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The cradle of social knowledge: Infants' reasoning about caregiving and affiliation

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ABSTRACT

Considerable research has examined infants' understanding and evaluations of social agents, but two questions remain unanswered: First, do infants organize observed social relations into larger structures, inferring the relationship between two social beings based on their relations to a third party? Second, how do infants reason about a type of social relation prominent in all societies: the caregiving relation between parents and their babies? In a series of experiments using animated events, we ask whether 15- to 18-month-old infants infer that two babies who were comforted by the same adult, or two adults who comforted the same baby, will affiliate with one another. We find that infants make both of these inferences, but they make no comparable inferences when presented with the same visible events with voices that specify a peer context, in which one adult responds to another laughing adult. Thus, infants are sensitive to at least one aspect of caregiving and organize relations between infants and adults into larger social structures.

1. Introduction

From an early age, infants understand and evaluate social agents based on their actions and interactions. Infants selectively interact with people who cooperate with or help one another (Hamlin, Wynn, & Bloom, 2007), who share the infant's preferences (Mahajan & Wynn, 2012), and who speak with the accent of the infant's social partners (Kinzler, Depoux, & Spelke, 2007). Infants also demonstrate early proficiencies in making inferences about others' affiliative behaviors. Before the end of the first year, infants infer that characters will affiliate with others who have helped them (Kuhlmeier, Wynn, & Bloom, 2003) or expressed shared food preferences (Liberman, Kinzler, & Woodward, 2013), and they infer that members of social groups will act alike (Powell & Spelke, 2013). Nevertheless, two questions have received little attention from investigators of early social cognitive development. First, can infants organize observed social relations into larger structures, inferring an affiliative relationship between two social characters based on their relations to a third party? Second, do infants understand events in which an adult comforts a baby as social interactions that can support social inferences?

Despite the ubiquity, universal properties, and evolutionary importance of kinship relations (e.g., Hamilton, 1964; Kemp & Regier, 2012; Murdock, 1949; Nowak, Tarnita, & Wilson, 2010), children's explicit understanding of kinship develops slowly. Five-year-old children apply terms such as *grandmother* to childless women of advanced age over youthful mothers of a parent (Landau, 1982), and many younger children judge that friends are as likely as siblings to have the same grandmother (Spokes & Spelke, 2016). Nevertheless, implicit knowledge about basic parent-child relations may be a foundational aspect of social understanding, as infants' earliest and most important social interactions commonly occur with immediate kin.

Parent-child interactions have three prominent features that distinguish them from other affiliative social interactions. First, they are asymmetric: given adults' greater knowledge, skill, and power, parents act for the benefit of their children without expecting or receiving comparable reciprocation. Second, parent-child exchanges often center on acts of comforting, nurturance, and aid: although unrelated adults may respond to infants' positive social overtures, parents are expected to respond to positive overtures and also to infants' needs and cries, both in human and non-human primate groups (Cheney & Seyfarth, 1990). Third, parent-child relations figure in a network of family relations. Two parents of a single child typically are partners, and two children with the same parent typically are siblings.

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Recent research provides evidence that infants are sensitive to asymmetric relationships in a different context: that of dominance. By 6- to 9- months, infants infer that members of numerically larger groups will dominate members of smaller groups (Pun, Birch, & Baron, 2016). At 10 months, infants infer that the larger of two characters will win a competitive interaction (Thomsen, Frankenhuis, Ingold-Smith, & Carey, 2011). By 15 months, infants show nuanced inferences about social rank and dominance across multiple contexts: if one character dominates another character by taking a desired location, for example, infants infer that the same character will prevail in a competition over objects, even if the two characters are equal in size and appear outside any group context (Mascaro & Csibra, 2012, 2014). Moreover, infants' memory for dominance relations is modulated by the structure of multiple social pairs: they show better memory for relations between familiar pairs of individuals that are consistent with a linear dominance structure (Mascaro & Csibra, 2014). Nevertheless, no study has tested whether infants attribute dominance relations to pairs of individuals who interact for the first time, based on the individuals' relations to others within a dominance hierarchy.

Regarding parental care, one set of studies provides evidence that 12- to 16-month-old infants make inferences about caregiving interactions between two characters of unequal size (Johnson, Dweck, & Chen, 2007; Johnson et al., 2010). Infants were familiarized with an event in which two characters moved together and then became separated, after which the smaller character emitted a baby's cry. On test trials, the larger character either returned to the crying baby or continued to move away from the baby. Infants with secure attachment styles, but not those with insecure attachment styles, looked significantly longer at the latter event, suggesting they inferred that the larger character would return to the crying baby (Johnson et al., 2007). In further studies, infants with secure attachment styles also looked longer at test events in which a baby approached an unresponsive character rather than a responsive character (Johnson et al., 2010). In contrast, infants with ambivalent or avoidant attachment styles showed the reverse effect (Johnson et al., 2010). Thus, infants' inferences concerning the behavior of adults toward babies and babies toward adults are modulated by infants' social perceptions and motivations toward their own caregivers. These findings show that infants find animated adult-baby comforting interactions to be socially meaningful, although they do not reveal how richly infants interpret these interactions. Here, we use these animated events to ask whether infants are sensitive to the interconnectedness of adult-child relations within a social network.

Sensitivity to interconnected sequences of social actions has been shown in studies of infants' evaluations of characters who help or hinder other characters. Infants show systematically different preferences for a helper character, depending on whether the character that it helps has previously engaged in prosocial or in antisocial behavior toward a third character (Hamlin, Wynn, & Bloom, 2011). Caregiving is a moral obligation, like helping, which is centered on aid, so infants may reason about caregiving interactions in a similar manner to helping. In addition, infants at 16 months can track and infer conflict between two groups of characters: If they see characters cooperate with others within their group and then see some members of each group participate in inter-group conflict, infants infer that other members of the two groups will engage in intergroup conflict as well (Rhodes, Hetherington, Brink, & Wellman, 2015). No study reveals, however, whether infants' reasoning about the structure of social networks supports inferences about affiliation between characters who have never been seen to interact directly. In particular, we do not know whether infants make inferences about potential social affiliation between novel pairs of individuals, based on the prior interactions of those individuals with other parties.

The present experiments address this question in 15- to 18-month-old infants. We show infants several baby-adult interactions like those of the responsive adult in Johnson et al.'s studies using size and voice to indicate adult-baby interactions, and we test whether infants use these interactions to interpret future interactions involving novel pairs of individuals. When infants view two crying babies who each are comforted by the same adult, do they infer a social relationship between those babies and infer that they will affiliate with one another in the future? When they view two adults who each comfort the same crying baby, do they infer a social relationship between those adults and similarly infer that the adults will affiliate? Experiments 1, 2, 5, and 6 address these questions and provide evidence for both inferences. If infants infer affiliation in these cases, however, further questions arise. First, is this inference specific to interactions between babies and adults or is it more general? Experiment 3 begins to address this question by presenting characters of all the same size and all with adult voices, providing initial evidence for specific inferences about baby-adult interactions. Second, what information defines a context in which infants infer a network of baby-adult relations: Do infants respond to comforting interactions with baby cries and adult coos only when the adult is of greater size, and/or when infants and adults can be grouped together by their spatial positions or perceptual features? Experiments 4 and 6 address these questions.

2. Experiment 1

The present experiments used animated displays involving abstract social characters and a preferential looking method (after Johnson et al., 2007). In Experiment 1, 15- to 18-month-old infants were familiarized with a series of events involving five animated characters with eyes (Fig. 1 and Video S1). Three characters were small and similar in appearance to the baby in Johnson et al. and emitted baby cries (hereafter, "babies"). Two characters were larger and similar in appearance to the adult in the same study and emitted adult coos (hereafter, "adults"). In Johnson et al., the single baby and adult were similar in shape but differed in size and color. In Experiment 1, all the characters differed in shape and color, and adults again were larger than babies.[1] To make these five-character events more compelling and memorable, however, the adults on each side always responded to the baby on the same side, and they had somewhat similar shapes and colors (see Fig. 1). Thus, the side baby characters shared some perceptual features with the adult characters who comforted them, as is typical for members of the same family. The central baby was paired with each of the two adults for half the infants, however, and so was not perceptually more similar to one of the adults or side babies.

Infants were familiarized with three comforting events in which each baby cried, one adult approached the baby, who quieted, and then both characters moved gently in a synchronous "rocking" pattern. The babies on the two sides were soothed by different adults, and the central baby was soothed by the same adult as one of the other two babies. On each test trial, the three babies appeared without the adults, and one of the two side babies approached the central baby, upon which that pair of characters "danced" together in a synchronous, circling motion (after Powell & Spelke, 2013; Video S2). In prior studies of infants, these motions were found to convey social affiliation between the characters (Powell & Spelke, 2013). Babies soothed by the same adult or by different adults danced together on alternating test trials; infants' looking time to these events was measured and compared. If infants infer

[1] For interpretation of color in Figs. 1, 4, 8, and 10, the reader is referred to the web version of this article.

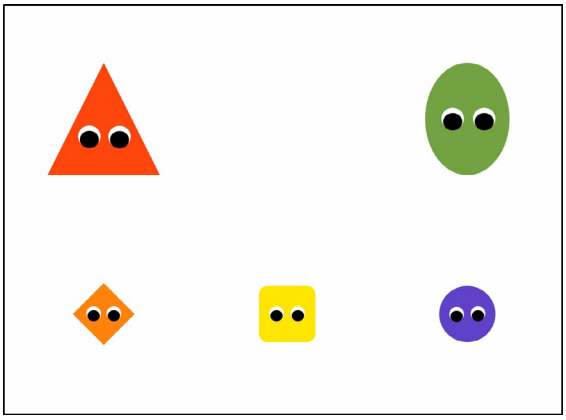

Fig. 1. Scene of the animated stimuli presented to infants in Experiments 1 and 2.

that two babies who are comforted by the same adult are socially related[2] in some way, then they should not be surprised to see these babies affiliate with one another. Therefore, infants should look longer when a baby approaches another baby who was comforted by a different adult.

