live observers. Prior to testing, each infant's gaze was calibrated using the standard calibration routine for the eye tracker. An attention-getting stimulus was presented at five locations (the four corners of the screen and the center) as the infants tracked their locations. The experimenter controlled the progression through the stimuli, moving on to the next location only once the child had fixated on the prior location. If the calibration for a particular location was poor, it was repeated. After initial calibration, this process was repeated for validation. If the validated fixations were within 1° visual angle from the calibration fixations, the calibration was considered acceptable, and the experiment advanced to stimulus presentation. If not, the calibration procedure was repeated until this threshold was met.

Parents were instructed to hold their infant on their lap and allow their child to look freely during the session. They were also asked not to talk to their infant, point to the screen, or otherwise influence their infant's looking pattern. During the task, each 10 s trial was preceded by a small attention-getting stimulus in the center of the screen to re-center the child's gaze. The attention-getting stimulus was presented on the screen until it was fixated on by the infant, at which point the experimenter progressed to the next PLD stimulus presentation. See Fig. 2 for a visual representation of this procedure.

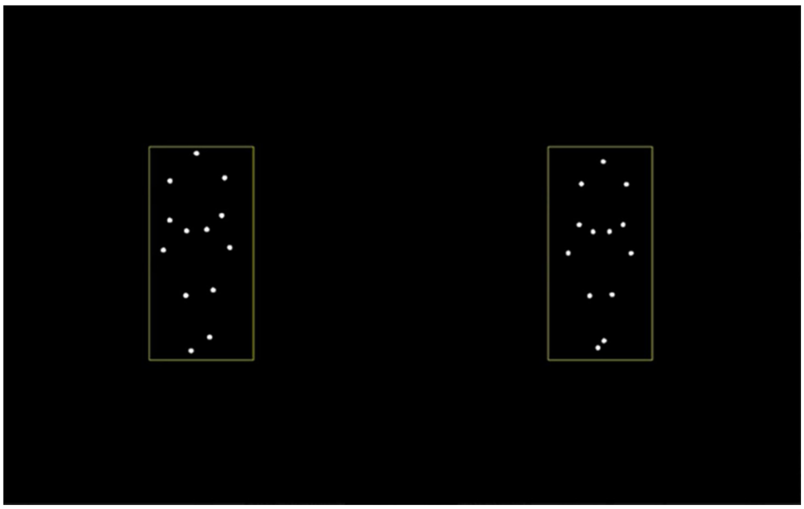

Fig. 1. Still image example of PLD stimuli presented to infants in Study 1. Boxes designate areas of interest (AOIs), and were not visible to the infants during stimulus presentation.

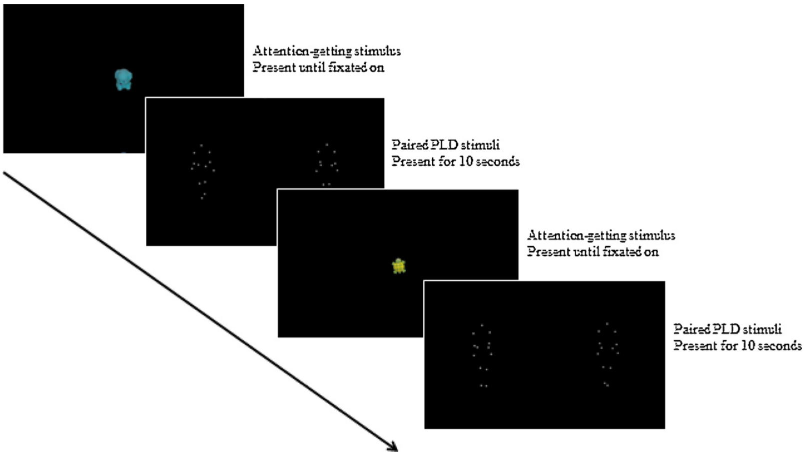

Fig. 2. Example of how the first 2 trials (out of 18) may appear to a given infant, with attention-getting stimuli immediately preceding 10-s PLD stimulus trials.

