CHILD DEVELOPMENT

Child Development, July/August 2014, Volume 85, Number 4, Pages 1477–1490

Social Knowledge Facilitates Chunking in Infancy

Aimee E. Stahl and Lisa Feigenson
Johns Hopkins University

Two experiments investigated whether infants can use their rich social knowledge to bind representations of individual objects into larger social units, thereby overcoming the three-item limit of working memory. In Experiment 1, 16-month-olds (n = 32) remembered up to four hidden dolls when the dolls had faced and interacted with each other in pairs, but not when they faced and interacted with the infant, suggesting that infants chunked the dolls into social pairs. In Experiment 2 (n = 16), infants failed to remember four dolls when they faced each other without interacting, indicating that interaction between the dolls was necessary to drive chunking. This work bridges a gap between social cognition and memory by demonstrating that infants can use social cues to expand memory.

A classic signature of working memory is the limited amount of information it can store. When representing or manipulating information over brief durations, observers show strict capacity limits; for example, in many studies adults remember information from four individual items, but no more (e.g., Brady, Konkle, & Alvarez, 2011; Cowan, 2001; Luck & Vogel, 1997; Sperling, 1960). This limit appears to be in place from early in development. Across a range of paradigms, infants remember up to three items at a time, but show poor memory when more than three items are presented (e.g., Barner, Thalwitz, Wood, & Carey, 2007; Feigenson & Carey, 2003, 2005; Feigenson, Carey, & Hauser, 2002; Ross-Sheehy, Oakes, & Luck, 2003). For example, infants who watched one, two, or three objects being hidden inside a box and then saw only a subset of these retrieved continued to search the box for the missing object(s). In contrast, infants who saw four or more objects hidden failed to continue searching (Feigenson & Carey, 2003, 2005; Feigenson & Halberda, 2008; Rosenberg & Feigenson, 2013).

However, this limit on working memory capacity sometimes can be overcome via chunking—that is, by binding representations of individual items into sets that represent both the individual item and the larger chunk. Such chunking creates more efficient representations, resulting in observers being able to remember more information than they could in the absence of chunking. Adults have been shown to chunk items in memory using a variety of different cues, including perceptual similarity, semantic relatedness, and statistical co-occurrences between items (e.g., Brady, Konkle, & Alvarez, 2009; Chase & Ericsson, 1982; Chase & Simon, 1973; Cowan, 2001; Ericsson, Chase, & Faloon, 1980; Gobet & Clarkson, 2004; Mathy & Feldman, 2012; Miller, 1956; Simon, 1974). In one well-known example, expert chess players correctly remembered the locations of more pieces on a chessboard than did novice players, but only when the pieces were arranged as in an actual chess game (as opposed to in random configurations; Chase & Simon, 1973; Gobet & Simon, 1998). This suggests that the experts' chess knowledge allowed them to recognize and remember meaningful configurations of pieces that could then be "unpacked" into their individual components. In addition, adults also can rapidly learn relations among individual items within the timeframe of a single experimental setting, and can use these chunks to expand the total number of items remembered over brief durations (e.g., Brady et al., 2009).

Recent studies reveal related chunking abilities early in development, indicating that chunking does not rely on formal instruction and is unlikely to require conscious strategizing. In one series of experiments, 14-month-old infants saw arrays of equally spaced identical objects, then watched as all the objects were hidden inside a box. Then, infants

This work was supported by a National Science Foundation Graduate Research Fellowship to Aimee E. Stahl and a James S. McDonnell Scholar Award to Lisa Feigenson. We thank the families who participated and Justin Halberda for helpful discussion.

Correspondence concerning this article should be addressed to Aimee E. Stahl, Department of Psychological & Brain Sciences, Johns Hopkins University, 3400 N. Charles St., Baltimore, MD 21218. Electronic mail may be sent to astahl4@jhu.edu.

 0009-3920/2014/8504-0013
DOI: 10.1111/cdev.12217

were allowed to reach into the box to retrieve the objects. When one, two, or three objects had initially been hidden, infants appropriately searched longer when only some of the objects had been retrieved than if all had been retrieved—for example, after seeing three objects hidden and two of these retrieved from the box, infants continued searching for the third object. However, when four or more objects had been hidden and any subset of these retrieved, infants failed to continue searching (Feigenson & Halberda, 2004, 2008), demonstrating that infants' working memory for the objects was limited. In contrast, when the same four objects were presented in two spatially separated groups (chunks) of two prior to hiding, infants successfully continued to search for the correct number of hidden objects. This suggests that infants can use spatial proximity to bind representations of individual objects into chunks, with a resulting benefit to memory performance.

Besides spatial information, infants also can use semantic knowledge to chunk representations in memory. Fourteen-month-old infants who saw two toy cats and two toy cars hidden in a box successfully remembered all the objects even in the absence of spatial cues. These objects could not have been grouped based on perceptual cues alone, as infants succeeded even when shown two perceptually different cats and two perceptually different cars. This contrasts with infants' failure to remember a single array of four different cats or four different cars (Feigenson & Halberda, 2008).

Although the above research shows that infants can use categorical knowledge to drive chunking, little is known about what other types of information infants can employ to this end. Of particular interest is whether infants can use finer grained, within-category distinctions to support the hierarchical restructuring of memory. One potentially rich source of such information is infants' knowledge of the social world. Infants are highly attuned to social information, preferentially attending to faces over nonsocial stimuli at only a few hours after birth (Farroni et al., 2005). This attention to socially relevant information appears to drive other aspects of infant cognition. Infants can use social information to individuate objects (Bonatti, Frot, Zangl, & Mehler, 2002), imitate others (Hamlin, Hallinan, & Woodward, 2008; Meltzoff, 1995), direct attention to particular areas of a visual scene (e.g., Johnson, Slaughter, & Carey, 1998; Wu & Kirkham, 2010), and make inferences about the traits and goals of social entities (e.g., Gergely, Nádasdy, Csibra, & Biró, 1995; Hamlin, Wynn, & Bloom, 2007; Kinzler, Dupoux, & Spelke, 2007; Woodward, 1998). Social cues also can influence what types of information infants store in memory. Infants remember the identity (but not the location) of an object when a social agent points at it, but remember only the location of the object when the agent reaches for it (Yoon, Johnson, & Csibra, 2008).

