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### Cognitive Representations of Social Relationships and their Developmental Origins

Ashley J. Thomas  
Harvard University, Department of Psychology  
athomas@g.harvard.edu

**Short Abstract:** In this paper, I use findings from infant psychology to propose that humans have core knowledge of social relationships. I propose that these representations allow even infants to categorize relationships into a model (following relational models theory, i.e., communal sharing, authority ranking, or equality matching) and compute their strength (based on factors like expectation of future interaction, obligations, and commitment). Throughout the paper, I review evidence in support of this proposal and consider alternative explanations.

**Long Abstract:** In the human mind, what is a social relationship, and what are the developmental origins of this representation? I consider findings from infant psychology and propose that our representations of social relationships are intuitive theories built on core knowledge. I propose three central components of this intuitive theory. The purpose of the first component is to recognize whether a relationship exists, the purpose of the second is to characterize the relationship by categorizing it into a model and to compute its strength (i.e., intensity, pull, or thickness), and the purpose of the third is to understand how to change relationships through explicit or implicit communication. I propose that infants possess core knowledge on which this intuitive theory is built. This paper focuses on the second component and considers evidence that infants characterize relationships. Following Relational Models Theory (A. P. Fiske, 1992, 2004) I propose that from infancy humans recognize relationships that belong to three models: communal sharing (where people are ‘one’), authority ranking (where people are ranked), and equality matching (where people are separate, but evenly balanced). I further propose that humans, and potentially infants, recognize a relationship’s strength which can be thought of as a continuous representation of obligations (the extent to which certain actions are expected), and commitment (the likelihood that people will continue the relationship). These representations and the assumption that others share them allow us to form, maintain, and change social relationships throughout our lives by informing how we interpret and evaluate the actions of others and plan our own.

**Keywords:** cognitive development; infant cognition; social affiliation; social relationships; social hierarchy

From the moment we are born and throughout our lives, we depend on social relationships for our happiness (Buettner et al., 2020; Demir, 2010), well-being (Cohen, 2004; Kawachi & Berkman, 2001; McCrory et al., 2022), and survival (Alvarez, 2000; Silk, 2007). For most people, life is made meaningful because of our social relationships. We rejoice when babies are born or when people get married. We go into mourning when our loved ones leave us by choice or by death. Every day, we act to maintain or change our existing relationships and create new ones. For example, depending on our culture, we may ‘know’ it is acceptable to eat off our spouse’s plate but unacceptable to eat off our boss’s plate. We may wait for the boss to start a meeting to maintain a deferential relationship or do a favor for a coworker to maintain a cooperative one. We might bring a rose to a friend to create an intimate relationship or

advocate that our book club vote on the next book instead of having one person decide. We more intensely care for and love our children than other children. We go into deep mourning when some people die but not when others do. To make sense of these situations, we cannot simply think of others and ourselves as individuals who have traits (e.g., ‘good’, ‘evil’) or individuals that belong to social groups (e.g., ‘Armenian’, ‘Red Sox fan’). We must also think about social relationships between individuals. How do people acquire this shared knowledge of relationships? In this paper I propose that knowledge of social relationships is based on core knowledge: early developing or innate knowledge (A. P. Fiske, 1991; L. A. Hirschfeld, 2001; Kaufmann & Clément, 2014; Tatone, 2017; Thomsen & Carey, 2013). The structure of this core knowledge shapes how adults think about social relationships. First, I will characterize adult knowledge of social relationships and then I will present evidence that this intuitive theory is shaped by knowledge that appears in infancy.

## **Core knowledge of social relationships: a proposal**

When humans, including young children, reason in domains such as physics, navigation, and psychology, we use intuitive theories, which are interconnected systems of knowledge that allow us to make sense of varied and unfamiliar situations and plan appropriate actions (S. Carey, 1987; Gelman, 2005; Gerstenberg & Tenenbaum, 2017; Gopnik & Wellman, 1994). These intuitive theories are proposed to be built on very early developing or innate knowledge called ‘core knowledge’. Core knowledge serves as inductive biases: it supports infants’ ability to organize the vast amounts of information in their environment and direct infants’ attention to relevant information (S. Carey, 2009; Kemp & Tenenbaum, 2008; Spelke, 2022, p. 20; Spelke & Kinzler, 2007; Tenenbaum et al., 2011; Ullman & Tenenbaum, 2020; Xu, 2019). Core knowledge therefore shapes intuitive theories. What are intuitive theories of social relationships and what core knowledge shapes them?

First, consider the core components of intuitive physics and psychology. The core components across these domains are analogous. When we reason about physics, we reason about entities (things in the world), properties of the entities (e.g., heavy, smooth), and forces (how entities change properties); when we reason about psychology, we reason about agents (a specific type of entity), states (psychological or physical), and actions (how agents change states) (refer to Spelke, 2022; Ullman, 2015 page 200; and Liu, 2022; Liu et al., 2024). I propose that our intuitive theory of relationships has analogous core components: connections (who is socially connected?), characteristics (what type of connection is it and how strong is it?), and communication (the way that connections are established, maintained, and changed). That is, much the same way we reason about properties of entities and states of agents, we reason about the characteristics of relationships. Much the same way that we represent forces to be the vehicle by which entities change or maintain their properties (e.g., a force causes a change in the location of a ball) and we represent actions as the vehicle by which agents change or maintain states (e.g., a person moves their hand to reach for an object), we represent communication as the vehicle by which a social connection changes or maintains its characteristics (e.g., accepting a hug from someone to communicate social closeness). This communication can be explicit (e.g., saying, ‘I declare my allegiance and loyalty to you’) or implicit (e.g., expressing comfort with using the same spoon as a family member). Like the core components in physics and psychology, each of these components have foundations in infancy. In this paper, I focus on the second component: characterizing relationships. I propose that two basic computations determine the way humans represent characteristics of social relationships: categorizing the connection by model and computing the strength of the social connection.

While the core components of each domain are analogous, and the domains interact, reasoning about social relationships goes beyond the domains of physics and psychology (for a discussion about the interdependence of intuitive psychology and physics, refer to Liu, 2024). Consider first that intuitive physics helps us understand the actions of people (or agents more generally). We can use our knowledge of agents as physical bodies to know it is unlikely that a person will walk through a wall. However, we need more than an understanding of the physical world to make sense of many actions of agents: when we see a person turn left to reach a door, we cannot only use intuitive physics to understand the action—we

also need a representation of the person's goal. Likewise, some behavior cannot be understood by only representing a single agent's mental state. Take the notion from intuitive psychology, in which people expect agents to act efficiently toward achieving goals (S. Carey, 2009; Gergely & Csibra, 2003; Jara-Ettinger et al., 2016; Liu et al., 2017; Spelke, 2022). If we observe someone bowing and moving out of the way for someone else and then moving forward on their path, without an understanding of relationships, the action seems irrational. We could explain this action as evidence that the bower is prosocial, but it would not tell the whole story. If we know that relationships are at play, we understand that bowing communicates a certain role in a relationship (A. P. Fiske & Schubert, 2012; Kajanus et al., 2019; Thomas, Radkani, et al., 2022 refer to Box 2).

## **What do core representations of relationships allow us to do, and how are they distinct from representations of traits or groups?**

Like representations of traits and social groups, representations of social relationships constrain and affect the way we explain and evaluate behavior. The difference between representations of traits, relationships, and groups is that they each lead to different generalizations. To illustrate, imagine you are on the subway, and you see someone return a dropped wallet. Without other social cues, you may attribute the behaviors to traits—for example, the wallet-dropper is forgetful, and the wallet-returner is kind. This could lead you to change predictions about the behaviors of the actors toward most people. For example, the wallet-returner may open a door for someone, and the wallet-dropper may be late for a meeting. Now imagine that the two people are wearing Red Sox hats, and the wallet-returner says, 'Go Red Sox', as they return the wallet. Here you may explain the interaction in terms of social groups, leading you to predict, for example, that the wallet-returner will extend prosocial behaviors to other people wearing Red Sox hats. The wallet-returner might even be less likely to help a person wearing a Yankees hat. In other words, the representation of groups would afford predictions concerning people who belong to the group of Red Sox Fans. Finally, imagine you see the same interaction, but first, the two people kiss. Here you would likely infer that the pair is a romantic couple. This could lead to predictions that are constrained to the couple. For example, the wallet-returner might hold open a door for their lover but may not be more likely than others to hold open a door for a stranger. You would be surprised to see them hug or kiss seemingly unrelated people on the subway.<sup>1</sup> One way of visualizing the distinction between these representations is to imagine a social network, where nodes are individuals, and connections between nodes are interpersonal relationships. Trait inferences change your expectations about how nodes will act toward most other nodes, group inferences update your expectations about different aggregates of nodes and how nodes from these aggregates interact, while relationship inferences change your expectations about the lines between nodes and how those two nodes will interact (refer to Box 3). Thus, infants' representations of social relationships would lead them to make different predictions than representations of traits and groups. Next, I will describe in detail how humans, including infants, may recognize relationships.

## **How do we recognize relationships?**

So far, I have described the components of a relationship representation: connections, characteristics, and communication. Next, I proposed their function—they allow humans to make sense of

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<sup>1</sup> The question of attribution is a classic question in social psychology—*when* do people attribute a person's actions to traits compared to 'the situation'? (Kelley & Michela, 1980). One interesting question related to this classic work as well as the current proposal is: how does statistical learning over a lifetime, explicit teaching and other types of learning affect a person's tendencies to explain actions based on traits, relationships, or groups. While we know children use statistical reasoning to distinguish between context and trait causes about the cause of people's actions, more work could be done on this topic (Seiver et al., 2013).

interactions between individuals, updating predictions about whether and how people will interact. What follows is that relationship representations, require us to track individuals. The ability to track individuals has deep phylogenetic roots. For example, chimps recognize group mates even after decades of separation and they better remember those with whom they had closer relationships (Lewis et al., 2023). This ability has also been found in elephants, horses (Proops et al., 2009), sheep (Kendrick et al., 2001), and even wasps (Sheehan & Tibbetts, 2008). Human newborns recognize their mother's face (Field et al., 1984), scent (Vaglio, 2009), and voice (DeCasper & Fifer, 1980). Humans as young as four months (Kosakowski et al., 2022, 2024), have specialized face regions in the brain whose connectivity to other regions suggest that this specialization is driven by social value, perhaps associated with forming relationships with individuals (refer to Powell et al., 2018).

But recognizing relationships goes beyond tracking individuals. How do we know that individuals are connected? It may depend on recognizing cues that people are mutually aware.<sup>2</sup> Newborn infants recognize many cues of social awareness: they distinguish direct gaze from averted gaze (e.g., Farroni et al., 2002), prefer infant directed speech (e.g., Cooper & Aslin, 1990), are aware of contingency, (e.g., Bigelow, 1999; Bigelow et al., 2008; refer to Csibra, 2010) and Spelke, 2022 for an in depth review). As observers, infants as young as 12 months differentiate when others look at each other compared to when they don't, and expect people to look at one another when communicating (Beier & Spelke, 2012). Thus, infants may use cues of mutual awareness, such as mutual gaze, contingency, or joint attention, to infer whether a connection exists at all (refer to Wolf & Tomasello, 2023).

## How do we characterize relationships?

### Categorizing Relationships by Model

While inferring a connection would allow infants to predict whether people will interact, characterizing relationships would allow infants to predict *how* they will interact. How might infants do so? Alan Fiske's Relational Models Theory proposes that humans understand nearly all aspects of social life by categorizing relations using four basic models. Fiske calls them models because he proposes they coordinate nearly all aspects of social life including predicting, planning, and evaluating behavior. The first model is communal sharing, where people are seen as 'one'. People in communal sharing relations feel they overlap or share something. This can include shared land, bodily substances like blood, or experiences like suffering or a love of a cuisine. In authority ranking, people are ranked. People differentiate themselves, taking on different responsibilities, levels of prestige, and/or privilege. Examples of ways that people are ranked include age, gender, birthright, knowledge or skill. In equality-matching relations, people are seen as distinct but equal. People are motivated to keep an even balance and are aware of imbalances. Examples include voting, returning favors, and start-lines in a race.<sup>3</sup> (refer also to (Clark & Mills, 1979; Graeber, 2012). In support of this theory, Alan Fiske and colleagues have amassed ethnographic and behavioral evidence that suggests that universally, humans think about relations using these four basic models (A. P. Fiske, 1992; A. P. Fiske & Haslam, 2005; Graeber, 2012; Rai & Fiske, 2011). In part, because there is evidence that relational models are culturally widespread, Fiske proposes that infants have innate knowledge of these models (refer also to (Kaufmann & Clément, 2014; Tatone, 2017; Thomsen & Carey, 2013).

