Infants Infer Social Relationships between Individuals who Engage in Imitative Social Interactions

Vanessa Kudrnova (ucjuudr@ucl.ac.uk)
University College London, Gower Street London WC1E 6BT
Elizabeth Spelke (spelke@wjh.harvard.edu)
Harvard University, 33 Kirkland Street Cambridge, MA 02138
Ashley Thomas (athomas@g.harvard.edu)
Harvard University 33 Kirkland Street Cambridge, MA 02138

Abstract

Infants are born into rich social networks and are faced with the challenge of learning about them. Previous research shows that infants learn about individuals when they observe their social interactions, but it is not clear whether they infer their social dispositions, their social relationships to one another, or both. The current studies address this question in 12-month-old infants and 16- to 18-month-old toddlers who observe social interactions involving imitation. In Studies 1 and 3, infants and toddlers expected that imitators, compared to non-imitators, would respond to their social partners' distress. Likewise, they expected the targets of imitation, compared to non-targets, to respond to their partner's distress. In Study 2, these expectations did not generalize to interactions with a new partner, providing evidence that infants learned about the relationships between individuals as opposed to their dispositions. In Study 3, infants' did not make predictions about responses to laughter, suggesting that infants see imitation as indicative of a specific kind of social relationship. Together, these results provide evidence that infants and toddlers learn about the social relationships of unknown individuals by observing interactions involving imitation.

Keywords: imitation; infant cognition; social development; social relationships

Introduction

Human infants face the challenge of learning about the people in the large social networks into which they are born, as well as the relationships that make up this social network (Kaufmann and Clément 2014; Thomsen and Carey 2013; Thomas, n.d.). Over their first year, infants' social skills expand (Tomasello 2016), as does the number of people they interact with (Helfrecht et al. 2020; Hrdy and Burkart 2022). Thus, with minimal language to guide them, infants face a particular challenge when learning about their social worlds: they must rely in part on observations to learn about the dispositions and relationships of the people around them.

One challenge when observing social interactions is that the same behavior can be indicative of either a person's social dispositions or their social relationships, and different generalizations follow from the two diagnoses. For example, imagine you see an adult playfully imitating a child. If you explain the adult's behavior by inferring a disposition of the adult (e.g., they are 'playful' or 'kind') then you should predict that the adult will be playful with other children, and you should make no predictions about the actions of the child. In contrast, if you explain the adult's imitative behavior by inferring a relationship between the adult and the child, predictions about the adult's behavior toward other children are not warranted, but predictions about the child's behavior toward that adult are warranted. The present studies investigate whether 12-month-old infants and 16- to 18month-old toddlers make inferences about prosocial dispositions or affiliative relationships when they observe social interactions that involve imitation. If they make inferences about relationships, we reasoned, their predictions should be constrained to the individuals involved in the interaction they observe. If they make inferences about prosocial dispositions, their generalizations should be unidirectional and should extend to situations in which the imitator interacts with new individuals.

Of course, the way that people act in a single social interaction can be diagnostic of both the person's dispositions and their relationship to others. However, some social behaviors, including speaking, smiling or even laughing, are often directed to strangers and are more indicative of dispositions, whereas other social behaviors that are more often directed to known social partners, such as comforting or imitating, may be more indicative of relationships (Buchheim et al. 2009; Fiske 1992; Cheney and Seyfarth 1990; Bachorowski and Owren 2001; Devereux and Ginsburg 2001). Research on infant social cognition suggests that infants' inferences may differ, depending on the social actions they observe: They may infer dispositions more readily when they observe social actions that occur more often toward strangers, and they may infer social relationships more readily when interactions include social behaviors characteristic of social relationships. Accordingly, we reasoned that if infants make inferences about relationships, their predictions should be constrained to specific social reactions. However, if infants make inferences about prosocial dispositions, their generalizations should extend to other reactions.

