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Brief Report

Infants' use of movement synchrony to infer social affiliation in others

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ABSTRACT

Infants socially engage with others and observe others' social interactions from early in life. One characteristic found to be important for signaling and establishing affiliative social relationships is physical coordination and synchronization of movements. This study investigated whether synchrony in others' movements signals affiliation to 12- and 15-month-old infants. The infants were shown a scene in which two characters moved either synchronously or non-synchronously with a third character in the center. Next, the center character made an affiliation declaration and subsequently approached and cuddled one of the two characters. Using measures of gaze, we gauged infants' inferences about whom the center character would affiliate with before the cuddling took place. We found that 15-month-olds, but not 12-month-olds, inferred that the center character would affiliate with the previously synchronous character, suggesting that they can make inferences about others' affiliation based on movement synchrony. The findings are discussed in terms of their relevance to the infants' personal preferences and the potential importance of first-person experience in the development of social cognition.

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Introduction

Human infants are remarkable at extracting social information from their surroundings. Through interacting with their caretakers and observing other people interact, infants learn about how social bonds are formed and how different individuals react to each other. For example, similarity cues, such as a common language and skin color, guide both infants' own social preferences and their expectations about others' social interactions (Kinzler, Shutts, & Correll, 2010).

One similarity cue that has recently been shown to influence infants' social preferences is movement synchrony (i.e., precise matching of the timing of rhythmic movements between interactants). Infants like and help those who have moved synchronously with them (Cirelli, Einarson, & Trainor, 2014; Tunçgenç, Cohen, & Fawcett, 2015). Yet, we do not know whether infants make inferences about others' social interactions based on movement synchrony. This would be an additional cue for infants to use to interpret others' behaviors and relationships as they learn about the social world through observation. The current study aims to determine whether infants infer that synchronous others will affiliate.

Even young infants use their prior observations to make inferences about others' future actions and social preferences. For example, during the first year of life, infants already expect others to prefer someone who helped them over someone who hindered them with their goal, such that they not only look longer at an event depicting an agent approach a hinderer as opposed to a helper (Lee, Yun, Kim, & Song, 2015; see also Choi & Luo, 2015) but also spontaneously visually anticipate an agent to approach a helper when their gaze is examined using eye tracking (Fawcett & Liszkowski, 2012). The latter method of tracking infants' eye gaze in the face of incomplete events, as compared with employing a violation of expectation method where outcomes are known, has the potential to reveal how infants make inferences based on limited information. Furthermore, this ability to quickly direct gaze to where it is most relevant would be valuable for infants to navigate complex visual scenes, making it an important aspect of development to investigate.

In all of these studies, however, behaviors that are explicitly targeted to another individual (e.g., helping/hindering someone with a goal) are used to provide the socially valenced information. Yet, such explicit action–outcome links might not be available to the observers and/or might not be a reliable source of information in real-life social interactions. Substantive social information is also conveyed through subtler means such as the similarity of physical features, preferences, or body movements (Haun & Over, 2015). In adults, certain movement characteristics, such as physical coordination and synchronization of movements, can signal social closeness and one's ability and desire for prosocial engagement (Knoblich & Sebanz, 2008). One recent study with 9-month-old infants also revealed that such indirect social cues influence inferences about others' social interactions, such that infants expected others to interact positively with individuals who share similar food preferences and to interact negatively with those who do not (Liberman, Kinzler, & Woodward, 2014).

Do infants similarly infer social affiliation when others move synchronously with each other? From early in infancy, infants and caretakers display coordinated movements that can be either synchronous or complementary in nature (Crown, Feldstein, Jasnow, Beebe, & Jaffe, 2002; Jasnow & Feldstein, 1986). Over time, the prevalence of these coordinated movements can influence aspects of the children's social, cognitive, and communicative development (Jaffe et al., 2001). Mounting experimental studies corroborate these observational findings by showing that rhythmic synchronous movements can facilitate affiliation and prosociality during infancy. A recent study showed that infants prefer social agents who moved in a synchronous rhythm with them at 12 months but not at 9 months of age (Tunçgenç et al., 2015). Importantly, infants in that study did not prefer synchronous others in a nonsocial context, suggesting that movement synchrony is preferable specifically in relation to social interactions.

