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RESEARCH ARTICLE

Infants' identification of gender in biological motion displays

Scott P. Johnson[1] | **Mingfei Dong**[2] | **Marissa Ogren**[1] | **Damla Senturk**[2]

[1]Department of Psychology, University of California, Los Angeles, CA, USA

[2]Department of Biostatistics, University of California, Los Angeles, CA, USA

Correspondence
Scott P. Johnson, Department of Psychology, UCLA, Los Angeles, CA 90095, USA.
Email: scott.johnson@ucla.edu

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Abstract

Infants' knowledge of social categories, including gender-typed characteristics, is a vital aspect of social cognitive development. In the current study, we examined 9- to 12-month-old infants' understanding of the categories “male” and “female” by testing for gender matching in voices or faces with biological motion depicted in point light displays (PLDs). Infants did not show voice–PLD gender matching spontaneously (Experiment 1) or after “training” with gender-matching voice–PLD pairs (Experiment 2). In Experiment 3, however, infants were trained with gender-matching face–PLD pairs and we found that patterns of visual attention to top regions of PLD stimuli during training predicted gender matching of female faces and PLDs. Prior to the end of the first postnatal year, therefore, infants may begin to identify gender in human walk motions, and perhaps form social categories from biological motion.

Infants discriminate female from male stimuli from an early age, and they appear to identify some gender-typed characteristics *amodally*—that is, detectable across two or more senses. (In this paper, we use the term *gender* to denote biological sex assigned at birth, predominantly female or male; American Psychological Association, 2020.) For example, by 3–4 months, infants raised primarily by their mothers have been found to prefer female to male faces (de Boisferon et al., 2014) and were better able to recognize individual females (Quinn et al., 2002). Also by 4 months, infants appear to distinguish between characteristics of female and male voices (Werker & McLeod, 1989) and there is a clear preference for infant-directed speech (Cooper & Aslin, 1990), which shares acoustic features with female speech patterns (Fernald & Kuhl, 1987). In addition, when tested with an intermodal matching method, 8-month-olds looked longer at a gender-matching face when simultaneously hearing a vowel produced by a female or male (Patterson & Werker, 2002), and 9-month-olds matched gender in female faces and voices producing infant-directed speech (Poulin-Dubois et al., 1994). Moreover, Walker-Andrews et al. (1991) found that 6-month-olds increased their looking to a dynamic female or male face when the gender-appropriate voice was heard in temporal synchrony with the facial movements.

These studies suggest that even young infants may have some knowledge about gender as a social category that is independent of stimulus modality. However, it remains unclear how infants may interpret gendered stimuli in other domains that are common in infants' early input, such as body movements. This question is important because infants' knowledge of social categories, including gender-typed characteristics, is a vital aspect of social cognitive development (Bigler & Liben, 1992, 2006; Ramsey et al., 2004), and both children and adults categorize body movements on the basis of gender differences in walk motions (Johnson et al., 2007, 2010; Troje, 2002).

Here, we used a visual preference paradigm to test the possibility that infants recognize gender in *biological motion*. Biological motion stimuli comprised “point light displays” (PLDs) created by recording reflective markers placed on women's and men's heads, shoulders, elbows, hands, waists, knees, and feet as they walked on a treadmill; PLDs consist of marker motions alone (Figure 1). Johansson (1973) reported that adults quickly and spontaneously recognize human figures in PLDs, and adults readily ascertain a number of social categories in PLDs (Troje, 2002), including gender (Kozlowski & Cutting, 1977; Mather & Murdoch, 1994).

Visual mechanisms that support perception of biological motion are in place early. Newborns look longer at upright versus inverted human PLDs (Bidet-Ildei et al., 2014), and by 3 months, infants differentiate walking from running (Booth et al., 2002). By 6 months, infants recognize walk direction (Kuhlmeier et al., 2010) and discriminate canonical PLDs from those in which limb rigidity (Bertenthal et al., 1987), bilateral symmetry of gait (Booth et al., 2002), or causality (Fox & McDaniel, 1982) are disrupted. By 9 months, more complex actions are detected, including PL versions of infants' own leg motions (Schmuckler & Fairhall, 2001) and visual patterns specifying limb occlusion in PLDs (Bertenthal et al., 1985), and by 14 months, infants discriminate PLD pairs representing non-disrupted versus disrupted (inverted) social interactions (Galazka et al., 2014). These studies reveal increasingly sophisticated processing of dynamic features in PLDs with development. Critically, however, there is no evidence to our knowledge that infants identify gender in PLDs, although there is evidence that infants can discriminate female versus male bodies and walk motions, which we discuss next.