In M. Goldwater, F. K. Anggoro, B. K. Hayes, & D. C. Ong (Eds.), *Proceedings of the 45th Annual Conference of the Cognitive Science Society.*

There are reasons to think that older infants and toddlers do make distinctive inferences about social relationships and social dispositions. In past research, infants inferred relationships after observing responses to distress and after seeing actions that implied saliva-sharing, both of which occur more frequently between people who know one another than between strangers. In one study, 15- to 17-month-old toddlers expected that two small characters who were previously comforted by the same large character, or two large characters who comforted the same small character, would affiliate by approaching one another and coordinating their actions; (Spokes and Spelke 2017). In another study, infants as young as 8 months predicted that individuals who shared saliva would be more likely to respond to one another's distress, compared to individuals who shared a toy or who touched one another (Thomas et al. 2022). Importantly, infants' predictions were constrained to the individuals in the interactions: after first seeing the salivasharing interactions and then seeing a different individual express distress, infants did not expect the saliva-sharer to respond. Infants' expectations also were constrained to social actions that typically occur between socially related individuals: they did not expect saliva sharers to respond more than non-sharers to their partner's speech, a response that commonly occurs toward strangers. These findings suggest that infants infer social relationships rather than individual dispositions after viewing specific social actions that commonly occur between individuals in established relationships.

Regarding social actions that are likely to occur between strangers, infants seem to infer dispositions from observing social interactions. For example, infants reach for and look longer at helpers: prosocial individuals who adopt the goals of others (see (Woo, Tan, and Hamlin 2022) for review). They reach for those who distribute resources equally (Geraci and Surian 2011), and those who defer in conflicts by letting someone else pass (Thomas and Sarnecka 2019). These preferences have been interpreted as evidence for 'an innate moral core' (Woo, Tan, and Hamlin 2022; Hamlin 2013) in which infants evaluate others based on whether they are morally good or bad. Related dispositional interpretations of these studies are that infants prefer to interact with those who adopt the goals of others because such individuals are good social partners (Powell 2021) or that infants are more interested in those who act to produce new outcomes (Spelke 2022). The implication behind all these interpretations is that when infants see someone being prosocial to someone, they are motivated to interact with them because they infer a disposition: someone who acts pro-socially toward one person is likely to act pro-socially toward others, including the infant herself. It is also worth noting that at least in one study, 12-month-old infants did not reach more often for those who comfort others compared to those who do not, possibly because comforting is more indicative of social relationships than of dispositions (Thomas, Saxe, and Spelke 2020).

What category does imitation fall into? While infants show both preferential looking and reaching for imitators (Powell and Spelke 2018b), it is unclear whether infants see imitation as a cue to dispositions or relationships. First, 8-month-old infants expect members of social groups (individuals who coordinate their actions by moving in a synchronized circle) to imitate one another as opposed to members of another social group (Powell and Spelke 2013). These expectations are unlikely to be the result of inferred dispositions, because when the groups are established, members of both groups do the same actions. The key variable in this study is whether characters are part of the same or different groups. Moreover, 4-month-old infants expect imitators to approach the target of their imitation, consistent with inferences of social relationships (Powell and Spelke 2018a). However, these young infants have asymmetric expectations. They do not expect the targets of imitation to approach the individual who initiated the imitation. Moreover, while 4-month-old infants preferentially look at imitators, and 12-month-old infants reach for imitators, neither age group seems to prefer the targets of imitation (Powell and Spelke 2018b; Thomas, Saxe, and Spelke 2020, 2022). Infants' distinction between initiators and responders in prosocial interactions could be evidence that younger infants attribute dispositions to imitators. That is, being the individual who initiates imitation may be evidence of an intent to be prosocial, whereas being the target of imitation can happen unintentionally. On the other hand, the most relevant relationships to infants are caregiving relationships, which are often asymmetrical in obligations and interactions (Powell 2022). Thus, young infants may see imitation as indicative of relationships that are asymmetrical.

One set of results strongly suggests that 12-month-old infants see imitation as a cue to relationships: they distinguish between the targets of their parent's imitation and the targets of a stranger's imitation (Thomas, Saxe, and Spelke 2022), reaching for and expecting social engagement from the targets of their parent's imitation but not the targets of an unfamiliar adult's imitation. Importantly, in this study, the parents had a friendly and contingent interaction with two puppets, but only imitated one. These results suggest that the infants see their parent's imitation as more relevant to themselves than the imitation of strangers, potentially because they see it as a distinct cue of relationships that differs from friendliness or speaking to one another.