Infants are also attuned to interactions among social agents. For example, 6-month-olds show different looking patterns when viewing interacting social partners who faced each other versus partners who faced away from each other (Augusti, Melinder, & Gredebäck, 2010), and 10-month-olds expect that a communicative agent should be facing another agent (rather than an inanimate object) when interacting (Beier & Spelke, 2012). Older infants appear sensitive to other physical cues about agents' social relationships. Eighteen-month-olds who viewed dolls that faced each other in an affiliative stance subsequently were more likely to offer help to an experimenter who appeared to be in need, relative to infants who saw the same dolls facing away from each other in a nonaffiliative stance (Over & Carpenter, 2009). This suggests that infants not only attend to and form expectations about social entities (e.g., entities with faces or entities that interact contingently; Johnson et al., 1998) but that they also pay attention to more subtle aspects of the interrelations among social agents.

In light of this evidence that infants are highly sensitive to social information, our goal in the present experiments was to explore the intersection of infants' social knowledge and their working memory abilities. Specifically, we sought to determine whether infants can use observed interactions between socially relevant objects to bind representations of these individual objects into larger chunks, thereby increasing memory. That is, we examined whether social knowledge can influence the kinds of units infants store in memory. To measure infants' memory and their ability to chunk objects, we used the manual search task that has been utilized in previous investigations of infants' working memory (Barner et al., 2007; Feigenson & Carey, 2003, 2005; Feigenson & Halberda, 2004, 2008; Rosenberg & Feigenson, 2013; Van de Walle, Carey, & Prevor, 2000). In Experiment 1, we examined whether 16-month-old infants could remember more hidden objects when the objects could be chunked based on the social cues of affiliative stance and reciprocal interaction. To preview our results, we found that infants successfully remembered four identical hidden objects only when provided with these social chunking cues. In Experiment 2, we attempted to determine which cues were critical by examining whether objects needed to interact with each other to be chunked, or whether merely being positioned in an affiliative stance was sufficient. Our results suggest that seeing objects interact socially was required for infants to successfully chunk.

Experiment 1

In both Experiments 1 and 2, we used the manual search task to measure infants' ability to remember hidden objects. Previous investigations have revealed that infants between 14 and 20 months old consistently fail to remember more than three identical objects at a time in the absence of spatial or linguistic chunking cues (Barner et al., 2007; Feigenson & Carey, 2003, 2005; Feigenson & Halberda, 2004, 2008). In Experiment 1, we presented infants with arrays of equally spaced identical objects that either were within their working memory capacity (i.e., one or two objects), or were expected to be beyond their working memory capacity (i.e., four objects). Fully crossed with this factor of memory load, we also presented infants with dolls that either faced each other in pairs and interacted contingently within a pair, or dolls that faced and interacted with the infant. We predicted that regardless of which types of social cues were presented, infants would successfully remember the number of hidden objects in within-capacity arrays (i.e., arrays of one or two objects). However, we predicted that infants would only successfully remember arrays of four hidden objects when the dolls could be grouped into social pairs, in which dolls within a pair faced and interacted with each other.

Method

Participants

Thirty-two healthy full-term infants between the ages of 15 and 17 months (range = 15 months 1 day to 17 months 4 days; M = 16 months 2 days) participated; 19 of them were female. Seventeen additional infants were excluded due to fussiness (5), equipment failure (1), experimenter error (1), parental interference (3), and failure to produce the dependent measure (7). The infants who did not produce the dependent measure refused to search in the box due to shyness, fear of reaching through the paneled opening, or lack of interest. The experimenter attempted to coax infants into reaching, but was unsuccessful. Similar refusals, and exclusion using the same criterion, have been observed in other studies using this method (e.g., Feigenson & Carey, 2003, 2005; Feigenson & Halberda, 2004, 2008), although our attrition rate is higher than average. During the critical measurement periods in the task, the experimenter disengaged from the infant so as not to influence their searching (see below)—it is likely that the very thing the task was designed to elicit (a sense of social interaction) may have distracted infants from searching for the hidden objects (importantly, our exclusion criterion eliminated roughly equal numbers of infants across all testing conditions). The final sample was predominantly Caucasian and middle class from the greater Baltimore area.

Stimuli

Infants watched objects being hidden in a black foam-core box (40.5 × 25 × 12 cm). The front face of the box had an opening that was covered in blue spandex (13 × 7.5 cm) with a horizontal slit through which infants could reach and retrieve objects, but not see. The back face of the box had an opening concealed with black felt through which the experimenter could surreptitiously reach and withhold objects on critical trials (see below). The stimulus objects were four identical Lego Duplo dolls (measuring 6.5 cm high) and four identical white toy cats in standing posture (measuring 8 cm high). All the objects had faces that were clearly visible when viewed from the front or the side. Different sets of dolls were used in each test block to keep infants attentive and motivated.

Design

All infants were tested with one block of trials containing numbers of objects expected to be within their working memory capacity (one- vs. two-object block), and one block of trials containing numbers of objects believed to be outside of their working memory capacity (two- vs. four-object block). In addition, all infants were tested with one block of trials in which the dolls faced each other and interacted contingently with each other in pairs (Doll × Doll interaction), and one block of trials in which the dolls faced the infant and interacted with the infant (Doll × Infant interaction). These were fully crossed so that half of the infants viewed the Doll × Doll interaction for the one- versus two-object block and the Doll × Infant interaction for the two- versus four-object block, and the other half viewed the reverse. Which memory load (one vs. two or two vs. four objects), which condition (Doll × Doll or Doll × Infant interaction), and which doll type (Lego Duplo dolls or cats) appeared in the first block were counterbalanced across infants.

For the Doll × Doll interaction, the experimenter placed the dolls atop the box facing the infant, then turned them to face each other and enacted a brief "conversation" in which the dolls appeared to greet each other. Thus, postural information (the dolls faced each other) and contingent social interaction (the dolls greeted each other) were both available for infants to use as a basis for binding the dolls into social pairs. For the Doll × Infant interaction, the experimenter placed the dolls atop the box facing each other, then turned them to face the infant and enacted a brief "conversation" with the infant. Hence, the number of movements and greetings was matched to those in the Doll × Doll interaction; the only difference was whether the dolls faced and interacted with each other or with the infant.

Procedure

Infants sat in a high chair with the experimenter kneeling beside them. Infants first were familiarized to the box and were encouraged to retrieve a set of toy keys that they saw being hidden inside. After infants had successfully retrieved the keys, the test trials began.

One- versus two-object block

This block contained three different measurement periods: one object (none remaining), two objects (more remaining), and two objects (none remaining). Each of these three measurement periods was presented twice. Half of the infants saw the Doll × Doll interaction for this block of trials, and half of the infants saw the Doll × Infant interaction.