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<sup>2</sup> I thank Herissa Lamothe for proposing this and thinking this through with me. She is currently working on computational models to test the hypothesis that mutual awareness is key to naive sociology.

<sup>3</sup> Relational Models Theory proposes that market pricing and equality matching are distinct models, but it is unclear to me whether they need to be. In both types of relationships individuals are motivated to maintain balance, but in one people are required to think about ratios as opposed to 1:1 balance. For example, if you mow my lawn in the summer and I clear your snow in the winter, are we in an equality matching relation (we each do favors) or market pricing (we reason that mowing and clearing are relatively equal in by some fungible metric)? By the logic of relational models we are using market pricing, but the relationship itself seems like equality matching.

## Computing a relationship's strength

While models can tell us what to expect even in fleeting social interactions, computing a relationship's strength would tell an infant what to expect over many interactions, across time and contexts. This idea overlaps with proposals in many theories of social relationships, including proposals about pull (A. P. Fiske & Fiske, 2007), attachment (M. D. S. Ainsworth et al., 1974), interdependence (Rusbult & Van Lange, 2008), thickness (Margalit, 2017, p. 2), and strength (Granovetter, 1973). I propose that each of these proposed concepts relate to one underlying representation which I call "relationship strength". Relationship strength is a continuous computation: it informs the extent to which we are committed to someone (i.e., the strength of our intention to maintain the connection) and/or the extent we feel obligated toward someone (i.e., the extent to which certain actions are normatively expected). Relationship strength does not necessarily describe the 'strength' of the model (e.g., how highly ranked we see someone or how much overlap we have with someone, though this may be correlated). The computation occurs in relationships for each model. While people can be highly committed to many things, the extent to which they are committed to single individuals over time<sup>4</sup> and across contexts<sup>5</sup> determines the relationship's strength. For example, a highly devoted teacher may feel committed to teaching because she is generally motivated to impart knowledge on the next generation. However, if this commitment is not directed toward specific individuals the relationships would be relatively weak. By contrast, a teacher could have strong relationships with her students, if she is committed to individuals across contexts and intends to maintain relationships with them even after the course is over. Likewise, you might feel highly obligated to help victims of a hurricane, but if your obligation is not directed toward individuals, or if your obligation is not caused by a relationship, then it wouldn't be evidence of a strong relationship.

Relationships that fall under each of the three relational models can be relatively weak or strong. However, the likelihood of very strong or very weak relationships may vary depending on the governing relational model people use in a single relationship. Below are examples of relationships in each relational model that are relatively strong or weak. For example, you might feel much closer and more committed to your spouse than a teammate but use the logic of communal sharing in both relationships. The logic of communal sharing can even happen in fleeting relations, such as when people feel as one with strangers at a concert, sports, or religious event. Likewise, authority ranking relations can also be strong or weak: one mentee could be devoted to their mentor, while another may see their mentor as a temporary boss to whom they feel no allegiance and do not expect their relationship to continue after the employment has ended. Authority ranking can also occur in fleeting interactions, such as when people feel they owe deference to a judge in court. Interestingly, Graeber suggests that equality matching relations encourage weak relationships since when 'debts' are fully paid, there is no necessity to interact in the future (Graeber, 2012). Thus, communal sharing relationships and authority ranking relationships may have a larger range of 'strength' as opposed to equality matching. Even so, equality matching relations can sometimes be strong and long-lasting, such as between neighbors who have long been doing favors for one another, or weaker, such as children taking turns at a playground. Each model may have different emotions tied with strength, which could serve as one cue to infer a strong relationship (e.g., attachment or 'kama muta' A. P. Fiske et al., 2016) in communal sharing relationships; allegiance in authority ranking relationships; and trust in equality matching relationships).

One untested hypothesis about relationship strength is that the stronger a relationship (i.e. the stronger you feel attachment, allegiance and loyalty, the more you expect the relationship to continue, and the stronger you imagine the bond), the less replaceable the relationship and person. If this is true, then it might be one reason why we mourn more when stronger relationships end (Harris, 2018). Take, for

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<sup>4</sup> Imagine people in a summer fling saying, "I will love you very intensely for exactly 93.6 days" versus people avowing their love "forever". The later situation would likely be seen as indicative of a 'stronger' relationship.

<sup>5</sup> In some sense this is embedded in the argument against nepotism – people assume that at work people will continue to care deeply and favor their family members.



example, one's relationship with their children. In almost all situations, a person's child is completely non-interchangeable. One would certainly notice if their spouse brought home the wrong child from school. The immense number of resources parents put into raising children is directed toward specific individuals. At least in most times and places, and possibly even for non-human primates (Goldsborough et al., 2020; Monsó & Osuna-Mascaró, 2021), the death of a child is often considered one of the worst things that can happen to someone, and parents do not feel that the death of their child can be solved by having a new child. Or consider that when people describe ending a relationship with one's child via other means, they often do so in terms of death (e.g., 'he is dead to me now'). This may be because death feels like the only way one can end a relationship with one's child. On the other extreme, you may not care much about which of your colleagues accompanies you to lunch or who helps you with an error in your code. If the colleague gets fired, and another person takes that colleague's place then the person wouldn't think it's the *same* relationship, but it is conceivable that they would think the new relationship could replace the old one. The owner of a factory may see workers as individuals, but individuals who can easily be replaced by any worker who has the same skills. One can also think of friendships or acquaintance relationships that can easily be swapped or replaced<sup>6</sup> (refer R. M. Carey & Markus, 2017 for evidence that the extent to which people think friendships can/should be replaced varies with social class in the United States).

## **Is this intuitive theory built on core knowledge of social relationships? If so, what would this core knowledge be?**

I propose that our intuitive theory of social relationships is built on core knowledge. Elizabeth Spelke describes core knowledge as something between belief and perception; Susan Carey theorizes it to be iconic in form<sup>7</sup> (S. Carey, 2009). Furthermore, core knowledge is innate, skeletal, largely automatic, and evolutionarily old. Core knowledge is abstract and cannot be computed from perceptual input alone. It persists throughout the lifespan and serves as the foundation of later developing representations, which are heavily influenced by cultural input, statistical learning, and explicit teaching.

Core knowledge of social relationships allows infants to track individuals and their social connections. Like other core knowledge, these representations act as inductive biases that enable learning. I further propose that infants recognize relationship models. These models are analogous to the ones found in Relational Models Theory: communal sharing, where individuals are like 'one', authority ranking, asymmetrical relationships where individuals are ranked, and, equality matching, reciprocal relationships where individuals are separate. They may be substantiated as edges of graphs, with nodes representing individuals and edges representing relationships that are undirected for communal sharing, directed for authority ranking, and bidirectional for equality matching (refer to Figure 1). These model representations could be innate. Another possibility is that they could be learned from the combination of more basic

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<sup>6</sup> Many songs and poems explore this topic. For example, in Prince's 'Nothing Compares to You' the singer tries to do things or interact with people that may replace 'you'. For example, 'I can put my arms around every girl I see, but they only remind me of you' suggests the singer has tried but failed to replace 'you' with others. Other parts of the song suggest that the singer tries to replace the relationship with other actions, such as, 'eating dinner at a fancy restaurant. The implication is that this bond was a strong one!

<sup>7</sup> Iconic representations, unlike symbolic representations, bear some resemblance to the target of the representation, but are still more abstract than indices. For example, a footprint or a stop sign would be an indexical representation because it is physically connected to the target. Words are symbolic because they need not bear resemblance to the target. Diagrams or graphs are iconic, there is a direct translation between the meaning and the attributes of the sign. Note, Fiske proposes that different relationships are substantiated in the mind as different forms of representation. Specifically, following Peirce's semiotics, communal sharing is indexical, authority ranking is iconic, and market pricing is symbolic. He argues that Piaget's concrete operational stage is the best way to think about what constitutes equality matching in the mind (A. P. Fiske, 2004). I think it is more likely they all take the same form, but this is a very difficult thing to study.

social relationship representations (i.e., connections between people: two people are aware of one another) and abilities to recognize general relations (e.g., nominal, ordinal, interval, and ratio).

One way research could help us disambiguate these possibilities is to consider the literature on object recognition. When infants categorize objects they better individuate and remember them. A six-month-old infant is not surprised when a toy duck is replaced by a toy truck, but is surprised when a doll's face is replaced with a ball (Kibbe & Leslie, 2019). Finally, adults categorize objects at the same time they recognize them (Grill-Spector & Kanwisher, 2005). Thus, understanding how young infants distinguish relationships may help us understand whether they categorize them from an early infancy.

Whether the models are innate or early developing, infant representations of relationships are simpler than later-developing representations: they have the structure without the details. A key difference between infant and adult representations is likely that infants do not fully represent the minds of individuals within a relationship (Favre & Sornette, 2015). This is also supported by the fact that species with simpler representations of others' minds recognize relationships analogous to the three relational models (Haslam, 2013; Verbeek, 2006).

Using Authority Ranking as an example, young infants likely recognize asymmetrical relationships but may not understand the various ways rank is cued or construed. Relational Models Theory describes Authority Ranking relationships as those where one person is motivated to protect and guide, while the other is motivated to follow. These relationships are distinguished from dominance relationships, which occur when weaker individuals defer to avoid harm. By contrast, the analogous representation in infants is unlikely to be dominance or legitimate authority. As outlined below, infants do recognize relevant cues that occur cross-species, such as physical size that are associated with dominance, and do use these cues to predict behavior. However, it is unlikely they fully represent the motivations of the individuals until the second year of life. For example, toddlers distinguish between different types of asymmetrical relationships, which may include different motivations of high- and low-ranking individuals, a distinction that would require representing the minds of the individuals involved.

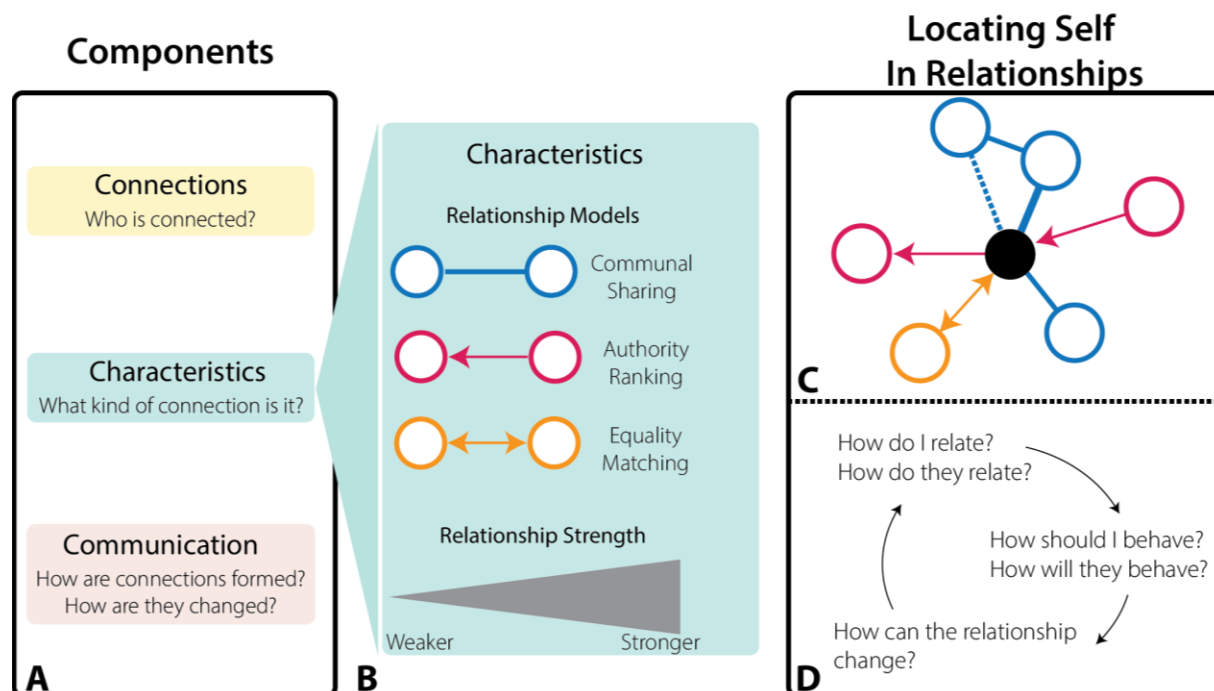
The skeletal nature of the infant representations allows learning of the vast cross-cultural variation in how relationships are established and marked. For example, gender, tattoos, hairstyles, clothing, and race have all been valid indicators of relative social rank in different cultures and times. Yet, they are not valid cues in all cultures, and different instances have meant different things. Or take an even more specific example. In some cultures, taking off a head covering in front of someone means that you have a family or intimate relationship with them. In other cultures, head coverings are only worn for fashion or utility and give little to no information about relationships. Infants in some cultures would need to come to know that head coverings can tell you something about social closeness, while those in other cultures would need to ignore it. Of course, this presents a learning challenge—if infants are born with abstract knowledge about relationships, they would need some way to connect perceptual input to this knowledge.