2.1. Materials and methods

2.1.1. Participants

Participants were 16 full-term infants (8 girls and 8 boys) ranging in age from 15 to 18 months (mean age: 16.79 months; range: 15.53–18 months) from the Cambridge and Boston area. A sample size of 16 was predetermined based on adequate counterbalancing and previous infant research (e.g., Hamlin et al., 2007; Liberman et al., 2013), and data collection stopped once this number was reached. Infants received a gift after the study, and parents were reimbursed for their travel. An additional 3 infants were tested but excluded because of fussiness.

2.1.2. Materials

Infants saw an animated display with five social characters with distinctive geometrical shapes and colors (Fig. 1; Video S1). The two larger, adult characters appeared at the top of the screen, above three smaller, baby characters. Each character entered the display individually, paused at specific location, and then jumped while making the same computer-generated bouncing noise. This initial sequence introduced each of the figures as an agent capable of self-propelled motion. Next, infants saw two sets of three familiarization trials (Video S1). At the start of each trial, two baby characters moved sequentially to the bottom of the screen and closed their eyes. Then the remaining baby, with eyes open, pulsated and cried, and one of the two adults responded to the cry by moving toward the baby in distress as if to soothe it, whereupon the baby stopped crying, the adult made a brief soothing noise, and the two rocked back and forth in unison. For all infants, babies on the sides of the display were comforted by the adult on the same side, who also was similar (but not identical) to the baby character in shape and coloring. Half of the infants saw the central baby comforted by the adult on each side. Each of the three babies cried and was soothed by an adult in the three familiarization trials, with the sides of the adults and the two outer baby characters and the order of the first two familiarization trials counterbalanced across subjects. The third familiarization event therefore presented the central baby being soothed by an adult who had previously soothed another baby.

After the familiarization trials, the adult characters disappeared, and infants saw three rounds of two test trials involving only the three baby characters (Video S2). In alternating test trials, one of the side babies approached the central baby, and the two babies moved to a new location of the display where they danced together by making small, semicircular movements around a large, circular path, in synchrony with a rhythmic sound. The second test trial consisted of the same events, but now the other baby approached and danced with the central baby. Thus, the test trials demonstrated alternating social affiliation between babies who previously were soothed by the same adult and babies who previously were soothed by different adults. A chime and moving star drew infants' attention back to the center of the screen before each test trial. The order of the expected and unexpected test events was counterbalanced across participants.

2.1.3. Procedure

All familiarization and test trials were infant-directed, such that an infant's cumulative looking to the display was measured until the infant looked away for 2 consecutive seconds or looked for a maximum of 45 seconds. Infants had to look for a minimum of 0.5 seconds. One coder, unaware of condition, watched infants from a live video feed and coded infants' looking continuously for the entire experiment. An experimenter, unable to see the stimuli, initiated the start of each trial at the last audible noise in each event. Trials started toward the end of the animated events to emulate previous studies of infant social cognition, where coding began when animations ended (e.g., Johnson et al., 2007, 2010; Liberman et al., 2013; Powell & Spelke, 2013; Pun et al., 2016). For familiarization events, trials began after an adult made a soothing noise, prior to the adult and baby rocking back and forth. For test, each trial began after the figures' last motions and sounds (i.e., the fourth sound; Video S2). A second independent, condition-blind observer coded a random 25% of subjects' looking times from video, and the inter-rater correlation was 0.985. (For additional methods, see Supplementary Materials.)

2.1.4. Predictions and analyses

The primary question concerned whether infants who had viewed only the interactions of the babies with the adults would infer affiliation between the two babies who were soothed by the same adult. If they did, then we predicted that they would show systematically different looking on test events presenting affiliation between babies who had been soothed by the same vs. different adults. We tested this prediction in two ways. First, we performed a 2 (Test Event) by 3 (Trial block) repeated-measures ANOVA, testing for a main effect of test event. As a further analysis, we then performed a two-tailed paired *t*-test on infants' looking times on the first pair of test trials: i.e., the first time they saw the interactions between the pairs of test characters.

2.2. Results

2.2.1. Familiarization trials

A trial type (first, second, or third baby) by trial block (first, second) repeated-measures ANOVA on looking times during the familiarization trials revealed only a main effect of trial block, $F(1,15) = 7.12$, $p = 0.018$, $\eta_p^2 = 0.32$, reflecting decreasing attention over the familiarization period. There were no other main effects or interactions.

2.2.2. Test trials

Fig. 2 presents the principal findings from this analysis. The ANOVA revealed only a main effect of trial block, $F(2,30) = 3.48$,

[2] By "social relatedness" we do not imply that infants infer familial relations between the characters. We consider how infants might interpret the relationship between the baby and adult characters in the General Discussion.

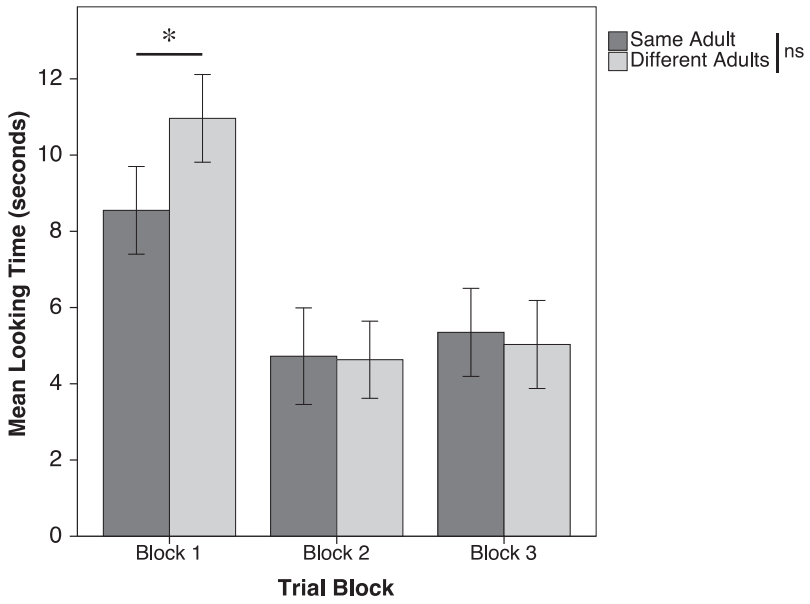

Fig. 2. Looking times for expected and unexpected test events in Experiment 1 ($n = 16$), involving affiliation between babies who were comforted by the same/different adult (s). In the first test pair, infants looked longer to the unexpected event ($^*P < 0.05$), but there was no main effect of infants' looking to the two events (ns). Error bars represent within-subjects 95% confidence intervals (Cousineau, 2005).

$p = 0.044$, $\eta_p^2 = 0.19$, reflecting decreasing attention over the test session. There were no other main effects or interactions: in particular, no main effect of Test Event.

On the first block of test trials, infants looked longer to the test event involving an affiliative interaction between two unrelated babies, $t(15) = 2.235$, $p = 0.041$, two-tailed, $d = 0.56$; eleven infants looked longer at the first test event of affiliation between two babies soothed by different adults, three infants looked longer to affiliation between two babies soothed by the same adult, and two infants showed no preference (i.e., less than 0.5 s difference; see Supplementary Materials for additional methods), $p = 0.029$, two-tailed binomial test. Thus, infants looked longer at the test event involving babies who had been soothed by different adults on the first test trial, but they did not maintain this pattern over the rest of the test session.

In summary, the primary analysis of Experiment 1 provided no evidence that infants made inferences about affiliation between baby characters soothed by the same adult, but the analysis of infants' longer looking patterns on the first test pair suggested that such an effect may be real but short-lived. To pursue that suggestion, we replicated Experiment 1 on an independent sample of infants.

3. Experiment 2

3.1. Materials and methods

The method of Experiment 2 was identical to that of Experiment 1. Participants were 16 new infants of the same age (9 girls and 7 boys; mean age: 16.88 months; range: 15.67–18.77 months). An additional 3 infants were tested but were excluded because of experimenter error (1), fussiness (1), or parental interference (1). The principal predictions and analyses were the same as in Experiment 1, except that a one-tailed test was used in a confirmatory analysis of the first-trial effect from Experiment 1. Further analyses compared the findings of the two experiments and tested for differences for infants with and without siblings. The inter-rater correlation between the live coder and a second independent coder for a random 25% of subjects' looking times was 0.97.

3.2. Results

3.2.1. Familiarization trials

Infants showed no differential looking patterns at the three crying and comforting interactions: the 3 (trial type) by 2 (trial block) repeated-measures ANOVA revealed no main effects or interactions in Experiment 2 ($ps > 0.25$). Across Experiments 1 and 2, a 3 (trial type) by 2 (trial block) by 2 (experiment) repeated-measures ANOVA showed a main effect of trial block, $F(1,30) = 7.03$, $p = 0.013$, $\eta_p^2 = 0.19$, reflecting decreasing attention, and no other main effects or interactions.

3.2.2. Test trials

Fig. 3 presents the principal findings of this experiment. The ANOVA revealed main effects of trial block, $F(2,30) = 4.54$, $p = 0.019$, $\eta_p^2 = 0.23$, reflecting decreasing attention, and test event, $F(1,15) = 5.68$, $p = 0.031$, $\eta^2 = 0.28$, showing longer looking to the presentations of an affiliative interaction between babies who were soothed by different adults. Ten babies looked longer at the test events with babies soothed by different adults, four babies showed the opposite pattern, and two babies showed no preference ($p = 0.029$, one-tailed binomial test). As in Experiment 1, infants looked longer in the first test trial pair to the events presenting an affiliative interaction between two unrelated babies ($t(15) = 2.327$, $p = 0.017$, one-tailed, $d = 0.58$). Eleven babies showed this effect, and five babies showed the opposite effect ($p = 0.038$, one-tailed binomial test).