Doll × Doll interaction. For one-object (none remaining) measurement periods, only a single doll was presented and thus it was not possible to enact a reciprocal posture or social exchange between dolls. Instead, the experimenter moved the single doll and enacted its conversation so as to match the cues provided in the other measurement periods. First, the experimenter said, "Watch this," and placed the doll on the box facing the infant. Next, the experimenter said, "Look!" and turned the doll to face sideways (to the infant's right). She tilted the doll forward (facing the empty space on the box) and said, "Hello!" while moving the doll up and down slightly to indicate that it was speaking. If infants looked away while the experimenter presented these social cues, she attracted their attention back to the objects to ensure that infants attended equally across the conditions (this was true across all object presentations, on all trials). The experimenter then pointed to the doll and said, "Look at this!" She let the infant observe the doll for approximately 2 s before inserting it through the spandex-covered slit in the front face of the box. The experimenter then pushed the box toward the infant and said, "What's in there?" All infants successfully reached in and retrieved the object, which the experimenter then immediately took from them and placed out of sight under the table. A 10-s measurement period followed (one object, none remaining) during which the infant's searching (defined as having one or both hands inserted through the spandex-covered slit up to or past the knuckle closest to the palm) was measured. Throughout this measurement period the experimenter kept her head bowed and remained silent. After 10 s, the experimenter pulled the box out of the infant's reach, said, "Good job," and the trial ended. If the infant was still reaching in the box at the 10-s mark, the experimenter allowed the trial to continue until the infant removed their hand(s), then immediately ended the trial by pulling the box out of the infant's reach.

For two-object (more remaining) measurement periods, the experimenter first said, "Watch this," and placed both dolls on the box facing the infant (Figure 1a). Next, she said, "Look!" and turned the dolls inward to face each other. She tilted the first doll toward the second and said, "Hello!" while moving the doll up and down slightly to indicate that it was speaking, then tilted the second doll toward the first and said, "Hello!" in the same manner and voice (Figure 1b). The experimenter then pointed to the dolls while saying, "Look at this!" and let the infant observe the dolls for approximately 2 s (Figure 1c) before inserting both into the box (Figure 1d). As she did this, the experimenter surreptitiously used her other hand to reach through the concealed opening in the back of the box and grasp one of the dolls, which she then held out of reach in the back of the box. The experimenter then pushed the box toward the infant and said, "What's in there?" The infant was allowed to reach in and retrieve the doll that was not secretly being withheld (and all infants did so). Once the infant had retrieved the doll, the experimenter immediately took it and placed it out of sight under the table. A 10-s measurement period followed (two objects, more remaining) in which the experi-

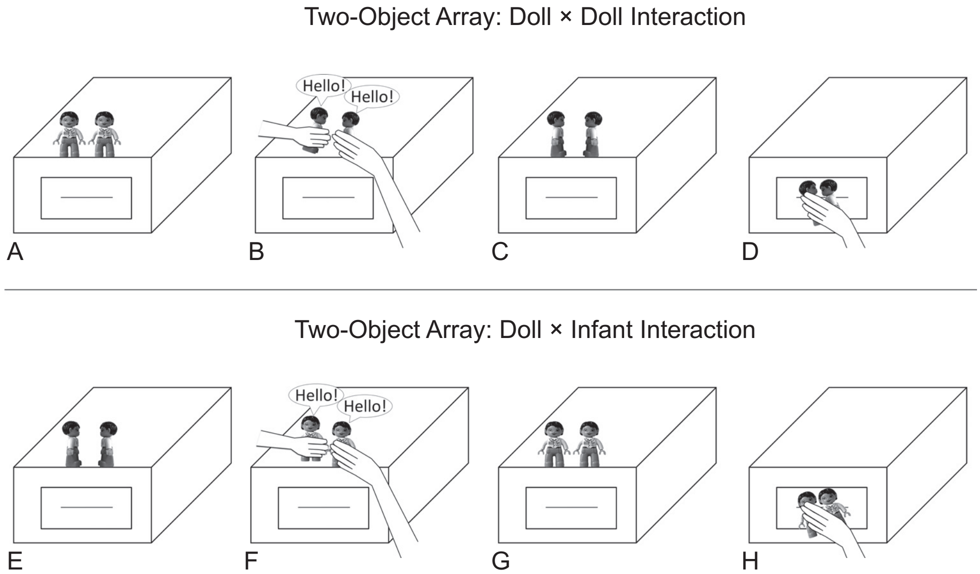

Figure 1. Sequence of events leading up to the two-object (more remaining) measurement period for the one- versus two-object block in Experiment 1. Panels A–D: Doll × Doll interaction; Panels E–H: Doll × Infant interaction. (a) Experimenter places two dolls atop box, facing the infant. (b) Experimenter turns the dolls to face each other, tilts one toward its facing partner and says, "Hello!" then repeats this for the other doll in the pair. (c) Both dolls are briefly left in place, facing each other. (d) Experimenter hides both dolls inside the box, and then infants are allowed to search. (e) Experimenter places two dolls atop box, facing each other. (f) Experimenter turns the dolls to face the infant, tilts one forward and says, "Hello!" then repeats this for the other doll in the pair. (g) Both dolls are briefly left in place, facing the infant. (h) Experimenter hides both dolls inside the box, and then infants are allowed to search.

menter looked down and remained silent. After 10 s, the experimenter reached into the box and "found" the second doll, showing it to the infant briefly before placing it out of sight under the table. A final 10-s measurement period followed (two objects, none remaining) during which the box was again expected to be empty because at this point two objects had been hidden and both had been seen retrieved. After the 10 s had passed, the experimenter said, "Good job" and pulled the box out of the infant's reach.

Doll × Infant interaction. In this same one- versus two-object block, the other half of the infants viewed the Doll × Infant interaction. On one-object (none remaining) trials, the experimenter said, "Watch this," and placed the doll on the box facing sideways to the right. Next, the experimenter said, "Look!" and turned the doll to directly face the infant. She tilted the doll forward toward the infant and said "Hello!" while moving the doll up and down slightly to indicate that it was speaking. The rest of the one-object (none remaining) measurement period proceeded exactly as described for the Doll × Doll interaction.

On two-object (more remaining) trials, the experimenter said, "Watch this," and placed both dolls on the box facing each other (Figure 1e). Next, she said, "Look!" and turned the dolls so that they faced the infant. She tilted the first doll toward the infant and said, "Hello!" then tilted the second doll toward the infant and said, "Hello!" while moving the dolls up and down slightly as they "spoke" (Figure 1f). The experimenter left the dolls in place for approximately 2 s (Figure 1g) before hiding them in the box (Figure 1h). The rest of the two-object (more remaining) and two-object (none remaining) measurement periods proceeded exactly as described for the Doll × Doll interaction.