Some cues might be recognized with either very little learning or no learning (refer also to Fiske & Schubert, 2012; Thomsen & Carey, 2013). Cues that can be learned with very little or no input may be related to evolutionarily old mechanisms. Physical closeness, including touch and exchanging bodily fluids, correlates with communal sharing relationships and strength of relationships in many cultures and species, and it is also related to mothers caring for their young. Physical size tends to highly correlate with formidability, which is what determines dominance rank in many species (Huntingford, 2013; Smith & Price, 1973). Infants may need very little or even no input to form expectations about the relation between differences in size and asymmetrical relationships (refer to Authority Ranking section below). Finally, reciprocal relationships are often, though not always, based on the exchange of goods; thus, equal resource distribution may be a salient cue of equality matching relationships. If there are innate inductive biases that relate to specific cues, then we would expect most humans to recognize them. Humans may take advantage of this to communicate about relationships (Astuti et al., 2004). Many cultures have ceremonies that feature saliva-sharing and physical contact, for example, dances where people hold hands or ceremonies where people drink from the same ceremonial cup. Likewise, many cultures make high-ranking individuals, whose bodies are not necessarily large, appear larger using thrones, headdresses, crowns, monuments, etc. (A. P. Fiske & Haslam, 2005; Thomsen & Carey, 2013). On the other side of the

spectrum, humans recognize and use many cues that are arbitrary and must be learned. Examples include some military rank symbols, specific labels (e.g., ‘madame’, ‘sister’), and wedding rings.

Below, I review evidence that supports the hypothesis that humans possess innate or very early representations of social relationships. I organize the paper by relational model type and consider any evidence that infants infer the strength of connection within these types. While some of this proposal is supported by currently available evidence, other parts of the proposal have yet to be tested. Specifically, several studies support the proposal that infants represent relationships analogous to communal sharing and authority ranking relationships. In contrast, fewer studies support the idea that infants recognize equality matching relationships. Finally, existing studies only hint that infants represent the strength of relationships. This paper does not cover the vast amount of literature on children’s and adults’ ideas of social relationships, nor on how ideas about social relationships develop over the lifespan through cultural learning and first-person experience. Instead, it describes evidence that infants can recognize and categorize relationships. This knowledge lays the foundation for our adult intuitive theory of relationships.

## INTUITIVE THEORY OF RELATIONSHIPS



**Figure 1. Intuitive Theory of Relationships (A)** The components of our intuitive theory of relationships are connections (which individuals are connected), characteristics (what is the relationship model, and what is the strength of the connection?), and communication (how are connections formed, maintained, or changed?). **(B)** People represent the characteristics of relationships along two dimensions: relational model and strength. **(C)** People (black dot) must locate themselves in relationships and learn about potential new social connections (dotted line). **(D)** This is a process of asking how people relate, what behaviors follow from different types of relationships, and what behaviors or actions might change these relationships or groups.



# Core Knowledge of Relationships: Evidence from Infants

## Communal Sharing

In Relational Models Theory (A. P. Fiske, 2004), communal sharing relations occur when people understand themselves to be one and act in ways that reinforce this representation. In these relationships, people have expectations of care without expectations of direct reciprocation. They are mutual but not necessarily symmetrical. At least in stronger versions of these relationships, people understand their fate to be shared. People express communal sharing by accentuating similarities rather than differences. If infants have knowledge that allows them to categorize an interaction as communal sharing, they could quickly learn culturally specific cues such as whether it is normal to kiss on the mouth or spit on the forehead, when it is appropriate to hug someone, or which pieces of clothing tell you about social closeness. Below, I review evidence that suggests infants possess abstract representations of relationships that may support these more complex adult representations.

### Are non-human animals sensitive to communal sharing relationships?

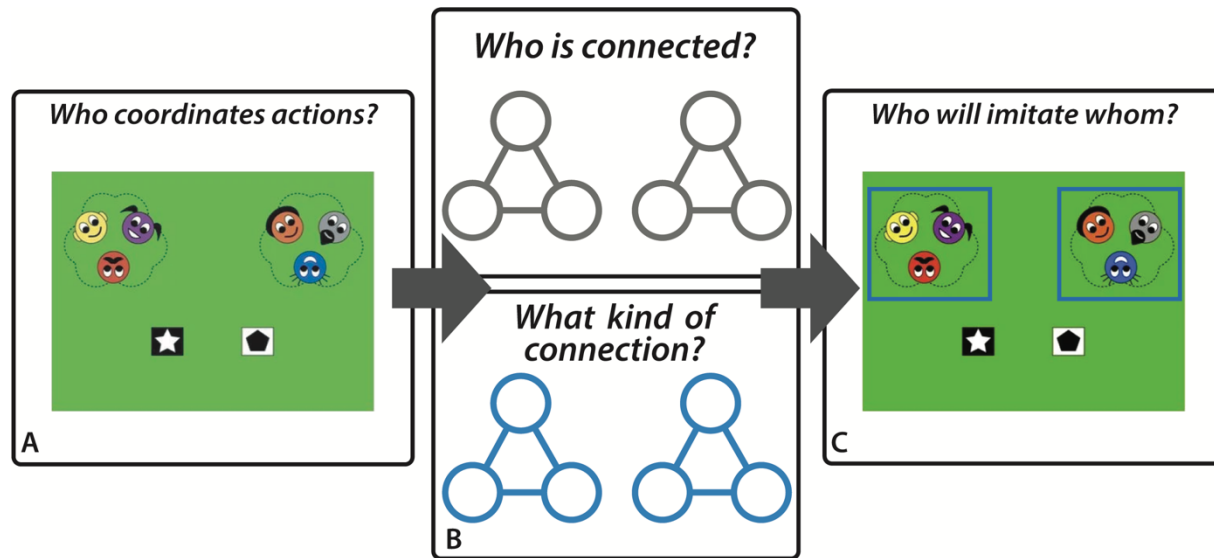
This model has straightforward connections to affiliative relations and associated cues found in other species, including kin, pair-bond relationships (Alcock, 2009) and ‘friendships’, which are characterized as long-lasting affiliative bonds with unrelated individuals who are not sexual mates (Cheney & Seyfarth, 2012; Proops et al., 2021). Primatologists have observed that close physical contact between individuals predicts long-term interaction. Examples include grooming, lip-smacking, or other group-specific behaviors, such as putting hands in one another’s mouths (Perry et al., 2003; Silk et al., 2013). Individuals in several species, such as baboons, vervet monkeys, and chimpanzees, also reason about these relationships as third-party observers. This suggests that they form abstract representations of social relationships (Cheney & Seyfarth, 2008, 2012; Seyfarth & Cheney, 2012). For example, when an individual expresses distress, they look toward that individual’s kin as though they expect that kin will be more likely than non-kin to respond (Cheney & Seyfarth, 1990; Seyfarth & Cheney, 2012). While the nature of these representations, as well as the process through which they are formed, is not yet known, the findings suggest that our ability to reason about these types of relationships could be supported by evolutionarily old mechanisms.

### Are infants sensitive to cues of communal sharing?

#### *Observing Social Interactions*

During the first year of life, humans recognize cues of people acting as one, including when individuals imitate one another, act in rhythmic synchrony, respond to distress, eat together, or share bodily fluids. For example, in one set of studies, 8-month-old infants saw animations in which two triads of animated characters moved their bodies in rhythmic synchrony (Powell & Spelke, 2013). When observing a new scene, infants expected that the characters would imitate the actions of the members of their triad as opposed to the other triad. Importantly, infants did not match ‘same’ with ‘same’: infants expected imitation among triads when the characters had different physical characteristics (i.e., were different colors and had different styles of hair). Likewise, when the characters looked the same but failed to coordinate their actions, infants did not expect imitation. Infants could not have used trait inferences to make predictions. The characters do the same actions in the familiarization events, what differs are their social partners, thus infants likely see relationships. Why might these studies be evidence for representations of communal sharing? In both the familiarization and the test events, the characters made themselves appear to be one unit. To adults, this coordinated action looks like a dance: each character does

the same thing at the same time, moving in a circle. In the test events, infants expected that individuals would again make themselves alike by imitating each other's actions. It is unlikely that the 8-month-old infants from the United States had much experience with people dancing, much less had the opportunity to compare subsequent behavior of individuals who dance together or not. Yet, infants recognized a cue that, in many cultures, identifies communal sharing relationships.



**Figure 2.** Stills of stimuli (green background) and diagram depicting the hypothesized underlying representation in Powell and Spelke, 2013. (A) What infants observed in the study. (B) hypothesized cognitive representation (C) What infants observed during the test trial and the prediction that they made. Diagrams were added by me.

Expectations that arise from recognizing similarity may emerge even earlier. Four- and 5-month-old infants expect a character to approach another character it had previously imitated rather than one it had merely responded to (Powell & Spelke, 2016). However, these young infants did not expect imitation to predict mutual responses: they did distinguish scenes where a character approached someone who had previously imitated the character. Like young infants, twelve-month-old infants anticipated that a puppet who imitated an actress would respond to her distress. Unlike young infants, they also expected the targets of imitation to respond, suggesting expectations of mutual behaviors (Kudrnova et al., 2024; refer also to Pepe & Powell, 2023). Moreover, their expectations did not extend to individuals outside the initial interaction or to scenes where the actress laughed, suggesting they saw imitation as a cue of relationships. While there are several reasons why infants may have shown different patterns of results across the two studies, one explanation is that responses to distress are a better measure of relationship representations than approach behavior (for example, we approach objects we like but we can only comfort another person). It is also possible there is a developmental change such that younger infants see imitation as evidence that “A likes B” which would only affect predictions about A’s behavior toward B, while older infants see it as evidence that “A is connected to B,” which would also change predictions about B’s behavior.

The results reviewed thus far suggest that young infants use social cues in which individuals make themselves more like someone else to predict subsequent behavior. Converging evidence comes from another study, 9-month-old infants expected members of synchronized triads to help each other, rather

than members of other triads, in a right-of-way conflict (Pun et al., 2021). Infants and toddlers also use other cues in which people make themselves more alike to predict future affiliative behavior. For example, toddlers (aged 2 1/2 years and 17 months) expect that individuals who refer to themselves by the same label will support each other (Jin & Baillargeon, 2017; Ting et al., 2019; Ting & Baillargeon, 2021). Infants as young as 6 months expect people who announce the same preferences for food and express positive emotions when eating together to be friendly toward one another (Lieberman et al., 2016, 2021).

Interestingly these behaviors can be construed, at least by adults, as intentional—they are things people do to make themselves more like others. In the study with the dancing groups, intentional similarity was compared to happenstance similarity (i.e., individuals who happen to look alike). This suggests that infants use intentional actions to recognize communal sharing relationships. Infants also reach for puppets who express the same preference as the infant, but only when the puppet expressed their preference after the infant, not when the puppets expressed their preference first. This suggests that the communicative act of choosing the same mittens as the infant influenced the infant's evaluation (Mahajan & Wynn, 2012; Spelke, 2022).<sup>8</sup> Likewise, 12-month-old infants expect that people who wear the same clothing will support one another (Ting et al., 2019). However, they no longer expect support when similar clothing has an instrumental purpose (Bian & Baillargeon, 2022). The distinction between intentional similarity and happenstance similarity is central to the way that many scholars in fields such as Anthropology and Sociology conceive of social relationships: relationships are created through intentional communication and actions (Ingold, 2018). While I do not propose that young infants need to represent the minds of the individuals to infer a communal sharing relationship, they may be more sensitive to actions that have cues of intentionality, perhaps because those cues have been more useful over evolutionary time.