Preliminary analyses of the combined data from Experiments 1 and 2 revealed no main effects of gender, test event order, or the adult character that served as the shared adult for two babies (triangle vs. oval), and no interactions. Accordingly, a 2 (experiment) by 3 (trial block) by 2 (test event) repeated measures ANOVA compared infants' looking patterns across the two experiments. This analysis revealed main effects of experiment, $F(1,30) = 5.08$, $p = 0.032$, $\eta_p^2 = 0.15$, with overall greater attention in Experiment 2; trial block, $F(2,60) = 7.72$, $p = 0.001$, $\eta_p^2 = 0.21$, with decreasing attention across pairs of trials; and test event, $F(1,30) = 6.51$, $p = 0.016$, $\eta_p^2 = 0.18$, with longer looking to the events presenting affiliation between the babies soothed by different adults. There also

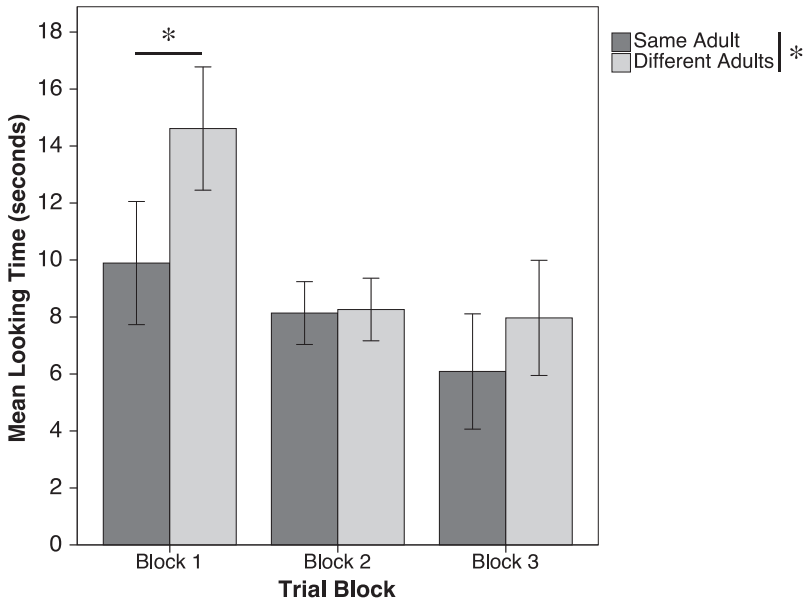

Fig. 3. Looking times for expected and unexpected test events in Experiment 2 (n = 16), involving affiliation between babies who were comforted by the same/different adult (s). In the first test pair and across test events, infants looked longer to the unexpected event ($^*P < 0.05$). Error bars represent within-subjects 95% confidence intervals (Cousineau, 2005).

was a trial block by test event interaction, $F(2,60) = 3.54$, $p = 0.035$, $\eta_p^2 = 0.11$, reflecting that the effect of test event occurred primarily in the first trial block. There were no other interactions.

3.2.3. Effects of sibling experience

Further analyses, based on the combined data from Experiments 1 and 2, were undertaken to investigate whether infants' personal experience with siblings influenced their reactions to the test events. Previous studies have found that individual differences within infants' own families predicted their interpretations of comforting events (Johnson et al., 2007, 2010). If infants interpret the present events as familial relations, the test events could be seen as pseudo-sibling relations, so having experience with sibling relationships could potentially drive the expectations seen in the test events. Of the 32 infants in these two experiments, 17 infants did not have any siblings according to families' reports. A 2 (siblings versus no siblings) by 3 (trial block) by 2 (test event) repeated-measures ANOVA, performed on all 32 infants, revealed the same principal findings as the first combined analysis, with no main effects or interactions involving the presence/absence of siblings (for further results, see Supplementary Materials).

3.3. Discussion

Across two experiments, 15- to 18-month-old infants looked longer to affiliation events between babies soothed by different adults, indicating that these events were more novel or surprising. This finding suggests that infants take account of past comforting interactions between babies and adults when interpreting future affiliation of babies with one another. More generally, infants appear to infer connections between two individuals who have not interacted directly, based on each individual's past interaction with the same third party. This effect occurred both for infants with siblings and for those without siblings (see Supplementary Materials). Although infants' responses to adult-child interactions that are similar to the present events are modulated by aspects of their relationship to their own parents (Johnson et al., 2007, 2010), we find no evidence for modulation by sibling relationships in the present studies.

Does infants' reasoning about the social relations presented in Experiments 1 and 2 depend on inferences that are specific to adult-child interactions, or on inferences that apply to any social relationship? In Experiment 3, we began to address this question by altering the nature of the social interactions presented during familiarization. Instead of an adult comforting a crying baby, we presented events in which one adult character approached and interacted with a second adult character of the same size, who initiated the interaction by laughing in a manner suggestive of affiliative interactions between adult peers.

4. Experiment 3

Experiment 3 used the same events and methods as Experiments 1 and 2, but removed all cues to an adult-child relationship presented in those experiments. On familiarization trials, three characters again initiated an interaction by vocalizing ("callers") and two characters answered their calls ("responders"). The sizes of the two responders were reduced without changing their shapes, however, so that all characters were approximately equal in size. Because size no longer distinguished the three initiators of the interaction from the two responders, the textures of the responding adults were altered to create a different visual cue that distinguished these roles. Moreover, callers emitted positive adult vocalizations (laughter) instead of baby cries; the callers therefore did not appear distressed, and the responders' approach did not appear to calm or comfort them.

The familiarization events otherwise were the same as in Experiments 1 and 2: The two side callers each were approached by the responder on the same side, with similar shape and coloring, and the central caller was approached by each of the two responders for half the infants. The test events were exactly the same as in Experiments 1 and 2. If infants' social inferences in Experiments 1 and 2 stemmed from general inferences about any social relationships, then looking patterns should be the same in Experiment 3. In contrast, if infants' inferences were more specific to baby-adult relations or to comforting interactions, then looking patterns in Experiment 3 might differ.

4.1. Materials and methods

The method was the same as that of Experiments 1 and 2, except as follows. The sample size was predetermined to be equal to the union of the first two experiments in order to compare performance to all 32 infants from Experiments 1 and 2, and data collection stopped once this sample was collected: 32 full-term infants (16 male and 16 female; mean age: 16.40 months; range: 15.5–18.37 months). An additional 4 infants were tested but excluded because of fussiness (1) or parental interference (3). A second independent coder measured from video a random 25% of subjects' looking times, and the inter-rater correlation with the original coder was 0.99.

Infants saw the same animated displays as in Experiments 1 and 2 except for three changes to the familiarization trials (Fig. 4 and Video S3). First, the two larger figures that represented adults were presented at the same size as the other characters. Second, because callers and responders no longer were distinguished by a size cue, we introduced a texture cue to distinguish the characters playing these two roles: the responders were given a texture pattern that distinguished them from the three callers. Third, the callers each made the sound of an adult female laughing instead of the sound of a baby's cry; the duration of the laughing calls was matched to the baby cries in the previous experiments. The displays were otherwise unchanged. Critically, the test displays were identical to those of the previous experiments (Video S2).

Infants again saw two sets of three familiarization events followed by three sets of two test trials. The principal analyses were the same as the combined analyses of Experiments 1 and 2; they tested whether infants infer positive social interactions between the central character and the side character who had previously interacted with the same social partner. In addition, a 2 (experiment: 1–2 vs. 3) by 3 (trial block) by 2 (test event: same social partner vs. different social partner) ANOVA tested for differences between infants' patterns of looking at the test events that followed baby-adult interactions (Experiment 1–2) vs. adult-adult interactions (Experiment 3). Finally, two analyses were performed on the looking times of the first trial block, when the pairs of test characters interacted for the first time. A one-tailed *t*-test asked whether the infants in Experiment 3 showed the same first-trial looking difference as in Experiments 1 and 2, and a 2 (experiment) by 2 (test event) ANOVA compared the size of this difference across the two studies.

4.2. Results

4.2.1. Familiarization trials

Infants showed approximately equal looking at all the familiarization trials in this experiment. A 3 (trial type) by 2 (trial block) repeated-measures ANOVA on looking times to the familiarization events revealed no main effects or interactions (ps > 0.05). A further 2 (Experiment: 1–2 vs. 3) by 3 (trial type) by 2 (trial block) repeated-measures ANOVA revealed a main effect of trial block, $F(1,62) = 7.47$, $p = 0.008$, $\eta_p^2 = 0.11$, qualified by a triple interaction between experiment, trial type, and trial block, $F(2,124) = 3.79$, $p = 0.025$, $\eta_p^2 = 0.06$. Overall, infants decreased their attention to familiarization events across trials, but they did so at different rates. For the first two trial types, involving the side pairs of social agents, infants decreased their looking to the second showing of each of these events more in Experiment 3 (with peer interactions) than in combined Experiments 1 and 2 (with caregiving interactions). However, in the third trial type, involving a responder (adult soother or peer) that was already paired with a different caller, infants in Experiments 1–2 showed a steeper decrease in looking across trial blocks, whereas infants in Experiment 3 showed sustained looking. Despite these differences, there was no main effect of experiment, so infants looked at familiarization events equally across experiments.

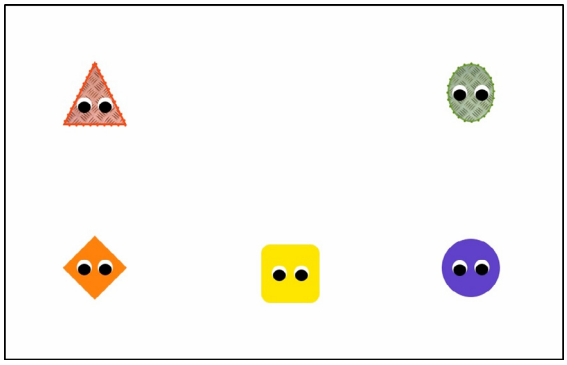

Fig. 4. Scene of the animated stimuli presented to infants in Experiment 3.