Taken together, this body of work suggests that infants make inferences when they observe social interactions. Social actions that are more likely to occur in social relationships lead to inferences about relationships, while actions that often occur between strangers lead to inferences about dispositions. The experiments do not reveal, however, how infants view imitation. On the one hand, the preferences of infants suggest that they attribute a prosocial disposition to imitators. If so, then infants should expect that future prosocial behavior will be applied to other individuals. On the other hand, infants' infer that they themselves are related to new individuals who have been imitated by their own parent,

suggesting that they see imitation as a cue to social relationships. If so, then infants' predictions should be constrained to the individuals they observe imitating one another. Moreover, their predictions about future actions should be constrained to actions that occur in social relationships and should exclude actions that commonly occur between strangers. Previous studies have not systematically tested these possibilities.

A series of three experiments investigated whether infants' inferences about imitation were based on inferred relationships or inferred dispositions. In these studies, we show infants two sets of interactions between a central human actor and two flanking puppets. In the actor condition, one puppet imitates the central person, and the other puppet does not, allowing us to compare infants' predictions about imitators and non-imitators. In the target condition, one puppet is imitated by the central person and the other is not, allowing us to compare infants' predictions about those who are imitated compared to those who are not imitated. In Study 1, we ask whether 11- to 12-month-old infants and 16- to 18month-old toddlers expect imitators and their targets to respond to their social partner's distress. In Study 2 we ask whether infants' expectations are limited to the individuals involved in the original interactions, or whether they expect imitators to be responsive to anyone who expresses distress.

In Study 3, we ask whether infants' expectations are limited to responses to distress—i.e., social reactions that occur more often in relationships or whether their expectations extend to responses to laughter—i.e., a social behavior that occurs commonly in interactions with strangers. Infants appear to use laughter, like comforting, as a cue of another person's future behavior (Hoicka and Wang 2011; Mireault et al. 2014). Amazingly, infants differentiate naturalistic colaughter audio that occurred between friends compared to that which occurred between strangers, we reasoned that the recordings we made of people laughing alone would most likely fall into the stranger category (Vouloumanos and Bryant 2019). Therefore, we reasoned if infants failed to generalize beyond the individuals in the interaction and beyond comforting, then their inferences were more likely based on an inferred relationship between those who imitate and are imitated.

We reasoned if infants failed to generalize beyond the individuals in the interaction and beyond comforting, then they more likely inferred a social relationship between the parties to an imitative interaction.

Study 1

Pre-registered here: https://osf.io/eg9pf

Participants. 34 infants (*Mmonths* = 11.94, *SD* = .26, range = 11.6-12.4, 10 female and 24 male) and 31 toddlers (*Mmonths* = 17.52, *SD* = .67, range = 16.60-18.67, 20 female and 11 male). Participated in the study. See pre-registration for more information about stopping rule and analysis plan.

Materials and Procedure. For all the familiarization events and test events, we made films using 'monster' puppets that were 14" tall. Each infant saw two conditions: (1) In the Actor Imitation Condition, infants saw a scene with an adult person flanked by two different colored puppets. First, the person made a noise (e.g. 'kazaa, kazaa' see Figure 1, TOP left). Then, after the person turned to one of the puppets, the puppet made either the same or different noise (e.g., 'piku, piku', spoken by a different voice). Then, the person looked forward and made the same noise that she made in the beginning of the scene. Finally, the person turned toward the other puppet who either made the same or different noise (e.g., 'kazaa, kazaa',' spoken by a different voice) (See Figure 1). Thus, one puppet imitated the person, and one puppet did not. (2) In the Target Imitation Condition (see Figure 1 right), the roles of the person and the puppets reversed. Infants saw a different person flanked by a different pair of puppets, all of whom made different vocalizations. First, one puppet vocalized, and the person responded by making the same or a different sound. Then, the other puppet vocalized, and the person responded in the opposite manner. Thus, one puppet was imitated by the central persona and one puppet was not. In both conditions, the central person had a friendly vocal interaction with both puppets but had an imitative interaction with only one.

After each familiarization condition, participants were presented with three test trials. In the main confirmatory Anticipatory test trial, the actor expressed distress (the actor frowned, said, "Oh no!" and put their head in their hands, see Thomas et al., 2022). The dependent variable was anticipatory looking: after the expression of distress, the scene was paused for 8 seconds during which time infants' anticipatory looks and duration of gaze toward the left and right puppet were coded. Next came a social preference test (8s), in which the puppets appeared on-screen and only one voice called out to the baby, saying, "Hi baby, hi!" (Thomas et al., 2022). Finally, infants saw a general preference test (8s) in which the puppets jiggled on the screen with upbeat music in the background. The order of conditions, gender of actors, puppet identity (e.g., blue puppet imitator vs. orange puppet is imitator), and side of imitator/imitated puppet was counterbalanced across participants. All infants saw both conditions.