In contrast to the proposal that intentional similarity matters, there is evidence that 9-month-old infants expect friendly interactions between people who speak the same language, which for people who speak one language could be construed as unintentional (Lieberman et al., 2017). Likewise, infants' first-person evaluations are affected by whether others share characteristics with their caregivers. For example, very young infants look more at faces who share the race of their caregivers (Bar-Haim et al., 2006; Quinn et al., 2008). Infants seem to prefer to interact with those who speak the same language as their caregivers (Kinzler, 2021). Interestingly, while infants look longer at same-race individuals, they do not prefer to take toys from them, suggesting that their visual preference might be based more on lower-level perceptual preferences than social preferences (Bar-Haim et al., 2006; Kinzler & Spelke, 2011; Quinn et al., 2008). In contrast to race, but agreeing with the results about language, 5-month-old infants preferentially look toward someone who had previously sung a familiar song (Soley & Sebastián-Gallés, 2015). (In this US American sample, this was 'Twinkle Twinkle Little Star'; they used parental report to confirm the infants had heard the song before). Eleven-month-old infants also prefer people who sing a familiar song that had only recently become familiar because their parents are assigned to sing it to them, but not when their parents were assigned to play the song from a toy. This is true even after several weeks of not hearing their parents sing the song (Mehr & Spelke, 2018). Because language and music are learned over social interactions, it may be a good cue of a person's history of social interactions (Kinzler, 2021). In line with the other studies covered earlier in the section, this body of work could reflect representations of communal sharing relationships. That is, singing the same songs or speaking the same language could be seen as evidence that individuals have made themselves more alike in the past. They could also represent representations of groups (refer to Box 3)

### Do infants think about relationship strength in communal sharing relationships?

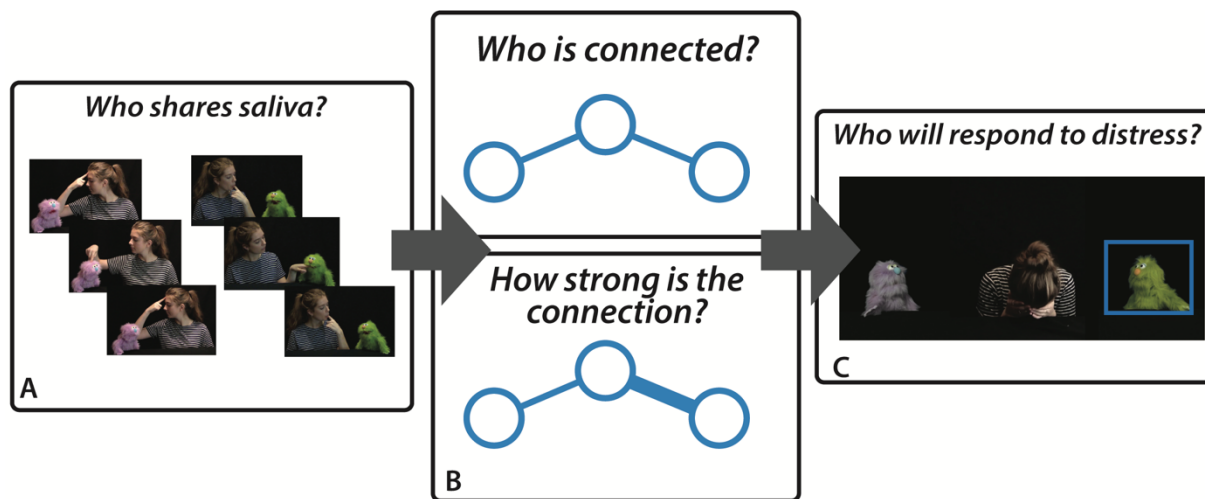
So far, I have argued that infants recognize communal sharing relationships. A series of studies suggest that infants may also recognize the strength of communal sharing relationships. Both infants (8 to 10 months old) and toddlers (16 to 18 months old) use interactions that include saliva-sharing, as opposed

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<sup>8</sup> An experiment could test this: ask whether infants still prefer puppets who make the same choice after them, when the puppet did not have perceptual access to the infants' choices.

to other cooperative interactions, to predict responses to distress (Thomas, Woo, et al., 2022). Across many cultures actions that require sharing bodily fluids through actions like kissing, drinking from the same cup, etc., are distinctively found in, and expected to be in, especially strong communal sharing relationships (e.g., Fiske, 2004; Hung et al., 2022; Miller et al., 1998; refer to supplementary materials of Thomas et al. 2022) In this study, an actress and a puppet ate from the same orange slice. Then, the same puppet and a different woman passed a ball back and forth. After the puppet expressed distress, infants and toddlers looked first and longer at the food sharer, suggesting they anticipated that the orange-sharer would respond. Importantly, these expectations were not driven by inferring the traits of the characters: participants did not anticipate the orange sharer to respond to an unfamiliar individual's distress. Moreover, toddlers did not expect the orange-sharer to respond to requests for balls. This was true in a subsequent experiment that did not include food: infants saw a woman put her finger in her mouth, put her finger in a puppet's mouth, and then back in her mouth. The same woman was then shown touching her and another puppet's forehead. Here, infants and toddlers expected the puppet who had been the recipient of the 'saliva-sharing' action to respond to the woman's distress, suggesting that their inferences did not depend on sharing food and showing that they had expectations that responses would be mutual.

Why might this be evidence that infants represent the strength of communal sharing relationships? As mentioned above, in many cultures, sharing bodily fluids is found in especially strong communal sharing relationships (refer to supplementary materials of Thomas et al., 2022), while the other actions may be found in many communal sharing relationships, both weak and strong. On the other hand, it is possible that the participants categorized saliva-sharing as communal sharing but categorized the other actions as evidence of some other kind of relationship. Future studies will be needed to disambiguate whether participants see the same model with ball-passing and saliva sharing, or different strengths. These findings leave open the possibility that infants represent relationship strength.

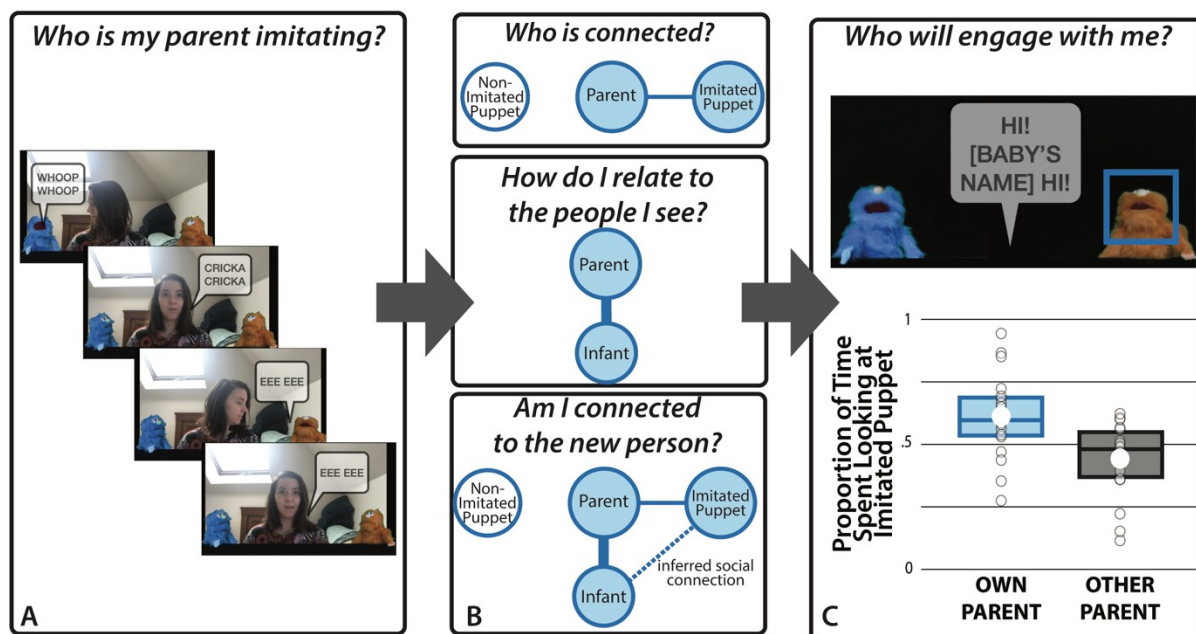


**Figure 3.** Stimuli (from experiment) and diagram of hypothesized underlying representation driving responses in Thomas et al., 2022. (A) What infants observed in the study. (B) hypothesized cognitive representation (C) What infants observed during the test trial and the prediction that they made.

Toddlers make inferences about triadic closure when observing cues of communal sharing relationships (i.e., if A and B are family, and A and C are family, then B and C are family; Spokes & Spelke, 2017 ). When 15-month-olds saw the same large character respond to the distress of two small

characters, they expected the small characters to be socially connected. They also expected two large characters who responded to the distress of the same small character to be socially connected. However, when the characters responded instead to laughter, toddlers no longer had these expectations. This suggests representations of strength: Responses to distress, unlike laughter, may be associated with stronger communal sharing relationships, and the logic of triadic closure may be especially true in networks of strong communal sharing relationships, such as in families. This idea is integral to Attachment Theory, where an infant's propensity to go to their attachment figures when distressed, but not in other situations, is a hallmark of a secure attachment (Bowlby & Ainsworth, 2013).

Do infants represent their own communal sharing relationships? In one study, infants used knowledge about their social relationships with their parents to infer whether they were socially connected to new individuals (Thomas, Saxe, et al., 2022). In this study, 12-month-old infants watched digitally edited videos of their parents interacting with two puppets. The parent showed affiliation toward one puppet by vocal imitation and had a friendly but non-imitative interaction with the other puppet by vocally responding. The question was whether the infant expected social engagement from the puppet their parent had imitated. During the test event, both puppets moved their mouths in synchrony while a friendly voice called the infant's name. Infants looked longer at the imitated puppet, suggesting they expected it to be the source of the voice. This inference was not due to attributing a friendly trait to the imitated puppet, as infants did not look more at the puppet when it appeared to have a friendly interaction with someone else off-screen. Crucially, infants' inferences were specific to interactions that involved their parents. When infants saw an unfamiliar adult (another infant's parent) interact with another set of puppets they no longer looked more at the imitated puppet. These results suggest that infants combine their knowledge of pre-existing relationships with observations of social interactions to discover new social connections. The study's details hint that infants may use cues of communal sharing relationships, such as imitation, to make these inferences. However, it remains an open question whether the strength of the infant-parent relationship was essential to their learning about new social connections.



**Figure 4.** Stimuli from experiment and diagram of hypothesized underlying representations from Thomas, Saxe, Spelke, 2022. (A) What infants observed in the study. (B) Hypothesized cognitive representation (C; Top) What infants observed during the test trial and the prediction that they made. (C; Bottom) Data from one experiment in Thomas, Saxe, Spelke 2022, infants spent more time looking



at the imitated puppet after they saw their parent's interactions (blue) but not after they saw another infant's parent's interactions (gray).

### Communal Sharing: Conclusions and Open Questions

In this section, I have argued that infants reason about observed interactions by using cues that occur in communal sharing relationships. They do this in situations they have likely not encountered before and about unfamiliar individuals, suggesting that they make predictions in these situations using abstract knowledge. The evidence here is suggestive that infants also represent the strength of communal sharing relationships. Many open questions remain.

First, many of these studies were originally interpreted as evidence that infants recognize groups. Why should we think about these studies as evidence of representations of relationships instead? In short, these studies do not provide any direct evidence that infants are generalizing beyond the interacting social partners (refer to Box 3 for a longer discussion). Second, in several of these experiments, infants may have used narrower representations of caregiver-child relationships, which are intimate and asymmetrical (refer to Thomas, Steele, Gopnik & Saxe, 2024), instead of a broader communal sharing representation. If caregiving relationships are the innate primitive it would agree with the argument in attachment theory that the quality of an infant's relationship with their caregivers acts as a model for all other relationships (M. D. Ainsworth, 1989). This is supported by findings that an infant's attachment to their parents affects their expectations about responses to distress (Biro et al., 2015; Johnson et al., 2010). Fiske argues that models can be used as a lexicon, so it is possible that caregiving relationships are those that take on both communal sharing and authority ranking depending on the context. Third, what are the computations that infants use to infer the category and strength of communal sharing relationships? For example, do infants use naïve utility calculus, where one computes costs and rewards to infer the value someone places on things (Powell, 2021)? In short, I am skeptical that this is the only computation that infants use to represent relationships as the logic does not easily apply to all of these findings. For example, saliva-sharing has a less than straightforward 'cost' (refer to Box 2). Relatedly, how should we interpret the current argument, considering the claim that humans have an innate moral core? (refer to Box 1). Moreover, it is unclear whether infants think about obligation or commitment that goes beyond the time frame of the experiments, which may be necessary components of strong relationships. Far more work could be done to address these any many other questions.

### Asymmetrical Relationships

In Relational Models Theory, asymmetrical relationships are authority ranking relationships, which occur in social hierarchies when people are ordered along a dimension (e.g., based on things such as physical size, age, skill, and military rank). In these relations, people have asymmetrical roles and often express the relation by accentuating asymmetries. For example, higher-ranking individuals are often made to appear larger (e.g., sitting on a throne, wearing a headdress, or sitting above others, such as a judge in a courtroom), brighter (e.g., wearing gold), or more important (e.g., being first or last in a procession, having a larger office).