4.2.2. Test trials

Fig. 5 presents the principal findings for this experiment. The 3 (trial block) by 2 (test event) repeated-measures ANOVA revealed a main effect of trial block, $F(2,62) = 7.94$, $p = 0.001$, $\eta_p^2 = 0.20$, reflecting decreasing attention across the test trials, and no other main effects or interactions. Across the three test pairs, 15 of 32 infants looked longer to the unexpected test events compared to 17 who showed the opposite pattern ($p = 0.57$, one-tailed binomial test). Infants showed no differential looking to the test events presenting interactions between socially related vs. unrelated adults. A paired-samples *t*-test revealed no difference between infants' looking at the test events on the first trial block ($t < 1$); 12 babies looked longer at the first test event between characters with different social partners, 17 babies showed the opposite pattern, and three babies showed no preference ($p = 0.77$, one-tailed binomial test).

Further analyses parallel to the preliminary analyses performed on the combined test data from Experiments 1 and 2 revealed no main effects of gender or test event order. There was a main effect of which shape interacted with the central character (triangle vs. oval), $F(1,24) = 6.7$, $p = 0.016$, $\eta_p^2 = 0.22$, with infants looking longer overall in test events when the shared social partner was the oval character. We therefore performed the principal analysis with and without this factor, and obtained no effects of test event in either analysis (for further results, see Supplementary Materials).

A 2 (experiment) by 3 (trial block) by 2 (test event) ANOVA, comparing the findings of Experiment 3 to those of Experiments 1–2 combined, revealed a main effect of trial block, $F(2,124) = 15.56$, $p < 0.001$, $\eta_p^2 = 0.20$, with decreasing attention across test trials, qualified by an experiment by trial block by test event interaction, $F(2,124) = 3.82$, $p = 0.025$, $\eta_p^2 = 0.06$. To further investigate this interaction, a follow-up 2 (experiment: 1–2 vs. 3) by 2 (test event) ANOVAs performed on infants' looking times for each trial block showed an interaction effect of test event by experiment on infants' looking on the first test pair: $F(1,62) = 5.338$, $p = 0.024$, $\eta_p^2 = 0.08$ (see Fig. 6).

4.3. Discussion

When size and vocal cues to baby-adult caregiving relations were replaced by cues suggestive of adult peer interactions, infants showed no differential looking to affiliation between individuals with a shared social partner. Although infants in Experiment 3 saw exactly the same test events as those in Experiments 1 and 2, they showed no looking preference for the events showing a social interaction between unrelated individuals. The prior familiarization in Experiment 3, which presented all the individuals as

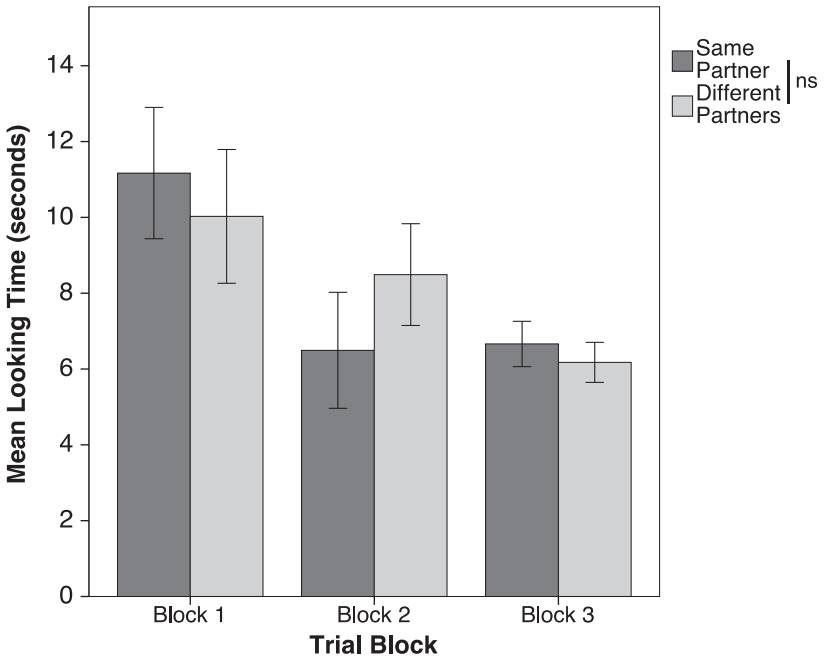

Fig. 5. Looking times for expected and unexpected test events in Experiment 3 ($n = 32$), involving affiliation between characters with the same/different social partner(s). Infants did not look longer to either test event in the first test pair or across test pairs (ns). Error bars represent within-subjects 95% confidence intervals (Cousineau, 2005).

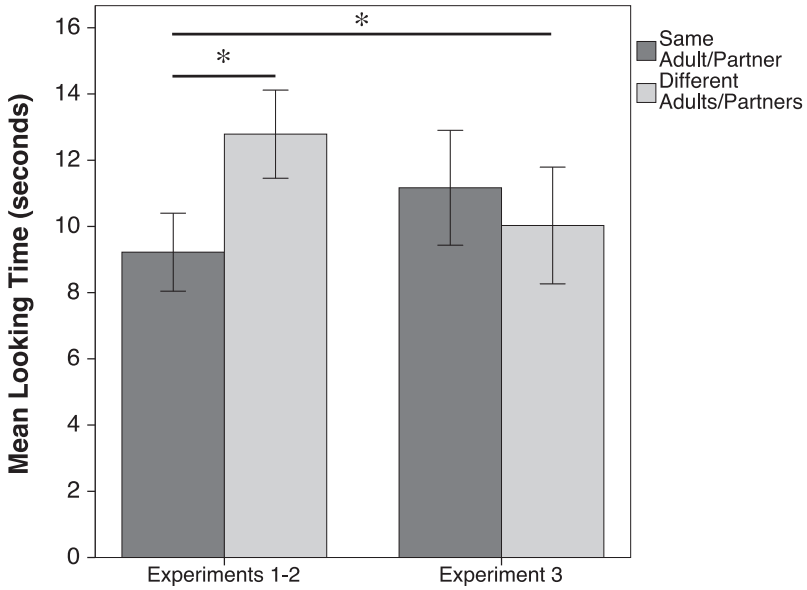

Fig. 6. Looking times for expected and unexpected test events in Experiments 1–3 in the first test pair ($n = 64$). There was an interaction between the difference in infants' looking to expected and unexpected test events in Experiments 1 and 2 and in Experiment 3 in the first test pair ($^*P < 0.05$). Error bars represent within-subjects 95% confidence intervals (Cousineau, 2005).

adults who interacted with other parties but were not comforted by those parties, markedly diminished infants' differential looking at the test events. Infants' early reasoning about social affiliation evidently is enhanced in social contexts presenting interactions between a crying baby and an adult who approaches and soothes the baby.

The findings of Experiment 3 also address alternative explanations for the findings of Experiments 1 and 2 that appeal to infants' responses to low-level features of the animated test displays. First, the test displays in all three experiments presented familiarization events in which adults approached infants either by moving straight downward or by moving downward to the left or right. These events were followed by test events in which the side character who shared a social partner with the central character approached from the same left or right direction that was presented during familiarization, rendering this direction of motion superficially more familiar. Such familiarity could have accounted for infants' looking at test in Experiments 1 and 2, but if it had, then the same patterns of looking should have been observed in Experiment 3, which presented exactly the same motions as the other experiments.

A second potential explanation appeals to differences in the familiarity of different characters' features. The two characters on each side of the screen shared the quality of being either pointy

or smooth in shape, and they were always paired together in familiarization events. The central character only interacted with one other character in familiarization that was either pointy or smooth, and then interacted with both pointy and smooth characters at test. Infants might have looked longer at the test event presenting affiliation between infants soothed by different adults not because they took account of the prior social interactions of the test characters with the same third party, but because one of the test events involved the central character in an interaction with a character who had a similar shape to that character's previous social partner. If familiarity of shape underlay infants' responses in Experiments 1 and 2, however, then those effects should have been observed in Experiment 3, in which the two pairs of side characters were similar not only in shape but in size. In contrast to this possibility, infants showed differential looking at the test events only in the first two experiments, presenting social interactions that infants of this age view as related to parental care (Johnson et al., 2007). Experiments 5 and 6 present further evidence that infants' responses are not explained by the familiarity of the motions or features of the characters in the test events.

Experiments 1–3 raise questions about infants' interpretation of caregiving events. One question concerns the role of size differences in infants' interpretation of social interactions as involving infants and adults. Studies of dominance reveal that differences in size are sufficient to elicit dominance inferences (Thomsen et al., 2011), but that these differences are not necessary: infants infer that one character will dominate another in future interactions if the two characters' past behavior is indicative of this dominance relation, even when the characters are equal in size (Mascaro & Csibra, 2012, 2014). Moreover, studies of infants' face perception reveal that infants are sensitive to age in faces, and that this sensitivity persists even if the sizes of the images of child and adult faces do not differ (Heron-Delaney et al., 2016). In Experiment 4, we ask whether infants' inferences about comforting interactions are similarly robust in the absence of size cues. We presented the events of Experiments 1 and 2 with one change: as in Experiment 3, all five characters were equal in size.

5. Experiment 4

Experiment 4 investigated whether infants respond to comforting interactions, and infer social relations among babies who are comforted by the same adult, when the babies and their comforters do not differ in size and only differ in whether they emit baby cries or adult coos. Although size cues can help to convey asymmetrical social relationships such as the relation of a parent to a child or of a dominant to a subordinate character, previous research suggests that infants use behavioral cues to social interactions even in the absence of size cues (Mascaro & Csibra, 2012, 2014). Not only do 12-month-old infants represent dominance relations when presented with social interactions in which the dominant and subordinate characters have the same size (Mascaro & Csibra, 2012), but infants as young as 7 months also represent positive interactions within different social groups in events involving as many as six characters when all characters are equal in size and each is perceptually distinct from the others (Powell & Spelke, 2013). Thus, we tested infants' responses to the comforting interactions of Experiments 1 and 2 with characters of equal size.