Recently, Tsang, Ogren, et al. (2018) reported results from two experiments that shed light on infants' perception of gender in PLDs. In the first experiment, Tsang et al. asked whether infants would show a preference for female (vs. male) PLDs, as they do for female (vs. male) faces (Quinn et al., 2002) and perhaps voices (Decasper & Prescott, 1984; Spence & Freeman, 1996; but see Werker & McLeod, 1989). Infants were presented with pairs of female and male PLDs side by side as their eye movements were recorded. Overall, infants looked longer at male PLDs, contrary to the authors' expectations of a female preference. Analysis of motion patterns in the PLD stimuli revealed that the speed and extent of dot motions were greater in male versus female PLDs, in the top regions in particular. This is a consequence of greater oscillation of arm and shoulder regions as men walk. Accordingly, the infants looked reliably more at the top and middle regions of male PLDs relative to the same regions of female PLDs, implying that infants' preference for male PLD was driven by differences in motion between the two genders.

In a second experiment, Tsang, Ogren, et al. (2018) asked whether infants would categorize PLDs according to gender, as they do for female versus male faces (Ramsey et al., 2005). Categorization is

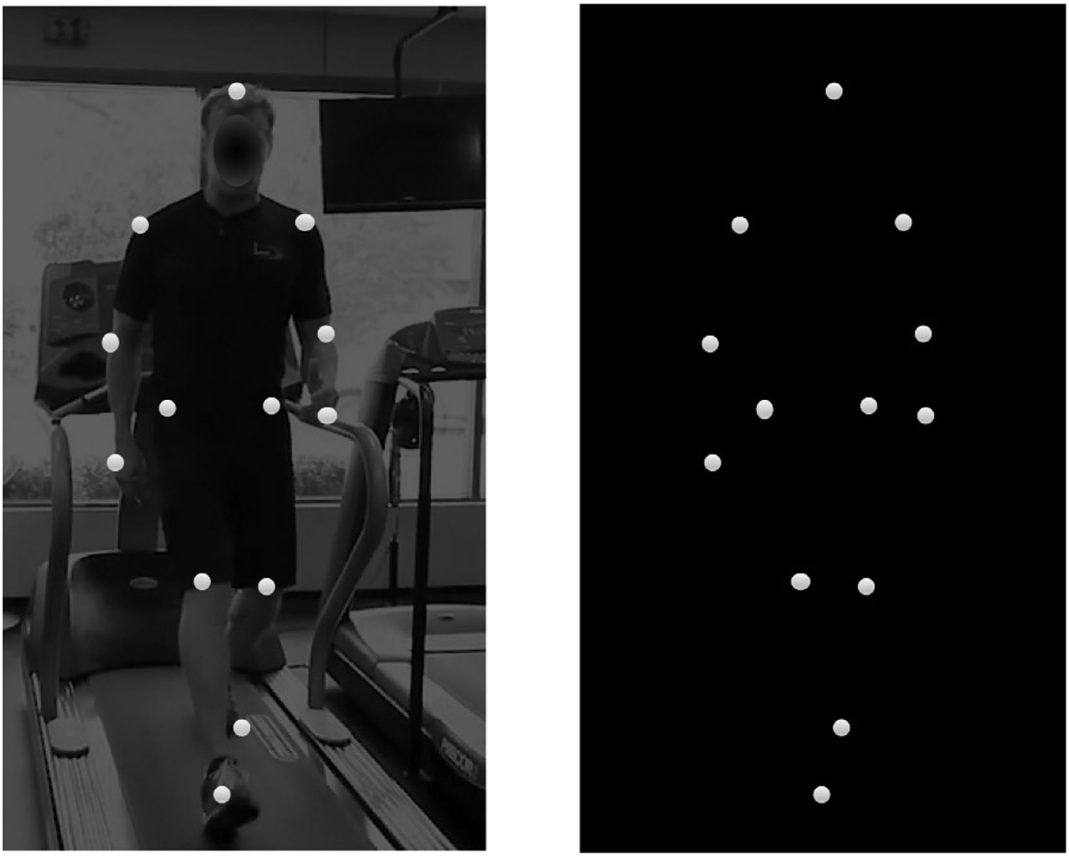

FIGURE 1 Point light displays (PLDs) are generated from walk motions by placing reflective markers on the body (left). Recordings of the "points of light" (right) were presented to infants