Two- versus four-object block

The two- versus four-object block contained three different measurement periods: two objects (none remaining), four objects (more remaining), and four objects (none remaining). Each of these three measurement periods was presented twice. Half of the infants saw the Doll × Doll interaction for this block of trials, and half of the infants saw the Doll × Infant interaction.

Doll × Doll interaction. On two-object (none remaining) trials, the experimenter sequentially placed two dolls atop the box facing the infant, saying, "Watch this!" for each object placement. The experimenter then said, "Look!" and turned the dolls inward to face each other. She tilted the first doll toward the second and said, "Hello!" then tilted the second doll toward the first and said, "Hello!" while moving each doll up and down slightly to indicate that it was speaking. The experimenter then pointed to each doll while saying, "Look at this!" and let the infant observe the dolls for approximately 2 s before inserting them into the box one at a time. The experimenter then pushed the box toward the infant and said, "What's in there?" The infant was allowed to reach into the box and retrieve both dolls. If they did not immediately do so, the experimenter reached in and retrieved the remaining doll(s) and showed them to the infant before placing both dolls out of sight under the table. She then pushed the box toward the infant and a 10-s measurement period ensued (two objects, none remaining).

On four-object (more remaining) trials, infants watched the experimenter place four dolls atop the box two at a time (thereby equating the number of movements to those in the two-object, none remaining measurement periods) and position them in an equispaced row facing the infant, saying, "Watch this!" for each pair of objects (Figure 2a). Next, the experimenter said, "Look!" and turned the first pair of dolls inward to face each other. The experimenter then tilted one doll toward its facing partner and said, "Hello!" and then did the same for the other partner in the pair, moving the dolls up and down slightly to indicate that they were speaking (Figure 2b). She repeated this for the second pair of dolls (Figure 2c). The experimenter then pointed to each pair of dolls while saying, "Look at this!" and left the dolls in place for approximately 2 s (Figure 2d), after which the experimenter inserted the two left-most dolls into the box (Figure 1e), followed by the two right-most dolls. As she inserted the second pair of dolls, the experimenter used her other hand to reach through the concealed opening in the back of the box and grasp two of the dolls, which she held out of reach in the back of the box. The experimenter then pushed the box toward the infant and said, "What's in there?" The infant was able to reach in and retrieve two dolls (and, as stated earlier, if they did not immediately do so the experimenter provided assistance), which the experimenter quickly took away and placed out of sight under the table. A 10-s measurement period followed (four objects, more remaining). After 10 s, the experimenter reached in through the front of the box and "found" the remaining two objects. She showed them to the infant and placed them out of sight under the table. A final 10-s measurement period followed (four objects, none remaining) during which the box was

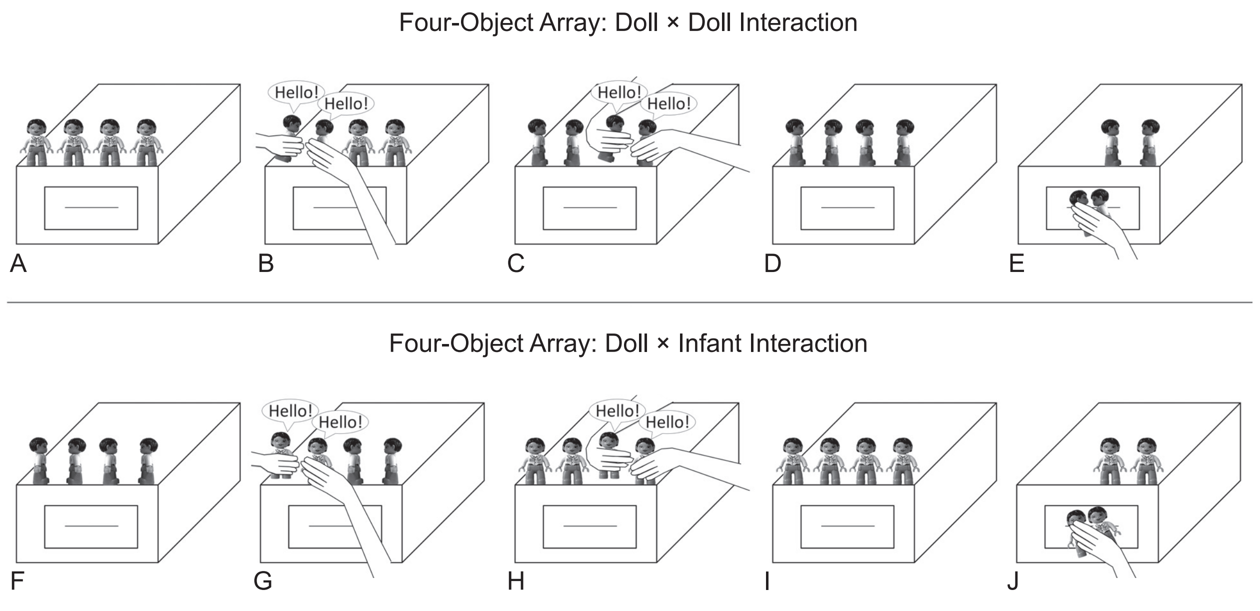

Figure 2. Sequence of events leading up to the four-object (more remaining) measurement period for the two- versus four-object block in Experiment 1. Panels A–E: Doll × Doll interaction; Panels F–J: Doll × Infant interaction. (a) Experimenter places four dolls atop box in equispaced row, facing the infant. (b) Experimenter turns two dolls to face each other, tilts one toward its facing partner and says, "Hello!" then repeats this for the other doll in the pair. (c) Experimenter repeats sequence B for the second pair of dolls. (d) All four dolls are briefly left in place, facing each other in pairs. (e) Experimenter hides dolls two at a time inside the box, and then infants are allowed to search. (f) Experimenter places four dolls atop box in equispaced row, facing each other in pairs. (g) Experimenter turns two dolls outward to face the infant, tilts one doll forward and says, "Hello!" then repeats this for the other doll in the pair. (h) Experimenter repeats sequence G for the second pair of dolls. (i) All four dolls are briefly left in place, facing the infant. (j) Experimenter hides dolls two at a time inside the box, and then infants are allowed to search.

again expected to be empty because at this point four objects had been hidden and all four had been seen retrieved. After the 10 s had passed, the experimenter said, "Good job" and pulled the box out of the infant's reach.