#### Do non-human animals think about hierarchical relationships?

Many animals form dominance hierarchies, where rank is usually defined by priority access to resources, such as food, territory, and mates. Sometimes, dominance rank is established by one's ability to inflict harm, which correlates with factors such as body size or coalition size. Other times it is inherited or arises from group dynamics (refer to Tibbetts et al., 2022 review; refer to Mandalaywala, 2022 about whether prestige-based hierarchies are present in non-human primates). Many dominance hierarchies form because it is in the interest of weaker individuals to yield in conflicts that they would otherwise lose.

Therefore, in dominance hierarchies, patterns of yielding in conflicts could be reliable cues about social rank (Smith & Price, 1973; van Vugt & Tybur, 2014).

Individuals in several species reason about relative rank when they observe patterns of yielding. Experiments show fish, birds, mice, and rats use transitive inference about dominance rank to make decisions about how to interact with new individuals (Grosenick et al., 2007; Paz-Y-Miño C et al., 2004). That is, after seeing that A is lower ranked than B, and B is lower ranked than C, the animals in the experiment are more likely to approach A than C. Field studies reveal that many other species, including hyenas, lions, dolphins, horses, and several species of primates, represent the dominance ranks of conspecifics in their group, for example, using dominance rank to predict support in conflicts (Seyfarth & Cheney, 2012). Chimpanzees also seem to connect spatial position with social rank (Dahl & Adachi, 2013). Finally, bonobos seem to prefer (they reach for) dominant individuals, even after observing interactions between simple characters (shapes with googly eyes) (Krupenye & Hare, 2018). While it is unclear how other species come to recognize cues of dominance, this work leaves open the possibility that learning mechanisms that lead to representations of dominance relations are evolutionarily old and prevalent even in human infants.

### Evidence that infants are sensitive to asymmetrical relationships.

Human infants do seem to represent dominance relations, using physical size and coalition size to predict who will yield in conflicts (Thomsen, 2019). In one study, 10-month-old infants from the United States expected smaller animated characters to yield to larger ones in a conflict. In this study, two characters (rectangles with eyes) had conflicting goals of crossing a platform in opposite directions, blocking one another's pathway. Then, one of the characters lowered its body (i.e., bowed) and moved aside, allowing the other to pass (Thomsen et al., 2011). Infants looked longer when the larger individual yielded to the smaller individual, as though it violated their expectations. In another study, Canadian 6-month-old infants were shown similar animations as described above, but the characters were the same size, here they expected a character with more allies to win (Pun et al., 2016). In another study, 12- to 16-month-old Japanese infants expected those who appeared lower in space to yield in conflicts over a resource (Meng et al., 2019). Why might these studies suggest that infants have abstract, and possibly, innate representations? Infants at these ages have likely seen conflicts. However, it is unlikely that infants at this age have observed a member of a dyad and a member of a triad in a right-of-way conflict and were able to compare the two outcomes. Together, these studies suggest that before the first year of life, infants compare the relative power of individuals (i.e., infants track who defers and who is larger, stronger, or has more allies). However, these studies do not provide evidence that infants understand these interactions in terms of relationships. Their predictions are based on the relative traits (larger, higher, or more-allied) of the individuals. In other words, there isn't evidence that infants use these interactions to update their belief about whether these individuals will interact again. Rather these studies provide evidence that infants have expectations about the outcome of an interaction given the individual traits.

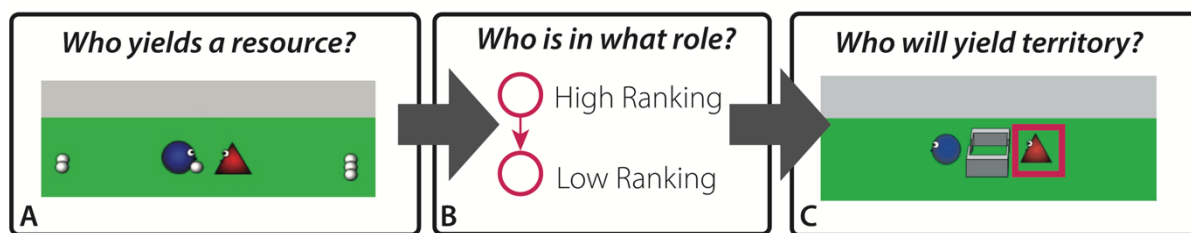
Do infants use this information to inform whom they approach, as other species do? In one study 10- to 16-month-old infants were shown the right-of-way conflict described above, but this time the two characters were equal in size. Here, infants reached for the individual who yielded (Thomas & Sarnecka, 2019). Infants' preferences in these studies did not seem to be based on preferences for helpers: infants reached for the yielder even after a 'foot race' which differed only in that the characters moved in the same direction. While there are several interpretations of why infants reach for yielders, these results provide further evidence that they recognize these conflicts as social interactions potentially relevant to themselves.

Other studies provide some evidence that infants do represent asymmetrical relationships: they expect hierarchical relations to be stable across situations. In one study, 12- and 15-month-old infants from Hungary were shown two animated characters who both wanted the same object. One of the characters yielded to the other. In a subsequent conflict over a territory, 15-month-olds and to a lesser extent, 12-month-olds, expected the same character who had ceded a resource to cede the territory. Importantly, infants in this study did not expect past winners to prevail in a conflict with a new individual,

suggesting that their expectations were not based on the traits of the individual but rather the relationships between the individuals (Bas & Sebastian-Galles, 2021; Mascaro & Csibra, 2012). At 17 months, toddlers expect rank to be related to resource distribution. When all else is equal, Italian and US American infants expect equal distribution—looking longer when an individual gets more than another (Geraci & Surian, 2011; Schmidt & Sommerville, 2011; Sommerville et al., 2013). However, 17-month-old toddlers from the US seem to expect that those who prevail in conflicts will get more resources (Enright et al., 2017).

Infants also use transitive inference to infer asymmetrical relations. Since transitive inference is useful only if there are stable relations, this provides further evidence that infants represent individuals and their asymmetric connections. For example, in forceful conflicts over a toy, 10-month-old infants from the United States use transitive inference to predict who will defer (Gazes et al., 2015). When infants first saw a cow puppet forcibly take a toy from a bear puppet, then the bear forcibly take a toy from a pig, infants looked longer when the cow puppet yielded to the pig puppet, suggesting it violated their expectations (Mascaro & Csibra, 2014). Relatedly, in another study, French 14-month-olds expected dominance relations to generalize across allies, learning ‘pyramid’ structures of dominance relations but not ‘tree’ structures (refer to Mascaro et al., 2023 for a longer discussion about why pyramid structures occur more often than tree structures).

In summary, in the first year of life, infants use cues of formidability to predict how individuals will behave in conflicts. Around the end of the first year, they seem to make sense of social interactions by representing asymmetrical relationships: using prior behavior in social interactions to predict behavior between those individuals in new and different social interactions. However, none of these studies ask whether these interactions lead infants to predict whether people will interact with one another. For example, would they expect the individual who deferred over a resource to be more likely than someone who had not been in the interaction to help the high-ranking individual? Thus, it is not clear that they are representing relationships or relations between individuals.



**Figure 5.** Stimuli used in Mascaro, 2012 and schematic (added here) of the proposed representations driving the inferences. (A) What infants observed in the study. (B) Hypothesized cognitive representation (C) What infants observed during the test trial and the prediction that they made.

### Dominance or Authority Ranking?

So far, I have reviewed evidence that young humans understand cues of dominance found in other species and that at least around the age of one, infants may recognize asymmetrical relationships. However, especially in human relationships, rank is often based on more factors than the ability to inflict

harm by being larger or by having more allies. In Relational Models Theory, authority-ranking relationships (A. P. Fiske, 1992; Henrich & Gil-White, 2001), higher-ranked individuals are expected to provide benefits, such as cultural knowledge, protection, and leadership. In these relationships, people are often made to appear larger by sitting on a throne or wearing a crown, which could be seen as ways to communicate formidability (Schubert et al., 2008). However, a person's rank does not need to be the result of true physical formidability. While the evidence so far suggests that infants recognize dominance relations, do they distinguish between dominance and other types of rank?

Some studies suggest that during the second year of life, humans begin to distinguish between legitimate authority and dominance. First, consider the finding described above where 10- to 16-month-old infants reach for a puppet who yields in a conflict. When toddlers aged 21 to 31 months (drawn from the same US American population) were presented with the same puppet show, they reached for the winner (Thomas et al., 2018). This reaching did not depend on competence: they did not reach for a winner when it won a 'foot race' instead of a face-to-face conflict. While there are several explanations for this developmental change (e.g., refer to Thomas, 2018 for a discussion), participants may have understood the conflict differently. Infants see these conflicts in terms of dominance and toddlers see them in terms of authority or prestige. If so, the change in representation could be the result of a better ability to represent motivations. In support of this view, toddlers no longer reach for the winner when the winner uses coercive force to win.

Seventeen-month-old toddlers also expect leaders to provide benefits: they expect that a puppet whose directions were previously followed will be the one to intervene in conflicts and punish those who did anti-social actions (Stavans & Baillargeon, 2019). US American and Italian toddlers form different expectations about future interactions, depending on the way that a high-ranking individual treats subordinates. Twenty-one-month-old toddlers saw one of two scenes. In the leader scene, a high-ranking character directed low-ranking characters, in the bully scene, the high-ranking character enforced its demands by hitting the subordinates on the head. When the leaders were absent, toddlers expected the subordinates to follow the requests of the leader to go to bed, but not the bully (Margoni et al., 2018). However, when the bully was present, toddlers expected the subordinates to obey. Interestingly, this study hints at inferences about the strength of an authority ranking relationship—the subordinates follow the leader's requests in the leader's absence, and thus seem to feel obligated or committed to the leader across time.

## **Asymmetrical Relationships: Conclusions**

To sum up, these studies show that infants recognize many cues of asymmetrical relationships. One interesting question, like those raised in the previous sections, is whether toddlers form a general representation of asymmetrical relationships or a more specific representation of caregiving relationships. The 21-month-olds who reach for 'winners' or distinguish leaders and bullies, may have seen the high-ranking individuals as caregivers. In one study, the leader requested that the subordinates 'go to bed', something that the 21-month-old toddlers likely had experienced repeatedly from their caregivers.

Another interesting question is the extent to which dominance relations can be thought of as relationships at all. Certainly, in some contexts, dominance need not be based on relationships (i.e., dominance can occur without any expectation of future interaction). For example, one person could defer to another person because they could inflict harm, without ever expecting to interact with them again. In the case of infants observing large and small characters in conflicts, their predictions can only be the result of comparing physical attributes. It is unclear whether observing the conflict and yielding leads them to form a representation of the individuals and their connection, which would lead to expectations of future interactions. Moreover, while dominance can be communicated by showing a 'commitment' to violence, for example, showing one's teeth or using threats, predicting behavior in these scenarios does not require a representation of commitment to the relationship itself. On the other hand, dominance can play a role in long-lasting relationships. However, an open question is whether people in the relationship think about their relationship in terms of dominance or are less likely to represent dominance in long-lasting or strong

relationships. In many cases high-ranking individuals might feel the need to express their power but often argue that they are doing so to keep order or protect subordinates (refer to A. P. Fiske & Rai, 2014 for several examples). By contrast, while roles and power are asymmetrical in legitimate authority relationships, lower-ranked individuals may usually expect benefits in these relationships, such as knowledge, protection, care, etc.<sup>9</sup> Thus, people may feel loyalty or allegiance more strongly when they see a high-ranking person as a legitimate authority.

It is worth pointing out that the distinction between legitimate authority, prestige, and dominance is not always cleanly disambiguated in relationships. Relationships are dominance relationships if the person yielding is acting to avoid harm and are legitimate if the person yielding sees the higher-ranking person as protective or just. Therefore, when humans evaluate asymmetrical relationships to be one or the other, we depend on inferences about the minds of those involved. This supports the idea that the early developing representation of asymmetry may be ambiguous regarding whether it is categorized as dominance or legitimate authority/prestige. Instead, the initial representation is more likely based on asymmetries that are easy to observe, such as physical size, patterns in yielding, etc., and subsequently may support learning of the different ways people can think about their asymmetric relationships. On the other hand, intentionality may matter to early representations of asymmetrical relationships. For example, if someone is physically larger but goes out of their way to make themselves seem smaller, who would infants or toddlers think is higher ranked? Moreover, the computation of strength and the understanding of loyalty or allegiance may only occur once children come to know that people can be ranked based on the benefits they provide. Future studies could investigate these questions as well as whether young humans recognize strength of asymmetrical relationships.

## **Equality Matching**

In Relational Models Theory, an equality matching relationship is symmetrical and occurs when people keep track of what they give or receive and are motivated to maintain an even balance. Equality matching relationships can be out of balance, but people are aware of the imbalance and are motivated to return the relationship to balance. Examples of stronger equality matching relationships would be people in a long-term business relationship or neighbors who have been doing favors for one another for many years. Examples of weak equality matching relations include children taking turns at the playground and people waiting in a queue for coffee.