Experimenters met infants and their parents via video chat. Parents were instructed to have their infants sitting in a highchair or on their lap and to remain neutral during the experiment. The videos were presented to the infants via screen sharing, and their faces were recorded using the video chat software. Their gaze was coded offline by experimenters who were blind to the condition. See preregistration for more details.

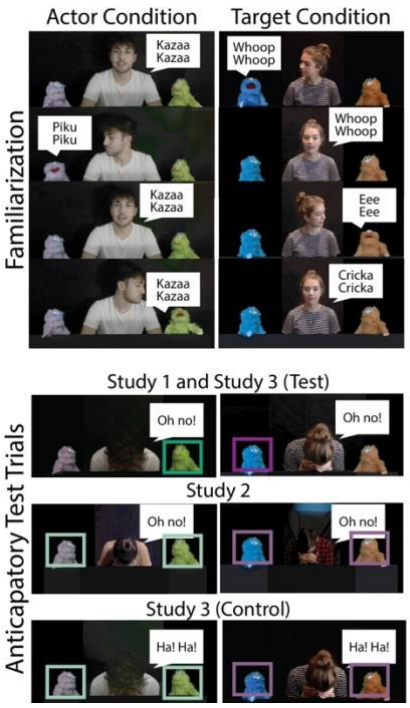

Figure 1. [TOP] Familiarization used in the three experiments. [BOTTOM] Anticipatory Test Trials. Boxes added around puppets to show predicted looking patterns

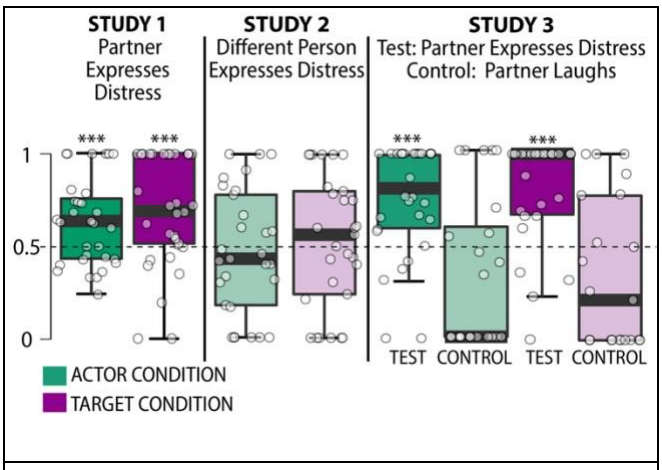

Figure 2. Boxplots of the proportion of time infants spent looking at puppets in imitative interaction during the anticipatory looking trials across three experiments. White dots represent the proportion of time that individual infants' spent looking at the puppet who imitated compared to the puppet who did not imitate; or toward the puppet who had been imitated compared to the puppet who had not been imitated. Black bars are medians. Created using JASP. *** indicate Bayes Factor >10.

Study 1 Results

Infants. In the actor condition, infants looked first (22/32; BF_{10}=2.017, considered weak evidence) and longer (*M*=.633, *SD*=.233, BF_{10}=14.62) at the puppet who imitated the central actor. In the target condition, infants looked first (26/33; BF_{10}=59.14) and longer (*M*=.684, *SD*=.299, BF_{10}=24.79) at the puppet that had been imitated by the central actor. These anticipatory looks did not seem to be due to general interest: infants did not look longer at the imitator in either of the preferential-looking tests (Actor: *Mspeaking*=.496, *SD*=.155, BF_{01}=5.31; *Mmusic*=.525, *SD*=.154, BF_{01}=3.52; Target: *Mspeaking*=.456, *SD*=.218, BF_{01}=2.61; *Mmusic*=.497, *SD*=.128, BF_{01}=5.36; See Figure 2).

Toddlers. In the actor condition, toddlers looked first (23/30; BF_{10}=17.1) and longer (*M*=.647, *SD*=.279, BF_{10}=10.14) at the puppet who imitated the central actor. Likewise, in the target condition, toddlers looked first (23/31: BF_{10}=8.51) and longer (*M*=.688, *SD*=.292, BF_{10}=20.94) at the puppet who had been imitated by the central actor. They did not look longer at the imitator in any of the preferentiallooking tests (Actor: *Mspeaking*=.459, *SD*=.279, BF_{01}=1.614; *Mmusic*=.486, *SD*=.105, BF_{01}=4.01; Target: *Mspeaking*=.536, *SD*=.128, BF_{01}=1.94; *Mmusic*=.493, *SD*=.147, BF_{01}=5.23; See Figure 2).