This experiment was identical in displays and procedure to Experiments 1 and 2 with one exception: the adult characters were equal in size to the baby characters (Video S4). As before, infants were familiarized with events in which each baby cries, and one of the two adults responded by approaching and rocking with the baby, making an adult coo noise and ending its cries. Then infants were tested with the same events as in Experiments 1–3 (Video S2). If infants represent the social interactions as involving caregiving, and if they perceive caregiving interactions in the absence of differential character size, then they should look longer at test events involving affiliation between babies soothed by different adults, as in Experiments 1 and 2. In contrast, if infants require a size cue to represent caregiving, then they should look equally at the two test events, as in Experiment 3.

5.1. Materials and methods

Participants were 16 infants of the same age as in Experiments 1–3 (7 girls and 9 boys, mean age, 16.78 months, range: 15.67–18.47 months). An additional 2 infants were tested but excluded because of fussiness. The principal predictions and analyses were the same as in Experiment 3. Further analyses, parallel to those in Experiment 3, compared the findings of the different experiments. A second independent coder coded a random 25% of subjects' looking times from video, and the inter-rater correlation with the original live coder was 0.98.

5.2. Results

5.2.1. Familiarization trials

A 3 (trial type) by 2 (trial block) repeated-measures ANOVA on looking times during the familiarization events revealed no main effects or interactions (ps > 0.05). A 3 (trial type) by 2 (trial block) by 3 (experiment 1, 2, present) repeated-measures ANOVA showed a main effect of trial block, $F(1,45) = 7.34$, $p = 0.01$, $\eta_p^2 = 0.14$, reflecting decreasing attention over time, and no other main effects or interactions.

5.2.2. Test trials

Fig. 7 presents the principal findings of this experiment. A 3 (trial block) by 2 (test event) repeated-measures ANOVA revealed a main effect of test event, $F(1,15) = 5.16$, $p = 0.038$, $\eta_p^2 = 0.26$: overall, infants looked longer to test events showing affiliation between babies soothed by different adults. Across all three test pairs, 11 infants looked longer to the unexpected event, four looked longer to the expected event, and one showed no preference ($p = 0.018$, one-tailed binomial test). Infants showed no reliable looking distinction between the two test events during the first test pair ($t(15) = 1.13$, $p = 0.28$); 10 infants looked longer to the event presenting affiliation between babies who had been comforted by different adults, and six showed the reverse pattern ($p = 0.11$, one-tailed binomial test). Additional analyses revealed no main effects or interactions of gender, test event order, or which adult comforted the central character (triangle vs. oval) on infants' looking to test events.

A further analysis served to compare infants' looking patterns in this experiment to those of Experiments 1 and 2. A 3 (experiment) by 3 (trial block) by 2 (test event) ANOVA revealed main effects of trial block, $F(2,90) = 5.5$, $p = 0.006$, $\eta_p^2 = 0.11$, and test event, $F(1,45) = 11.56$, $p = 0.001$, $\eta_p^2 = 0.20$, with greater looking on earlier trials and to test events of affiliation between babies soothed by different adults. There were no other main effects or interactions: in particular, no effects involving the factor of experiment. There was also no trial block by test event interaction, in contrast to the analysis of Experiments 1 and 2 alone. Thus, infants in this experiment showed the same overall pattern of longer looking to the social interaction between the babies soothed by different adults, with suggestive but non-significant differences in the temporal course of that effect.

A further 2 (experiment) by 3 (trial block) by 2 (test event) ANOVA comparing Experiment 4 to Experiment 3 revealed main effects of trial block, $F(2,92) = 3.12$, $p = 0.049$, $\eta_p^2 = 0.06$, and test event, $F(1,46) = 6.15$, $p = 0.017$, $\eta_p^2 = 0.12$, as well as a test event by

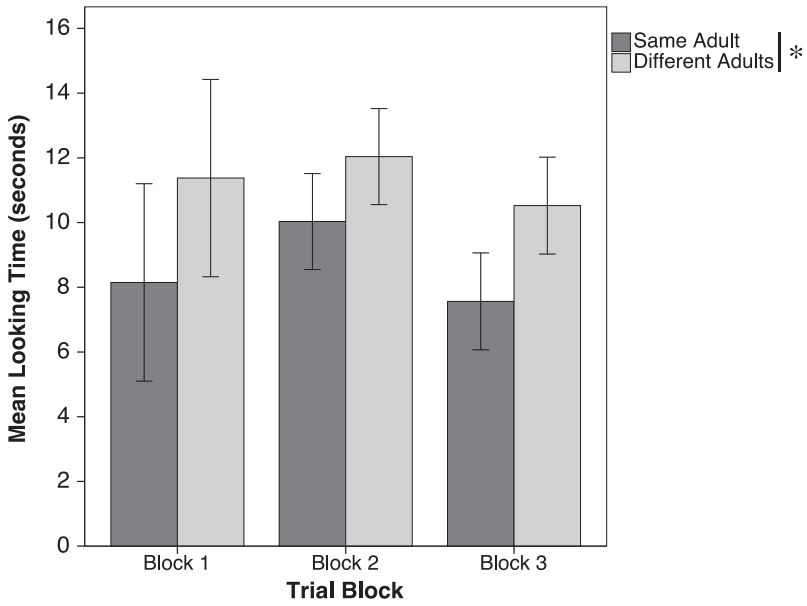

Fig. 7. Looking times for expected and unexpected test events in Experiment 4 (n = 16), involving affiliation between babies who were comforted by the same/different adult (s). Across test events, infants looked longer to the unexpected event ($^*P < 0.05$), though infants did not look longer to either event in the first test pair. Error bars represent within-subjects 95% confidence intervals (Cousineau, 2005).

experiment interaction, $F(1,46) = 5.14$, $p = 0.028$, $\eta_p^2 = 0.10$. Infants in Experiment 4 looked longer at the different-partner test events than those in Experiment 3. This interaction, which is similar to that found in the analysis comparing Experiment 3 to Experiments 1 and 2, isolates the change in the sound cue (adult laughter rather than baby crying), rather than the change in the size cue (same-sized social partners rather than partners of different sizes) as the critical variable accounting for the negative findings of Experiment 3.

5.2.3. Effects of sibling experience

Finally, we analyzed looking patterns for all infants tested in Experiments 1, 2, and 4, who do not have siblings: a total of 23 infants. A 2 (siblings versus no siblings) by 3 (trial block) by 2 (test event) repeated-measures ANOVA of all 48 infants revealed a main effect of trial block, $F(2,92) = 5.42$, $p = 0.006$, $\eta_p^2 = 0.11$, showing decreasing attention, a main effect of test event, $F(1,46) = 11.03$, $p = 0.002$, $\eta_p^2 = 0.19$, with infants looking longer to unexpected events. There were no other main effects or interactions: crucially, no effects of the presence vs. absence of siblings. Analyses focused on the subset of infants with no siblings revealed the two principal effects observed across Experiments 1, 2, and 4: longer looking to affiliation between babies soothed by different adults, both on the first test pair and overall (see Supplementary Materials).

5.3. Discussion

In Experiment 4, infants looked longer to affiliation events between babies who had been comforted by different adults, despite the absence of any size cues to aid in processing the baby-adult relations. Statistical analyses provided evidence for patterns of looking in Experiment 4 that were similar to those in Experiments 1 and 2, and different from those in Experiment 3, even though Experiments 3 and 4 presented nearly identical displays except for the vocalizations. Thus, as with dominance behaviors (Mascaro & Csibra, 2012), infants used behaviors to interpret comforting interactions between baby and adult characters when no size cue to age was present. The negative findings from Experiment 3 are not explained by the presentation of characters of equal size.

Nevertheless, the looking patterns of infants in Experiment 4 emerged somewhat differently over time. Instead of showing a robust looking pattern in the first test trial pair, infants' looking to the two types of events began to diverge across the three test pairs and reached significance overall. Although the triple interaction of Experiment, Test Event and Trial block was not significant, analyses focused on the first trial block suggest that size cues may be helpful in signaling and tracking the relationships among the five characters in Experiments 1 and 2. Nevertheless, size cues are not necessary in order for infants to make inferences about the social interactions between the baby and adult characters.

Experiment 4 also provides evidence against a potential alternative account of the negative findings of Experiment 3. Because Experiment 3 presented five same-sized callers and responders whereas Experiments 1 and 2 presented callers and responders that differed in size, infants' superior performance in Experiments 1 and 2 could have been observed not because they involved adult-baby interactions but because the characters in those studies were more visually discriminable. The findings of Experiment 4 show that it is the differences in age and/or emotional state (crying babies rather than laughing adults) rather than the difference in size that produced the positive findings in Experiments 1 and 2. This conclusion is consistent with the evidence that infants interpret the comforting interactions in Experiment 4 as they do in Experiments 1 and 2 and in past research (Johnson et al., 2007), as interactions between distressed babies and adults who soothe them.

Two remaining differences between Experiments 1, 2, and 4, on one hand, and Experiment 3, on the other, therefore could account for our differing findings. First, Experiments 1, 2, and 4 presented infants with comforting interactions, whereas Experiment 3 did not. The comforting interactions that infants observed onscreen may link to emotionally important interactions within the family, eliciting meaningful social processing. Second, Experiments 1, 2, and 4 required infants to infer unseen social relationships between baby characters, whereas Experiment 3 required infants to infer unseen social relationships between adult characters. Infants may recognize the baby characters as similar to them and attend to them more than the adult characters. Thus, infants may excel

at tracking and interpreting interactions between babies but not adults. Experiment 5 aimed to distinguish between these two possibilities, by presenting infants with comforting interactions in a task requiring inferences not about babies, but about the adults who respond to them.