Doll × Infant interaction. In this same two- versus four-object block, the other half of the infants saw the Doll × Infant interaction. On two-object (none remaining) trials, the dolls were placed on the box facing inward. Next, the experimenter said, "Look!" and turned each doll to directly face the infant. She tilted one doll forward toward the infant and said, "Hello!" and then repeated this for the other doll. The two-object (none remaining) measurement period followed exactly as described for the Doll × Doll interaction.

On four-object (more remaining) trials, the experimenter first placed all four dolls on the box in an evenly spaced row, facing inward in pairs (Figure 2f). Next, she said, "Look!" and turned the first pair of dolls outward so that they faced the infant. She tilted the first doll toward the infant and said, "Hello!" then tilted the second doll toward the infant and said, "Hello!" (Figure 2g). She then repeated this for the second pair of dolls (Figure 2h). As in the other conditions, the dolls were briefly left in place (Figure 2i) before being hidden in the box (Figure 2j). The measurement periods for four objects (more remaining) and four objects (none remaining) followed exactly as described for the Doll × Doll interaction. Critically, the objects, presentation timing, and number of movements were equated between the Doll × Doll interaction and Doll × Infant interaction conditions.

Given previous demonstrations that arrays of one and two objects are well within infants' working memory capacity (Feigenson & Carey, 2003, 2005; Ross-Sheehy et al., 2003), we predicted that infants would succeed on the one- versus two-object block regardless of whether they viewed the Doll × Doll interaction or the Doll × Infant interaction. Specifically, we predicted that infants would search longer on the two-object (more remaining) measurement periods, when two dolls had been hidden but only one retrieved, than either the one-object (none remaining) or the two-object (none remaining) measurement periods, when all the objects seen hidden had been retrieved. In contrast, we predicted that infants would succeed with the four-object arrays only when provided with the social chunking cues from the Doll × Doll interaction condition. That is, we predicted that infants would search longer on four-object (more remaining) measurement periods than either two-object (none remaining) or four-object (none remaining) periods, but only when they had just seen the dolls face each other and interact contingently in pairs.

A trained observer who was unaware of testing condition coded infants' searching offline, frame by frame, using Preferential Looking Coder (Libertus, 2011). A second observer recoded 25% of the participants, and coder agreement averaged 0.95.

Results and Discussion

One- Versus Two-Object Block

We first analyzed infants' search patterns for the one- versus two-object block. Because different infants saw the Doll × Doll interaction and the Doll × Infant interaction, we analyzed their data separately.

Doll × Doll interaction

For infants who saw the Doll × Doll interaction, we first examined whether there was any difference in searching across the two measurement periods when the box was expected to be empty. We found that there was not; infants searched equally on one-object (none remaining; $M = 1.45$) and two-object (none remaining; $M = 1.36$) periods, $t(15) = 0.239$, $p = .81$, and therefore we collapsed these scores into an average score that reflected infants' searching when no more objects were expected to remain in the box. Next, we examined whether infants searched longer after seeing two objects hidden and just one object retrieved ($M = 2.58$) than when the box was expected to be empty. To do so, we calculated a difference score by subtracting the average searching times on the collapsed none remaining trials from average searching times on more remaining trials. This difference score was significantly greater than chance, $t(15) = 2.964$, $p = .01$, indicating that infants successfully continued searching after seeing two objects hidden and only one retrieved (Figure 3a).

Doll × Infant interaction

For infants who viewed the Doll × Infant interaction, we examined the data in the same way. We again found that infants searched equally on one-object (none remaining; $M = 1.74$) and two-object (none remaining; $M = 1.49$) measurement periods, $t(15) = 0.527$, $p = .61$, and therefore we collapsed these scores. Again, we calculated a difference score by subtracting the average searching times on none remaining trials from average searching times on more remaining trials ($M = 3.23$). We found that this difference score was significantly greater than chance, $t(15) = 2.746$, $p = .02$, indicating that infants again

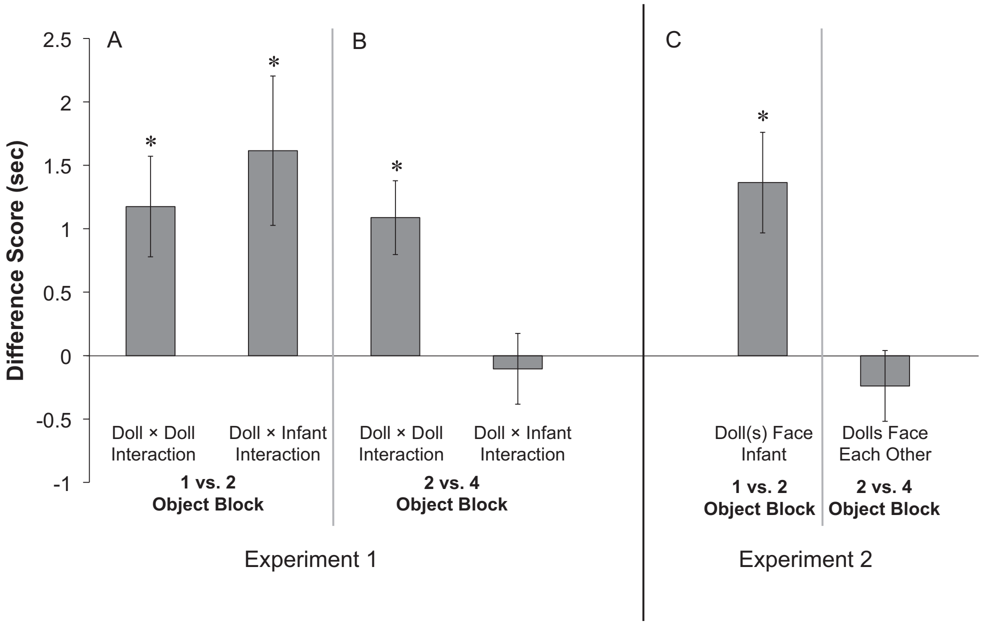

Figure 3. Results from Experiment 1: Panels A and B; results from Experiment 2: Panel C. (a) Mean difference scores (more remaining searching minus average none remaining searching) for the one- versus two-object block. (b) Mean difference scores for the two- versus four-object block. (c) Mean difference scores for the one- versus two- and two- versus four-object blocks. Error bars represent standard error of the mean.
$^{*}p < .05$

successfully continued searching after seeing two objects hidden and only one retrieved (Figure 3a).

