



Early understanding of ownership helps infants efficiently organize objects in memory

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ABSTRACT

Knowing who owns what is challenging because it is often invisible to direct perception. Yet, the concept of ownership can be instrumental for organizing representations of the world. Here we investigated whether 16-month-olds ($N = 64$) can already use *ownership* to mentally organize a scene, binding representations of individual objects into higher order sets to overcome working memory limits. We found that infants failed to remember four identical objects when a single social agent possessed all four (Experiment 1). However, when two distinct agents possessed two identical objects each, infants successfully remembered all four by chunking them into two sets of two (Experiments 2 and 3). Infants were not merely using the agents as perceptual landmarks; they failed to chunk when two objects each were placed in front of distinctive inanimate objects (Experiment 4). Together, these results suggest that infants can harness abstract knowledge of personal ownership to organize the contents of memory.

1. Infants use ownership cues to chunk objects in working memory

The concept of ownership is important for understanding others' behavior, intentions, and moral status (e.g., see Nancekivell et al., 2019; Noles & Keil, 2011; Friedman & Ross, 2011 for reviews); a single action can be interpreted as either positive or negative, acceptable or transgressive, depending on one's understanding of the ownership relations in a scene. For example, drinking a cup of coffee raises no eyebrows if it belongs to me. But the same action is entirely inappropriate if the coffee belongs to someone else. Further, knowing who owns what can support a wealth of inferences – I might infer that the teenager's Starbucks order is probably heavy on the cream and sugar, whereas her dad's is more likely to be black. And who owns an object can dictate its worth – David Lynch's used coffee cup would generate bids at auction, whereas my identical cup has no value at all.

Although ownership plays an important role in organizing our thoughts about the world, it is not always straightforward to determine, in large part because who owns what often is not directly observable (e.g., Nancekivell et al., 2013, 2019 for reviews). Sometimes ownership is indicated by physical contact – you might infer that the cup of coffee I am holding belongs to me, even though it looks like all of the other cups at the coffee shop, simply because I am holding it. On the other hand, physical contact is not required in order to infer ownership – the coffee cup on the table is mine, even though I am not physically touching it. In fact, one can even say the cup of coffee is mine before I have ever seen it or held it, by virtue of the fact that I previously paid for it.

Despite the abstract nature of ownership, young children are remarkably sophisticated in their reasoning about it, using a variety of

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cues to infer who owns what. Children often assume that whoever first possesses an object is likely its owner (e.g., Blake & Harris, 2009; Friedman & Neary, 2008; Friedman et al., 2011, 2013; Pesowski & Friedman, 2016; see also Friedman, 2008 for similar results with adults). But importantly, children do not require that someone have physical contact with an object in order to own it (Blake & Harris, 2009; Blake et al., 2012; Friedman & Neary, 2008; Gelman et al., 2012; Rossano et al., 2011). Children can use an object's history to determine ownership status (e.g., Gelman et al., 2012, 2016; Goulding & Friedman, 2018; Kanngiesser et al., 2010; Nancekivell & Friedman, 2013), for instance by inferring that objects with traces of use (e.g., a thumb print) are more likely to be owned than objects without such traces (Gelman et al., 2016). Furthermore, verbal statements can override cues of physical contact and first possession – children who see someone holding an object understand that a different person is the owner if told so (Blake et al., 2012). And children can use general knowledge, including stereotypes of who is likely to own what, to make inferences about ownership – they expect that a boy is the likely owner of a truck even if a girl is playing with it (Malcolm et al., 2014). As children get older, they understand that ownership can be transferred. Four-year-olds, but not two- or three-year-olds, appreciate that objects can have new owners (Blake & Harris, 2009; see also Kanngiesser et al., 2010; Kim & Kalish, 2009).

Children also demonstrate an understanding of the rights of ownership. They object when someone uses another's possession without obtaining permission (e.g., Kanngiesser & Hood, 2014; Rossano et al., 2011; Schmidt et al., 2013), and make assumptions about what is permissible to do with objects based on the objects' ownership status (e.g., Kim & Kalish, 2009; McEwan et al., 2016; Nancekivell & Friedman, 2017; Neary & Friedman, 2014; Neary et al., 2009; Rossano et al., 2015; Schmidt et al., 2013; Van de Vondervoort & Friedman, 2015). For example, children believe that people are more entitled to use their own objects (and objects that do not belong to anyone) than objects that belong to someone else (Neary & Friedman, 2014). Furthermore, young children can use ownership information to make predictions. Two-year-olds predict that someone will feel sad when one of their possessions goes missing (Pesowski & Friedman, 2015), and by three years they can form a reverse inference, determining ownership based on others' observed emotional states (e.g., inferring that the broken object is owned by the sad individual in a group; Pesowski & Friedman, 2016). What is more, children use ownership information to predict others' knowledge and actions: preschool-aged children assume that individuals will be knowledgeable about objects that they own (Nancekivell et al., 2020) and will use objects that belong to them, even when someone has a better alternative (Noles & Gelman, 2014; Pesowski & Friedman, 2018).

Children's own experiences with what belongs to them or to their family members may play an important role in this early concept of ownership. Older children show better memory for objects that belong to them than objects that belong to someone else (Cunningham et al., 2013). From early on, children can identify the owners of familiar objects – most typically, objects that belong to themselves and/or a parent (e.g., Brownell et al., 2013; Fasig, 2000; Ross et al., 2015). In one study, children as young as two successfully identified themselves or their parents as owners of objects brought from home. They also recognized and communicated ownership of their own toys both verbally and non-verbally, using terms like “mine” and “yours,” and attempting to regain possession when their own toys were being held by another child (e.g., Ross, 1996; Ross, 2012; Ross et al., 2015).

The findings reviewed above indicate that, by the preschool years, children readily deploy the concept of ownership to reason about the physical and social world around them. What are the earlier developmental underpinnings of this ability? While a large body of work has examined the understanding of ownership in verbal children, fewer studies have probed the concept of ownership during the infancy period. However, a handful of studies suggest emerging competence between the first and second years of life. Saylor et al. (2011) found that 12-month-olds understand person-specific language that signifies ownership, such as the word “my.” Infants saw two balls each placed into a bucket, and an experimenter labeled one as either “the ball” or “my ball” and left the room. Upon returning the experimenter asked, “Where's my ball?” Infants who heard “my ball” during the initial labeling reached for the previously-labeled ball significantly more than infants who heard “the ball.” By 14- to 18- months, infants can indicate which individuals own certain objects, for example saying “Mommy” or “Daddy” when shown their parents' belongings (Fasig, 2000; Golinkoff & Markessini, 1980; Rodgon & Rashman, 1976). And at around 18 months of age, some infants begin to produce possessive pronouns like “mine” and “yours” (Hay, 2006; Tomasello, 1998).