6. Experiment 5

Many experiments provide evidence that infants make social inferences about adults who speak the same language (e.g., Kinzler et al., 2007), are helpful to others (e.g., Kuhlmeier et al., 2003), or express similar preferences (e.g., Liberman et al., 2013). No experiment reveals, however, whether infants infer affiliation between two adults who have interacted with the same third party. Experiment 5 tested for this inference in the context of adult-baby comforting interactions, by modifying the familiarization and test events from Experiments 1–4. Whereas Experiments 1, 2 and 4 presented three babies and two adults and assessed infants' inferences concerning social interactions between pairs of babies, Experiment 5 presented three adults and two babies (Fig. 8; Video S5) and assessed infants' inferences concerning social interactions between pairs of adults. We asked whether infants infer, at test, that adults who comforted the same baby will affiliate with one another.

In familiarization, infants saw two sets of three comforting events, in which one of two baby characters cried, and one of three adult characters soothed the baby by approaching, contacting, making an adult coo noise, and rocking in synchrony. Two adults soothed the same baby, and a third soothed the second baby. At test, infants saw only the three adults, moving in pairs in the same synchronized, affiliative dances as in Experiments 1–4. The test events alternated between events of affiliation between two adults who had soothed the same baby and two adults who had soothed different babies.

6.1. Materials and methods

Participants were 16 infants of the same age as in Experiments 1–4 (8 girls and 8 boys, mean age, 16.73 months, range: 15.8–17.7 months). One additional infant was tested but excluded for parental interference. The principal predictions and analyses were the same as in Experiment 1. Further analyses compared the findings of the different experiments. A second independent coder watched a random 25% of subjects' looking times from video; the inter-rater correlation with the original live coder was 0.977.

Infants saw a similar animated display with five social characters, except there were three larger, adult characters at the top of the screen and two smaller, baby characters at the bottom (Fig. 8; Video S5). After each character entered the display individually as in previous experiments, infants saw two sets of three familiarization trials. At the start of each event, one of the two baby characters moved to the bottom of the screen and closed its eyes. Then the remaining baby, with eyes open, pulsated and cried, and one of the three adults responded to the cry as in Experiments 1, 2 and 4. For all infants, adults on the sides of the display comforted the baby on the same side in the first two comforting events. Half of the infants then saw the central adult comfort each of the two babies. Trial orders and counterbalancing were the same as in all the previous experiments.

After familiarization, only the three adult characters remained. In alternating test trials, one of the side adults approached the central adult, and the two adults moved to a new location lower on the display where they danced together in the same manner as in the test events for Experiments 1–4. All other aspects of the test displays and procedure were the same as in Experiments 1–4.

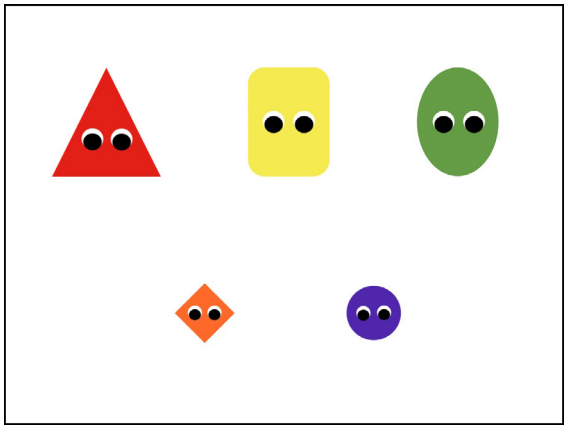

Fig. 8. Scene of the animated stimuli presented to infants in Experiment 5.

6.2. Results

6.2.1. Familiarization trials

A 3 (trial type) by 2 (trial block) repeated-measures ANOVA on looking times during the familiarization events revealed no main effects or interactions (ps > 0.05).

6.2.2. Test trials

The principal findings for this experiment are shown in Fig. 9. A 3 (trial block) by 2 (test event) repeated-measures ANOVA revealed main effects of trial block, $F(2,30) = 14.03$, $p < 0.001$, $\eta_p^2 = 0.48$, and test event, $F(1,15) = 7.76$, $p = 0.014$, $\eta_p^2 = 0.34$, with decreased looking over time and with longer looking to test events showing affiliation between adults who comforted different babies. There was also a trial block by test event interaction, $F(2,30) = 3.7$, $p = 0.037$, $\eta_p^2 = 0.20$. Across all test pairs, 13 infants looked longer at the test event showing affiliation by adults who responded to different babies, and three infants showed the opposite pattern ($p = 0.002$, one-tailed binomial test). Infants showed this pattern on the first pair of test trials: i.e., the first time they viewed the adult-adult affiliative interactions ($t(15) = 3.23$, $p = 0.003$, one-tailed, $d = 0.64$). In the first test pair, 12 infants showed this pattern, two showed the opposite pattern, and two looked roughly equally ($p < 0.001$, one-tailed binomial test).

Additional analyses of between-subjects factors revealed no main effects of gender or which baby the central adult comforted (diamond vs. circle). There was a main effect of test order, $F(1,8) = 12.02$, $p = 0.008$, $\eta_p^2 = 0.60$, with infants looking longer to all test events when they saw the expected event first in each test pair. Crucially, there was no test event by test order interaction, $p = 0.49$ (for further results, see Supplementary Materials).

A further analysis compared infants' looking patterns in Experiment 5 to those in Experiments 1 and 2. This 3 (experiment) by 3 (trial block) by 2 (test event) ANOVA revealed the same main effects of trial block, $F(2,92) = 16.66$, $p < 0.001$, $\eta_p^2 = 0.27$, and test event, $F(1,46) = 12.99$, $p = 0.001$, $\eta_p^2 = 0.22$, and the same trial block by test event interaction, $F(2,92) = 7.19$, $p = 0.001$, $\eta_p^2 = 0.14$. There were no other main effects or interactions: in particular, no effects involving the factor of experiment. Therefore, infants showed the same patterns of looking to affiliation events among adults who soothed the same versus different babies (Experiment 5) as they did to affiliation events among babies soothed by the same versus different adults (Experiments 1 and 2).

A similar 2 (experiment) by 3 (trial block) by 2 (test event) repeated-measures ANOVA compared Experiment 5 to Experiment 3: the other experiment testing inferences about affiliation between adults. This analysis revealed main effects of trial block,

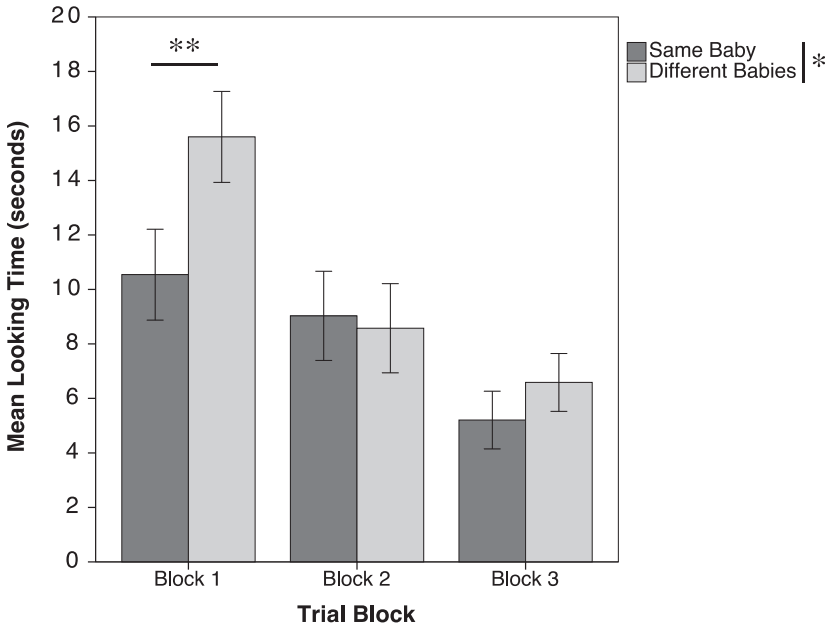

Fig. 9. Looking times for expected and unexpected test events in Experiment 5 (n = 16), involving affiliation between adults who comforted the same or different babies. In the first test pair and across test events, infants looked longer to the unexpected event (**P < 0.01; *P < 0.05). Error bars represent within-subjects 95% confidence intervals (Cousineau, 2005).

$F(2,92) = 20.06$, $p < 0.001$, $\eta_p^2 = 0.30$, and test event, $F(1,46) = 5.16$, $p = 0.028$, $\eta_p^2 = 0.10$, qualified by a marginal interaction of test event by experiment, $F(1,46) = 4.03$, $p = 0.051$, $\eta_p^2 = 0.08$, and by a stronger, triple interaction of trial block, test event and experiment, $F(2,92) = 3.63$, $p = 0.03$, $\eta_p^2 = 0.07$. Infants looked longer at the test events showing affiliation between unrelated adults in Experiment 5 than in Experiment 3 on the first pair of test trials, and marginally longer overall. There were no other main effects or interactions. Infants' patterns of looking in Experiment 5 thus differed from those observed in Experiment 3, while closely corresponding to the patterns observed in Experiments 1 and 2.

6.3. Discussion

In this experiment, infants looked longer to affiliation events between adults who cared for different babies, relative to adults who cared for the same baby. Infants' inferences about affiliation by adults who engaged in comforting interactions were similar to their inferences about affiliation by the babies who were the recipients of such comforting interactions (Experiments 1, 2, and 4). Moreover, infants responded to interactions between adults who had previously approached crying babies somewhat differently than they responded to adults who had previously approached laughing peers (Experiment 3). When interpreting which adults might interact, infants therefore used past adult-baby comforting events to interpret novel relationship dyads.