To examine whether social cues affected infants' memory for arrays of one and two objects, we compared infants' difference scores across the Doll × Doll interaction and Doll × Infant interaction conditions. We found no difference, $t(30) = 0.621$, $p = .54$.

Two- Versus Four-Object Block

Next, we analyzed infants' search patterns in the two- versus four-object block. Again, because different infants saw the Doll × Doll interaction versus the Doll × Infant interaction, we analyzed their data separately.

Doll × Doll interaction

For infants who saw the Doll × Doll interaction, we first examined whether there was any difference in searching across the two measurement periods when the box was expected to be empty. We found that there was not; infants searched equally on two-object (none remaining; $M = 2.10$) and four-object (none remaining; $M = 1.73$) periods, $t(15) = 1.354$, $p = .20$, and so we collapsed these scores. We next examined whether infants searched longer after seeing four objects hidden and just two retrieved ($M = 3.0$) than when the box was expected to be empty. To do so, we calculated a difference score by subtracting the average searching times on none remaining trials from average searching times on more remaining trials. This difference score was significantly greater than chance, $t(15) = 3.745$, $p = .002$, indicating that after observing the Doll × Doll interaction, infants who saw four dolls hidden and only two of them retrieved successfully continued searching in the box for the remaining objects (Figure 3b).

Doll × Infant interaction

For infants who viewed the Doll × Infant interaction, we examined the data in the same way. We again found that infants searched equally on two-object (none remaining; $M = 2.33$) and four-object (none remaining; $M = 2.36$) measurement periods, $t(15) = -0.075$, $p = .94$, and therefore we collapsed these scores. Again, we calculated a difference score by subtracting the average searching times on none remaining trials from average searching times on more remaining trials ($M = 2.24$). This time we found that this difference score was no greater than chance, $t(15) = -0.376$, $p = .71$, indicating that after observing the Doll × Infant interaction, infants who saw four dolls hidden and only two of them retrieved did not continue searching the box for the remaining objects (Figure 3b).

To examine whether social cues affected infants' memory for four-object arrays, we compared infants' difference scores from the Doll × Doll interaction and Doll × Infant interaction conditions. We found that infants' performance differed by condition: Difference scores for infants in the Doll × Doll interaction condition were significantly greater than those for infants in the Doll × Infant interaction condition, $t(30) = 2.963$, $p = .01$.

As predicted, we found that infants successfully remembered arrays of one and two hidden objects regardless of whether the objects in these arrays faced and interacted contingently with each other (Doll × Doll interaction) or whether they faced and interacted with infants (Doll × Infant interaction). As in previous investigations (Feigenson & Carey, 2003, 2005), infants searched longer after seeing two identical objects hidden and retrieving just one of them, relative to searching after seeing two objects hidden and retrieving both, or after seeing a single object hidden and retrieving it. In addition, we found that infants successfully remembered arrays of four identical objects, but only when provided with socially relevant chunking cues in the Doll × Doll interaction condition. When four identical dolls were seen to turn and face each other and interact contingently in pairs, and then all four dolls were hidden in the box and two of the four were retrieved, infants successfully continued searching for the missing objects. In contrast, infants who saw the same four dolls turn toward and interact with the infant, then saw the four hidden in the box and two of the four retrieved, did not show this pattern of success. As in previous studies, infants who did not chunk the objects appeared unable to represent four objects at once.

The findings of Experiment 1 suggest that in addition to using spatial proximity and perceptual and/or category cues to chunk objects in memory (Feigenson & Halberda, 2004, 2008; Rosenberg & Feigenson, 2013), infants can chunk using their knowledge of the social world. Infants have previously shown sensitivity to the affiliative relations between socially relevant objects (Over & Carpenter, 2009). Here, we show that infants appear to harness this sensitivity to group together objects that behave affiliatively, and to represent these objects as a chunk. Doing so appears to allow infants to remember more total objects.

The findings of Experiment 1 raise the question of which social cues were required to support infants' chunking. In Experiment 1 when infants successfully chunked four objects, they saw dolls positioned facing each other in an affiliative posture, and also saw the dolls speak to each other in a reciprocal exchange. Previous studies have found that infants are sensitive to both affiliative stance (Over & Carpenter, 2009) and contingent behavior (Deligianni, Senju, Gergely, & Csibra, 2011; Johnson et al., 1998). Therefore, in Experiment 2 we sought to determine whether both of these sources of social information are required to support infants' chunking, examining whether infants could use affiliative posture, in the absence of contingent interaction, to chunk objects in memory.

Experiment 2

To better understand the social cues that motivate infants' chunking, in Experiment 2 we examined whether infants could chunk four-object arrays when no contingent interaction information was provided—that is, whether infants could chunk socially relevant objects based solely on the objects' positions relative to one another. Because Experiment 1 confirmed that infants can represent arrays of one and two objects regardless of the dolls' stance and behavior, we presented all infants with a one- versus two-object block in which the dolls faced the infant (i.e., in which no social cues were provided), and with a two- versus four-object block in which the dolls faced each other in pairs, but the dolls no longer interacted.

Method

Participants

Sixteen full-term infants between the ages of 15 and 17 months (range = 15 months 6 days to 17 months 0 days; M = 15 months 24 days) participated; nine of them were female. Nine additional infants were excluded due to fussiness (4), experimenter error (1), equipment failure (1), sibling interference (1), and failure to produce the dependent measure (2).

Stimuli

Infants saw four identical Lego Duplo zookeeper dolls (which had also been used in Experiment 1) as well as a set of four identical Strawberry Shortcake dolls (8 cm high). The box was the same as that in Experiment 1.

Design

Infants were tested with a one- versus two-object block and a two- versus four-object block. Because in Experiment 1 we found no effect of social cues on infants' ability to remember within-capacity arrays, and because previous studies show that infants can remember one and two objects without chunking (Feigenson & Carey, 2003, 2005), in the one- versus two-object block we always presented the dolls facing the infant: This was called the doll(s) face infant condition. Because infants in Experiment 1 and in previous studies have consistently failed to remember four objects in the absence of chunking cues, in the two- versus four-object block, we always presented infants with dolls that faced each other in affiliative pairs: This was called the dolls face each other condition. Whether infants were first tested with the one- versus two-object block or the two- versus four-object block was counterbalanced, as was whether the Lego dolls or the Strawberry Shortcake dolls were used in the one- versus two-object block.