Study 1 Discussion

In Study 1, we found that infants and toddlers expected both social partners in an imitative interaction to respond to the other's distress. This was true both when they had observed puppets who had imitated a central actor and when they had observed puppets who had been imitated by the central actor. These findings provide evidence that infants and toddlers interpreted the imitative interaction as evidence that the interactive partners were socially related to one another.

Study 2

In Study 2, we tested a further prediction that follows from the findings of Study 1: infants' and toddlers' expectations concerning the individuals involved in an imitative interaction should be limited to those parties: Infants' inferences about social relationships should not generalize to situations in which a new person, who was not included in the initial interactions, expressed distress. In contrast, if infants infer the social dispositions of parties to an imitative interaction, they should have no expectations about who would respond to the distress of the unfamiliar individual.

Pre-registration: https://osf.io/x43ma

Participants. 30 infants (*Mmonths* = 11.90, *SD* = .24, range = 11.54-12.3, 20 female and 10 male) and 27 toddlers (*Mmonths* = 17.72, *SD* = .53, range = 16.64-18.51, 16 female and 11 male) participated in the study. See pre-registration for the stopping rule.

Procedure and Materials. The procedure was the same as in Study 1, except that in the Anticipatory test trial, the central actor was replaced by a new human actor who was not featured in the imitative interactions during familiarization.

(See Figure 1)

Study 2 Results

Infants. In the actor condition, infants did not look first (16/29; BF_{01}=6.48) nor longer (*M*=.465, *SD*=.338, BF01=8.003) at the puppet who imitated the central actor. Likewise, in the target condition, infants did not look first (12/29; BF_{01}=8.02) nor longer (*M*=.526, *SD*=.360, BF_{01}=3.75) at the puppet who had been imitated by the central actor. They also did not look more at either puppet in any of the preferential-looking tests (Actor: *Mspeaking*=.507, *SD*=.155, BF_{01}=4.24; *Mmusic*=.499, *SD*=.154, BF_{01}=5.96; Target: *Mspeaking*=.456, *SD*=.218, BF_{01}=4.93; *Mmusic*=.471, *SD*=.138, BF_{01}=9.73; See Figure 2)

Toddlers. In the actor condition, toddlers did not look first (14/26; BF_{01}=3.89) nor longer (*M*=.497, *SD*=.261, BF_{01}=5.27) at the puppet who imitated the central actor. In the target condition, toddlers also did not look first (13/28; BF_{01}=4.18) nor longer (*M*=.54, *SD*=.25, BF_{01}=2.01) at the puppet who had been imitated by the central actor. They also did not look longer at either puppet in any of the preferentiallooking tests (*Mspeaking*=.53, *SD*=.19, BF_{01}=2.48; *Mmusic*=.52, *SD*=.13, BF_{01}=2.36; *Mspeaking*=.488, *SD*=.17, BF_{01}=6.39; *Mmusic*=.474, *SD*=.117, BF_{01}=10.112; See Figure 2).

Study 2 Discussion

In Study 2, we found that neither infants nor toddlers expected those who were involved in an imitative interaction to respond to an uninvolved person's distress. This finding agrees with the findings of Study 1 and provides further evidence that inferences about imitators and their targets focus on the social relationship between those individuals rather than on their individual dispositions.

Study 3

In Study 3, we asked whether infants' predictions about future interactions differed, depending on whether an action was likely to elicit a response from a stranger or from someone in an established relationship. Specifically, we asked whether infants expected those involved in imitative interactions to respond to one another's laughter. When a person expresses distress, their distress is most likely to elicit a response from others who know them. In contrast, when a person suddenly laughs, even strangers may respond to them (Owren and Bachorowski 2003; Devereux and Ginsburg 2001). In Study 3 we tested this prediction only in infants, because we found positive evidence that age did not affect the results in Studies 1 and 2 (see Supplementary Materials). We also sought to replicate our findings from Study 1. We randomly assigned infants to one test condition, which was identical to the test conditions in Study 1, and one control condition, in which the central character laughed instead of expressing distress during in the Anticipatory looking test trials.