2.2. Results and discussion

Individual trials were removed from analyses if the infant looked at the screen for less than 2 s of the 10-s trial. This resulted in removal of an average of 1.23 (SD = 2.07) out of 18 possible trials per participant. To be included in the final analysis, infants had to provide usable data from at least 2 trials of each emotional condition. For each individual trial, infant dwell time to each AOI was recorded, as well as total dwell time to the screen. These dwell times were then summed across all trials of the same trial type (e.g., all 6 angry-neutral trials). Number of trials per condition included in the final analyses were as follows: Angry-Neutral: M = 5.81, SD = .57; Happy-Neutral: M = 5.58, SD = .70; Sad-Neutral: M = 5.38, SD = 1.13.

Dwell times were converted to proportions, and attention to a particular PLD was calculated as the amount of time spent attending to that AOI divided by overall attention to the screen for that trial. As it was possible for infants to look somewhere on the screen other than the two AOIs, the two proportions did not necessarily sum to 1. Proportions were calculated in this manner so that the proportion scores directly represented infants' attention to each of the stimuli (as opposed to the other stimulus or the blank space surrounding the PLDs). Three separate t-tests were conducted to assess differences in proportion of looking to the PLDs for each pairing. We corrected for multiple comparisons using a Bonferroni correction, yielding a new alpha level of .017. Infants looked more to the angry (M = .50, SD = .11) than the neutral PLDs (M = .37, SD = .08), $t(25) = 3.89$, $p = .001$, 95% CI [.06, .20], looked more to the happy (M = .51, SD = .09) than the neutral PLDs (M = .36, SD = .07), $t(25) = 4.96$, $p < .001$, 95% CI [.09, .21], and looked more to the neutral (M = .46, SD = .11) than the sad PLDs (M = .36, SD = .09), $t(25) = -2.87$, $p = .008$, 95% CI [−.17, −.03] (Fig. 3).

These results appear to indicate that infants discriminated each of the three emotional PLD pairings, looking longer at angry over neutral, happy over neutral, and neutral over sad. Discrimination may stem from preferences based on emotional content of the stimuli, which is available to adults (Atkinson et al., 2004, 2007). However, discrimination may also stem from total motion of the PLDs. It is important to note that during initial stimulus creation, the PLD actors were permitted to walk on the treadmill at a pace of their own choosing for each of the emotional conditions, and thus may have produced different numbers of gait cycles and therefore different amounts of total movement for each 10-s emotional walk. Prior research has shown that 16- and 20-week-old infants prefer

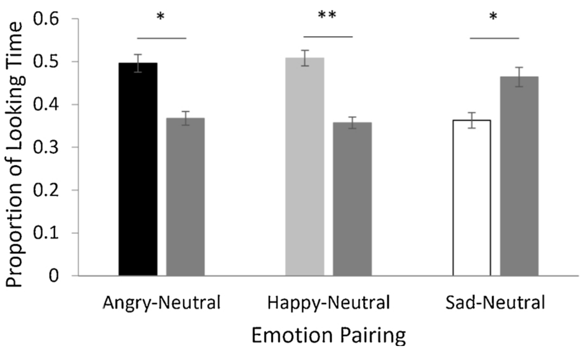

Fig. 3. Results of Study 1 (upright PLDs), with looking to the neutral stimulus presented in dark gray, looking to the angry stimulus presented in black, looking to the happy stimulus presented in light gray, and looking to the sad stimulus presented in white. Error bars indicate SEM. * p < .017, ** p < .001.

objects moving with greater velocity (Dannemiller & Freedland, 1989) and that 4- to 18-month-olds look longer at PLDs with higher motion speeds and higher spans of motion (Tsang et al., 2018). To investigate the influence of total motion of PLDs in our study, we conducted a motion analysis on the stimuli used in Study 1.

We calculated *total motion* for each stimulus, operationalized as the mean Euclidean distance in pixels per frame traveled by the 13 markers for each PLD during the 10 s video. We then compared average total motion for the six angry, happy, and sad PLDs to the average total motion for the 18 neutral PLDs. Our results revealed that the angry PLDs ($M = 23.34$ pixels/frame, $SD = 2.86$) had more total motion than the neutral PLDs ($M = 15.93$ pixels/frame, $SD = 2.39$), $t(22) = 6.28$, $p < .001$, the happy PLDs ($M = 22.03$ pixels/frame, $SD = 3.71$) had more total motion than the neutral PLDs, $t(22) = 4.71$, $p < .001$, and the neutral PLDs had more total motion than the sad PLDs ($M = 11.21$ pixels/frame, $SD = 1.80$), $t(22) = 4.41$, $p < .001$. In each stimulus pairing, therefore, the infants looked more to whichever PLD had more total movement, implying that low-level total motion preferences may have been more important in guiding infant attention than emotional content *per se*. To further investigate this possibility, we conducted Study 2.