These findings provide evidence against two alternative interpretations of the findings of Experiments 1–4. First, they show that the negative findings of Experiment 3, relative to the positive findings of Experiments 1 and 2, were not caused by lack of interest in adult characters. Infants' inferences about affiliation between the adult characters were as strong in Experiment 5 as were their inferences about affiliation between the baby characters in previous experiments. Second, Experiment 5 provides further evidence against the possibility that infants' test trial looking patterns in Experiments 1, 2, and 4 stem from differences in the relative familiarity of the motions presented on those test trials. In Experiments 1–4, the side character at test who had previously shared a social partner with the central test character approached the central character from a direction that was also presented during familiarization. Thus, the test-trial approach motions of the character who previously shared a social partner were more familiar than the test-trial motions of the character who did not across experiments. In Experiment 5, in contrast, the reverse is the case: the approach motion direction of the character who did *not* share a social partner with the central character was more familiar at test, because two of the three characters moved in that direction to approach the babies during familiarization. Thus, the relative familiarity of the test patterns of motion does not account for infants' responses across this series of experiments.

Experiment 5 suggests that infants encode and interpret comforting interactions not only as informative about babies, whose crying prompts the interaction, but also about adults, whose approach and rocking serves to soothe the babies and end their cries. When presented with caregiving interactions, infants determine, remember, and form inferences not only about the party who expresses emotion, but also about the party whose approach and interaction modulate that emotion. Indeed, we find no difference between infants' inferences about actors and recipients of comforting interactions. Infants thus seem robustly sensitive to caregiving interactions and use them to understand larger social networks of adults as well as babies.

A final experiment was conducted to test the robustness of these inferences. In all of the preceding experiments, social interactions among the five characters were supported by relationships of perceptual similarity: each side character whose crying or laughing initiated each social interaction, and each corresponding side adult who responded to that character, were similar to one another in shape and coloring. Although the negative findings of Experiment 3 show that these feature relations were not sufficient to produce inferences about affiliation among characters with a shared social partner, the relations nevertheless may be necessary, and we presented them for two reasons. First, people who care for one another often are members of the same family, and family members tend to resemble one another. It is possible, therefore, that infants use family resemblances, in part, to infer which characters will affiliate

with one another. Second, the events presented during familiarization, involving five distinct, novel characters engaged in three distinct social interactions, likely placed high demands on infants' memory. Both visual and spatial cues could have served to lessen these demands.

Nevertheless, infants may interpret and remember caregiving interactions even in the absence of such feature similarity. In past research, infants have inferred that members of a single social group will engage in the same actions not only when group members had similar appearance but when they did not; although, infants' looking patterns suggested that interactions between perceptually heterogeneous social group members were more difficult to process or remember (Powell & Spelke, 2013). Experiment 6 tested for this ability.

7. Experiment 6

Experiment 6 introduced the same social scenarios as in Experiment 5, with changes in the shapes of the characters that reduced their feature differences, and with changes in the pairings of characters that eliminated any feature similarity between the pairs of side characters (Fig. 10; Video S6). Experiment 6 also introduced a change in procedure, aimed to aid infants in remembering the characters and their social interactions: it included three more re-familiarization scenes, in which each adult character soothed one baby character, before the second and third blocks of test trials. As in Experiment 5, we tested whether infants infer, at test, that adults who comforted the same baby will affiliate with one another.

7.1. Materials and methods

Participants were 16 infants of the same age as in Experiments 1–5 (8 girls and 8 boys, mean age, 16.67 months, range: 15.67–18.5 months). Three additional infants were tested but excluded due to fussiness (2) or parental interference (1).

The materials were the same as in Experiment 5 except as follows. To eliminate featural similarity between the pairs of side characters, the edges of all the pointed figures were rounded, the orange diamond was rotated, and the pairings of the side figures from the previous experiments were reversed (Fig. 10; Video S6). Familiarization events were the same as in Experiment 5. At test, the side characters alternately approached the central character by moving horizontally, and then the two characters moved vertically together rather than on a familiar diagonal motion before beginning the affiliative dance. All other materials and animations were the same as in Experiment 5.

The introduction, familiarization, and first two test trials proceeded in the same order as in Experiment 5. After the first two test trials, infants were shown each of the familiarization trials one more time (re-familiarization) in an effort to compensate for the increasing demands on memory that the removal of featural cues likely produced (Powell & Spelke, 2013). The first two re-familiarization events were presented for a set amount of time, proceeding to the next trial after 5 seconds, and the third was infant-directed, and proceeded after the infant looked away for two seconds or a maximum looking of 45 seconds. After re-familiarization, infants saw two more test trials. They then saw another three re-familiarization events followed by the final two test trials. The principal predictions and analyses were the same as in Experiment 5. Further analyses compared the findings of the different experiments. A second independent coder watched a random 25% of subjects' looking times from video; the inter-rater correlation with the original live coder was 0.91.

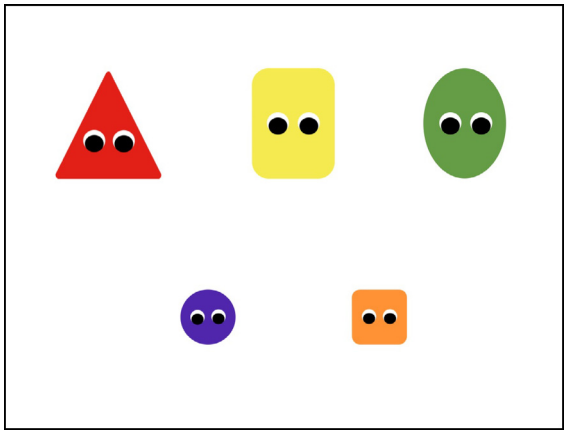

Fig. 10. Scene of the animated stimuli presented to infants in Experiment 6.

7.2. Results

7.2.1. Familiarization trials

A 3 (trial type) by 2 (trial block) repeated-measures ANOVA on looking times during the familiarization events revealed no main effects or interactions ($ps > 0.05$). Infants' looking to re-familiarization was only measured after the third event, so their looking times to the two re-familiarization blocks were compared to looking on the third and sixth trials of familiarization. A 4 (trial block) repeated-measures ANOVA on looking times during those four trials revealed only a main effect of trial block, $F(3,45) = 2.97$, $p = 0.042$, $\eta_p^2 = 0.17$, reflecting decreasing attention.

7.2.2. Test trials

The principal findings of the test trials for this experiment are shown in Fig. 11. A 3 (trial block) by 2 (test event) repeated-measures ANOVA revealed a main effect of test event, $F(1,15) = 7.19$, $p = 0.017$, $\eta_p^2 = 0.32$, with longer looking to test events showing affiliation between adults who comforted different babies. Overall, twelve babies looked longer to the unexpected events, and four looked longer to the expected events ($p = 0.011$, one-tailed binomial test). On the first pair of test trials, infants looked longer to events presenting affiliation between adults who cared for different babies, relative to adults who cared for the same baby ($t(15) = 2.77$, $p = 0.007$, one-tailed, $d = 0.69$). In the first test pair, 12 infants looked longer to unexpected trials, and four looked longer to the expected trials ($p = 0.011$, one-tailed binomial test), supporting the overall pattern of results.

Additional analyses of between-subjects factors on overall looking to test events revealed no main effects of gender, test event order, or which baby the central adult comforted (circle vs. square). There was a test event by test order interaction, $F(1,8) = 21.01$, $p = 0.002$, $\eta_p^2 = 0.72$, with infants who saw the unexpected event first showing a greater difference in looking than infants who saw the expected event first (for further results, see Supplementary Materials).

An additional analysis compared infants' looking patterns in Experiment 6 to those in Experiment 5. This 2 (experiment) by 3 (trial block) by 2 (test event) repeated-measures ANOVA revealed main effects of trial block, $F(2,60) = 13.53$, $p < 0.001$, $\eta_p^2 = 0.31$, and test event, $F(1,30) = 14.34$, $p = 0.001$, $\eta_p^2 = 0.32$, and a trial block by test event interaction, $F(2,60) = 4.43$, $p = 0.016$, $\eta_p^2 = 0.13$. There were no other main effects or interactions: in particular, no effects involving the factor of experiment. Therefore, infants showed the same patterns of looking to affiliation events among adults who soothed the same versus a different baby, regardless of the presence or absence of featural resemblances within pairs of characters.

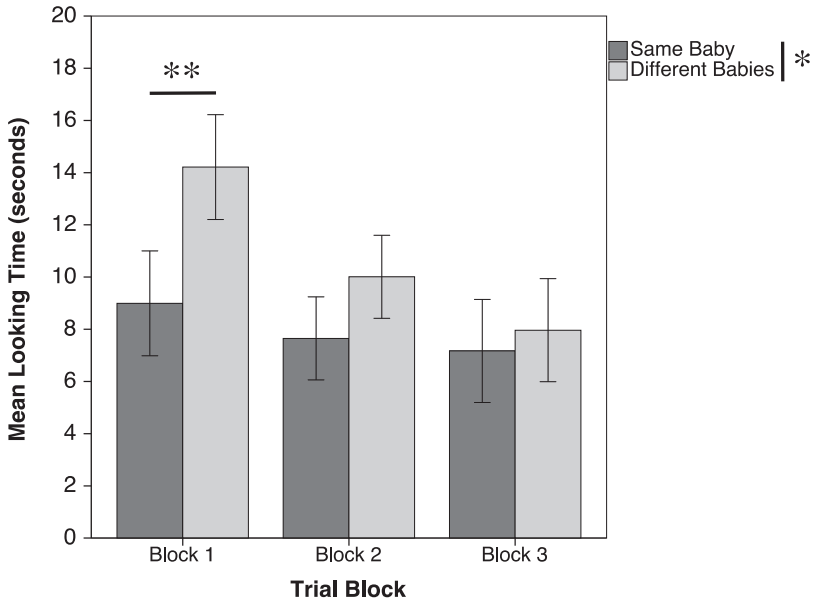

Fig. 11. Looking times for expected and unexpected test events in Experiment 6 ($n = 16$), involving affiliation between adults who comforted the same or different babies. In the first test pair and across test pairs, infants looked longer to the unexpected event ($^{**}P < 0.01$; $^{*}P < 0.05$). Error bars represent within-subjects 95% confidence intervals (Cousineau, 2005).