a fundamental cognitive activity that guides the grouping of objects and events by organizing low-level structure and more abstract relations (Mervis & Pani, 1980), and in adults, social categorization appears to be an obligatory aspect of social life (Allport, 1954). In the Tsang et al. study, categorization was tested by habituating infants with a series of either male or female PLDs, followed at test by presentation of paired male and female PLDs, neither of which had been seen before. If infants formed a gender-based category (e.g., a category "female walk motions"), they should look longer at the test stimulus from the other category (in this example, at the male PLD test stimulus). This happened only for infants who were habituated to male PLDs—not for infants habituated to female PLDs. In other words, infants appeared to categorize PLDs produced by men, but not by women.

Notably, categorization in the Tsang, Ogren, et al. (2018) study was facilitated by attention to PLDs' upper regions. As noted, these upper regions are particularly diagnostic for determining gender differences because men's shoulders and arms undergo greater translatory motion than women's when walking (Troje, 2002; Tsang et al.). These findings suggest that infants discriminate female from male biological motion and establish perceptual categories based on gender-specific walk motions, presumably an important step toward forming gender-based social categories (cf. Ramsey et al., 2005). Moreover, patterns of visual attention to PLDs may be important to their discrimination. However, these results do not provide evidence that infants identify gender *per se* in PLDs, because gender was confounded with dot motion. Other studies have found that infants as young as 3.5 months scan female and male bodies differently (White et al., 2018, 2019) and, by 5 months, appear to match faces and bodies according to gender (Hock et al., 2015). These studies are important in providing evidence for early processing of gender categories, but they do not necessarily shed light on categorization of PLDs by gender.

In the current study, we used a visual preference method to address the possibility that infants might identify gender in PLDs. In three experiments, we presented infants with side-by-side female and male biological motion stimuli (recorded from a woman and a man) as infants heard a female or male voice (Experiments 1 and 2) or viewed a female or male face presented between the motion stimuli (Experiment 3). We reasoned that longer looking at the PLD that matched the voice or face would constitute evidence that infants identified their common gender (Figure 2; cf. Bahrick et al., 1998). As noted previously, there is evidence for infants' intermodal gender matching across voices and faces (Patterson & Werker, 2002; Poulin-Dubois et al., 1994; Walker-Andrews et al., 1991), but it remains unknown whether infants can match gender across voices and PLDs, or across faces and PLDs.

Gender matching was computed as a looking time preference for female or male PLDs that matched a female or male voice (Experiments 1 and 2) or face (Experiment 3) divided by total looking. Experiment 1 tested for "spontaneous" voice–PLD gender matching after initial familiarization to silent PLD pairs. In Experiments 2 and 3, we aimed to facilitate performance by presenting female and male voices and faces with individual PLDs during familiarization to "train" gender matching. We focused on 9- to 12-month-olds in this study due to recent findings that infants at this age begin to analyze motion patterns in PLDs to discriminate emotions (Ogren et al., 2019), modulate face scanning when hearing speech (Tsang et al., 2018), and discriminate between patterns of dot motions that specify animacy to adults (viz. acceleration, high turning rates, and attraction; Frankenhuis et al., 2013). Infants at this age, therefore, are increasingly capable of sophisticated social information processing, and so we reasoned they may also provide evidence for gender matching of voice or face and PLDs.

1.1 | Analysis plan

We first analyze data aggregated across the familiarization and test phases of the three experiments to test for a male PLD preference (cf. Tsang, Ogren, et al., 2018). Next, we analyze for gender matching at test in each experiment, followed by analyses of relations between individual differences in

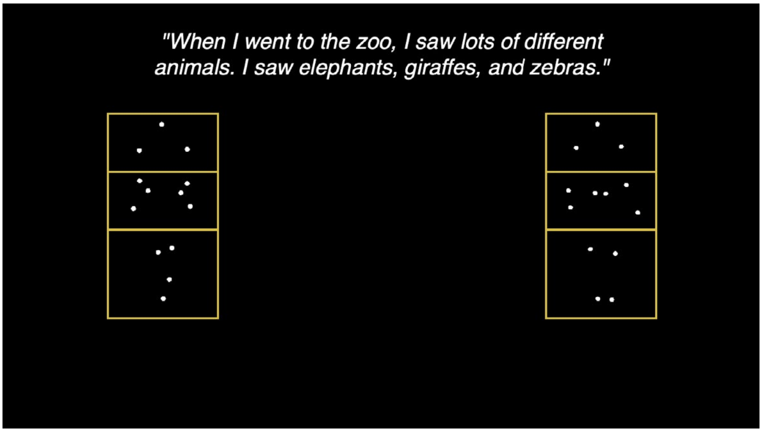

FIGURE 2 Female (left in this example) and male (right) PLDs were viewed as a female or male voice was heard (Experiments 1 and 2). Rectangles depict boundaries for top, middle, and bottom "areas of interest" and were not present in the stimuli. See text for details