By 14 months of age, movement synchrony also affects infants' prosocial behaviors. Infants who were bounced with an adult synchronously subsequently helped that adult more than those who were bounced with the adult non-synchronously (Cirelli, Einarson, et al., 2014; Cirelli, Wan, & Trainor, 2014). Follow-up studies further revealed that infants did not help a neutral individual more following synchronous movement (Cirelli, Einarson, et al., 2014; Cirelli, Wan, et al., 2014) unless that individual

was affiliated with the synchronizing adult (Cirelli, Wan, & Trainor, 2016). Therefore, it can be speculated that the prosocial outcomes of synchronous movements do not stem from a generalized positivity effect; instead, movement synchrony signals specific information about the interactants' social relationship that guides infants' preferences and behavior.

It is not known, however, whether infants can use movement synchrony to make inferences about others' social relationships from a third-person perspective. The current study investigated whether infants use the synchronous timing of others' movements as a cue to their affiliation. To that end, we presented 12- and 15-month-olds with videos in which two toy characters performed rhythmic movements either synchronously or non-synchronously with a third character in the center. Following this, the center character declared an affiliative intention and then approached one of the two characters (the synchronous or non-synchronous character). Infants' gaze to the two outer characters prior to the approach event was measured to reveal which of the characters the infants interpreted as being the one with whom the center character was more affiliated.

Based on existing literature regarding infants' understanding of others' social interactions and synchrony preference around the first year, we hypothesized that infants would expect the center character to affiliate with the synchronous character more than the non-synchronous character, as indicated by gaze to the synchronous character after the affiliation statement was made but before the approach took place. Previous research suggests that infants link synchronous movements to social affiliation at 12 months of age when they are part of the interaction (Tunçgenç et al., 2015). However, given the relatively small effect size of that study and the other prosocial effects of synchrony that are apparent at 14 months of age (Cirelli, Einarson, et al., 2014), this link may be just beginning to emerge at around these ages. Therefore, although we had a directed hypothesis for 15-month-olds, the current study was more exploratory with regard to 12-month-olds. It is possible that recognizing the link between synchrony and social affiliation in others would develop only after infants have gained sufficient first-person experience acting in synchrony with others, which might not have occurred yet for the 12-month-olds. We also explored any possible relations between the infants' inferences of others' affiliation and their personal preferences for others who have moved in synchrony by assessing the relation between infants' own looking preferences before the affiliation declaration took place and their gaze in conjunction with the affiliation declaration.

Method

Participants

In total, 33 12-month-olds ($M = 12.04$ months, $SD = 0.23$; 17 girls) and 32 15-month-olds ($M = 14.94$ months, $SD = 0.24$; 15 girls) were included in the final sample. An additional 9 infants (4 girls) participated but were not included in the final sample due to unwillingness to participate ($n = 1$ 12-month-old), not understanding the language of the experiment ($n = 1$ 15-month-old), and not having at least 20 s of looking to the synchronous/non-synchronous motion in either of the video sequences ($n = 3$ 12-month-olds and $n = 4$ 15-month-olds). Participants were recruited from a list of families in a medium-sized university town who had expressed interest in participating in infancy research. Families were given a gift card worth approximately 10 euros for their participation. The study was approved by the local ethical committee.

Stimuli

Each participant viewed two video sequences lasting approximately 5 min in total. In all videos, three stuffed animals (bears or dogs, depending on the sequence) sat next to each other. Having two full video sequences allows for twice as many test trials and, thus, more power in the data set. The center character differed in color from the two outer characters, and the two outer characters had different colors of scarves that distinguished them (see Fig. 1). All speech was presented in the local language but is translated to English here.