## **Evidence of Equality Matching in Non-Human Species**

Some behaviors in non-human species indicate that there might be phylogenetic precursors to the logic underlying these relationships. Vampire bats share more of their blood meal with bats who have shared with them in the past (Denault & McFarlane, 1995). There is reciprocal grooming among bonded females of white-faced capuchins, chacma baboons, and bonnet macaques (Manson et al., 2004; Muroyama, 1991; Perry et al., 2003; Ventura et al., 2006). Experiments also show that captive brown capuchins may use the logic of reciprocity: previous sharing predicts whether food-taking is tolerated (de Waal, 2000). While it is unclear how these behaviors arise, it leaves open the possibility that this logic is evolutionarily old.

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<sup>9</sup> If the hypothesis about stronger relationships being less replaceable is correct (i.e., that stronger relationships, regardless of the model, means that people are less interchangeable), then it should also apply here. The stronger a legitimate authority relationship is, the less interchangeable the high-ranking individual should be. In strong authority ranking relationships, people may mourn if a leader gets replaced by a new one, and feel that relationship will change if they do. By contrast, if an interaction or relation is based strictly on dominance, then the higher ranking person should be highly interchangeable with other individuals in as much as their level of formidability is the same.



## Evidence that infants are sensitive to cues of equality matching.

Do infants represent equality matching relationships? I will first review studies about infants' expectations about resource distribution, though of course, each relational model can be applied to situations in which resources are shared or distributed. US American and Italian infants expect that resources will be distributed equally when they are given no prior information about the relationship between the interactants. For example, at 19 months, 9 months, and 4 months, infants expect people to divide two resources equally rather than unequally between two animated puppets or characters (Buyukozer Dawkins et al., 2019; Sloane et al., 2012; Surian & Margoni, 2020; Ziv & Sommerville, 2017). Importantly, across these studies, these expectations depend on the recipients being agents as opposed to inanimate objects.

By 16 months, infants also seem to prefer those who distribute equally. They reach more often for a photo of a puppet who had distributed resources equally than for a photo of a distributor who had given all the resources to one of two characters (Geraci & Surian, 2011). Moreover, 16-month-olds expect a puppet who observes uneven versus even distributions to approach the even distributor. Likewise, 13- and 16-month-old infants choose to accept a toy offered by a person who allocated equally to two others as opposed to a person who allocated unequally (Lucca et al., 2018). By 25 months, toddlers are more likely to help a person who has distributed resources equally to two agents than a person who distributed resources unequally (Surian & Franchin, 2017). Each of these studies indicates an expectation or positive judgment of equal distribution. That is, given *no information about relationships*, infants seem to expect that two individuals will be given the same amount. But do these studies shed light on how representations of equality-matching relationships? While they do provide evidence that infants have early expectations about resource distribution, they do not tell us whether seeing equal resource distribution prompts infants to predict future interactions. Rather infants seem to infer traits of the distributor. (Mascaro et al., 2023) By contrast, an equality-matching relationships should be marked by even balance over time and across contexts between individuals.

Other studies suggest that infants have the cognitive tools to recognize these relationships. There are two studies in which toddlers use interactions in one situation to make predictions about interactions in another situation. In one study, 21-month-old toddlers were shown two characters who were asked to clean up toys (Sloane et al., 2012). When both characters helped, they expected equal distributions, but when one helped, they expected the more helpful character to get more. However, this study does not directly test the relationship between the recipients of the resources, since the requester/distributor is a third party.

In another study with 17-month-olds, they saw that one character worked harder on a task, and then the characters distributed resources to themselves (Wang & Henderson, 2018). Here infants expected the one who worked harder to get more. Thus, toddlers tracked the extent of equality in one context (working) to make predictions in another context (resource distribution), suggesting that they may have inferred a relationship.

Denis Tatone and colleagues have more directly tested whether infants have the cognitive tools to represent equality matching relationships. They reasoned that infants should have different expectations about giving actions, where someone intentionally gives objects, as opposed to 'tolerated' taking, where someone still loses an object, but the intentions of the interactants are more ambiguous. In a series of studies, this was shown to be true. Here, Hungarian 12-month-old infants were shown interactions in which one character either gave an object to another character or took an object away from another character. The question was, would infants be more likely to encode the identities of the actor and the receiver when the actor gave compared to when the actor took? After watching giving interactions, infants seemed to expect that the 'giver' would continue to give to their social partner: they looked longer when the giver took something from, as opposed to when they gave something to, the original recipient (Tatone et al., 2015). Moreover, infants did not seem to encode the interactions by representing traits (e.g., 'generous') because they did not expect the giver to give to an individual who had not previously been in the interactions. The pattern of results was different after seeing that an actor took an object. Infants were

not surprised when that actor then gave to the recipient. Likewise, infants keep track of the objects that are given to someone else but not those that are taken (Tatone et al., 2021). Together, these studies suggest that infants pay special attention to giving actions. They encode what object was given, suggesting that they can keep track of equality<sup>10</sup>. But they also track the identities of the interactants and the direction of these actions, suggesting they could encode the relationship. Since equality matching relationships require tracking equality, these are necessary components to recognizing these types of relationships. But do infants expect that the balances will be evened out?

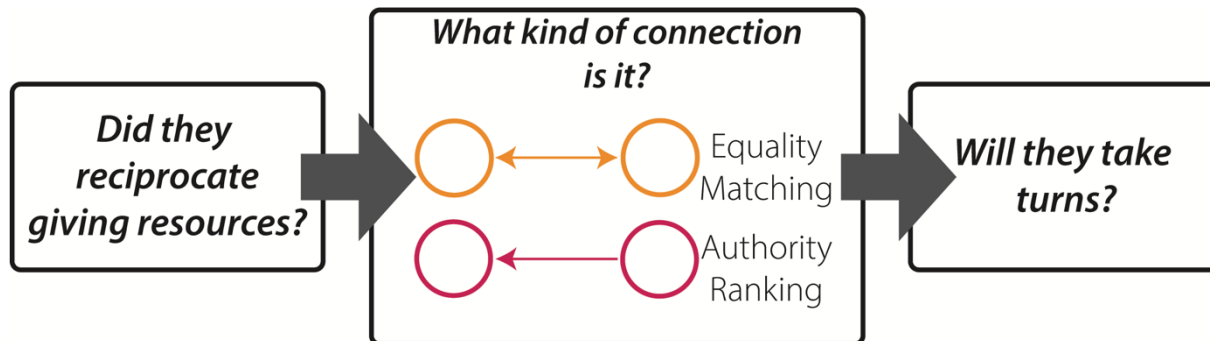
In another set of studies, infants not only encoded these aspects of the interaction but also expected reciprocation of giving actions. For example, in one study, they saw one character (A) give an object to another (B). Then, they saw a third character (C) take an object from B. They then expected B to give to A, as opposed to give to C. They also expected B to give to A, compared to B taking from A (Tatone, 2017; Tatone & Csibra, 2020)<sup>11</sup>. Further studies suggest that infants distinguish between characters who are given an item, as opposed to when those characters engage in ‘tolerated taking’ (i.e., take an item without protest from the other character). In both actions, a character ends up with one more resource, but infants seem to see the interactions in different ways. When infants observe giving actions, they encode the direction of giving and receiving. However, when they observe tolerated taking, they encode neither. Tatone and Csibra argue that tolerated taking is more diagnostic of communal sharing relationships, in which are mutual, not symmetric and in which people do not track the direction or value of shared resources. Similarly, forceful taking should be more diagnostic of authority ranking, where one needs to track the direction but not necessarily the value of the object (since it will not be repaid). Equality matching is different—the interactants must keep track of the direction of giving and the object that is transferred, since part of the relationship is keeping an even balance (refer to Tatone, 2017, 2020; and footnote for a longer discussion).

Taken together, these studies provide evidence that infants encode the necessary parts of social interactions that would enable them to represent equality matching relationships. They have at least rudimentary expectations of even balance. Importantly, these expectations are not the result of infants inferring traits of individuals, as they do not expect individuals to perform the same actions toward individuals not involved in the interaction. However, future studies could more directly test whether infants represent equality matching relationships, in which equality matching is maintained over time and across contexts. For example, one could ask whether infants expect even balance in one situation (e.g., giving resources) to generalize to even balance in another situation (e.g., taking turns). Moreover, that they expect that two individuals who maintain even balance will be more likely to interact with one another than those who had not previously interacted or interacted in a different way.

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<sup>10</sup> It is an open question whether they can track ‘value’, though work on naïve utility calculus suggests they may be able to (Liu et al., 2017).

<sup>11</sup> Note: Tatone & Csibra, 2020 argue that different types of exchange may cue different types of relationships. Specifically, tolerated taking should cue communal sharing relations, and the direction of resource transfer need not be represented; priority access and forceful taking should cue authority ranking relationships, and the direction of resource transfer needs to be represented; and giving should cue equality matching, and the direction of resource transfer needs to be represented.



**Figure 6.** Logic of a possible study asking whether infants recognize equality matching relationships and use this representation to predict future interactions.

Do infants compute strength for equality matching relations? So far, there is no evidence that this is the case. For equality matching relations, trust may be the important dimension: the larger the imbalance is allowed, the stronger an equality matching relation might be. For example, if I do many favors in a row for you and we are in an equality matching relationship, it could signal that I trust you will eventually ‘repay’ the debt. In many cultures, it is customary to give gifts whose value cannot be directly computed. This allows a sort of never-ending chain of gift-giving in which the debt can never be perfectly evened out (Carmichael & MacLeod, 1997; Graeber, 2012; Mauss, 1925; Fiske personal correspondence). Future studies could ask whether young humans make different inferences depending on the size of the inequality allowed in repeated interactions, which would imply that they are computing something about the size of the imbalance in an equality matching relation.

## Conclusions

Humans depend on social relationships throughout our lives. It is in the context of social relationships that almost all learning, language, and cultural innovation occurs. Relationships are what people spend the most time thinking about and what people most often point to when asked what makes their lives meaningful. Given the centrality of relationships to our survival and well-being, as well as the evidence that strength and models seem to matter in relationships cross-culturally and in other species, human infants may be prepared to reason about them, especially since unlike most other species, our survival from birth depends on a social network beyond our primary caregivers (Hrdy, 2009; Hrdy & Burkart, 2020). This early dependence on multiple relationships may have led to evolved capacities to recognize relationships, including the commitment of others, how others relate to one another and the infant themselves, and how new relationships form. The empirical work reviewed in this paper supports the claim that infants not only track relationships but also the characteristics of those relationships.

There are several caveats to consider. First, the study of infant representations of social relationships in cognitive development is relatively new. In other domains there are more comparative

studies, brain imaging studies, and computational models that provide convergent evidence and better descriptions of their computational frameworks. Second, these results may be biased due to the culturally homogenous sample. Many questions remain about how early representations change because of culturally specific experiences.

A related question is, how infants learn about their place in their social networks. The question of how humans begin to understand themselves in relation to the world has been studied in the domain of navigation (refer to Spelke 2022 and Newcombe, 2019) suggesting that infants are able to understand themselves in relation to other things. I reviewed one study that touches on egocentric representations of relationships and there is a complementary study with 3 and 4 year olds which suggest they understand network connections –knowing for example that if a stranger knows the participant’s favorite food, it is likely the stranger learned it from speaking to the participant’s parent (Chuey et al., 2023). However, it is unclear the extent to which infants think about themselves in relationships and as part of their social world. Future work could investigate this.

Related to the question of learning is the extent to which people, including infants, think about relational models as either highly context-specific and variable within single relationships, or constrained and inflexible. Adults, for example, can see the same person as relating to them in different ways. For example, someone could be your boss at work and your teammate in a rec-basketball league. If relationships are highly context-specific from the start, then it would present an even more difficult learning problem. Fiske proposes that a single relationship can take on any of these models depending on the context. If so, how do people know which one to use and how would young infants learn cues? Being too flexible within single relationships would mean that the representations lose their predictive power which would add to the learning problem for infants and young children. One solution is that people may compute probabilities for each model (e.g., A relationship with a colleague could be a 3/10 on authority ranking, 9/10 on equality matching, and 1/10 on communal sharing). These probabilities could act as priors on acceptable or expected behaviors, used in combination with other contextual cues. This may also lead to learning new categories (which often have names, suggesting they are not core knowledge, which should be common to all Spelke, 2022). Take for example spousal relationships in the United States today. They often take on the form of strong communal sharing relationships. While divorce is possible, people explicitly commit to one another for life. Moreover, people do not usually keep track of equality: just because one person gives the other a bouquet of roses does not necessarily mean that their partner “owes” them a box of chocolates. However, they can easily take on an equality matching model in some contexts: reminding your spouse that it is “their turn to do the dishes.” In diary studies, adults are more likely to mix up proper names of people with whom they have the same type of relationship (A. P. Fiske et al., 1991) and more so than people that they know who have the same characteristics such as gender, or race. This suggests that people represent governing relationship types for specific relationships. However, more work could be done on this front.