scanning patterns during familiarization and at test. The latter analyses are particularly important to understand how scanning patterns (e.g., attention toward the top regions of PLDs) may be related to gender-matching performance.

1 | METHOD

1.1 | Participants

Nineteen infants (8 female, *M* age = 10.3 months, range = 8.8–12.3 months) composed the final sample for Experiment 1, 20 infants (10 female, *M* age = 9.9 months, range = 8.9–11.3 months) composed the final sample for Experiment 2, and 19 infants (8 female, *M* age = 10.5 months, range = 9.3–11.4 months) composed the final sample for Experiment 3. Data from an additional 14 infants were excluded due to fussiness (13) or experimenter error (1). The sample size in each experiment exceeds sample sizes in previous studies of infants' intermodal matching of social stimuli (*N* = 16; Bahrick et al., 1998; Flom & Whiteley, 2014; Patterson & Werker, 2002; Walker-Andrews et al., 1991) and in studies of infants' intermodal matching of non-social stimuli (*N* = 12–16; Kobayashi et al., 2005; Walker et al., 2010; Bremner et al., 2011). The present study was conducted according to guidelines laid down in the Declaration of Helsinki, with written informed consent obtained from a parent or guardian for each child before any assessment or data collection. All procedures involving human subjects in this study were approved by the North General Institutional Review Board at the UCLA.

1.2 | Stimuli

PLD stimuli used in Experiments 1–3 consisted of PLDs from 6 men and 6 women who were recruited for purposes of recording walk motions (Tsang, Ogren, et al., 2018). We selected PLDs (from 20 used by Tsang et al.) that were most frequently identified as the correct gender (minimum 77.7% correct) by undergraduates (*N* = 32, 22 female) recruited for purposes of validating PLD gender. Each PLD measured 12.9 cm (12.2° visual angle at the infant's 60 cm viewing distance) by 7.1 cm (6.8°) and was positioned so its center was 8 cm from the left or right edge of the screen at test (Figure 2). PLDs were edited to seamlessly loop through walk cycles. Voice stimuli used in Experiments 1 and 2 consisted of 10-s audio clips recorded from 10 adult males and 10 females, each using infant-directed speech and following a script. We selected the 6 male and 6 female clips that were most frequently identified as the correct gender (minimum 96% correct) by undergraduates (*N* = 59, 32 female) recruited for purposes of validating voice gender. Face stimuli used in Experiment 3 consisted of White female and male faces from the Chicago Face Database (Ma et al., 2015). Each face measured 12.9 × 12.9 cm (12.2 × 12.2°). Adult ratings of femininity and masculinity in female and male faces, respectively, were highly reliable ($\alpha > .999$) in the original validation data, indicating that adults readily identified the faces' genders. We selected the 9 male and 9 female faces with the highest “attractiveness” ratings from the original validation data.

1.3 | Procedure

Stimuli were presented on a 61.5-cm monitor using an Apple G5 computer. The experimental protocol was scripted using Experiment Builder (SR Research, Ottawa, Ontario, Canada). Each infant sat on a caregiver's lap approximately 60 cm from the display. We used an EyeLink 1000 eye tracker (SR Research) to record eye movements at 500 Hz. Each infant's point of gaze was calibrated prior to testing with a 5-point calibration scheme in which a single stimulus (an expanding and contracting target) was placed in the center, top left, bottom left, top right, and bottom right in random order as the infant watched and was monitored by an experienced observer. When the observer determined that infant's visual attention was on target during calibration at each of the 5 points, he or she pressed a key that indicated that the point of gaze matched the target location. Calibration accuracy was checked with an additional presentation of each target in turn. If any point of gaze was not calibrated, the process was repeated until all 5 targets were calibrated for each infant.