3. Study 2

In a within-subjects design, we presented infants with the same stimuli used in Study 1 in an inverted orientation. Inversion disrupts the processing of biological motion stimuli among adults (Dittrich, 1993; Pavlova & Sokolov, 2000) and infants (Bertenthal et al., 1987). We reasoned that if inversion does not disrupt infant processing of the stimuli (i.e., if the results from Study 2 are similar to those in Study 1), this would suggest that infants' discrimination of the stimuli is driven by low-level total motion preferences. In contrast, if infants in Study 2 fail to discriminate the PLDs, this would provide evidence for infants' holistic processing of the PLD stimuli in Study 1, because the upright orientation is necessary to support perception of emotional biological motion.

3.1. Method

3.1.1. Participants

A sample of 26 healthy, full-term infants (12 male) ranging from 10.45 to 20.30 months ($M_{age} = 15.04$, $SD_{age} = 2.44$) participated in the study. An additional four infants were excluded from the final dataset due to excessive fussiness (N = 3), or failure to meet calibration criteria (N = 1). Of the final sample, 23 infants had at least one parent who had completed four years of college. The ethnic/racial background of participants was as follows: Caucasian (N = 13), Multiracial (N = 8), Hispanic/Latino (N = 2), Asian (N = 2), Black/African-American (N = 1). Participants were recruited in the same manner as described in Study 1, and were also given a small gift for participating.

3.1.2. Materials and apparatus

The same stimuli and eye tracker were used in Study 2 as in Study 1, except stimuli were presented in an inverted orientation (rotated 180°), as shown in Fig. 4.

3.1.3. Procedure

The same procedure described in Study 1 was used for Study 2.

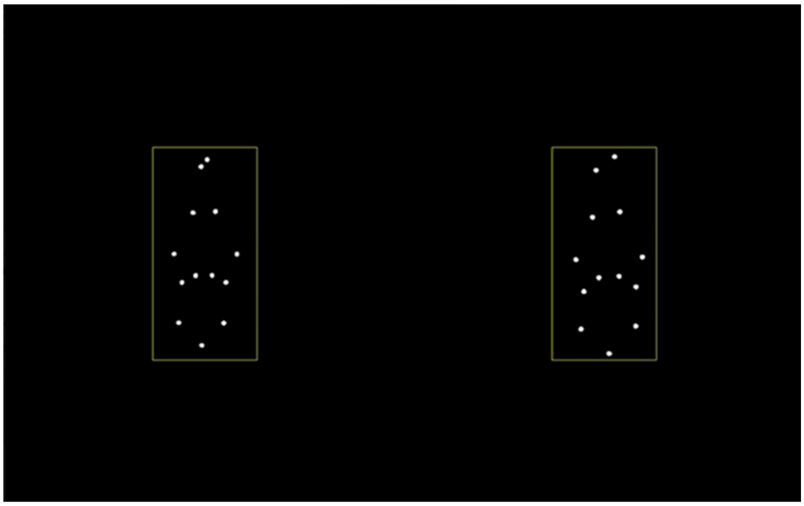

Fig. 4. Still image example of inverted PLD stimuli presented to infants in Study 2. Boxes designate areas of interest (AOIs), and were not visible to the infants during stimulus presentation.

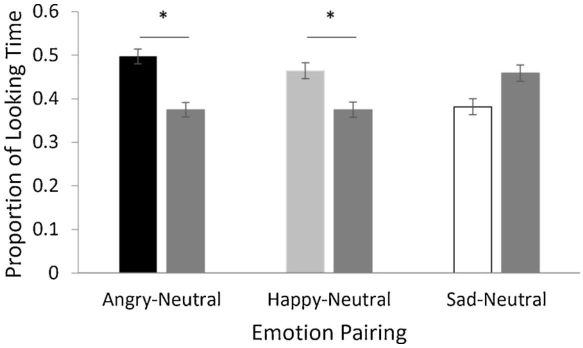

Fig. 5. Results of Study 2 (inverted PLDs), with looking to the neutral stimulus presented in dark gray, looking to the angry stimulus presented in black, looking to the happy stimulus presented in light gray, and looking to the sad stimulus presented in white. Error bars indicate SEM. * $p < .017$.