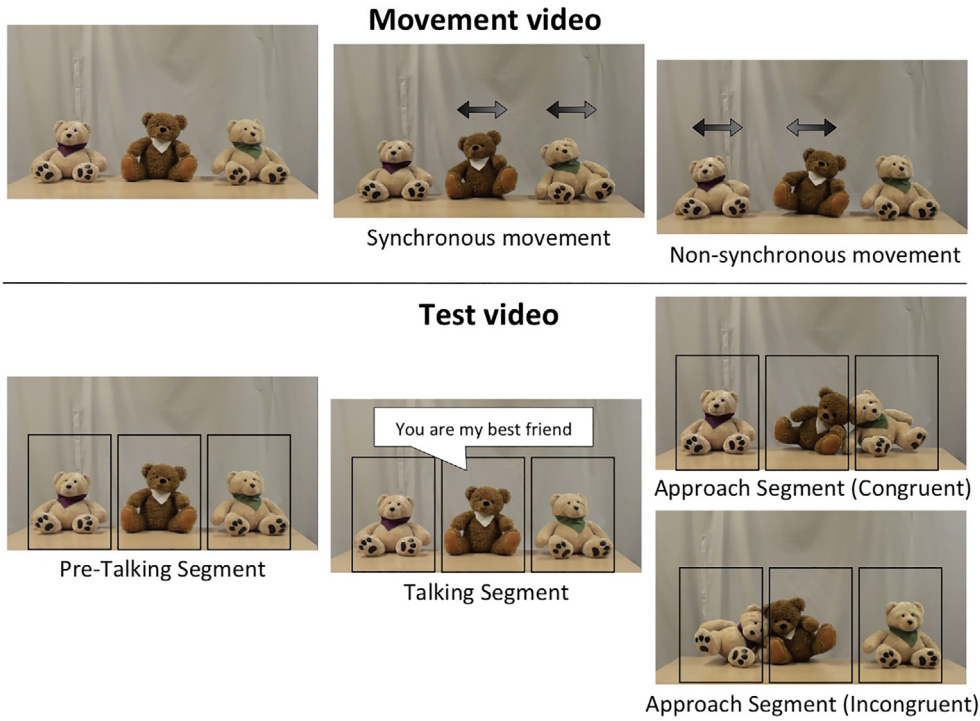

Fig. 1. Screen shots taken from the Movement and Test videos. In the Movement video, the center character moved synchronously with one outer character and moved non-synchronously with the other outer character. The Test video was divided into three segments: *pre-talking* (the three characters sit still) *talking* (the center character says "You are my best friend!"), and *approach* (the center character leans toward and cuddles with either the previously synchronous character [congruent] or the previously non-synchronous character [incongruent]). Frames indicating AOIs, arrows indicating movement, and text boxes are added here for clarity.

In each sequence, there was a Movement video (~110 s) and a Test video (~18.5 s). Two repetitions of the Test video were presented to ensure sufficient exposure to the stimuli and reliability of the infants' responses. The Movement video began with the center character on screen and then the outer characters entering from their respective sides. Then, the center character and one outer character said "Hey, let's go," with their talking indicated by nodding of their heads, and they started to bounce up and down (dogs) or sway side to side (bears) for 15 s. Then, the center character and the other outer character said "Hey, let's go," and they began to move in the same manner. In the Movement video, one outer character moved synchronously with the center character (both every 517 ms) and the other character moved non-synchronously (one every 594 ms and the other every 458 ms). Movement speeds and durations were selected based on a similar previous study (Tunçgenç et al., 2015). The synchronous and non-synchronous motions were repeated within the video so that infants were shown a total of 30 s of each movement type.

Next, two repetitions of the Test video were shown. The Test video was divided into three segments. In the *pre-talking* segment, the three characters sat still next to each other for 3.5 s. Then, in the *talking* segment, the center character said "You are my best friend!" in a positive tone but did not yet turn to either outer character (5 s from the time the talking began). Finally, in the *approach* segment, the center character leaned toward one outer character and the two made a cuddling motion before returning to their sitting positions (5 s).

The videos were presented in one of 16 possible versions, which were counterbalanced for which animals (dogs or bears) appeared in the first or second sequence, whether the center character

approached the synchronous character in the first or second sequence, which color scarf the synchronous character wore, which side the synchronous character sat on, and whether the non-synchronous character moved faster or slower than the center character.