Infants in each experiment first viewed 6 familiarization trials followed by 12 test trials in psuedorandom order (no more than three trials consecutive before switching sides). Each trial lasted 10 s and was preceded by an attention getter to center the infant's gaze. Side of presentation (male or female left first) and voice or face (female or male first) were counterbalanced across infants. In Experiment 1, familiarization trials consisted of PLD pairs (one female and one male side by side) with no audio, and test trials consisted of PLD pairs accompanied by either male or female audio (6 trials of each). Six of the PLDs (3 female and 3 male) were seen during both familiarization and test trials, and each PLD stimulus was seen twice during test trials. In Experiment 2, familiarization trials consisted of a single, center-positioned PLD (female or male, 3 trials of each) accompanied by a gender-matched voice to train voice–PLD gender matching, and test trials consisted of PLD pairs accompanied by either male or female audio (6 trials of each). Finally, in Experiment 3, familiarization trials consisted of a single PLD (female or male, 3 trials of each) accompanied by a gender-matched face to train face–PLD gender matching), and test trials consisted of PLD pairs accompanied by either male or female face in the center (6 trials of each; see Figure 3). A different female or male face was shown on each trial (familiarization and test).

2 | RESULTS

Attention to each PLD was operationalized as dwell times (accumulated points of gaze) in "areas of interest" (AOIs) surrounding top, middle, and bottom areas of each PLD (Figure 2). Across experiments, there were no significant differences in female versus male infants' performance, side of stimulus presentation, or order bearing on our hypotheses; therefore, we collapsed across these variables for analyses we report below.

2.1 | Overall male PLD preference

We first tested for an overall male PLD preference (cf. Tsang, Ogren, et al., 2018) by analyzing data aggregated across familiarization and test phases of the three experiments. Data for this analysis consisted of mean dwell times (summed across top, middle, and bottom AOIs) in female and male PLDs during familiarization and test. A 2 (PLD gender) × 2 (Phase: familiarization vs. test) × 3 (Experiment) mixed ANOVA, with repeated measures on the first two factors, revealed a significant main effect of PLD gender, $F(1, 55) = 6.10$, $p = .017$, $\eta_p^2 = .10$, the result of greater looking overall at male PLDs ($M = 26.70$ s, $SD = 6.86$) versus female PLDs ($M = 25.02$ s, $SD = 7.23$; see Figure 4a). There was also a significant main effect of Phase, $F(1, 55) = 128.83$, $p < .001$, $\eta_p^2 = .70$, reflecting greater looking overall during the test phase ($M = 32.08$ s, $SD = 10.03$, 12 trials) than familiarization ($M = 19.64$ s, $SD = 10.03$, 6 trials), and a significant main effect of Experiment, $F(2, 55) = 7.26$,