Notably, most demonstrations of ownership understanding in infancy have involved highly familiar objects—typically objects with which infants would have had many months of prior experience at home. It remains less clear how adept infants are at representing third party ownership relations between unfamiliar individuals and novel objects (but see Saylor et al., 2011, for one success at such reasoning). Furthermore, although previous studies have shown that infants can identify the owners of familiar objects (e.g., Mommy's toothbrush; Fasig, 2000; Golinkoff & Markessini, 1980; Rodgon & Rashman, 1976), it is unknown whether concepts of ownership also play a role in organizing infants' mental representations. For example, if infants can recognize several objects as belonging to an individual (e.g., Mommy's toothbrush, Mommy's shirt, Mommy's bag), can they condense that information to more efficiently remember it as “Mommy's stuff”?

In the current experiments, we examined the origins of ownership as an organizing concept in early development. Specifically, we asked whether infants can use ownership information to hierarchically reorganize a scene into “chunks” based on the relationships between owners and objects. We did this by testing the impact of ownership information on infants' working memory. Previous studies find that infants can typically keep track of up to three individual items in working memory (e.g., Barner et al., 2007; Feigenson & Carey, 2003, 2005; Feigenson et al., 2002; Feigenson & Halberda, 2004; Oakes et al., 2011; Ross-Sheehy et al., 2003; Zosh et al., 2011; see Kibbe, 2015 for review). For example, when three objects are hidden in a box and only a subset is retrieved, infants persist in searching for the remaining object(s), relative to when all of the hidden objects have been retrieved. But strikingly, when four objects are hidden and any subset retrieved, infants fail to continue searching (e.g., Barner et al., 2007; Feigenson & Carey, 2003, 2005). However, infants can overcome this working memory limit by “chunking” individual items into higher order sets, thereby creating more efficient representations (as shown in work on adult working memory, e.g., (Chase & Ericsson, 1981; Gobet & Simon, 1998; Mathy & Feldman, 2012). For example, whereas infants typically fail to remember four identical objects, they succeed if the objects

were spatially separated into two groups of two prior to hiding (e.g., Feigenson & Halberda, 2004; Rosenberg & Feigenson, 2013). The spatial separation apparently prompted infants to hierarchically reorganize their representations into two chunks (or sets), with each chunk containing two individual objects. These compressed representations are more efficiently stored in memory (Thalmann, Souza, & Oberauer, 2019), allowing infants to remember the two chunks instead of the four individual objects.

Infants can use a variety of cues to motivate chunking. They can use perceptual similarity to chunk an array into sets (e.g., a set of two objects of type A and a set of two objects of type B; Feigenson & Halberda, 2008; Moher et al., 2012), and can use temporal co-occurrences between otherwise unrelated objects to form chunks (e.g., can form a chunk comprised of a red circle and a blue cross, if these had previously appeared together in repeated pairings; Kibbe & Feigenson, 2016). Infants also chunk on the basis of semantic knowledge of object kinds: while they fail to remember four non-identical objects from a single category (e.g., four different cats), they succeed in remembering four objects from two different categories (e.g., two different cats and two different cars; Feigenson & Halberda, 2008). Infants also can use their early social knowledge to chunk items in working memory, successfully remembering four identical dolls as two sets of two when, prior to hiding, the dolls contingently interacted with each other in pairs (Stahl & Feigenson, 2014). Similarly, infants can use linguistic information to identify social group members, and in turn use this information to chunk. Infants remembered four identical dolls when pairs of dolls spoke the same language (e.g., one pair spoke Mandarin and one pair spoke German), but not when one pair of dolls produced backward Mandarin speech and the other pair produced backward German speech (Stahl & Feigenson, 2018).

Thus, various cues support working memory reorganization early in life. The types of information that have been shown to motivate this—including basic visual features like color and shape, as well as spatial location, object kind, social affiliation, and language spoken—all reflect sources of information to which infants show sensitivity from their earliest months. For example, infants automatically process object shape and color by 3 months of age (Colombo et al., 1995; Gerhardstein et al., 1999), and can differentiate between distinct non-native languages at birth (Nazzi et al., 1998; Ramus, 2002). But can more nascent knowledge also support early chunking? The concept of ownership presents an interesting case, because although who owns what plays a vital organizational role in adults' understanding of the world, ownership understanding emerges later in children's development compared with the other known motivators of chunking (e.g., Blake & Harris, 2009; see Nancekivell et al., 2013 for review), and also likely emerged more recently in human evolutionary history (e.g., Rakoczy & Schmidt, 2012; Rochat, 2011; but see also Brosnan, 2011; Stake, 2004). Furthermore, as reviewed above, ownership is an especially abstract concept, for which there often is little perceptual evidence available for determining the relevant relationships.

Here we asked whether infants can use their early understanding of ownership relations to chunk object representations in working memory. If so, this would suggest both that infants can motivate chunking using a feature even less available to direct perception than those previously studied, and also that the early concept of ownership plays a dynamic organizational role in early cognition. First, in Experiment 1, we sought to replicate previous findings that infants fail to remember four identical objects in the absence of chunking cues. We presented infants with the objects in a social context, and with cues to ownership, but because all of the presented objects were owned by a single individual, there was no basis for chunking the array into smaller sets. As expected, we found that infants failed to represent four objects concurrently. Next, in Experiment 2, we asked whether infants could chunk an array of four identical objects into two sets of two when two distinct individuals were each shown to physically possess half of the objects. We found that infants successfully used this ownership information to remember all four hidden objects. In Experiment 3, we asked whether infants could still chunk the array of four objects into sets when one original owner transferred half the objects each to two distinct individuals, who never physically touched the objects. We found that infants still succeeded in chunking, despite the cues to ownership being more challenging. Finally, in Experiment 4 we confirmed that infants were chunking using representations of ownership, rather than low-level perceptual information. When the social individuals who had served as the "owners" of the objects in Experiments 1–3 were replaced by inanimate blocks, infants failed to chunk even when all other aspects of the presentation were the same as in Experiment 3. Together, these findings implicate early use of the concept of ownership to reorganize the contents of working memory.

1.1. Experiment 1

In all of the experiments in the present series we used the manual search paradigm to measure infants' ability to represent hidden objects in working memory (Barner et al., 2007; Feigenson & Carey, 2003, 2005; Feigenson & Halberda, 2004, 2008; Kibbe & Feigenson, 2014; Rosenberg & Feigenson, 2013; Stahl & Feigenson, 2014, 2018; Van de Walle et al., 2000). First, in Experiment 1, we sought to replicate previous findings that infants can represent one and two hidden objects in working memory, but fail to represent four objects in the absence of chunking cues (e.g., Feigenson & Carey, 2003; 2005). Infants first were presented with one, two, or four equally spaced identical blocks, which were all shown to be possessed by one stuffed animal. To demonstrate ownership, the animal physically held and placed the object(s) atop a box, and referred to them as "mine" (for evidence that infants understand some ownership-relevant language by this age, see Saylor et al., 2011). Then the blocks were hidden in the box, after which either a subset or all of them were retrieved. We subsequently measured whether infants continued to search the box longer when more blocks were expected to remain inside relative to when the box was expected to be empty. We predicted that infants would remember the hidden arrays when one or two objects had been presented, as these are well within their working memory capacity; thus we predicted that infants would successfully continue searching after two objects had been hidden and only one of these had been retrieved. However, we expected that infants would fail to remember four hidden objects, as there was no obvious basis for infants to subdivide the array of four blocks into chunks. That is, we predicted that infants would fail to keep searching after four objects had been hidden and only two of these had been retrieved.