Study 3 was pre-registered here: https://osf.io/tde6w

Participants 30 infants (*Mmonths* = 11.90, *SD* = .24, range = 11.54-12.3, 20 female and 10 male) participated in the study. See pre-registration for the stopping rule. This study is ongoing, but we report what we have so far.

Procedure and Materials The procedure was the same as in

Study 1, except that in the Anticipatory test trial, the central actor expressed laughter before putting their head in their hands and down on the table. We also conducted but did not code the two preferential-looking tests since we found null results across two studies, across two conditions, across two age groups (See Figure 1).

Study 3 Results

Replicating Study 1, in the actor condition when the central character expressed distress, infants looked longer (*M*=.740, *SD*=.3292, BF_{10}=48.35) at the puppet who imitated the central actor. Infants also looked first at the imitator (16/21; BF_{10}=9.29). Likewise, in the target condition: infants looked longer (*M*=.744, *SD*=.342, BF_{10}=10.1) at the puppet who had been imitated by the central actor. So far, we have only found weak evidence that they look first at the imitated puppet (10/15, BF=1.22). The pattern of results was different in the control conditions, where the central actor laughed instead of expressing distress. In the actor control condition, infants did not look first (5/13; BF_{01}=5.18) nor longer (*M*=.395, *SD*=.402, BF_{01}=5.84) at the imitator. Likewise, in the target control condition, infants did not look first (3/13; BF_{01}=3.95) nor longer (*M*=.429, *SD*=.425, BF_{01}=5.51) at the puppet who had been imitated by the actor. (See Figure 2)

General Discussion

In three studies, we find evidence that 12-month-old infants infer relationships when they observe imitation. In Studies 1 and 3, participants looked first and longer at imitators compared to non-imitators after the imitator's social

partner expressed distress. Likewise, participants looked first and longer at puppets who were imitated compared to puppets who were not imitated after the imitated puppet's social partner expressed distress. In Study 2, we reasoned that if participants' anticipatory looks were based on inferred relationships, they should no longer have expectations when a person uninvolved in the initial interactions expresses distress. However, if their anticipatory looks were based on inferred dispositions, they should expect the puppets to extend their reactions to a person uninvolved in the initial interactions. We found evidence for the former: when the new person expressed distress, infants and toddlers looked neither first nor longer at the puppet who was involved in the imitative interaction. Finally, in Study 3, we found evidence that infants' predictions do not generalize to responses to laughter: a social behavior that often elicits responses from strangers. After infants observed the same imitative interactions, they did not expect imitators nor their targets to respond to the laughter of their social partner. Taken together, these results suggest that by 12 months of age, infants infer relationships between the individuals involved in imitative interactions.

The present findings differ from those found in previous studies of infants who were younger than those tested here. Four-month-old infants, who were presented with imitative interactions performed by animated characters, developed asymmetrical expectations concerning the characters' future social behavior. When reasoning about imitators, they expected the imitators to approach their social partners (i.e., the targets of their imitation). However, they did not expect the targets of imitation to approach their social partners (i.e., the individuals who had imitated them). While comparisons across studies that use different displays and dependent variables should be interpreted with caution, it is possible that the difference in these findings reflects a developmental change from 4 to 12 months: younger infants may have more limited expectations about the targets of social actions. If this is true, it would perhaps be unsurprising given that the most relevant relationships to a 4-month-old infant are caregiving relationships, which involve many asymmetrical obligations and interactions. It is possible that over the first year of life, as infants become more competent social partners, they come to have more symmetrical expectations about the initiators and targets of imitative interactions.

The present findings differ from the implications of previous research in a further way: In our studies, infants' inferences were constrained to the people involved in the interaction. In previous studies with infants of the same age, infants reach for imitators. Why would they do this, if imitation were not viewed, in part, as indicative of a prosocial disposition? First, it is possible that infants expect imitators to have some social dispositions—they may be more friendly, helpful, or engaging with others-- but not other social dispositions—they may not be more responsive to the distress of unknown others. However, the findings of Study 3 cast doubt on the hypothesis that infants expect imitators to be more friendly, because infants did not expect imitators to respond more readily to laughter even of their social partners. Second, infants may see themselves as part of the initial interactions. In almost all studies that investigate social evaluations, the characters involved in the interactions direct attention toward the infant participant. A key difference therefore between the infant in these experiments and the adult who was not part of the initial interactions, but expressed distress in Study 2, is that the uninvolved individual was not shown observing the initial interactions. Future studies could test whether infants expect imitators to respond to the distress of someone who had observed, but not been involved in, the initial interactions. Finally, infants' tendency to look at and reach for imitators may be motivated by their interest in those individuals and their potential future behavior rather than by inferences about the potential social value of those individuals to the infant. For example, infants may view imitators as more competent, because their behavior requires a capacity to plan actions with second order goals (Spelke 2022). Future studies could also ask whether infants expect helpers and imitators to be more competent.