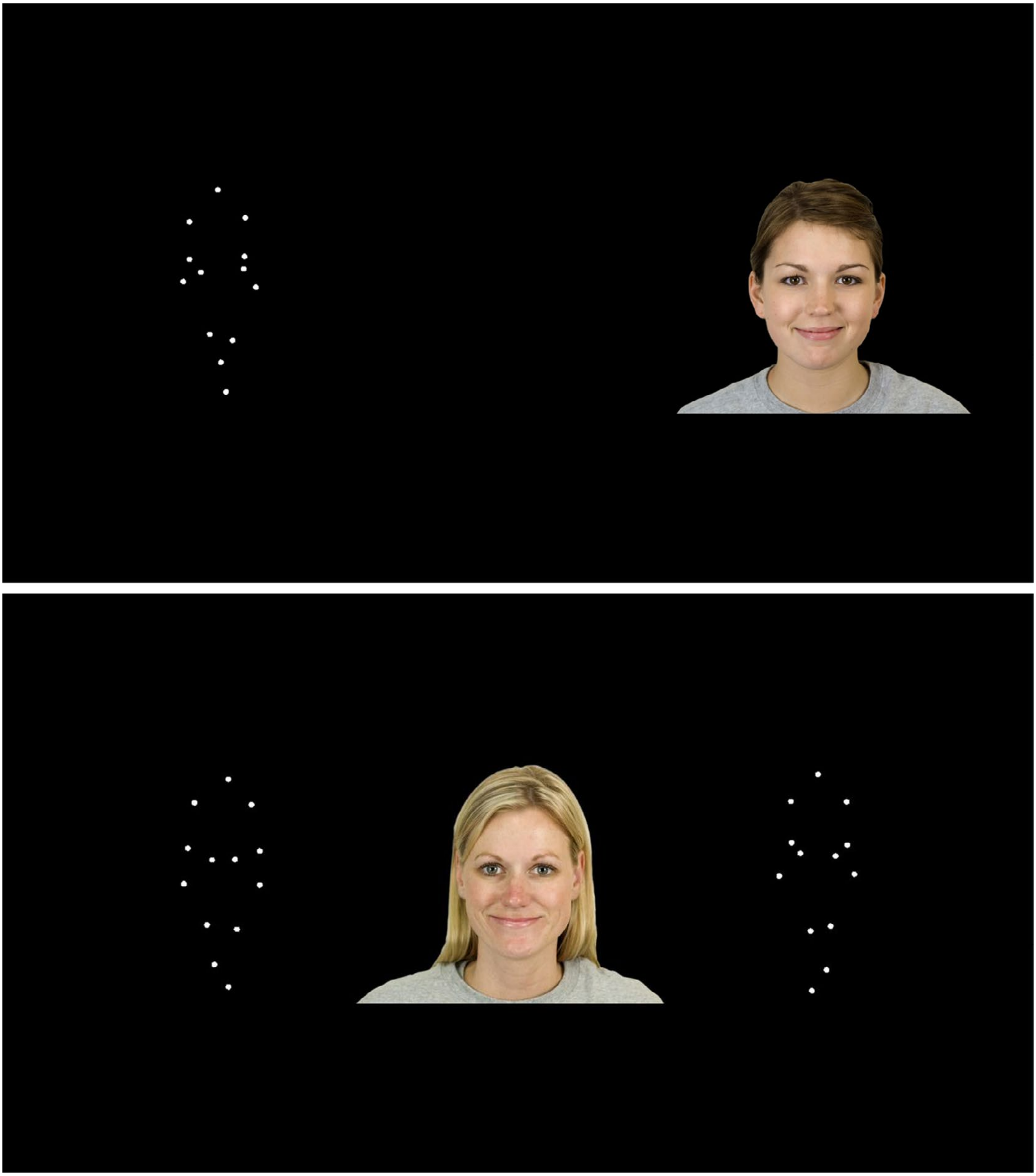

FIGURE 3 Top: Faces were paired with gender-matched PLDs during familiarization (Experiment 3). Bottom: At test, faces were presented with gender-matched (right) and mismatched (left) PLDs

$p = .002$, $\eta_p^2 = .21$, stemming from higher dwell times in Experiment 1 ($M = 28.67$ s, $SD = 5.57$) and Experiment 2 ($M = 27.68$ s, $SD = 8.03$) versus Experiment 3 ($M = 21.22$ s, $SD = 5.69$) due to the presence of the face alongside the PLDs in Experiment 3. There were no other significant main effects or interactions. Infants in the present study, therefore, showed greater interest in male PLDs over female PLDs, consistent with results of Tsang et al.

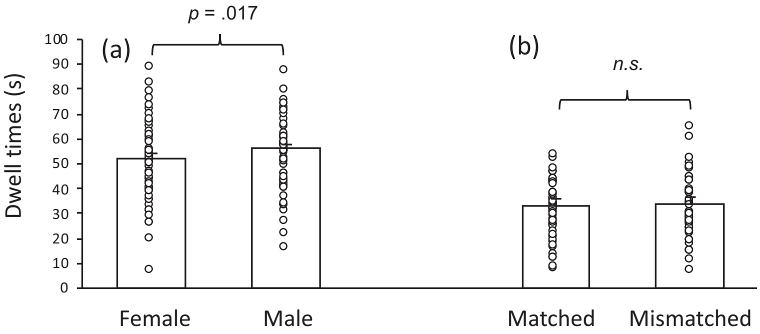

FIGURE 4 PLD dwell times plotted as individual data points and means. (a) There was an overall preference for male PLDs (data from both familiarization and test). (b) There was no overall preference for PLDs whose gender matched a voice or face gender (data from the test phase only). Error bars denote standard error of the mean.