Procedure

Infants sat on their parent's lap approximately 50 cm from the screen of a Tobii TX300 eye tracker (Tobii Technology, Stockholm, Sweden), which has a reported accuracy of 0.5 visual degrees and freedom of head movement within 37 × 17 cm. Before beginning the study, a 5-point calibration was used with the requirement that all points were successfully calibrated.

Data reduction and analyses

Data were processed in the MATLAB-based open source program TimeStudio (MATLAB Version 8.5.0; TimeStudio Version 3.15; http://www.timestudioproject.com; Nyström, Falck-Ytter, & Gredebäck, 2016; the analysis tools and settings used in this study can be downloaded from the TimeStudio program using uwid: ts-85a-8e7). Areas of interest (AOIs) were created for the whole screen during the entire Movement and Test videos and for each of the characters during each segment of the Test video (pre-talking, talking, and approach). Durations of looking into each AOI were obtained. For the pre-talking and talking segments of the Test video, difference scores were calculated for looking to the synchronous character minus looking to the non-synchronous character; for the approach segment, a difference score was calculated for looking to the approached character minus looking to the unapproached character. Segments with no looking to either outer character were excluded (11% of pre-talking, 21% of talking, and 9% of approach segments). Data gathered from the two video sequences and the two repetitions of the Test video within each sequence were not aggregated, which served to increase accuracy and reliability of the responses and power in the analyses. Therefore, each participant had a total of two scores (for Sequences 1 and 2) for overall looking to the screen in the Movement and Test videos and four difference scores (for Tests 1 and 2 in Sequences 1 and 2) for looking to the outer characters during the Test video. These individual data points were analyzed using linear mixed-effect models in R (Version 3.11; R Core Team, 2015) with the package lmerTest (Version 2.0-30). Random intercepts for participant were included in all analyses to account for individual variability. Accounting for individual variability in a mixed-effects model leads to more powerful analyses than having that variability included as error as in a typical regression model (Baayen, Davidson, & Bates, 2008).

Results

No effects of participant gender on looking difference scores were found in the pre-talking segment ($b = 0.039$, $SE = 0.109$, $t = 0.362$, $p = .718$), the talking segment ($b = -0.014$, $SE = 0.127$, $t = -0.112$, $p = .911$), or the approach segment ($b = 0.107$, $SE = 0.237$, $t = 0.450$, $p = .653$). Furthermore, whether infants were viewing the first or second video sequence, or the first or second test trial within a video sequence, did not affect their difference scores for any of the segments (all $ps > .10$; see Table 1 for trial-by-trial descriptive data for each segment). Finally, whether infants saw congruent or incongruent approaches in their first video sequence did not affect their difference scores for any of the segments (all $ps > .10$).

We assessed infants' inferences about the center character's affiliation using infants' looking difference scores in the talking segment (i.e., from when the center character declared an affiliative intent to until just before beginning to move; 5 s). An initial model revealed an age difference, with 15-month-olds looking more toward the synchronous character than 12-month-olds ($b = 0.103$, $SE = 0.041$, $t = 2.541$, $p = .014$; see Fig. 2). Each age group was then examined separately to determine whether their looking differed from chance level (i.e., a difference score of zero). These models showed that whereas 15-month-olds looked more toward the synchronous character than chance (*inter-*

Table 1
Mean looking times (and standard deviations) to synchronous and non-synchronous characters by video sequence and trial for each segment.

			Pre-talking segment		Talking segment		Approach segment			
			Sync	Non-sync	Sync	Non-sync	Sync		Non-sync	
							Approached	Unapproached	Approached	Unapproached
15 months	Sequence 1	Trial 1	.39 (.49)	.29 (.34)	.33 (.44)	.13 (.23)	1.33 (0.81)	.12 (.17)	1.90 (1.04)	.08 (.15)
		Trial 2	.36 (.48)	.29 (.30)	.35 (.50)	.27 (.35)	1.51 (0.89)	.09 (.17)	1.63 (1.00)	.11 (.26)
	Sequence 2	Trial 1	.45 (.55)	.30 (.34)	.29 (.33)	.23 (.27)	1.68 (1.21)	.08 (.13)	1.36 (1.02)	.03 (.07)
		Trial 2	.35 (.41)	.28 (.38)	.35 (.64)	.12 (.23)	1.39 (1.02)	.13 (.26)	1.58 (0.96)	.19 (.38)
12 months	Sequence 1	Trial 1	.41 (.44)	.53 (.64)	.38 (.58)	.62 (.74)	1.73 (1.08)	.19 (.30)	1.68 (1.08)	.14 (.22)
		Trial 2	.41 (.34)	.72 (.60)	.25 (.34)	.36 (.42)	1.26 (0.92)	.21 (.28)	1.56 (0.87)	.16 (.24)
	Sequence 2	Trial 1	.46 (.42)	.51 (.40)	.42 (.54)	.28 (.40)	1.54 (1.23)	.15 (.30)	1.28 (1.08)	.02 (.09)
		Trial 2	.38 (.52)	.58 (.65)	.27 (.41)	.43 (.55)	1.43 (1.26)	.13 (.24)	1.40 (0.83)	.10 (.26)