2. Method

2.1. Participants

Sixteen healthy full-term infants between the ages of 15 and 17 months participated (range = 15 months, 5 days – 16 months, 25 days; mean = 15 months, 24 days; 8 female). This sample size and age range were chosen based on previous experiments using similar methodology (e.g., Feigenson & Carey, 2003; Feigenson & Halberda, 2004; Stahl & Feigenson, 2014; 2018). Five additional infants were excluded due to fussiness (2) or refusal to reach into the box on at least half of the measurement periods (3).

2.2. Stimuli

The objects were hidden in a black foam-core box (40.5 × 25 × 12 cm), which had a spandex-covered opening in its front face (13 × 7.5 cm). The spandex had a horizontal slit through which infants could reach and retrieve objects, but not see. The back of the box had an opening covered with black felt through which the experimenter could surreptitiously reach and withhold objects. The stimulus objects were four identical wooden blocks (measuring 3 cm); these were presented by four plush animals: a brown and white dog, a gray koala, a black and white cow, and a pink pig (all 12 cm wide × 13 cm high) (Fig. 1).

2.3. Design

Infants were tested with one block of measurement periods that presented arrays of objects expected to be within their working memory capacity (1 vs. 2 object block), and one block that presented arrays of objects expected to exceed their working memory capacity (2 vs. 4 object block). The 1 vs. 2 object block contained two trials in which the stuffed dog “owned” all of the objects, and two trials in which the koala “owned” all of the objects. The 2 vs. 4 object block contained two trials in which the cow “owned” all of the objects, and two trials in which the pig “owned” all of the objects. Half the infants were tested with the 1 vs. 2 block first, and half were tested with the 2 vs. 4 block first.

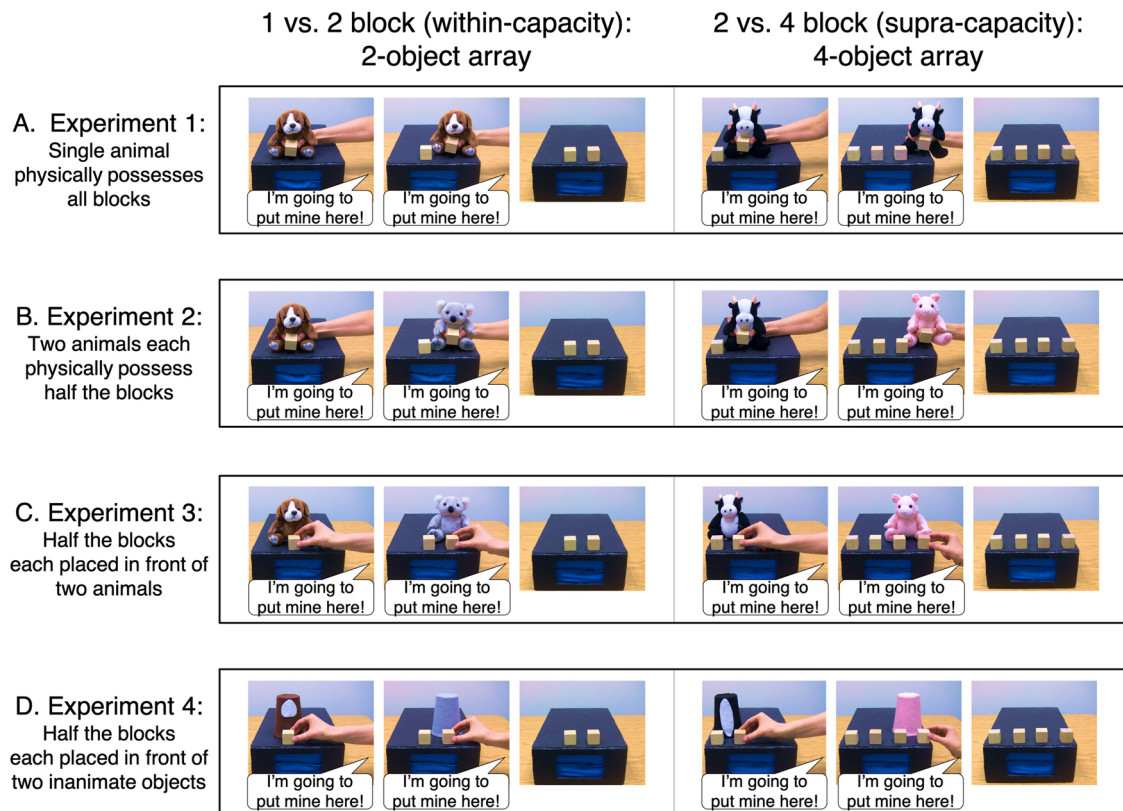


Fig. 1. Sample event sequences in Experiments 1–4 for two-object arrays in the 1 vs. 2 block (left) and four-object arrays in the 2 vs. 4 block (right).

2.4. Procedure

Infants sat in a high chair at a child-sized table, with the experimenter kneeling beside them and parents sitting behind them. First the experimenter familiarized infants with the box by hiding a set of toy keys inside and encouraging infants to retrieve them. After infants had successfully retrieved the keys, the test blocks began.

2.5. 1 vs. 2 object block

Each 1 vs. 2 object block contained three measurement periods: 1-Object (None Remaining), 2-Objects (More Remaining), and 2-Objects (None Remaining). Each of these three measurement periods was presented twice.

1-Object (None Remaining) measurement period: The experimenter held the stuffed dog (or koala) above the box and said, “Watch this!” She showed infants as she made the dog move under the table and return holding a block. She grasped the dog around its back, so that she could hold the block between her thumb and index fingers—this way it appeared that the dog was holding the block between its paws. The experimenter positioned the dog above the box, wiggling it back and forth to draw infants’ attention, and said “I’m going to put mine here!”—acting as though the dog were speaking. Infants then saw the dog place the block atop the box, saying, “See?” before disappearing under the table. The experimenter then pointed to the block and said, “Look at this!” If infants looked away during this presentation, the experimenter called their attention back to the stimuli, ensuring that infants attended equally across all conditions (this was the case for all object presentations across all experiments). The block remained visible atop the box for approximately 2 s before the experimenter inserted it through the spandex in the front face of the box (making sure infants watched as she did so). The experimenter then pushed the box toward infants and said, “What’s in there?” After infants had reached in and retrieved the block (which all infants did, across trials), the experimenter immediately took it from them and placed it out of sight under the table. A 10-second measurement period followed (1-Object, None Remaining) during which infants’ searching was measured. Searching was operationalized as having one or both hands inserted through the spandex-covered slit up to or past the knuckle closest to the palm. Throughout this measurement period, the experimenter looked down and remained silent to avoid giving infants any cues about whether she believed the box contained further objects. After 10 s the experimenter removed the box from infants’ reach, said “Good job,” and the measurement period was considered over. If infants still had one or both hands in the box at the 10-second mark, the experimenter allowed them to continue searching until they removed their hand(s), after which the measurement period immediately ended.