2.2 | Overall gender matching

Next, we analyzed for gender matching at test in each experiment—that is, the extent to which infants looked at the PLD on either side of the display that matched the male or female voice or face. Data consisted of dwell times in top, middle, and bottom AOIs in each matched and mismatched PLD (relative to the voice or face) seen during the test phase. A 2 (matched vs. mismatched PLD) × 2 (matching stimulus: female vs. male) × 3 (AOI) × 3 (Experiment) mixed ANOVA, with repeated measures on the first three factors, revealed a significant main effect of Experiment, $F(2, 55) = 3.50$, $p = .037$, $\eta_p^2 = .11$; dwell times were higher in Experiment 1 ($M = 17.52$ s, $SD = 4.99$) and Experiment 2 ($M = 17.03$ s, $SD = 5.93$) versus Experiment 3 ($M = 13.58$ s, $SD = 3.85$) due to the presence of the face between the PLDs in Experiment 3. There was also a reliable effect of AOI, $F(1, 55) = 55.00$, $p < .001$, $\eta_p^2 = .50$, due to differences in dwell times in the three AOIs (top $M = 1.06$ s, $SD = 1.09$; middle $M = 9.31$ s, $SD = 4.49$; bottom $M = 5.68$ s, $SD = 4.06$). There were no other significant main effects or interactions. Overall, therefore, infants did not look longer at a PLD that matched the gender of an accompanying voice or face.

2.3 | Individual differences in scanning patterns

The final set of analyses examined relations between individual differences in scanning patterns during familiarization and at test. In particular, we were interested in the possibility that attention to the top regions of PLDs would facilitate gender matching. For each of the three experiments, we computed linear regressions with gender matching during testing phase as outcome, and dwell times in top, middle, and bottom AOIs for female and male PLDs during the training phase as predictors (see Figure 2). We analyzed for female and male gender matching separately. For Experiments 1 and 2, none of the regression analyses yielded statistically significant results (for brevity, details of these results are not reported). For Experiment 3, however, we found that female gender matching was predicted by attention in the top AOIs. Specifically, higher dwell times in the top AOI of the female PLD during familiarization, and lower dwell times in the top AOI of the male PLD, each significantly predicted longer looking at the female PLD at test (see Figure 5 and Table 1). For male gender matching, the outcomes were not statistically significant. Analyses of dwell times in middle and bottom AOIs did not reveal significant effects on gender matching.

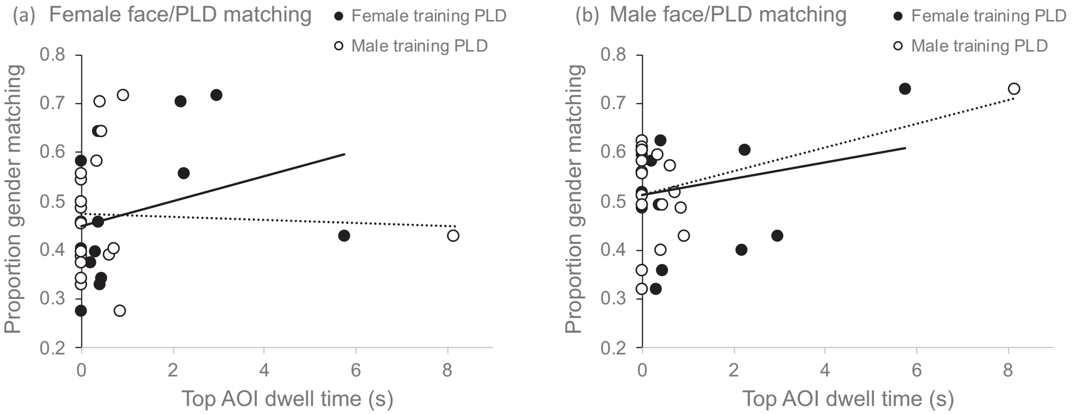

FIGURE 5 Attention to the top AOIs in female and male PLDs during familiarization predicted gender matching at test for female stimuli (a) but not male (b) stimuli

TABLE 1 Standardized regression coefficients predicting gender matching, Experiment 3

		B	*SE*	*β*	*p*
Female face/PLD matching					
Dwell times, female top AOI		1.395	.264	1.092	.005
Dwell times, male top AOI		−.849	.295	−.961	.011
Adjusted R^2	.329				
F	5.414				.016
Male face/PLD matching					
Dwell times, female top AOI		−.418	.385	−.406	.294
Dwell times, male top AOI		.552	.267	.775	.055
Adjusted R^2	.158				
F	2.693				.098

3 | DISCUSSION

We used an intermodal matching method to test the possibility that 9- to 12-month-old infants would match gender in voices and faces with human biological motion. Overall, the infants we observed looked longer at male versus female PLDs, replicating earlier work (Tsang, Ogren, et al., 2018). However, infants did not match gender in voices with PLDs either spontaneously (Experiment 1) or after training trials with gender-matched stimuli (Experiment 2). When infants were trained with face–PLD pairs, in contrast, gender matching of female faces with PLDs was predicted by attention to the top areas of PLDs seen during training (Experiment 3).