3.2. Results and discussion

Individual trials were removed from analyses if the infant looked at the screen for less than 2 s of the 10-s trial. This resulted in removal of an average of 1.46 (*SD* = 2.63) out of 18 possible trials per participant. To be included in the final analysis, infants had to provide usable data from at least 2 trials of each emotional condition. Number of trials per condition included in the final analyses were as follows: Angry-Neutral: *M* = 5.50, *SD* = .95; Happy-Neutral: *M* = 5.62, *SD* = .90; Sad-Neutral: *M* = 5.42, *SD* = .95.

Dwell time in each pairing was calculated using the same proportions as Study 1, and a Bonferroni correction was also used. In the inverted orientation, infants looked more to the angry PLDs (*M* = .50, *SD* = .09) than the neutral PLDs (*M* = .37, *SD* = .09), $t(25) = 3.81$, $p = .001$, 95% CI [.06, .19], looked more to the happy PLDs (*M* = .46, *SD* = .09) than the neutral PLDs (*M* = .37, *SD* = .09), $t(25) = 2.72$, $p = .012$, 95% CI [.02, .16], but did not discriminate the neutral PLDs (*M* = .46, *SD* = .10) from the sad PLDs (*M* = .38, *SD* = .09), $t(25) = 2.24$, $p = .034$, 95% CI [−.14, −.01] (Fig. 5).

Similar to infants in Study 1, infants in Study 2 preferred PLDs with more total movement in the angry-neutral and happy-neutral pairings. Infants did not provide evidence of discriminating neutral and sad PLDs, perhaps because the sad and neutral stimuli were more similar in total motion than the other stimulus pairings. The overall pattern of results suggests that infants' discrimination of the stimuli in Study 1 was driven largely by low-level total motion preferences, as there was little disruption in discrimination when the stimuli were inverted.

Nevertheless, it is possible that evidence for infants' processing of emotional PLDs might be revealed from comparisons of PLDs with distinct emotional valence but similar motion patterns. Additional analysis of motion patterns to directly compare the non-neutral stimuli with one another revealed that the angry PLDs (*M* = 23.34 pixels/frame, *SD* = 2.86) had more total motion than sad PLDs (*M* = 11.21 pixels/frame, *SD* = 1.80), $t(10) = 8.80$, $p < .001$, and happy PLDs (*M* = 22.03 pixels/frame, *SD* = 3.71) had more total motion than sad PLDs, $t(10) = 6.42$, $p < .001$. Angry PLDs and happy PLDs, however, did not differ significantly in terms of total motion, $t(10) = .685$, $p = .509$. We conducted Study 3, therefore, to directly pair each of the emotional stimuli with one another. Results can aid in determining whether infants can discriminate emotional PLDs with similar total motion, as well as provide direct comparisons of emotional walk motions without neutral walks. A key comparison in particular is angry vs. happy PLDs, which will test whether infants will prefer walk motions with a positive vs. negative valence (viz., happy vs. angry walk motions). In previous studies, infants were shown to prefer happy faces (Kim & Johnson, 2013), voices (Singh, Morgan, & Best, 2002) and even point-light faces (Soken & Pick, 1992) vs. foil stimuli, implying that infants identify and prefer happy content. Yet, separate bodies of research have identified that a negativity bias may exist in infancy (De Haan, Belsky, Reid, Volein, & Johnson, 2004; Vaish, Grossmann, & Woodward, 2008). In the event that either a positivity or negativity bias extends to infant perception of human walk motions, infants should spend different amounts of time looking to happy and angry PLDs in Study 3. Either pattern of results would suggest more holistic (as opposed to purely low-level total motion-based) processing of the emotional PLD stimuli.

4. Study 3

Study 3 presented infants with angry-sad, happy-sad, and angry-happy pairings of PLD walkers in both upright and inverted orientations in a within-subjects design.