2-Objects (More Remaining) measurement period: These were identical to the 1-Object measurement periods, except that the dog (or koala) presented two blocks rather than one (Fig. 1A). First the experimenter held the dog above the box and said, “Watch this!” She then moved the dog under the table, retrieved a block, and placed the block atop the box while saying, “I’m going to put mine here!” The dog said, “See?” and then moved under the table to retrieve another block. This sequence was repeated for the second block. Once the dog had placed the second block on the box, the experimenter returned the dog to its hiding place under the table, pointed to the two blocks, and said, “Look at this!” The blocks remained visible for approximately 2 s before the experimenter inserted both simultaneously into the front of the box. As she did this, she surreptitiously used her other hand to reach through the concealed opening in the back of the box; she used this hand to hold one of the blocks in the back of the box out of infants’ reach. The experimenter then pushed the box toward infants and asked, “What’s in there?” Infants could then retrieve the block that was within their reach. Once infants had retrieved the block, the experimenter immediately took it and placed it out of sight under the table. A 10-second measurement period immediately followed, in which the experimenter looked down and remained silent.

2-Objects (None Remaining) measurement period: After 10 s, the experimenter reached into the front of the box and “found” the second block that had been withheld, showed it to infants briefly, then placed it out of sight under the table. A final 10-second measurement period immediately followed, during which no objects remained in the box, because at this point two blocks had been hidden and both had been retrieved. After the 10 s, the experimenter said, “Good job” and moved the box out of reach, at which point the measurement period was considered complete.

2.6. 2 vs. 4 object block

Each 2 vs. 4 object block contained three measurement periods: 2-Objects (None Remaining), 4-Objects (More Remaining), and 4-Objects (None Remaining). Each of these was presented twice.

2-Objects (None Remaining) measurement period. The experimenter held the stuffed cow (or pig) above the box and said, “Watch this!” She showed infants as she made the cow move under the table, and return holding a block. As in the 1 vs. 2 object block, the experimenter used the cow’s arms to hold the block, so that it appeared the cow was manipulating it. She positioned the cow above the box, wiggling it back and forth to draw infants’ attention, and said, “I’m going to put mine here!”—acting as though the cow was speaking. Infants saw the cow place the block atop the box, saying, “See?” before returning under the table to retrieve a second block. This procedure was then repeated, after which the experimenter placed the cow out of sight under the table. She then pointed to the two blocks sitting atop the box and said, “Look at this!” The blocks remained visible for approximately 2 s before the experimenter inserted them into the box one at a time (making sure infants watched as she did so). The experimenter then pushed the box toward infants and said, “What’s in there?” Infants were then able to retrieve the two blocks. If they only retrieved one, the experimenter reached in and retrieved the other one. She showed both blocks to infants before placing them out of sight under the table. She then pushed the box toward infants and a 10-second measurement period followed (2-Objects, None Remaining).

4-Objects (More Remaining) measurement period. These were identical to the 2-Object measurement periods, except that the cow (or

pig) presented four objects rather than two (Fig. 1A). First the experimenter held the cow above the box and said, “Watch this!” She then moved the cow under the table, retrieving a block, and placed it atop the box while saying, “I’m going to put mine here!” The cow then returned under the table and reappeared holding a second block, which it placed atop the box, again saying, “I’m going to put mine here!” This sequence was then repeated two more times, until four blocks were positioned atop the box, all equally spaced. Once the cow had placed the fourth block, the experimenter returned it to its hiding place under the table, then pointed to each pair of blocks and said, “Look at this!” The blocks remained visible for approximately 2 s before the experimenter inserted them into the front of the box two at a time. As she did this, she surreptitiously used her other hand to reach through the concealed opening in the back of the box; she used this hand to hold two of the blocks in the back of the box out of infants’ reach. The experimenter then pushed the box toward infants and asked, “What’s in there?” Infants could then retrieve two blocks (the experimenter provided assistance if needed), which the experimenter quickly removed and placed out of sight under the table. A 10-second measurement period followed (4-Objects, More Remaining), in which the experimenter looked down and remained silent.

4-Objects (None Remaining) measurement period. After 10 s, the experimenter reached into the front of the box and “found” the remaining two blocks that had been withheld. She showed them to infants briefly, then placed them out of sight under the table. A final 10-second measurement period followed during which no objects remained in the box, because at this point four blocks had been hidden and all four had been retrieved. After the 10 s, the experimenter said, “Good job” and pulled the box out of infants’ reach.

A trained observer who was unaware of the testing condition to which infants had been assigned coded infants’ searching off-line, frame-by-frame, using Preferential Looking Coder (Libertus, 2011). A second observer recoded 25% of all participants, and coder agreement across all experiments averaged 0.96.

3. Results

3.1. 1 vs. 2 object block

First we asked whether infants successfully represented the presence of two hidden objects, as reflected by their continued searching for the missing objects if both objects had not yet been retrieved from the box (compared to when all objects had been retrieved). Analyses were conducted on infants’ mean searching across the two instances of each measurement period. We first computed the duration of infants’ searching when the box should be expected to be empty. We found that infants searched equally on the two measurement periods where nothing remained in the box (1-Object (None Remaining): $M = 2.17$ s, $SD = 1.76$, versus 2-Objects (None Remaining): $M = 1.82$ s, $SD = 1.88$), $t(15) = 1.10$, $p = .29$. We therefore combined these into a composite score reflecting infants’ average searching when the box was expected to be empty ($M = 1.99$ s, $SD = 1.70$). Then, to ask whether infants successfully kept searching when two objects had been hidden and only one of these retrieved, we subtracted each infant’s composite None Remaining searching from their searching on 2-Objects (More Remaining) measurement periods ($M = 3.10$ s, $SD = 1.80$). As expected, this difference score ($M = 1.11$, $SD = 1.43$) was significantly greater than zero, $t(15) = 3.10$, $p = .007$, Cohen’s $d = 0.78$ (Fig. 2). That is, infants searched significantly longer when two objects had been hidden but only one retrieved, relative to when one object had been hidden and retrieved, or when two objects had been hidden and both retrieved.