A related hypothesis is that people can view social interactions as occurring within frames. The linguist Ray Jackendoff, for example, describes bargaining as a competitive relationship (i.e., people are trying to get as much as they can from the interaction) that is framed in a cooperative one (i.e., acting as if they care about the other’s well-being). It is possible that, for example, in some cases when a parent punishes their child, even though they take on the logic of an authority ranking relationship (in which the child should listen to the parent because of their rank), it is framed within a deeper understanding that the parent and child are in a communal sharing relationship (that the parent is ultimately demanding obedience because they feel that any harm that may come to the child would be akin to harm coming to the parent (Jackendoff, 2009).

Another hypothesis is that infants may be less flexible than adults about which model a relationship can take on. At first glance, this contrasts with the relationship that they likely have the *most* experience with parent-child relationships. In the current US, these relationships often take on both authority ranking and communal sharing models. However, it is unclear how infants and young children see parent-child relationships and their role in them. For example, US American children only weakly expect preferential sharing between family members, as opposed to other prosocial relationships, and were

just as likely to say that a child would preferentially share resources with their parent as they were to say that a parent would preferentially share a resource with a child (Thomas et al., 2023). It is an open question how infants see caregiving relationships (Thomas et al., 2025). Our lab has preliminary evidence that expectations about caregiving are weak in younger infants (C. Steele et al., 2024) but robust in toddlers around the age of 15 months. Fiske proposes these models are a lexicon, thus this developmental change may be due to constraints in combining them. The current state of the data leaves open several possibilities for how infants think about caregivers—both their own caregivers and a caregiver concept—and how this relates to relational models.

Likewise, rather than categorizing relationships into distinct models, we may understand relationships along two dimensions, which map onto relative rank and affiliation (e.g., (Leary, 2004; Wiggins, 1979), or warmth and competence (S. T. Fiske, 2018). Rank (or competence evaluations) would tell us whether we are higher, lower, or have equal status with someone, and affiliation (or warmth) would tell us whether we have the same goals.

Many open questions remain about how these representations change over development. Young humans learn an immense amount about how relationships are expressed in their cultures and countless studies show that older children have rich intuitive theories about relationships (Afshordi & Liberman, 2020; Astuti et al., 2004; Bedrov et al., 2021; Chernyak et al., 2019; Enright et al., 2020; Liberman & Shaw, 2017, 2018, 2019; Mandalaywala et al., 2020; Marshall et al., 2022; Olson & Spelke, 2008; Shaw et al., 2012; Spokes & Spelke, 2016; Thomas, Hernandez, et al., 2022; Woo et al., 2024). As discussed in the introduction, a key developmental change is likely the extent to which mental state reasoning is incorporated into our understanding of relationships. While adults likely use mental state reasoning in representing relationships, it may be relatively rare. We may be more likely to consider others' mental states when explicitly thinking about trying to change or maintain relationships (e.g., 'Did I offend my boss?'; 'How can I show I want to be colleagues instead of the boss?'). Likewise, the assumption that others share ideas about relationships is likely later developing given constraints in infants' ability to represent the minds of two people at once (Southgate, 2020). In general, it is an open question how much one needs naïve psychology to reason about relationships, especially since other species have apparent limitations in mental state reasoning but seem to represent relationships. Reasoning about intentions, beliefs, and desires may be crucial in making sense of social actions and relationships, but we may only invoke these computationally costly representations when needed (refer to Malik & Isik, 2023 for discussion and Box 2). A related question is how we use other domains to reason about relationships including biology (e.g., (C. M. Steele & Thomas, n.d.) and the physical world.

Even considering these caveats, the evidence I have presented points strongly toward the possibility that from birth, humans are prepared not only to reason about the physical world or the minds of individuals, but we are also prepared to reason about relationships. We do so in ways that suggest we categorize relationships into models and compute their strengths. Future work could uncover the exact nature of the computations underlying these representations and how they may change throughout infancy, childhood, and adolescence.

## **Box 1: Innate Moral Core or Innate Representations of Relationships?**

How should we reconcile the claims I have made in this paper with the claim that infants have an 'innate moral core' (Woo et al., 2022)? This claim is supported by studies which have found that infants preferentially look toward and physically reach for helpers over hinderers, imitators over non-imitators, and those who distribute equally over those who do not (Hamlin, 2013; Woo et al., 2022). Arguments for an innate moral core implies that infants infer traits of the individuals (i.e., using the logic of, 'if they are nice to them, they will be nice to me'). But what traits do infants prefer? One way to interpret these findings is that infants reach for those who initiate or maintain prosocial relationships. Infants prefer those who help—which could be seen as one way to begin a communal sharing relation or an equality matching one; those who imitate, which could be interpreted similarly; those who distribute resources equally,



which could be seen as establishing an equality matching relationship; and those who defer in a conflict, which could be seen as an individual who is establishing an asymmetrical relationship.

Consider that infants prefer imitators. As discussed previously, at least 12-month-old infants seem to see imitation as evidence of relationships. We had replicated the finding that 12-month-olds reach for imitators over non-imitators and unexpectedly found that infants reach for those who are *not* imitated over those who had been (Thomas et al., 2020). Given this asymmetry in preferences and the asymmetry in expectations of 4-month-olds (remember, 4-month-olds expect imitators to approach the target of their imitation but do not expect the target of imitation to approach those who imitate them), we investigated whether older infants' expectations matched their reaching preferences.

First, we found that infants expected imitators to respond to their social partner's distress, as opposed to those who did not imitate. However, these expectations could be the result of either an inferred trait (the puppet who imitated is more responsive) or a relationship (the puppet imitated that individual and so will respond to that individual's distress). To disambiguate these possibilities, in the next experiment, rather than showing an imitating puppet and a non-imitating puppet, we showed infants a scene in which one puppet was imitated by the central actor and one was not. Being imitated does not give direct evidence of one's traits (one could be imitated without knowing it). To our surprise, infants also expected that the imitated puppet would respond to their partners' distress. In a third study, we found that infants did not have these expectations when a person uninvolved in the original interactions was in distress, suggesting that they did not infer traits. Finally, we found that infants do not expect imitative partners to respond to laughter, again suggesting they do not see imitation as a cue of who is more responsive, even toward their social partner. Taken together, these results present a puzzle: why do infants reach for imitators if they do not expect them to be more responsive to everyone? While infants may not expect the puppet to respond to all people's distress, they may still expect the puppet who imitates another individual to be more willing to create relationships. This would also explain the preference for non-imitated puppets, as the social initiation was not done by the imitated puppet and the non-imitated puppet is more socially available.

Admittedly, it is unclear why infants would prefer those who initiate relationships without inferring some sort of prosocial trait. These people might be seen as 'friendly', 'helpful', etc. If so, then it is unclear why infants seemingly generalize to themselves but not others. Another possibility is that infants generalize prosocial behavior toward themselves because of the way that experiments are set up. In many experiments, the people and puppets direct their attention toward the infant to keep their attention. Infants therefore may feel they are part of the social interaction. Their evaluations may, therefore, depend on these signs of awareness. There are two exceptions—one is in the hill paradigm in which the puppet's eyes are directed up the hill (Hamlin, 2014; Scarf et al., 2012). In this paradigm, however, the puppet may still appear to be looking at the infant, since both eyes are present (of note, reaching preferences of 6 month olds was not replicated in a multi-lab replication attempt; Lucca & Henderson, 2021). The other exception is in the right-of-way conflicts, in which infants reach for those who defer in a conflict. Here the puppets' faces appear to be looking away from the infant and toward its goal. While these two experiments raise questions about this proposal, it may be worth testing empirically. If so, some of the experiments reviewed in this paper only rule out broad generalizations. Of note, there are studies that suggest toddlers do generalize from a prosocial behavior in one context to a prosocial behavior in another context with new targets (Gill & Sommerville, 2023; Surian et al., 2018). For example, 14- to 27-month-old toddlers expect that a helper, but not a hinderer will distribute resources fairly to two new individuals. They also expect that someone who distributes things unfairly will hinder. Thus, it is possible that the ability to infer traits (which seems to be driven by tracking antisocial behavior) happens sometimes during toddlerhood or that different actions lead to different generalizations.

## **Box 2: Naïve Utility Calculus and Representing Relationships**

Are relationships most basically understood in terms of shared or adopted utility (Powell, 2021; Tatone, 2017)? In a recent proposal, Powell argues that representations of affiliation compute whether

people adopt the utility of others. This can happen when someone helps another person (i.e., takes on a cost so that another person can achieve their goal) or imitates another person (i.e., takes on a cost to achieve the same goal as someone else). One straightforward connection to the current proposal is that relationship strength is computed by adopted utility (Powell does not make this claim). While the connection between strength and utility is appealing, some examples call the connection into question. First, humans, including toddlers (Wameken & Tomasello, 2006; though see Barragan & Dweck, 2014) are happy to adopt the utility of strangers. These toddlers' expectations of future interactions is unknown, however adults help people whom we never expect to see again (e.g., helping a stranger pull their car out of a ditch). Young adults report taking on similar costs for strangers, acquaintances, and close relations (McGuire, 1994). Perhaps one way of reconciling this tension is that as adult observers, if we find out that a person adopts the utility of a stranger, then we shift our inference to be about traits instead of relationships (i.e., a parent who donates their kidney to their child is a good parent, but a person who donates their kidney to a stranger is a good person). The extent to which infants adjust their evaluations of prosocial behaviors based on different types of evidence could be tested.

We also fail to adopt the utility of even our closest relations. Take a parent who fails to adopt the utility of their toddler who wants another bowl of ice cream or a parent who fails to adopt the utility of an infant who reaches for a hot cup of coffee. An adult observer would assume that the parent's long-term goal is to increase the utility of the younger human. For example, the parent wants to help their child make healthy eating choices or avoid a burn. But do toddler or infants understand this? If not, it would lead to the uneasy hypothesis that infants and children do not see themselves in a strong relationship with their caregivers. Of course, infants and children are excellent statistical learners (Saffran, 2020), so it could be that unhelpful behavior from parents are overpowered by more helpful behavior. As a parent, I find this hypothesis to be less than straightforward, but it is an empirical question.<sup>12</sup> Interestingly, children do not seem to expect more altruism between family members than between friends. When asked whether someone will share with either a family member or friend, children do not expect that others will preferentially share with or help family members compared to other affiliates (Marshall et al., 2022; Spokes & Spelke, 2016; Thomas et al., 2023; Thomas, Woo, et al., 2022).

Perhaps a better candidate to infer relationship strength could be intimacy, such as physical or emotional intimacy (refer to Steele & Thomas; Thomas, Steele, Gopnik, Saxe for longer arguments). These cues may have become valid because of the costs and benefits associated with sharing bodily fluids and close physical contact. However, I think it is unlikely that infants recognize this. Disgust, especially social disgust, seems to develop relatively late (Rottman, 2014), suggesting young humans don't recognize overcoming 'disgust' as a cost. Infants differentiate actions that are difficult to distinguish based on utility alone (saliva-sharing vs. forehead touching, for example). Likewise, adults may see responses to distress costly because of emotional vulnerability, but it seems unlikely that infants see it this way. Ultimately these are open questions. To sum up, it seems that adopted utility could be one way we compute strength, but perhaps not the only way and it is unclear whether utility computations occur in all representations of relationships.

Can adopted utility calculus be used in the computations that allow us to recognize models? One can describe the models in terms of adopted utility: a communal sharing relation is one where we adopt each other's utility, an asymmetrical relationship is one where utility is adopted for one person but not the other, and a reciprocal or equality matching relationship is one where we adopt each other's utility exactly (this is not Powell's proposal but refer to Tatone 2017).

However, some examples also call this description into question. Another proposal is that the communication of utility is more important. A distinctive feature of communal sharing relations is that individuals do not keep track of relative costs and rewards. People's skills, resources, and 'rewards' are pooled, and people don't communicate about how much people are contributing or how much people are

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<sup>12</sup> A potentially impossible one to answer since it depends on the reasoning of the babies. What counts as helpful? What counts as harmful? How do we know how infants/toddlers are interpreting the actions in their everyday environment?

taking. In fact, in some situations, when people keep careful track in what ‘should be’ a communal sharing relation, it can seem cold or even evidence that the relationship is not a communal sharing one. For example, in the novel *The Joy Luck Club*, a married couple tries to keep everything strictly equal, and the implication is that they are not intimate.