Procedure

One- versus two-object block

The one- versus two-object block was structured as in Experiment 1 and contained three measurement periods: one object (none remaining), two objects (more remaining), and two objects (none remaining). In this block, all infants were tested in the doll(s) face infant condition. The experimenter said, "Watch this" as she placed the doll(s) atop the box facing outward toward the infant (rather than initially being placed facing each other and then being turned to face the infant as in Experiment 1). She pointed to the doll(s) and said, "Look at this!" The dolls were left visible for approximately 2 s, then were picked up by the experimenter and inserted into the box. Unlike in Experiment 1, the dolls never moved contingently with one another, and did not "speak." All other aspects of the way in which infants retrieved objects, the experimenter withheld objects, and the timing of the measurement periods were as in Experiment 1.

Two- versus four-object block

The two- versus four-object block also was structured as in Experiment 1 and contained three measurement periods: two objects (none remaining), four objects (more remaining), and four objects (none remaining). The experimenter said, "Watch this" as she placed the dolls in an equispaced row, positioned so that they faced each other in pairs (dolls face each other condition), unlike in Experiment 1 in which the dolls were initially placed facing the infant and then were turned to face each other. This was done so as to further remove any cues of contingent interaction between the dolls. As in the one- versus two-object block, and unlike in Experiment 1, the dolls did not "speak." The experimenter pointed to each pair of dolls while saying, "Look at this!" The dolls remained visible, facing each other in their affiliative posture (Figure 2f), for approximately 2 s, after which the experimenter picked them up and inserted them into the box. All other aspects of the way in which infants retrieved objects, the experimenter withheld objects, and the timing of the measurement periods were as in Experiment 1.

Searching was coded offline, frame by frame, by a trained observer who was unaware of testing condition. A second observer recoded 25% of the participants, and coder agreement averaged 0.98.

Results and Discussion

One- Versus Two-Object Block

For the one- versus two-object block, we first examined whether there was any difference in searching across the two measurement periods when the box was expected to be empty. We found that there was not; infants searched equally on one-object (none remaining; $M = 1.93$) and two-object (none remaining; $M = 1.90$) periods, $t(15) = 0.077$, $p = .94$, and therefore we collapsed these scores. We next examined whether infants searched longer after seeing two objects hidden and just one retrieved ($M = 3.28$) than when the box was expected to be empty. As in Experiment 1, we calculated a difference score by subtracting the average searching times on none remaining trials from average searching times on more remaining trials. This difference score was significantly greater than chance, $t(15) = 3.048$, $p = .01$, indicating that infants successfully continued searching after seeing two objects hidden and only one retrieved (Figure 3c).

Two- Versus Four-Object Block

Next, we analyzed infants' searching in the two- versus four-object block. First, we examined whether there was any difference in infants' searching when the box was expected to be empty. We found that there was not; infants searched equally on two-object (none remaining; $M = 3.10$) and four-object (none remaining; $M = 2.23$) measurement periods, $t(15) = 1.102$, $p = .29$, and therefore we collapsed these scores. We next calculated a difference score by subtracting the average searching times on none remaining trials from average searching times on more remaining trials ($M = 2.43$). In contrast to the one- versus two-object block, we found that this difference score did not differ from chance, $t(15) = -0.506$, $p = .62$, indicating that infants who saw four dolls hidden and only two of them retrieved did not continue searching the box for the remaining objects (Figure 3c).

Finally, we examined whether infants searched differently when presented with social cues that involved both affiliative stance and contingent interaction (Experiment 1) versus cues that involved only affiliative stance (Experiment 2). We first examined the one- versus two-object block by comparing the difference scores of infants in the Experiment 1 Doll × Infant interaction condition (in which the dolls faced and interacted with the infant) to the difference scores of infants in the Experiment 2 doll(s) face infant condition (in which the dolls faced the infant without interacting). We found that infants' difference scores did not differ across these two experiments, $t(30) = 0.34$, $p = .74$. Next, we examined the two- versus four-object block by comparing the difference scores of infants in the Experiment 1 Doll × Doll interaction condition (in which the dolls faced each other and interacted contingently in pairs) to the difference scores of infants in the Experiment 2 dolls face each other condition (in which the dolls faced each other in pairs without interacting). We found that the difference scores for infants in the Experiment 1 Doll × Doll interaction condition were significantly greater than those of infants in the Experiment 2 dolls face each other condition, $t(30) = 2.393$, $p = .02$. Therefore, seeing four identical objects interact contingently within pairs appeared to significantly benefit infants' memory.

General Discussion

In two experiments, we examined whether infants can use their rich social knowledge to restructure object representations in memory. First, in Experiment 1 we presented infants with arrays of identical dolls that were either expected to be within their working memory capacity, or were expected to exceed it. On half of the trials, the dolls were positioned in an affiliative posture (facing each other) and also greeted each other within pairs. On the other half of the trials, the dolls were positioned facing outward and greeted the infant rather than each other. We found that infants succeeded at representing one or two hidden dolls regardless of the types of social cues seen. However, infants only successfully remembered arrays of four hidden dolls when the dolls had been seen to face and interact with each other contingently in pairs before they were hidden. These results suggest that infants can use social information to bind representations of individual objects into larger social units, thereby increasing the total amount of remembered information. Second, in Experiment 2 we examined whether this ability relied on seeing contingent interaction between the dolls, or whether the affiliative posture alone was sufficient to motivate chunking. Here, we found that infants again remembered arrays of one and two hidden objects even without social cues. However, infants presented with four dolls that faced each other in pairs but did not interact contingently apparently failed to remember the objects. Although infants are sensitive to affiliative postural information alone (Over & Carpenter, 2009), it appears that seeing the dolls interact contingently was necessary for infants to restructure their memory representations into chunks.

These results raise a number of questions for further exploration. First, we found that infants successfully chunked four objects in memory when the objects had faced each other in pairs and interacted contingently, but failed to chunk four objects when the objects had faced each other in pairs without interacting. However, it remains unknown whether infants require multiple cues to chunk using social information, or whether contingent interaction alone is sufficient. Younger, 7-month-old infants have been shown to chunk when presented with multiple redundant cues (i.e., spatial chunking cues and featural chunking cues, both specifying the same chunks), but fail to chunk when provided with either spatial or featural cues alone (Moher, Tuerk, & Feigenson, 2012). To examine whether multiple redundant cues are also needed to drive infants' chunking using social information, infants could be presented with arrays of objects that face away from each other but still interact contingently. Moreover, it remains a possibility that other types of agentive stimuli might elicit stronger social representations than dolls do, and thus might not require multiple chunking cues.