3.2. 2 vs. 4 object block

We next used the same approach to examine infants’ performance when either two or four objects had been hidden. As before, analyses were conducted on infants’ mean searching across the two instances of each measurement period. We first computed the duration of infants’ searching when the box should be expected to be empty. We found that infants searched equally on the two measurement periods where nothing remained in the box (2-Objects (None Remaining): $M = 2.09$ s, $SD = 2.0$, versus 4-Objects (None Remaining): $M = 1.79$ s, $SD = 1.70$), $t(15) = 0.86$, $p = .40$. We therefore combined these into a composite score reflecting infants’ average searching when the box was expected to be empty ($M = 1.95$ s, $SD = 1.72$). Then we subtracted each infant’s composite None

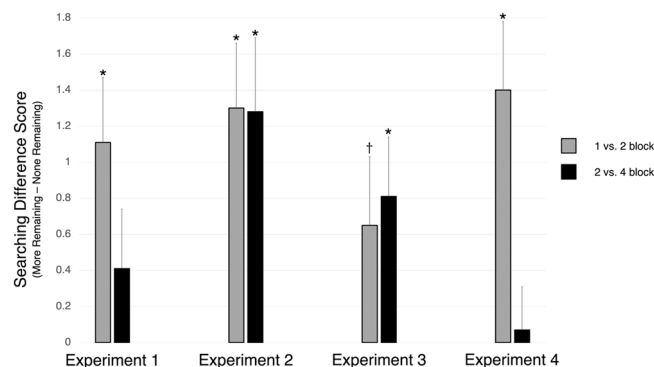


Fig. 2. Results from Experiments 1–4. Bars represent average difference scores (infants’ searching on More Remaining measurement periods minus infants’ searching on None Remaining measurement periods). Error bars represent standard error of the mean. * $p < .05$; † $p = .11$.

Remaining searching from their searching on 4-Objects (More Remaining) measurement periods ($M = 2.35$ s, $SD = 2.03$). As expected, and confirming the results of previous studies (e.g., Feigenson & Carey, 2003; 2005), this difference score ($M = 0.40$, $SD = 1.31$) was not significantly greater than zero, $t(15) = 1.22$, $p = .24$, Cohen's $d = 0.31$ (Fig. 2). That is, infants failed to keep searching when four objects had been hidden and only two retrieved, relative to when two objects had been hidden and both retrieved, or when four objects had been hidden and all of them retrieved.

4. Discussion

As in previous studies, infants succeeded at representing one and two hidden objects in working memory, but failed to represent four hidden objects (e.g., Feigenson & Carey, 2003, 2005). Because infants in Experiment 1 saw that a single animal “owned” all four blocks, and because the blocks were identical and equi-spaced, there was no basis on which to subdivide the array into chunks that could be more efficiently stored in memory.

4.1. Experiment 2

Having observed the typical pattern of working memory failure in Experiment 1, we were positioned to next ask whether infants could use the cue of ownership to motivate chunking a four-object array into two sets of two. Infants in Experiment 2 were, like infants in Experiment 1, presented with arrays of identical, equi-spaced objects. However, these infants saw that half of the objects were “owned” by one stuffed animal, and half by another (for arrays containing more than one object). We hypothesized that if infants can use ownership information as a chunking cue, they would successfully represent four hidden blocks as two sets of two, and thus continue searching the box after four blocks had been hidden and only two retrieved.

5. Method

5.1. Participants

Sixteen healthy full-term infants between the ages of 15 and 17 months participated (range = 15 months, 3 days – 16 months, 25 days; mean = 15 months, 29 days; five female). Fifteen additional infants were excluded due to fussiness (3), equipment failure (2), parental interference (1), inattentiveness (1), or refusal to reach into the box on at least half of the measurement periods (8). The attrition rate in this sample was higher than that in Experiment 1; in particular, more infants were excluded for refusing to reach into the box. Anecdotal observation suggested that because two animals were present on each trial, some infants became distracted and/or distressed at their disappearance and subsequently refused to search the box during the measurement period (instead, they pointed and attempted to look under the table for the animals). However, we found no evidence to suggest that the excluded infants differed in any other systematic way from the infants whose data were included in the analyses. The excluded infants were equally attentive to the object presentations, and there was no age difference between the excluded infants ($M = 15$ months, 21 days) and the rest of the sample. Importantly, the excluded infants refused to search equally across the two blocks of trials (three infants primarily refused to search in the within-capacity 1 vs. 2 object block, and two infants primarily refused to search in the supra-capacity 2 vs. 4 object block; three infants refused to search across both blocks); this argues against the possibility that these infants only refused to search on the trials that placed a higher demand on memory. Finally, we found that on the few measurement periods on which these infants did search, their data was comparable to that of the included infants.

5.2. Stimuli

The stimuli were identical to those in Experiment 1.

5.3. Design

As in Experiment 1, all infants were tested with a 1 vs. 2 object block and a 2 vs. 4 object block.

5.4. Procedure

5.4.1. 1 vs. 2 object block

As in Experiment 1, each 1 vs. 2 object block contained 3 measurement periods: 1-Object (None Remaining), 2-Objects (More Remaining), and 2-Objects (None Remaining), each presented twice.

1-Object (None Remaining) measurement period: This was identical to that in Experiment 1. The dog possessed the block and placed it on the box on one instance of the measurement period, and the koala possessed the block and placed it on the box on the other.

2-Objects (More Remaining) measurement period: This was identical to that in Experiment 1, except that within each of these measurement periods the dog possessed the first block and placed it atop the box, and the koala possessed the second block and placed it atop the box (or vice versa) (Fig. 1B). The dog and the koala were never visible at the same time (to equate the experience to that of Experiment 1, in which only a single animal was visible at a time). After the dog said, “I’m going to put mine here!” and placed its block on the box, it was moved out of sight under the table, and then the koala presented its block in the same manner. All other aspects of the

presentation and measurement periods (including the number of movements and utterances) were identical to those of Experiment 1: infants were allowed to retrieve one of the two hidden objects from the front of the box, and then their subsequent searching was measured while the experimenter secretly withheld the second object in the back of the box.

2-Objects (None Remaining) measurement period: After 10 s the experimenter retrieved the missing object, at which point the box was once again empty and infants' searching was again measured.

5.5. 2 vs. 4 object block

Each 2 vs. 4 object block contained 3 measurement periods: 2-Objects (None Remaining), 4-Objects (More Remaining), and 4-Objects (None Remaining). Each of these was presented twice.