4.1. Method

4.1.1. Participants

A sample of 26 healthy, full-term infants (12 male) ranging from 11.07 to 18.40 months ($M_{age} = 15.29$, $SD_{age} = 2.23$) participated in this study. An additional four infants were excluded from the final dataset due to excessive fussiness. Of the final sample, 21 infants had at least one parent who had completed four years of college. The ethnic/racial background of participants was as follows: Hispanic/Latino (N = 8), Caucasian (N = 7), Asian (N = 6), Multiracial (N = 5). Participants were recruited in the same manner as described in Studies 1 and 2, and were also given a small gift for participating.

4.1.2. Materials and apparatus

The same apparatus was used in Study 3 as in Study 1 and Study 2. We excluded the neutral PLDs but used the same six angry, happy, and sad PLDs as in the previous studies. Each of the remaining stimuli was paired with the others (angry-happy, angry-sad, happy-sad). Each pairing occurred six times, for 18 total trials (as in the previous studies). Half of the trials for each pairing were presented upright and the other half were inverted, for a total of three trials for each stimulus pairing in each orientation. The stimuli were presented in six blocks of three, with blocks alternating between upright and inverted presentations. Infants were randomly assigned to view either the upright or inverted orientation first. Each block included every stimulus pairing once in a randomized order, with the constraint that the same emotion was not presented on the same side more than three times in a row, regardless of block.

4.1.3. Procedure

The same procedure described in Studies 1 and 2 was used for Study 3.

4.2. Results and discussion

Individual trials were removed from analyses if the infant looked at the screen for less than 2 s of the 10-s trial. This resulted in removal of an average of 1.08 (*SD* = 1.87) out of 18 possible trials per participant. To be included in the final analysis, infants had to provide usable data from at least 1 trial in each of the 6 conditions. Number of trials per condition included in the final analyses were as follows: Upright Angry-Happy: *M* = 2.81, *SD* = .49; Upright Angry-Sad: *M* = 2.88, *SD* = .33; Upright Happy-Sad: *M* = 2.85, *SD* = .37; Inverted Angry-Happy: *M* = 2.85, *SD* = .37; Inverted Angry-Sad: *M* = 2.73, *SD* = .60; Inverted Happy-Sad: *M* = 2.81, *SD* = .49.

t-tests were used to investigate differences in proportions of dwell time to the stimuli in each pairing. With six total comparisons in this study, our Bonferroni correction led to an alpha level of .008. There was no significant difference in looking to the upright angry (*M* = .47, *SD* = .15) and upright happy PLDs (*M* = .46, *SD* = .16) PLDs, $t(25) = .20$, $p = .841$, 95% CI [−.11, .13]. However, infants did demonstrate longer looking to the upright angry (*M* = .58, *SD* = .17) than upright sad PLDs (*M* = .35, *SD* = .17), $t(25) = 3.52$, $p = .002$, 95% CI [.10, .37], and longer looking to the upright happy (*M* = .54, *SD* = .13) than upright sad PLDs (*M* = .39, *SD* = .13), $t(25) = 3.03$, $p = .006$, 95% CI [.05, .26].

Results were similar for inverted stimuli. There was no significant difference in looking to the inverted angry (*M* = .52, *SD* = .12) and inverted happy PLDs (*M* = .40, *SD* = .13) PLDs, $t(25) = 2.35$, $p = .027$, 95% CI [.01, .21]. In contrast, infants demonstrated longer looking to the inverted angry (*M* = .55, *SD* = .15) than inverted sad PLDs (*M* = .37, *SD* = .14), $t(25) = 3.30$, $p = .003$, 95% CI [.07, .29], and longer looking to inverted happy (*M* = .57, *SD* = .17) than inverted sad PLDs (*M* = .36, *SD* = .16), $t(25) = 3.19$, $p = .004$, 95% CI [.07, .34] (Fig. 6).

The results of Study 3 indicate that the infants did not discriminate the angry and happy stimuli, which were comparable in terms of total movement. However, they did discriminate angry-sad and happy-sad pairings, in both cases preferring the PLD with more total movement. These results lend further support to the idea that infants in Studies 1 and 2 discriminated differences in emotional walk motion from low-level total motion preference as opposed to more holistic processing of the stimuli.