Note. The approach segment is further divided by cases in which the character was approached or not. Note that Sequence 1 is the first of the videos seen by participants, and Sequence 2 is the second set. Trials refer to the two repetitions of the Test video in a video sequence; within a sequence, both trials depicted approaching either the synchronous character (congruent) or the non-synchronous character (non-congruent).

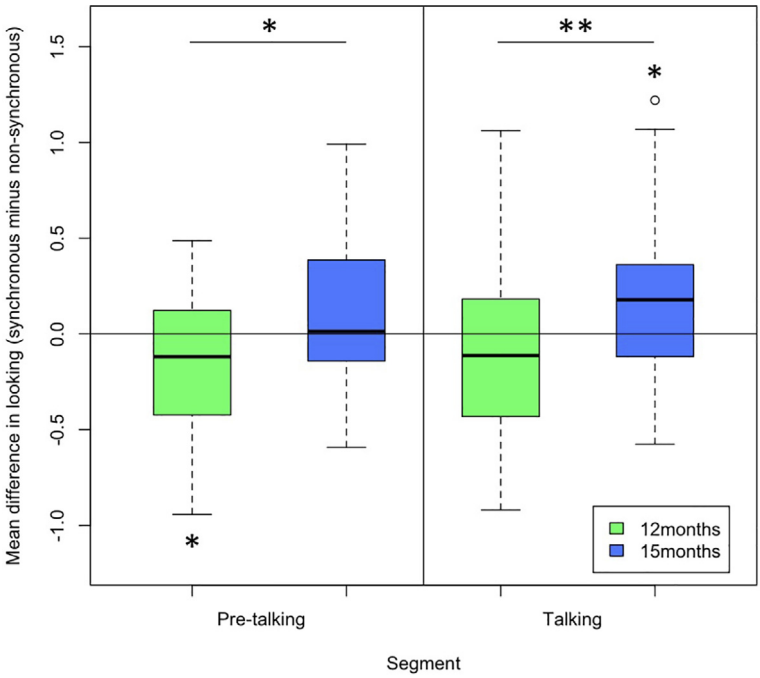

Fig. 2. Boxplot showing averaged difference scores for participants in each age group during the pre-talking and talking segments, with positive scores indicating a preference for the synchronous character compared with the non-synchronous character ($^{*}p < .05$; $^{**}p < .01$). Horizontal lines indicate medians, boxes indicate data within the 25th to 75th percentiles, and whiskers indicate data within the 5th to 95th percentiles.

cept = 0.199, *SE* = 0.081, *t* = 2.453, *p* = .020), 12-month-olds' looking did not differ from chance (*intercept* = −0.112, *SE* = 0.088, *t* = −1.266, *p* = .215).

Infants' own preferences for the synchronous versus non-synchronous characters were assessed using their looking difference scores in the pre-talking segment (i.e., before the center character declared affiliation; 3.5 s). The first model revealed a significant age difference (*b* = 0.098, *SE* = 0.034, *t* = 2.852, *p* = .006; see Fig. 2), with 15-month-olds looking more toward the synchronous character than 12-month-olds. Separate models then compared looking with chance level for each age group, revealing that 15-month-olds did not differ from chance in their looking (*intercept* = 0.113, *SE* = 0.073, *t* = 1.551, *p* = .131), whereas 12-month-olds looked significantly more to the non-synchronous character (*intercept* = −0.181, *SE* = 0.076, *t* = −2.381, *p* = .019).