2-Objects (None Remaining) measurement period: This was identical to that in Experiment 1, except that the cow possessed one block and placed it atop the box, saying "I'm going to put mine here!" and then disappeared under the table, and the pig possessed the other block and placed it atop the box (also saying, "I'm going to put mine here!") and then disappeared under the table. As in Experiment 1, the experimenter then inserted both objects one at a time into the box, and infants were allowed to reach in and retrieve both. The experimenter then immediately took the objects away and placed them out of sight under the table, and infants' searching was measured for 10 s

4-Objects (More Remaining) measurement period: This was as in Experiment 1, except that the cow possessed two blocks and placed them atop the box one at a time (each time saying, "I'm going to put mine here!"), and then disappeared under the table, and then the pig possessed and placed two blocks atop the box one at a time (each time saying, "I'm going to put mine here!") and then disappeared under the table (Fig. 1B). As in Experiment 1, the four blocks were placed in an evenly spaced row on top of the box. The blocks remained visible for approximately 2 s before the experimenter inserted them into the box two at a time, and infants were allowed to reach in and retrieve two (while the experimenter surreptitiously withheld the other two out of reach in the back of the box). Infants' searching was measured for 10 s

4-Objects (None Remaining) measurement period: This was as in Experiment 1. The experimenter reached in and retrieved the remaining two objects, showed them to infants and then removed them from view, and infants' subsequent searching was measured for 10 s

6. Results

6.1. 1 vs. 2 object block

As in Experiment 1, we asked whether infants successfully represented the existence of two hidden objects, searching the box longer when one of the two was missing, relative to when all objects had been retrieved. First, a comparison of infants' searching on the two None Remaining measurement periods revealed that infants searched equally on these (1-Object (None Remaining): $M = 1.89$ s, $SD = 1.30$, versus 2-Objects (None Remaining): $M = 1.51$ s, $SD = 0.90$), $t(15) = 1.06$, $p = .31$. We therefore combined them into a composite score reflecting infants' average searching when the box was expected to be empty ($M = 1.70$ s, $SD = 0.86$), and subtracted each infant's composite None Remaining searching from their searching on 2-Objects (More Remaining) measurement periods ($M = 3.0$ s, $SD = 1.87$). As predicted, this difference score ($M = 1.30$, $SD = 1.44$) was significantly greater than zero, $t(15) = 3.61$, $p = .003$, Cohen's $d = 0.90$ (Fig. 2) – infants searched significantly longer when two objects were hidden in the box but only one was retrieved, relative when one object had been hidden and retrieved, or when two objects had been hidden and both retrieved.

6.2. 2 vs. 4 object block

We used the same approach to analyze infants' performance when either two or four objects had been hidden. We first computed the duration of infants' searching when the box should be expected to be empty. We found that infants searched equally on the two measurement periods when nothing remained in the box (2-Objects (None Remaining): $M = 2.18$ s, $SD = 1.89$ versus 4-Objects (None Remaining): $M = 2.10$ s, $SD = 1.96$), $t(15) = 0.19$, $p = .85$. We therefore combined these into a composite score reflecting infants' average searching when the box was expected to be empty ($M = 2.14$ s, $SD = 1.75$), and subtracted each infant's composite None Remaining searching from their searching on 4-Objects (More Remaining) measurement periods ($M = 3.42$ s, $SD = 1.67$). As predicted, this difference score ($M = 1.28$, $SD = 1.66$) was significantly greater than zero, $t(15) = 3.08$, $p = .008$, Cohen's $d = 0.77$ (Fig. 2). Infants successfully kept searching when four objects had been hidden and only two of them retrieved.

7. Discussion

Previous work has found that infants can use a variety of perceptual and conceptual cues to chunk representations of individual objects into sets. For example, as reviewed earlier, infants can use similarities in the colors and shapes of unknown objects (Feigenson & Halberda, 2008) and the ways in which these co-occur across time (Kibbe & Feigenson, 2013), as well as knowledge of the categories to which objects belong (Feigenson & Halberda, 2008), and social relationships between agents (Stahl & Feigenson, 2014; 2018) to hierarchically organize object representations in working memory. The results of Experiment 2 suggest that in addition, infants can use an abstract understanding of ownership in order to motivate chunking. When four identical objects were shown to be physically possessed by two distinct individuals (two by one owner and two by another), infants were able to hierarchically reorganize the

representations into two sets of two, thereby overcoming limits on working memory.

7.1. Experiment 3

Which cues are essential for infants to represent objects as belonging to a particular individual? Experiment 2 provided infants with multiple redundant and salient cues to ownership: each animal was the first and only individual to possess each block, had physical contact with it, and indicated it was theirs by using the possessive word “mine.” Yet young children also can identify ownership relations in less obvious circumstances: they can represent an object as belonging to someone in the absence of physical contact or even visual access (e.g., Blake et al., 2012; Gelman et al., 2012; Malcolm et al., 2014; Neary et al., 2009; Saylor et al., 2011). In addition, older children can update representations of ownership to reflect transfers of possession, acknowledging a new owner when an object is given as a gift (e.g., Blake & Harris, 2009).

Therefore, we next probed the limits of infants’ ownership representations by asking whether infants would chunk under more challenging conditions than those in Experiment 2. Experiment 3 made ownership relations less explicit in two ways. First, we presented infants with a sequence involving a transfer of resources from one single owner to two new individuals. Second, we removed physical contact between the new owners and the target objects, so that contact was no longer available as a cue to ownership. Infants first saw that the experimenter physically possessed all of the blocks—she indicated her ownership by using the word “mine.” Then she placed half of the blocks in front of one stuffed animal and half in front of the other, suggesting that she was giving the blocks to each of them. Then all of the blocks were hidden, without the animals ever having made physical contact with them. If infants can still represent ownership under these more nuanced conditions, they should again successfully chunk arrays of four blocks into two sets of two, each possessed by distinct social agents.

8. Method

8.1. Participants

Sixteen healthy full-term infants between the ages of 15 and 17 months participated (range = 15 months, 3 days – 16 months, 25 days; mean = 16 months, 10 days; six female). Thirteen additional infants were excluded due to fussiness (3), parental interference (1), inattentiveness (1), and refusal to reach into the box on at least half of the measurement periods (9). This attrition rate resembles that of Experiment 2, in which infants became highly distracted by the disappearance of the two animals and then stopped searching. As in Experiment 2, there were no age differences between infants who searched the box and infants who refused to search ($M = 16$ months, 2 days), and their refusal to search occurred roughly equally across the two trial blocks.

8.2. Stimuli

The stimuli were identical to those in Experiments 1 and 2.

8.2.1. Design

The design was identical to Experiments 1 and 2; infants were tested with a 1 vs. 2 object block and a 2 vs. 4 object block.

8.2.2. Procedure

The procedure was as in Experiment 2 with a few exceptions. Each measurement period began with an animal sitting on top of the box. The experimenter introduced the block(s), holding them herself (rather than having the animal retrieve and hold the blocks as in Experiments 1 and 2) and then placing them in front of the animals one at a time while saying, “I’m going to put mine here” with each placement. For measurement periods involving more than one animal, the experimenter placed the block(s) in front of the first animal, then moved that animal out of view under the table (while the block(s) remained in place atop the box). Then the second animal was placed atop of the box, and the experimenter placed the additional block(s) in front of that animal in the same manner as described above. Thus, the experimenter appeared to give the blocks to each of the animals, after which the animal(s) appeared to possess the blocks but did not physically touch them before the experimenter picked them up and inserted them into the box (Fig. 1C).