As noted previously, walking motions produced by men and women are especially distinct in the upper body (Troje, 2002), and infants attend to these areas in particular when categorizing PLDs produced by women and men (Tsang, Ogren, et al., 2018). When analyzing human walk motions, therefore, infants appear to distinguish between genders by attending to information that most reliably specifies their differences—that is, infants have to look in the "right place" (cf. Johnson et al., 2004, 2008). Results of the current study imply that the same may be true when infants' gender-based social categories begin to include representations of PLDs and faces. Interestingly, this pattern of results emerged only for gender matching within the visual modality; gender matching across multiple modalities may be more difficult (de Boisferon et al., 2015). In addition, gender matching was observed for female stimuli only, a result consistent with earlier work showing that infants may be better able to match female faces and voices versus male faces and voices (de Boisferon et al., 2015).

Infants observed by Tsang, Ogren, et al. (2018) preferred male PLDs, yet infants in Experiment 3 provided some evidence for matching female faces and PLDs, but not for male stimuli. This effect may arise from infants' greater familiarity overall with females than males (Rennels & Davis, 2008; Sai, 2005; Sugden & Marquis, 2017), thus facilitating recognition of the female PLD when paired with a female face. (This explanation implies that the male PLD preference reported by Tsang et al. stems in part from a novelty preference for males, as well as motion differences in walk motions between women and men.) In addition, Tsang et al. reported that male infants looked significantly longer at PLDs than did female infants. In the present study, male infants had higher dwell times to PLDs overall (across familiarization and test), $M = 25.65$ s ($SD = 6.8$), than did female infants, $M = 24.79$ s ($SD = 8.02$), but this difference was not statistically significant, $t(56) = .91$, $p = .37$. The reasons for the differences between these two studies are not clear, but it is noteworthy that testing conditions are rather distinct—for example, PLDs in the current study were usually presented with an accompanying voice or face. How these differences in method might yield specific patterns of PLD preference remains a question for future research.

Prior studies have shown that young infants appear to recognize social interactions such as contingency (Frankenhuis et al., 2013), causality (Rochat et al., 2004), and goals (Csibra et al., 1999) in dynamic two-dot displays and that 12-month-olds follow the gaze of a PLD turning to observe a target (Yoon & Johnson, 2009). These studies show that visual attention is keenly directed toward dynamic social targets early in life, and contemporary theories of social cognitive development seek to explain acquisition of social categories, such as gender, from these perceptual abilities. Developmental intergroup theory, for example, holds that social categories are rooted in "psychological salience" of observable characteristics, a function of perceptual discriminability and variability of features (Bigler & Liben, 2006, 2007). Such a system may operate in accord with the *contact hypothesis* of social perception (Sporer, 2001), which argues that contact with individuals from specific social groups fosters the ability to extract visual cues or invoke processing strategies that support recognition of individuals within these groups. Research on face categorization in infancy is consistent with this possibility. Infants' category of female faces may be more advanced in development than the male category (Ramsey et al., 2005) due to relatively more experience with exemplars from the female category of faces, given that infants tend to prefer female faces (Quinn et al., 2002) and spend more time with females than with males (Rennels & Davis, 2008; Sugden et al., 2014). Moreover, infants' recognition of emotion in body movements also appears to be influenced by specific experiences with different emotions (Heck et al., 2018). Body motion categories are perceptually complex (Bhatt et al., 2016), yet infants are able to discriminate female from male PLDs; initial PLD categories appear to be based on motion patterns and not necessarily conceptual knowledge of gender categories (Tsang, Ogren, et al., 2018).

The extent to which infant performance under tested circumstances may have stemmed from associative learning during the training phase with a familiar face category (female) remains unclear. For example, a longer training period might have led to more robust matching of female faces and voices with PLDs, and perhaps might also have led to gender matching for male stimuli. Alternatively, gender matching of PLDs with gender-specific features in faces and voices might depend on greater familiarity with female and male walk motions, and their distinctions) from everyday experiences. There may be considerable variability in these experiences (e.g., single parent vs. 2-parent households) that bear on gender categorization in infancy. These remain questions for future research. Nevertheless, the present study provides some evidence that by 9–12 months, infants begin to identify a key social category (gender) in human walk motions—the first evidence of which we are aware for infants' interpretation of human biological motion as comprising social categories.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest with regard to the funding sources for this study.

ORCID

Scott P. Johnson https://orcid.org/0000-0003-2970-184X
Marissa Ogren https://orcid.org/0000-0003-4441-5219

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