To examine whether infants' looking during the talking segment was driven by their own preferences for the characters, we used mixed-effects linear regression models to examine whether the looking difference scores in the pre-talking segment would predict those in the talking segment at each age. For 15-month-olds, there was no relation between difference scores across the two segments (*b* = 0.061, *SE* = 0.106, *t* = 0.571, *p* = .570), suggesting that infants' personal looking preferences were unrelated to their affiliation inferences. In contrast, for 12-month-olds, looking more at one character during the pre-talking segment predicted more looking to that character in the talking segment (*b* = 0.298, *SE* = 0.094, *t* = 3.160, *p* = .002).

During the approach segment, we expected strong looking biases toward the approached character due to the salience of the center character moving in that direction. However, this effect could be weaker in the incongruent trials because of infants' looking back to the synchronous character in line with their affiliation inference. A linear mixed-effects model tested this with age, congruent approach, and their interaction, predicting looking difference scores to the approached character minus the

unapproached character. There was no significant interaction ($b = 0.008$, $SE = 0.079$, $t = 1.000$, $p = .920$), and a further model including only age and congruence found that neither age ($b = 0.040$, $SE = 0.053$, $t = 0.756$, $p = .453$) nor congruence ($b = -0.147$, $SE = 0.118$, $t = -1.251$, $p = .212$) significantly affected looking to the approached character. Examining looking difference scores against chance confirms that infants looked more at the approached character in both congruent trials (*intercept* = 1.464, $SE = 0.118$, $t = 12.410$, $p < .001$) and incongruent trials (*intercept* = 1.600, $SE = 0.097$, $t = 16.480$, $p < .001$).

Discussion

The current study investigated infants' use of others' movement synchrony to infer affiliation. Fifteen-month-olds inferred that two characters that moved in synchrony would affiliate with each other, and this inference was not driven by personal preferences for others who move synchronously. In contrast, 12-month-olds did not infer affiliation based on synchronous movement and actually showed a personal preference for the character that had moved non-synchronously. Furthermore, 12-month-olds' looking was related across the phases measuring personal preferences and affiliation inference. This suggests that 12-month-olds' looking was likely driven by their own personal interest in the characters, whereas 15-month-olds' gaze reflected their inferences of the relation between the characters' synchronous behavior and affiliation.

Previous research has shown that 12-month-olds prefer those who move synchronously with them (Tunçgenç et al., 2015). However, 12-month-olds in the current study did not seem to infer affiliation among synchronously moving others when they observed from a third-person perspective. Although direct comparison across studies is not possible, this may indicate that personal social preferences based on first-person experiences with movement synchrony do not immediately inform inferences made about others' social preferences for synchrony from a third-person perspective. Instead, and given that other studies have reported the role of first-person experience in facilitating infants' perception of synchrony (Gerson, Schiavio, Timmers, & Hunnius, 2015) and others' goal-directed actions (Bakker, Sommerville, & Gredebäck, 2016), it seems possible that infants' experience over time in acting synchronously with caregivers and other liked individuals leads to a more general idea that synchrony often occurs with liked individuals, informing their inferences about others' synchrony and affiliation. Future research more directly examining the role of first- and third-person perspectives of synchronous movement will allow clarification of this developmental process and can also elucidate earlier observations of the long-term effects of synchronous infant–caretaker interactions (Jaffe et al., 2001).