Second, in asymmetrical relationships, it is not whether one person adopts the other’s utility that is the key distinction. At least with adults, helping itself can be interpreted as communicating both high and low status (Nadler & Chernyak-Hai, 2014). Subordinates often adopt the utility of leaders, but ‘mansplaining’ is critiqued because it implies that the man thinks they are higher status than the target of this explaining. Perhaps a better indicator is who decides whose utility is adopted. For example, take an academic mentor and mentee—both parties adopt the utility of one another in different circumstances. The mentee does not expect to get the largest office and so ‘takes a cost’ for their mentor. However, the mentor is expected to adopt the utility of the mentee in providing guidance. However, the mentor could probably give up their office and could decide guidance would do more harm than good with no penalty.

In equality matching relationships, a key marker is symmetry which requires that people keep track of whose utility is being adopted and communicate about imbalance. This is apparent when someone buys a coffee during one meeting and the other insists it is their turn to buy during their next meeting. There is an agreement, often explicit, that the utilities of both parties will be adopted at equal rates. Likewise in groups where voting occurs, the utility is matched in a way: each person has the same amount of influence. However, the utility can end up being asymmetrical in which some people’s goals are adopted. Yet, this wouldn’t necessarily change the relationship to be asymmetrical.

To sum up, it is possible, and perhaps likely, that the logic of naïve utility calculus plays a role in our representations of relationships in some contexts. However, it is less than clear that such computations could cover all relationship representations. An open question is what computational framework could.

### **Box 3. Groups and Relationships**

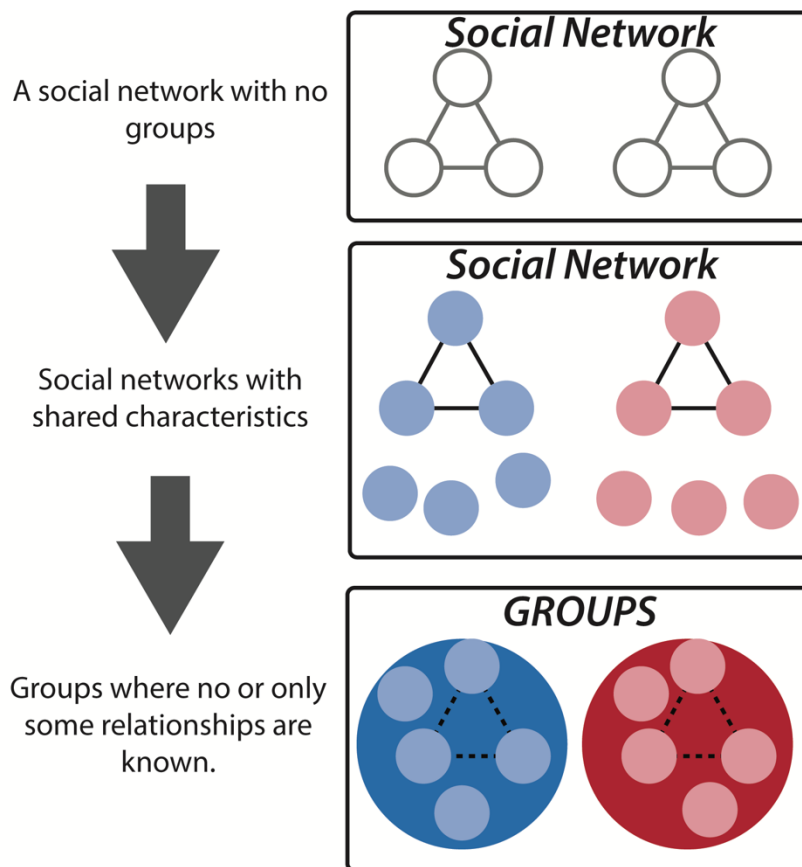
In this paper, I have argued that there are related but distinct representations of traits, relationships, and groups, each leading to different generalizations. Representations of relationships are constrained to the individuals involved, while representations of groups allow for generalizations beyond the individuals. Much of the work used to argue that infants represent communal sharing relationships was originally taken as evidence that they represent ingroups (Powell & Spelke, 2013; Spelke & Kinzler, 2007). This work was inspired by decades of research in social psychology showing that people and young children are prone to thinking about others in terms of ingroups and outgroups (refer to Dunham, 2018; S. T. Fiske, 2018; Shutts & Kalish, 2021; Tomasello, 2020). Indeed, the term ‘folk sociology’ was coined to argue that humans, including young children, are prone to thinking about aggregates of people (L. Hirschfeld, 2005).

However, in the work with infants that I review, there is little direct evidence that infants represent groups. Infants see two or three individuals in the same physical space doing something that makes them more alike. Then, infants’ expectations about those same individuals are tested. There is no evidence that infants generalize beyond the individuals in the scenes. While these studies leave open the possibility that infants’ expectations are based on representing groups, it is just as likely that they make predictions based on inferred relationships. Take, for example, (Powell & Spelke, 2013): in this study, three individuals coordinate their actions. We don’t know whether infants see the three individuals as an aggregate or whether they see three relationships. Would infants expect affiliation when they get evidence that people speak the same language but not during their social interaction? Furthermore, would infants expect people who are part of an aggregate will speak the same language?

There are reasons to think that infants’ ecological niche has led infants to represent relationships and social networks, as opposed to groups. Throughout our evolutionary history, care has mostly come from ‘mothers and others’ – that is, your primary caregivers and those with whom they have relationships (refer to Hrdy 2009). While it is true that these ‘others’ are also usually part of your

mother's group, there are many people in the group who do not provide care. Therefore, it may be more important for infants to track individuals and their relationships. As discussed in the introduction, human infants, as well as other animals track individuals, a prerequisite in tracking relationships, but not necessarily a prerequisite in tracking group membership.

Thinking about larger coalitional groups may become important as children are exposed to more people in and outside of their social networks. There are several studies with older children in which they do seem to represent groups. They are sensitive to the 'minimal group effect' in which they generalize based on arbitrary cues (Baron & Banaji, 2006; Chalik & Dunham, 2020; Dunham et al., 2011; Tajfel, 1982; Yang & Dunham, 2019). Importantly, these expectations and biases occur without direct evidence of interpersonal relationships (Chalik & Rhodes, 2020; Yang & Dunham, 2019) suggesting that children represent groups as I have defined them. Representations of groups may arise from 'scaling up' from representations of relationships, but this process of scaling up would involve generalizations beyond the direct observation of behavior of or between individuals (refer to figure 7). We may start by mapping out individuals and social networks, and over time, we notice or are told that certain shared characteristics help delineate these networks. This would be similar to the hierarchical learning theorized to be important to early learning in other domains (Ullman & Tenenbaum, 2020).



**Figure 7.** Here I illustrate what I mean when I propose that groups inferences may arise from making inferences about interpersonal relationships. One could map out relationships and networks, learn 'borders' of social networks, then learn (through explicit or implicit teaching) that characteristics delineate networks, including how people interact within and across networks (refer to Pietraszewski, 2021 and accompanying commentary as well as Cikara, 2021 for more detailed proposals about how

that may happen.) More people could be added to the network until you are no longer representing nodes and lines but instead an aggregate with fuzzy borders.

Exactly what leads people to infer group membership, and what kinds of predictions follow and when, is not a trivial question<sup>13</sup> (Cikara, 2021; L. A. Hirschfeld, 2001; Pietraszewski, 2021). I add to the problem by proposing that people's representation of social groups includes more than group membership; they also represent the social structure of groups and the relative strength of those groups (Lickel et al., 2006). Children recognize group structure and use these structures to generalize about the behavior of group members without any direct evidence of their interpersonal relationships or the behavior of individuals (Thomas, Mitchell, et al., 2022). People may also think about relationships between groups, such as some groups being higher ranked than others (refer to work on social dominance theory and system justification theory (Jost et al., 2004; Pratto et al., 2006), as well as evidence that children connect identity and status e.g., Mandalaywala et al., 2018) or some groups being more likely to work together while others are more likely to be in conflict (refer work on coalitional psychology; Cikara 2021; Gershman & Cikara, 2020). People, including children, see aggregates as though they are entities with single intentionality (Bloom & Veres, 1999; Sheikh & Hirschfeld, 2019), suggesting that we may call on our intuitive theory of relationships when considering relations between aggregates.

#### **Box 4: Navigation, Space, and Social Relationships**

Many scholars have invoked the metaphor of navigation when discussing how we reason about social relationships (Banaji & Gelman, 2013). Considering recent research into the hippocampus (Montagrin et al., 2018; Tavares et al., 2015) as well as theories from linguistics (Jackendoff, 2009), this may be appropriate. Our reasoning about navigation allows us to represent where we are, where we can go and gives us an anchor for memories (Spelke, 2022). When I think about my hometown, I don't think of 'a small town in the central, south part of the west coast' I think about 'Ojai'. Likewise, when I reason about my daughter, I don't reason about a small child with blond hair, blue eyes, and an impish smile, I think 'Ursula' (Spelke, personal correspondence). There may be overlaps in the way we reason about nodes as locations in space and nodes as locations in social networks. First, in many languages, people use spatial terms to describe social relationships and social interactions. We can locate ourselves or others in a family tree or a social network. You can feel 'close' to someone or 'distant'. Someone can stand 'above you' or be on 'equal footing'. You can even be in the 'same circle' as someone. None of these descriptions need people to be in the same physical space to have meaning, yet they are easily understandable. In this paper, I have been vague about the formal computations that are involved in our representations of social relationships. However, graph theory may be one avenue of research that could be fruitful in describing our cognition of social relationships with formal computational models (Kemp & Tenenbaum, 2008).

Another way that our reasoning about navigation may connect to our reasoning about social relationships is the computational modeling work done about planning. A recent proposal connects

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<sup>13</sup> Several recent papers have called for better characterizations and further specification of what we mean when we say, 'group'. These proposals, and others before (e.g., Hirschfeld 2005) point out that categorization based either on shared perceptual features or shared goals is unlikely to be the basis for inferring social groups. Take shared goals. We don't generally consider people waiting for a bus a social group, even though they all share a goal of getting on the bus. However, we might consider a 'food not bombs' chapter a social group, who share the goal of providing food for people and dismantling the US military. Or, take perceptual features: having freckles is a perceptually salient feature but is not (to the author's knowledge) used as the basis for defining meaningful social groups in any culture. In contrast, having darker skin is also a perceptually salient feature but has been used in certain times and places to define social groups.



intuitive psychology and spatial navigation (Ho et al., 2022). There may also be similarities in how we think about relationships. The proposal is that sometimes when we think about relationships, we think about them as objects in the world. Other times, when the status of our relationship is uncertain, or when we are trying to change a social relationship, we might go through the computationally costly process of simulating possible social actions, their consequences, and how this might affect the minds of our social partners and subsequently the relationship. For example, when someone knows that they are in a committed, communal sharing relationship it might mean that they go through actions the same way one does when they are in ‘auto-pilot’ mode in the car. You kiss your spouse goodbye without thinking twice about it. Errors such as calling your granddaughter the name of your daughter may be evidence of this kind of ‘auto-pilot’ mode where we represent the relationship with ‘just enough’ detail. On the other hand, when we think about changing or creating relationships, we might simulate many possible social actions or conversations that could take place. These ideas are tentative and speculative. More work could explore how the cognition involved in spatial navigation, planning our movements in space, and social ‘navigation’ may be connected.

### **Acknowledgments**

I thank Alan Fiske, Rebecca Saxe, Elizabeth Spelke, Mahzarin Banaji, the Cambridge Writing Group, and the New PI Writing Group, for comments and feedback on this paper. Many of these ideas were refined or came about via conversations. I owe many of these ideas to conversations over many years with Lotte Thomsen, Lindsey Powell, Alan Fiske, Rebecca Saxe, Elizabeth Spelke, Tomer Ullman, Michelle Hung, Denis Tatone, Setayesh Radkani, Emily Chen, Kirsten Lydic, Shari Liu, Susan Carey, Christina Steele, Mack Briscoe, Brandon Woo, Ashley Leung, Denisse Lopez, and Emma Yu, Herissa Lamothe, and too many others to name. Finally, this paper would not exist without the pact with Shari Liu, I am deeply grateful for her encouragement.

Financial support statement: The author was supported by the Mellon Foundation (1802-05529) as well as the Templeton Foundation (TWCF0639) during the writing of this paper.

Competing interests: none

Bio: Ashley J. Thomas, Assistant Professor of Psychology, is the principal investigator of the Thomas Lab, part of the Laboratory for Developmental Studies at Harvard University. We study how people think about social relationships with a focus on infants and children. I have published in *Open Mind*, *Collabra*, and *Proceedings of the National Academy of Sciences*, and *Science*. I have been awarded the Ruth L. Kirschstein Postdoctoral Individual National Research Service Award.

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