5. General discussion

We conducted three experiments to investigate the possibility that 10-20-month-old infants could discriminate emotional biological motion and whether low-level stimulus features, in particular total motion, were important for this discrimination. Study 1 revealed that infants can discriminate upright angry, happy, and sad walk motions from neutral. Study 2 found a similar pattern of results with inverted stimuli (with the exception that sad and neutral were not discriminated), indicating that results from Study 1

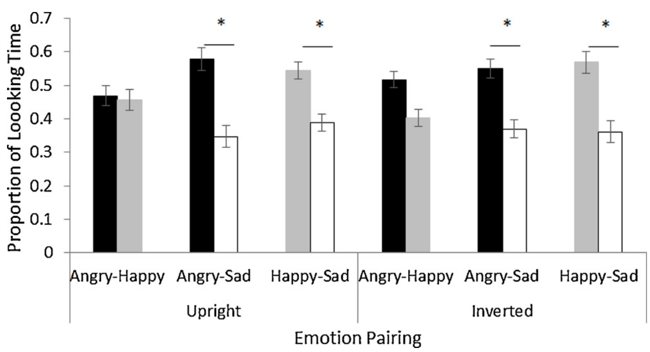

Fig. 6. Results of Study 3, with looking to the angry stimulus presented in black, looking to the happy stimulus presented in light gray, and looking to the sad stimulus presented in white. Error bars indicate SEM. * $p < .008$.

were likely driven by low-level total motion preferences. Study 3 supported this interpretation: Infants in this study discriminated sad from angry and happy PLDs both in upright and in inverted orientations, but provided little evidence of discriminating angry and happy PLDs in either orientation. Altogether, this pattern of findings aligns well with prior research indicating infant preference for faster movement by as early as 3 months of age (Dannemiller & Freedland, 1989; Finlay, Chorlton, & Boulton, 1991; Tsang et al., 2018), but provides little evidence that infants perceive emotional content *per se* in human biological motion.

Hock, White, Jubran, and Bhatt (2016) showed that infants as young as 5 months appear to process body postures holistically, as they were able to discriminate actual body configurations from configurations with limbs at abnormal orientations. Additionally, adults categorize emotions in PLDs independently of the velocity of dot motion (e.g., Johnson et al., 2011). The present results suggest that neither of these findings is directly relevant for infants' identification of emotional walk motions in PLDs, as the infants in our study did not appear to process the emotional PLDs holistically and relied on total motion for discrimination. PLDs in general provide minimal visual information (Johansson, 1973). Our PLD stimuli consisted of dot motions that were somewhat challenging even for adults to identify (see Table 1). Thus, the task was likely difficult for infants, which may have led them to rely on low-level total motion for discrimination. If this is the case, it may explain the result for our sad-neutral trials. The sad and neutral PLDs were statistically different in terms of total movement, yet they were closer to one another than any of the other pairings but angry-happy. Movement differences in this pair may have been more distinct when upright, perhaps reflecting some contribution from holistic information. It is also possible that something specific to the movements of the sad stimuli afforded more holistic processing than the other stimuli, a question for future research.

The results of infant visual preference for some emotional PLD pairs (e.g., angry-neutral) but not others (e.g., angry-happy) is indicative of infant discriminatory abilities. However, it is possible that similar patterns of infant visual preferences may be driven by different underlying mechanisms. For example, it is possible that infants may process the emotional walking PLDs holistically when they are presented upright, but then rely on low-level features when presented in the inverted orientation. Additionally, the present results leave open questions about how infants' own emotional development and emotional environment (e.g. family expressiveness, Ogren, Burling, & Johnson, 2018) might facilitate discrimination of PLDs from social content (cf. Tsang et al., 2018). These questions await further study.

In conclusion, our studies extend knowledge of infant perception of social content in human biological motion stimuli. Infants appeared to discriminate different emotional walking motions mainly from total motion patterns in the stimuli. Thus when total motion was similar across PLDs that exhibit distinct emotions (e.g., angry vs. happy walk motions), infants showed no preference, in contrast to studies providing evidence for preferences for happy emotional content (Kim & Johnson, 2013; Singh et al., 2002; Soken & Pick, 1992) or negative emotional content (De Haan et al., 2004; Vaish et al., 2008). These results provide insight into how emotional walking motions are perceived by infants, and suggests the importance of motion in guiding infant visual preferences for human biological motion.

Declarations of interest

None.

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