A strength of our study is that we used infants' gaze to assess their inferences about others' social behaviors before any outcomes were revealed. This method is more ecologically valid than violation of expectation paradigms because it assesses infants' inference making from limited information, a skill that enables the infants to direct their attention and plan their actions, thereby navigating the social world efficiently. Furthermore, studies that have directly compared looking time in violation of expectation paradigms with measures of gaze before an event is complete show that anticipating future actions is more cognitively advanced than reacting to past unexpected events (Daum, Attig, Gunawan, Prinz, & Gredebäck, 2012; Gredebäck & Melinder, 2010). Thus, our paradigm makes multiple levels of interpretation possible. We claim that infants in our study looked to a character following the affiliation statement because they inferred some level of liking between that character and the center character. However, a higher-level interpretation of our study could be that infants prospectively anticipated the center character to approach the synchronous character based on the affiliation statement, thereby predicting the outcome of the approach event before it unfolded. Conversely, a lower-level interpretation could be that infants associated synchronous movements with positivity more generally and not with the affiliation declaration specifically. Previous research shows that synchrony does not yield generalized prosociality in infants, supporting our interpretation of our findings (Cirelli, Wan, et al., 2014). Still, to test alternative explanations, future research could examine infants' reactions to declarations that are more directly linked to the forthcoming action (e.g., "You're my best friend! I'm going to hug you") and positive statements that are unrelated to the social interaction (e.g., "The weather is very nice. I am happy!").

We had two measures in addition to affiliation inferences. First, we investigated the infants' looking at the characters during the center character's approach, finding that at both ages infants looked more to the approached character whether the approach was toward the synchronous character or not. This suggests that the tendency to pay attention to the direction of motion overwhelmed any possible effect of checking back during an incongruent approach. Second, we examined infants' personal preferences to look at the synchronous versus non-synchronous character prior to the center character's affiliation declaration. Neither age group preferred to look at the previously synchronous character, which indicates that although infants may prefer those who move synchronously with themselves (Tunçgenç et al., 2015), they do not necessarily prefer those who move synchronously with others. This might have been because the observed synchronous movement indicated an affiliative relationship that the infants were not a part of; future research can investigate whether involving the infants in the relationship would change their third-party preferences. An unexpected finding was 12-month-olds' preference for the non-synchronous character. One possibility is that the visual mismatch of the non-synchronous motion required more time to process cognitively, leading 12-month-olds to remain interested in examining the non-synchronous character further. Future research could expand on these findings by decreasing processing demands for younger infants, for example, by using a habituation paradigm.

It could be argued that the meaning of the words in the affiliation declaration ("You are my best friend!") and/or the concept of friendship were not clear to the younger infants in our study, resulting in the apparent lack of affiliation inference for the 12-month-old group. However, mounting research shows that young infants can discriminate between statements based on their prosody and emotional content (Grossmann, Striano, & Friederici, 2005; Schachner & Hannon, 2011), prefer those who speak with positive emotionality regardless of the content of their speech at 10.5 months (Paquette-Smith & Johnson, 2015), and infer others' intentions based on the prosody of their speech (Esteve-Gibert, Prieto, & Liszkowski, 2017). Furthermore, previous research using a similar paradigm to ours shows that 9-month-olds use adults' utterances to infer their social affiliation (Liberman et al., 2014). Thus, we are confident that infants understood the positive nature of the affiliation declaration even if its exact content was not clear to them. Still, as described above, a lower-level explanation may be possible, such that infants associated positivity only with the synchronous character rather than inferring affiliation between the characters.

A second limitation is that the current study cannot disentangle whether synchrony signals affiliation or non-synchrony signals disaffiliation. Although all of the previous research with infants has only ever contrasted synchronous with non-synchronous motion (e.g., Cirelli, Einarson, et al., 2014; Cirelli, Wan, et al., 2014; Cirelli et al., 2016; Tunçgenç, Cohen, & Fawcett, 2015), several studies suggest that, at least in adults (Hove & Risen, 2009) and older children (Tunçgenç & Cohen, 2016), it is synchrony that increases affiliation rather than non-synchrony that decreases it. It would nevertheless be beneficial in future research to investigate this question during infancy by examining synchrony preferences in negative interaction scenarios (e.g., the center character declares disaffiliation) as well.

This study is the first to show that 15-month-olds infer affiliation based on others' synchronous movement. The effect was not observed at 12 months, thereby potentially pointing to the role of having sufficient first-person experiences with synchronous movements with liked others to inform the development of third-person inferences for the same relation. Thus, the findings broaden our knowledge about the importance of coordinated, synchronous movements for social affiliation during early development. Being able to recognize the role of movement synchrony as informative for others' affiliation could help infants to understand their social environment and the relationships of those around them.

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