9. Results

9.1. 1 vs. 2 object block

As in Experiments 1 and 2, we first asked whether infants successfully represented the presence of two hidden objects, searching the box longer when one of the two was missing, relative to when all of the hidden objects had been retrieved. First, a comparison of infants’ searching on the two None Remaining measurement periods revealed that infants searched equally on these (1-Object (None Remaining): $M = 2.13$ s, $SD = 1.44$, versus 2-Objects (None Remaining): $M = 2.01$ s, $SD = 1.90$), $t(15) = 0.28$, $p = .79$. We therefore combined these into a composite score reflecting infants’ average searching when the box was expected to be empty ($M = 2.07$, $SD = 1.43$), and subtracted each infant’s composite None Remaining searching from their searching on 2-Objects (More Remaining) measurement periods ($M = 2.72$ s, $SD = 2.21$). Contrary to our predictions, this difference score ($M = 0.65$, $SD = 1.52$) was not significantly greater than zero, $t(15) = 1.70$, $p = .11$, Cohen’s $d = 0.42$ (Fig. 2). Although the lack of increased searching on More

Remaining relative to None Remaining measurement periods is surprising, findings from Experiments 1 and 2, as well as those from numerous previous studies (e.g., Feigenson & Carey, 2003, 2005; Feigenson & Halberda, 2004; Stahl & Feigenson, 2014, 2018; Zosh & Feigenson, 2015) show that infants of this age can robustly represent one and two hidden objects, and succeed at demonstrating this in the manual search paradigm. It is unclear why the performance of infants in Experiment 3 did not reach significance. But because the 2 vs. 4 object block in this Experiment provided an opportunity to replicate the key finding of Experiment 2—that infants can use ownership cues to help them remember an array of four identical objects—here we focused on infants' performance in that block.

9.2. 2 vs. 4 object block

As in Experiments 1 and 2, we next analyzed infants' performance when either two or four objects had been hidden. First we computed the duration of infants' searching when the box should be expected to be empty. We found that infants searched equally on the two measurement periods when nothing remained in the box (2-Objects (None Remaining): $M = 2.23$ s, $SD = 1.88$ vs. 4-Objects (None Remaining): $M = 1.84$ s, $SD = 1.24$), $t(15) = 1.03$, $p = .32$. We therefore combined these into a composite score reflecting infants' average searching when the box was expected to be empty ($M = 2.04$ s, $SD = 1.40$), and subtracted each infant's composite None Remaining searching from their searching on 4-Objects (More Remaining) measurement periods ($M = 2.85$ s, $SD = 2.20$). As predicted, this difference score ($M = 0.81$, $SD = 1.31$) was significantly greater than zero, $t(15) = 2.48$, $p = .03$, Cohen's $d = 0.62$ (Fig. 2). That is, infants successfully kept searching when four hidden objects had been hidden and only two of them retrieved.

10. Discussion

The results of Experiment 3 suggest that infants may be able to represent a transfer of resources, and can use representations of transferred possessions to efficiently organize object representations in working memory. When the experimenter placed two blocks each in front of two distinct animals, infants still succeeded in chunking the array of four blocks into two sets of two—even when neither animal ever touched the blocks in their possession. These results align with those from other studies showing that infants and children can infer ownership even when an individual is not touching the owned object (e.g., Blake et al., 2012; Gelman et al., 2012; Malcolm et al., 2014; Neary et al., 2009; Saylor et al., 2011).

10.1. Experiment 4

The results of Experiments 2 and 3 show that infants successfully chunked four blocks into two sets if distinct social agents possessed each pair of blocks, with or without physical contact between agents and objects. However, an alternative explanation of our results is that infants were not using ownership information to chunk the objects (e.g., the cow owns two blocks and the pig owns two blocks), but rather used the two animals as spatial landmarks (e.g., two blocks were placed in front of the black and white object, and two blocks were placed in front of the pink object). Perhaps merely having a salient location associated with two of the blocks and another salient location associated with the other two blocks was sufficient to drive infants' successful search behavior in Experiments 2 and 3 (for evidence that by this age infants can use objects as salient landmarks, see Accredolo & Evans, 1980; Bushnell et al., 1995; Lew et al., 2000).

We addressed this possibility in Experiment 4 by replacing the animals with inanimate objects that were perceptually similar to the animals used in Experiments 1–3. If infants in Experiments 2 and 3 merely used the animals as perceptual landmarks to motivate chunking, then because perceptual landmarks were also provided in Experiment 4, they should again succeed at representing four-object arrays. However, if infants instead used an abstract ownership representation (e.g., "Cow owns these blocks; Pig owns these blocks") to motivate chunking, then infants in Experiment 4 should fail to remember the four-block arrays, because inanimate entities cannot be owners of objects.

11. Method

11.1. Participants

Sixteen healthy full-term infants between the ages of 15 and 17 months participated (range = 15 months, 3 days – 16 months, 25 days; mean = 16 months, 3 days; 8 female). Four additional infants were excluded due to fussiness (2), parental interference (1), and refusal to reach into the box on at least half of the measurement periods (1).

11.2. Stimuli

The stuffed animals from Experiments 1–3 were replaced with perceptually matched inanimate objects: cylinders that were the same height and width as the animals used in Experiments 1–3. These were covered in fuzzy felt that was the same color and roughly the same pattern as the animals (Fig. 1D).

11.3. Design

The design was identical to that of Experiment 3.

11.4. Procedure

The procedure was identical to Experiment 3, except that the inanimate objects were used instead of the animals (Fig. 1D).

12. Results

12.1. 1 vs. 2 object block

A comparison of infants' searching on the two None Remaining measurement periods revealed that infants searched equally on these (1-Object (None Remaining): $M = 1.22$ s, $SD = 1.05$ vs. 2-Objects (None Remaining): $M = 1.65$ s, $SD = 1.34$), $t(15) = 1.12$, $p = .28$. We therefore combined them into a composite score reflecting infants' average searching when the box was expected to be empty ($M = 1.44$, $SD = 0.91$), and subtracted each infant's composite None Remaining searching from their searching on 2-Objects (More Remaining) measurement periods ($M = 2.84$ s, $SD = 1.66$). As predicted, this difference score ($M = 1.41$, $SD = 1.51$) was significantly greater than zero, $t(15) = 3.73$, $p = .002$, Cohen's $d = 0.93$ (Fig. 2)—infants searched significantly longer when two objects were hidden in the box but only one was retrieved, relative to when the box was empty.

12.2. 2 vs. 4 object block

We used the same approach to analyze performance on this block. We found that infants searched equally on the two measurement periods when nothing remained in the box (2-Objects (None Remaining): $M = 1.92$ s, $SD = 1.81$ vs. 4-Objects (None Remaining): $M = 2.17$ s, $SD = 1.50$), $t(15) = 0.63$, $p = .54$. We therefore combined these into a composite score reflecting infants' average searching when the box was expected to be empty ($M = 2.05$ s, $SD = 1.46$), and subtracted each infant's composite None Remaining searching from their searching on 4-Objects (More Remaining) measurement periods ($M = 2.11$ s, $SD = 1.11$). We found that this difference score ($M = 0.07$, $SD = 0.97$) was not significantly greater than zero, $t(15) = 0.29$, $p = .78$, Cohen's $d = 0.07$ (Fig. 2). That is, infants failed to continue searching when four objects had been hidden and only two of them had been retrieved.