In summary, three experiments provide evidence that both 12-month-old infants and 16- to 18-month-old toddlers view imitation as a social behavior that is indicative of social relationships rather than individual dispositions. Infants' expectations of responses to distress were constrained to the individuals involved in the initial interactions. Moreover, infants did not expect those involved in the imitative interactions to respond to social behaviors that frequently occur between strangers, as they did not expect the imitators or individuals who were imitated to respond to the laughter of their social partners. Finally, infants' representations of relationships were abstract: they connected imitation to a very different type of social behavior (responses to distress) and applied their knowledge of imitation to learn about new social relationships.

Acknowledgments

Thank you to Beyza Kazan, Hayley Rhorer, María Garcia Garcia, Gabriel Chisolm, and Sam Gregory for help with data collection for help with data collection and creation of the events presented to infants. Thank you to the members of the Harvard Writing Workshop who gave feedback on many versions of this manuscript. This research was funded by NIH National Research Service Award 1F32HD096829 and the Center for Brains, Minds, and Machines, funded by the National Science Foundation STC Award CCF-1231216 and Siegel Foundation Award S4881. AJT was supported by the Templeton Foundation, TWCF-2021-20639

Understanding Caregiving: Biology, Psychology, & Policy during the writing of this manuscript. Parts of this manuscript were written for VK's senior thesis at Bath University.

References

Bachorowski, J. A., and M. J. Owren. 2001. "Not All Laughs Are Alike: Voiced but Not Unvoiced Laughter Readily Elicits Positive Affect." *Psychological Science* 12 (3): 252–57.

Buchheim, Anna, Markus Heinrichs, Carol George, Dan Pokorny, Eva Koops, Peter Henningsen, MaryFrances O'Connor, and Harald Gündel. 2009. "Oxytocin Enhances the Experience of Attachment Security." *Psychoneuroendocrinology* 34 (9): 1417–22.

Cheney, Dorothy L., and Robert M. Seyfarth. 1990. *How Monkeys See the World: Inside the Mind of Another Species*. University of Chicago Press.

Devereux, P. G., and G. P. Ginsburg. 2001. "Sociality Effects on the Production of Laughter." *The Journal of General Psychology* 128 (2): 227–40. Fiske, Alan Page. 1992. "The Four Elementary Forms of Sociality: Framework for a Unified Theory of Social Relations." *Psychological Review* 99 (4): 689–723.

Geraci, Alessandra, and Luca Surian. 2011. "The Developmental Roots of Fairness: Infants' Reactions to Equal and Unequal Distributions of Resources." *Developmental Science* 14 (5): 1012– 20.

Hamlin, J. Kiley. 2013. "Moral Judgment and Action in Preverbal Infants and Toddlers: Evidence for an Innate Moral Core." *Current Directions in Psychological Science* 22 (3): 186–93.

Helfrecht, Courtney, Jennifer W. Roulette, Avery Lane, Birhanu Sintayehu, and Courtney L. Meehan. 2020. "Life History and Socioecology of Infancy." *American Journal of Physical Anthropology* 173 (4): 619–29.

Hoicka, Elena, and Su-Hua Wang. 2011. "Fifteen-MonthOld Infants Match Vocal Cues to Intentional Actions." *Journal of Cognition and Development: Official Journal of the Cognitive Development Society* 12 (3): 299–314.

Hrdy, Sarah Blaffer, and Judith M. Burkart. 2022. "How Reliance on Allomaternal Care Shapes Primate Development With Special Reference to the Genus Homo." In *Evolutionary Perspectives on Infancy*, 161–88. unknown.

Kaufmann, Laurence, and Fabrice Clément. 2014. "Wired for Society: Cognizing Pathways to Society and Culture." *Topoi. An International Review of Philosophy*. https://doi.org/10.1007/s11245-0149236-9.