7.3. Discussion

Despite the absence of featural similarity between baby and adult pairs, infants still inferred which adults were likely to affiliate with one another based on whether they had comforted the same or different babies. Infants inferred that adults who soothed the same baby would be more likely to affiliate with one another than adults who soothed different babies, and they did so in the same manner as in Experiment 5. The changes in characters' motion during the test and the introduction of re-familiarization trials also did not alter the pattern of infants' looking. This finding also provides further evidence that infants' responses to the test events depended on the social behaviors and interactions that were presented in these experiments, rather than on the characters' colors, shapes or motion trajectories.

8. General discussion

Five experiments provide evidence that 15- to 18-month-old infants infer third-party affiliation between individuals that have never previously interacted, based solely on their past social interactions with a shared partner. Critically, the infants in Experiments 1, 2, 4, 5, and 6 used information from scenes showing crying babies, with adults approaching and soothing them, to interpret new acts of affiliation. These findings are not explained by preferential responses to baby over adult characters, or to characters who cried over characters who did not: infants used patterns of comforting interactions to infer affiliation not only between two babies who had cried, but also between two adults who had soothed the same crying baby while emitting no such salient vocalizations of their own. Thus, infants who viewed adults who soothed babies made inferences about both parties to this social interaction.

These experiments provide the first evidence that by 15 months, infants infer affiliation between two individuals who have not interacted directly and whose only connection is a mutual social partner. This demonstrates that a relationship between two people is a social currency comparable to other well-studied similarities (e.g., sharing a food preference: Liberman et al., 2013), and shows that infants notice and use this social information when observing others. These findings build upon recent evidence that 16-month-olds infer conflict between two individuals who have not interacted directly but whose partners were in conflict with each other (Rhodes et al., 2015). Predicting affiliation and conflict may emerge around the same age for infants, and future research could compare these types of interactions more directly.

The present experiments nevertheless suggest limits to infants' inferences about third parties with shared social partners. In Experiment 3, infants did not infer that two adult characters who had previously interacted with the same third party would affiliate with one another. This failure is striking, because the visual displays presented in that experiment were similar to those of all the other studies and nearly identical to those of Experiment 4. The vocalizations that initiated the social interactions mainly distinguished these experiments: in Experiment 3, the social interactions presented at familiarization were elicited by a laughing adult; in the other studies, they were elicited by a crying baby.

It is tempting to explain the negative findings of Experiment 3 by appealing to the effects of baby cries on infants' attention. Three such explanations might be offered. First, infants may view the baby's cry as a negative signal, and this signal may heighten their attention to the ensuing events, leading to better processing of social information. This explanation accords with evidence that infants show a negativity bias in processing social information (Vaish, Grossmann, & Woodward, 2008). Second, infants may interpret the cessation of crying as a positive outcome, and they may be predisposed to attend to actions with positive effects when inferring positive social bonds. Third, the adult laughing noise may have puzzled or intrigued infants, who either lost interest or attended longer to the events that it initiated.[3] Contrary to all three of these explanations, there were no differences in infants' looking time to the familiarization events presenting a baby's cry (Experiments 1 and 2) versus an adult's laughter (Experiment 3). Moreover, infants were no more responsive to test events presenting the infants who had previously emitted the salient cries (Experiments 1, 2, and 4) than to test events presenting the adults who had not (Experiments 5 and 6).

[3] We thank an anonymous reviewer for suggesting this possibility.

We suggest, therefore, that differences in attention do not account for the present pattern of findings. These findings are consistent, however, with a different family of explanations. Social interactions in which adults soothe crying babies may be especially meaningful to infants, who may be predisposed to view the participants in these interactions as social beings who participate in a network of relationships (Johnson et al., 2007, 2010). The present experiments add to the evidence that infants track these comforting relations. They build on previous findings by showing that infants form expectations not only about the reaction of an adult to a crying baby but also about the interaction of different adults or babies with one another, based on their shared social partners.

Nevertheless, the present experiments do not reveal what specific meanings infants give to the comforting events. It is possible that infants view socially related characters in these experiments as members of the same family. Infants may view two adult characters who comfort the same baby as parents who live together and care for one another as well as for their baby, and they may view two baby characters who are comforted by the same adult as siblings. Alternatively, all characters may simply be viewed as social beings who help specific others. Infants' interpretations both of the emotional cries and of the actions that assuaged them remain questions for future research.

Interestingly, infants without siblings made the same inferences as those with siblings, despite their markedly reduced opportunities to observe, as third parties, affiliative interactions between babies with a common caregiver (see Supplementary Materials). This finding, too, could be explained in either of two quite different ways. First, comforting interactions may be interpreted as signaling kinship relations of babies to parents and siblings in a biologically privileged manner, even for infants without any siblings of their own. Alternatively, comforting interactions may not be interpreted as indicative of kinship relationships at all, either in the present studies or in the studies of Johnson et al. (2007, 2010) on which they are based. On one hand, it is possible that the securely attached infants in Johnson et al.'s studies, who expected that their distress would be soothed consistently by their own parents, viewed the animated adult character as the parent of the baby character, and therefore generalized this expectation to inferences about those characters. Alternatively, securely attached infants may expect any known adult caregiver to respond consistently to their own cries, and they may view the adults in the comforting events only as caregivers, not as kin.

Thus, although infants inferred that the baby characters who were comforted by the same adult were socially related to each other in some way, the nature of the relationship remains unknown. Infants may have viewed the baby characters as siblings, cousins, neighbors, day-care classmates, or casual acquaintances. With or without siblings, moreover, the participants in these studies likely had multiple opportunities to observe caregiving and nurturing interactions, including those involving non-kin adults such as day care providers or teachers. Further research is needed to probe the origins and nature of the social inferences that the present experiments reveal.

We conclude that infants' looking behavior depends on the specific social context presented: a context that adults view as a caregiver soothing a crying baby and that infants in previous research connected to their own social world (Johnson et al., 2007, 2010). Infants may also reason about social networks involving adult peer relations, but the present studies suggest that similar amounts of evidence for social partnerships did not elicit the same inferences about adult partners of other adults as of adult comforters of infants, at least in the present context. The findings of Experiment 5 and 6 also cast doubt on the possibility that infants' responses depend on general predispositions to attend to characters who are similar to the self or who emit salient cries: they show that infants are sensitive to not only crying babies but the adults who respond to them, performing social inferences that could serve to establish a network of social relationships centered on the family. Regardless of whether infants of 15–18 months view baby-adult relations as specifically relating to kin or more broadly relating to familiar social groups, the experiments present initial evidence for early-developing reasoning about a culturally universal caregiving relation.

The studies raise questions regarding the properties and limits of infants' reasoning about caregiving relations and their more general understanding of kinship. First, do infants see baby-adult interactions as asymmetrical, as adults do, or do they infer that adults and babies will comfort one another reciprocally? Second, do infants infer that adults who comfort crying babies will nurture them in other ways: for example, by feeding and watching over them, as in universal kin-based relations of communal sharing (e.g., Fiske, 1991, 1992)? Third, do infants use experiences within their own families and social interactions to interpret caregiving interactions, as some previous findings suggest (Johnson et al., 2007)? Variations of the present experiments could serve to address these questions.

A further question concerns the specificity of the social actions that infants attribute to the characters they saw. Do infants see these adult-baby interactions specifically as caregiving or more generally as helping? Though baby cries that elicit an action of soothing evoke parent-child relationships for adults, it is possible that infants would make the same inferences for future affiliation given any social context of helping individuals in need. Future experiments, presenting adult characters who express distress and are comforted by other adult characters, could distinguish these possibilities.

Studies of infants' response to comforting interactions between adults might further clarify infants' interpretations of comforting events involving babies and adults that are all the same size (Experiment 4). Previous research on infants' understanding of dominance indicates that relative size cues are not necessary for perception of dominance relations (Mascaro & Csibra, 2012, 2014), but they do make detection and understanding dominance easier at young ages (Thomsen et al., 2011). Similarly, Experiment 4 provides evidence that size cues are not necessary for infants to infer relations among the participants in comforting interactions, but the slow emergence of this inference across trials suggests that size cues are helpful to infants when they are present (Experiments 1, 2, 5, and 6). Future experiments may usefully investigate the roles of size, vocalizations, and behavior in signaling the generational relationships that are fundamental to caregiving interactions and kinship systems.

Whatever the findings of such experiments, the present experiments broaden the category of helping events to which infants respond. In previous studies of helping, a protagonist had a specific goal—for example, climbing a hill (Hamlin et al., 2007), and other individuals assisted or hindered the protagonist in completing the goal. In the present experiments, a baby character elicited comfort from an adult character simply by crying, without exhibiting any explicit goal. Thus, the present social interactions may fall under the broader category of helping but they possess unique qualities that differentiate them from other forms of helping.

In summary, the present findings provide evidence that children begin at an early age to reason about a social interaction that adults perceive as parental care and comfort. Infants in their second year use this interaction to guide inferences about relations between individuals who have not interacted directly with one another but only with a common adult (Experiment 1, 2, 4) or common baby (Experiment 5, 6). Future research can investigate whether infants show similar inferences concerning these fundamental relations at even younger ages, before they begin to speak,

locomote independently, and, therefore, actively to choose their own social partners.

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Author contributions

A.C.S. and E.S.S. designed the research; A.C.S. collected and analyzed the data; and A.C.S. and E.S.S. wrote the paper. Both authors approved the final version of the manuscript for submission.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2016.11.008.

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