Finally, we compared infants' performance across experiments, asking whether infants performed differently in the experiments in which ownership cues were available for chunking (Experiments 2 and 3), relative to the experiments in which no ownership cues were available (Experiments 1 and 4). We conducted a repeated measures analysis of variance on infants' difference scores, with Memory Load (1 vs. 2 block, 2 vs. 4 block) as a within-subjects factor and Chunking Cues (Present: Experiments 2 and 3, Absent: Experiments 1 and 4) as a between-subjects factor. This revealed a main effect of Memory Load, with infants performing better overall on the 1 vs. 2 blocks than 2 vs. 4 blocks, $F(62) = 4.15$, $p = .046$, partial $\eta^2 = .06$. Critically, we also observed a significant interaction between Memory Load and Chunking Cues, $F(62) = 5.46$, $p = .02$, partial $\eta^2 = .08$. Post-hoc independent t-tests with an alpha level of .025 to correct for multiple comparisons revealed that Chunking Cues had no effect on infants' performance in the 1 vs. 2 block, when the number of presented objects was within working memory capacity, $t(62) = -0.77$, $p = .44$, Cohen's $d = -0.19$. However, Chunking Cues significantly improved performance in the 2 vs. 4 block, when the number of presented objects exceeded the limit on working memory capacity $t(62) = 2.43$, $p = .02$, Cohen's $d = 0.61$.

13. Discussion

Infants failed to chunk four objects into sets when the objects were simply placed in front of two distinct inanimate objects. Thus, infants' success in Experiments 2 and 3 likely depended on conceptual, not perceptual, cues of ownership. Because infants in Experiment 4 still represented one and two objects, the presence of the inanimate objects that served as perceptual landmarks did not impact infants' general ability to perform the task.

14. General discussion

Here we investigated infants' ability to use the concept of ownership to mentally reorganize their memory representations. In Experiment 1, infants failed to remember four identical blocks when all of those blocks were physically possessed by a single owner, replicating previous findings that infants cannot simultaneously represent four objects in the absence of chunking cues (e.g., Feigenson & Carey, 2003, 2005; Feigenson & Halberda, 2004, 2008; Kibbe & Feigenson, 2014; Stahl & Feigenson, 2014, 2018). In Experiment 2, infants were able to chunk four identical blocks into two sets of two – and remember all four – when provided with multiple salient cues to ownership: two animals were the first and only possessors of two blocks each, they indicated ownership with the word “mine,” and they physically possessed the blocks. In Experiment 3, infants still succeeded in chunking the four blocks into two sets even when the cues to ownership were less apparent: the experimenter first possessed the blocks and then transferred two blocks each to two distinct animals, who never physically touched the blocks. Finally, in Experiment 4, we ruled out that infants were merely using low-level perceptual information to chunk the array of objects: when the experimenter first possessed the blocks but then transferred two blocks each to two distinct inanimate objects (that were perceptually matched to the animals), infants failed to remember all four blocks. Together, these experiments show that infants can leverage ownership relations to hierarchically reorganize object representations in working memory. To our knowledge, this is one of earliest demonstrations of sophisticated ownership understanding in infancy, with infants recognizing ownership that does not involve familiar owners or objects, and requiring the representation of multiple owners and multiple objects concurrently.

Our results raise a number of open questions. First, in Experiment 3 when the experimenter initially possessed the blocks and transferred them to the animals, it is possible that infants interpreted the word “mine” as coming from the animals, thereby indicating that the blocks already belonged to each animal (rather than indicating they were first the experimenter’s and then were subsequently transferred). In this case, infants would still be representing ownership relations to support their chunking, but would not be representing a transfer of ownership. In addition, it is possible that infants in Experiment 3 chunked based on equal resource allocation, rather than on ownership information. Infants in previous studies attend to the ways in which resources are allocated amongst recipients; they expect individuals to share resources equally rather than allocating them in an uneven fashion (e.g., Geraci & Surian, 2011; Meristo & Surian, 2013; Schmidt & Sommerville, 2011; Sloane et al., 2012; Sommerville et al., 2013). The results of Experiment 3 therefore leave open the possibility that infants chunked the four objects into two sets of two based on the distribution of resources (e.g., “The experimenter shared half the blocks with the cow and half the blocks with the pig,”) rather than ownership (e.g., “The experimenter transferred ownership of blocks A and B to the cow and blocks C and D to the pig”). In addition, previous work finds that infants represent giving as a social action (Tatone et al., 2015; see also Schöppner et al., 2006; Hamlin & Wynn, 2011), and that representing giving relations appears to enhance infants’ encoding of the given object (Tatone et al., 2021). The results of Experiment 2—in which there was no giving or resource allocation, and yet infants chunked two blocks that were owned by one animal and two blocks owned by another—implicate the ability to chunk based on ownership. However, whether Experiment 3 indexes this same ownership concept, or instead taps the related concepts of giving or resource allocation, remains for future work.

Furthermore, it is unknown whether the use of the word “mine” was necessary for infants to successfully bind owners to their possessions. Infants understand some person-specific language relevant to ownership, such as “my,” “mine,” and “yours” (Hay, 2006; Saylor et al., 2011; Tomasello, 1998), and thus hearing “I’m going to put mine here” may have offered an important cue to ownership in our experiments. Follow-up work could examine infants’ performance using the utterance “I’m going to put *this* here,” to determine whether possessive language is required for infants to initiate chunking on the basis of ownership.

In addition, we do not yet know whether infants can combine their concept of ownership with other types of chunking cues. Adults do this readily—for example, I represent that I have a different phone number from you (using an understanding of ownership), and that each of our phone numbers can be subdivided using spatial and temporal cues—we chunk them into the area code (the first three digits), the exchange (the next three digits), and then the final four digits. Combining these ownership and spatiotemporal chunking cues allows me to remember our two phone numbers much more efficiently than I could remember 20 unrelated digits. Can infants also form multiple hierarchically embedded representations (see Rosenberg & Feigenson, 2013) involving ownership? For example, could infants represent a superset of objects owned by the pig, which is chunked into a set of red balls and a set of green triangles (where each of these sets contains at least two identical individual tokens), and a superset of objects owned by the cow, also chunked into a set of red balls and a set of green triangles? The ability to flexibly parse arrays using a range of cues, both conceptual and perceptual, would greatly facilitate the efficient organization of the contents of memory.

In summary, few studies have examined ownership understanding in infancy. The present experiments show that infants can use a variety of cues to determine ownership status, despite those cues being abstract and nonobvious. Further, infants use this sensitivity to interactions between social agents and objects in the world to chunk items in working memory, thereby overcoming typical representational limits.

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