Mireault, Gina C., Susan C. Crockenberg, John E. Sparrow, Christine A. Pettinato, Kelly C. Woodard, and Kirsten Malzac. 2014. "Social Looking, Social Referencing and Humor Perception in 6- and-12-Month-Old Infants." *Infant Behavior & Development* 37 (4): 536–45.

Owren, Michael J., and Jo-Anne Bachorowski. 2003. "Reconsidering the Evolution of Nonlinguistic Communication: The Case of Laughter." *Journal of Nonverbal Behavior* 27 (3): 183–200.

Powell, Lindsey J. 2021. "Adopted Utility Calculus: Origins of a Concept of Social Affiliation." *PsyArXiv*. https://doi.org/10.31234/osf.io/kuwgf.

———. 2022. "Adopted Utility Calculus: Origins of a Concept of Social Affiliation." *Perspectives on Psychological Science: A Journal of the Association for Psychological Science* 17 (5): 1215–33.

Powell, Lindsey J., and Elizabeth S. Spelke. 2013. "Preverbal Infants Expect Members of Social Groups to Act Alike." *Proceedings of the National Academy of Sciences* 110 (41): E3965-72. ———. 2018a. "Human Infants' Understanding of Social Imitation: Inferences of Affiliation from Third Party Observations." *Cognition* 170: 31–48.

———. 2018b. "Third-Party Preferences for Imitators in Preverbal Infants." *Open Mind* 2 (2): 61–71.

Spelke, Elizabeth S. 2022. *What Babies Know: Core Knowledge and Composition Volume 1*. Oxford University Press.

Spokes, Annie C., and Elizabeth S. Spelke. 2017. "The Cradle of Social Knowledge: Infants' Reasoning about Caregiving and Affiliation." *Cognition* 159 (February): 102–16.

Thomas, Ashley J. n.d. "Cognitive Representations of Social Relationships and Their Developmental Origins." *Under Review*.

Thomas, Ashley J., and Barbara W. Sarnecka. 2019. "Infants Choose Those Who Defer in Conflicts." *Current Biology: CB*, June. https://doi.org/10.1016/j.cub.2019.05.054.

Thomas, Ashley J., Rebecca Saxe, and Elizabeth Spelke. 2020. "Infants Use Imitation but Not Comforting or Social Synchrony to Evaluate Those in Social Interactions." cognitivesciencesociety.org. 2020. https://cognitivesciencesociety.org/cogsci20/papers/0357/0357.pdf.

Thomas, Ashley J., Rebecca Saxe, and Elizabeth S. Spelke. 2022. "Infants Infer Potential Social Partners by Observing the Interactions of Their Parent with Unknown Others." *Proceedings of the National Academy of Sciences of the United States of America* 119 (32): e2121390119.

Thomas, Ashley J., Brandon Woo, Daniel Nettle, Elizabeth Spelke, and Rebecca Saxe. 2022. "Early Concepts of Intimacy: Young Humans Use Saliva Sharing to Infer Close Relationships." *Science* 375 (6578): 311–15.

Thomsen, Lotte, and Susan Carey. 2013. "Core Cognition of Social Relations." In *Navigating the Social World: What Infants, Children, and Other Species Can Teach Us*, 17. Oxford University Press.

Tomasello, Michael. 2016. *A Natural History of Human Morality*. Harvard University Press.

Vouloumanos, Athena, and Gregory A. Bryant. 2019. "FiveMonth-Old Infants Detect Affiliation in Colaughter." *Scientific Reports* 9 (1): 4158.

Woo, Brandon M., Enda Tan, and J. Kiley Hamlin. 2022. "Human Morality Is Based on an Early-Emerging Moral Core." *Annual Review of Developmental Psychology*, December. https://doi.org/10.1146/annurev-devpsych-121020023312.

Hill, J. A. C. (1983). A computational model of language acquisition in the two-year old. *Cognition and Brain Theory*, *6*, 287-317.

Matlock, T. (2001). *How real is fictive motion?* Doctoral dissertation, Psychology Department, University of California, Santa Cruz.

Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.

Ohlsson, S., & Langley, P. (1985). *Identifying solution paths in cognitive diagnosis* (Tech. Rep. CMU-RI-TR-85-2). Pittsburgh, PA: Carnegie Mellon University, The Robotics Institute.

Shrager, J., & Langley, P. (Eds.) (1990). *Computational models of scientific discovery and theory formation*. San Mateo, CA: Morgan Kaufmann.