Second, it remains unclear whether perceptual factors may have played a role in infants' success in the current experiments. For example, in the Doll × Doll interaction condition of Experiment 1, the dolls leaned toward each other when interacting, and it is possible that this perceptual information induced spatial grouping of the dolls irrespective of social information. To rule out this possibility, future experiments could present infants with cues identical to those presented in the Doll × Doll interaction condition of Experiment 1, but with nonagentive objects (e.g., blocks) that were turned toward each other and emitted nonsocial sounds in alternation. If construing the objects as social entities was key to infants' success in Experiment 1, then infants who see nonagentive objects emitting nonsocial signals should fail to chunk.

Another open question concerns the socially relevant representations that infants can use to chunk. The present experiments suggest that infants can form chunks of two by binding representations of social entities that engaged in a reciprocal exchange. Hence, the representation underlying infants' chunk formation might be something like "social pair" or "partners." It remains unknown whether infants also can bind more than two individuals per chunk (but see Rosenberg & Feigenson, 2013), as when representing multiple individuals based on social relationships (e.g., members of one family vs. another; children vs. adults; boys vs. girls). Previous research shows that infants represent a wealth of information about a range of different types of social relationships, including who helps versus hinders others (Hamlin et al., 2007), who is dominant versus subordinate (Thomsen, Frankenhuis, Ingold-Smith, & Carey, 2011), and who is part of the infant's own linguistic in-group versus out-group (Kinzler et al., 2007). Future work may continue to explore the ways in which social knowledge can be used to structure memory by examining whether these sensitivities to social relationships affect infants' memory for the social agents.

Finally, more work is needed to characterize the resolution of infants' chunked representations. Although chunking objects together based on spatial proximity (Feigenson & Halberda, 2004), category knowledge (Feigenson & Halberda, 2008), statistical co-occurrences between items (Kibbe & Feigenson, 2013), and social cues (the present experiments) enables infants to remember more objects than they could otherwise, we currently know little about the nature of the chunked representations themselves. Of particular interest is whether a representation of a chunk is coarser, or less precise, than a representation of an individual object. Some evidence suggests that remembering increasing numbers of objects, even within the typical span of working memory, results in a loss of featural information (e.g., Alvarez & Cavanagh, 2004; Zosh & Feigenson, 2012). Chunking objects using social cues might increase the number of remembered objects, but at a cost to the resulting representations. For example, infants might not retain detailed featural information about the objects that were chunked (perhaps simply encoding each individual as "social agent" or "object" rather than remembering information about the individual token or the basic level kind). Alternatively, chunking on the basis of social cues might preserve featural information in memory. Past work has found a memory advantage for socially relevant stimuli, with adults having higher representational resolution for faces than for nonsocial objects (Scolari, Vogel, & Awh, 2008; Curby & Gauthier, 2007; see also Wong, Peterson, & Thompson, 2008). Future investigation is needed to better specify how infants' representations of a socially relevant chunk differ from their representations of individual objects.

In summary, the present experiments highlight the flexible nature of infants' memory computations. Although infants' working memory is capacity limited, infants can use multiple types of information to bind representations of individual items into chunks, thereby increasing memory efficiency. Thus, infants' knowledge of the social world may affect the structure of memory.

References

Alvarez, G. A., & Cavanagh, P. (2004). The capacity of visual short-term memory is set both by visual information load and by number of objects. *Psychological Science*, *15*, 106–111. doi:10.1111/j.0963-7214.2004.01502006.x

Augusti, E., Melinder, A., & Gredebäck, G. (2010). Look who's talking: Pre-verbal infants' perception of face-to-face and back-to-back social interactions. *Frontiers in Developmental Psychology*, *161*, 1–7. doi:10.3389/fpsyg.2010.00161

Barner, D., Thalwitz, D., Wood, J., & Carey, S. (2007). On the relation between the acquisition of singular-plural morpho-syntax and the conceptual distinction between one and more than one. *Developmental Science*, *10*, 365–373. doi:10.1111/j.1467-7687.2007.00591.x

Beier, J. S., & Spelke, E. S. (2012). Infants' developing understanding of social gaze. *Child Development*, *83*, 486–496. doi:10.1111/j.1467-8624.2011.01702.x

Bonatti, L., Frot, E., Zangl, R., & Mehler, J. (2002). The human first hypothesis: Identification of conspecifics and individuation of objects in the young infant. *Cognitive Psychology*, *44*, 388–426. doi:10.1006/cogp.2002.0779

Brady, T. F., Konkle, T., & Alvarez, G. A. (2009). Compression in visual working memory: Using statistical regularities to form more efficient memory representations. *Journal of Experimental Psychology: General*, *138*, 487–502. doi:10.1037/a0016797

Brady, T. F., Konkle, T., & Alvarez, G. A. (2011). A review of visual memory capacity: Beyond individual items and toward structured representations. *Journal of Vision*, *11*, 1–34. doi:10.1167/11.5.4

Chase, W. G., & Ericsson, K. A. (1982). Skill and working memory. In G. H. Bower (Ed.), *The psychology of* *learning and motivation* (Vol. 16, pp. 1–58). New York, NY: Academic Press.

Chase, W. G., & Simon, H. A. (1973). Perception in chess. *Cognitive Psychology*, *4*, 55–81. doi:10.1016/0010-0285(73)90004-2

Cowan, N. (2001). The magical number 4 in short term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences*, *24*, 87–114. doi:10.1017/S0140525X01003922

Curby, K. M., & Gauthier, I. (2007). A visual short-term memory advantages for faces. *Psychonomic Bulletin and Review*, *14*, 620–628. doi:10.3758/BF03196811

Deligianni, F., Senju, A., Gergely, G., & Csibra, G. (2011). Automated gaze-contingent objects elicit orientation following in 8-month-old infants. *Developmental Psychology*, *47*, 1499–1503. doi:10.1037/a0025659

Ericsson, K. A., Chase, W. G., & Faloon, S. (1980). Acquisition of a memory skill. *Science*, *208*, 1181–1182. doi:10.1126/science.7375930

Farroni, T., Johnson, M. H., Menon, E., Zulian, L., Faraguna, D., & Csibra, G. (2005). Newborns' preference for face-relevant stimuli: Effects of contrast polarity. *Proceedings of the National Academy of Sciences USA*, *102*, 17245–17250. doi:10.1073/pnas.0502205102

Feigenson, L., & Carey, S. (2003). Tracking individuals via object-files: Evidence from infants' manual search. *Developmental Science*, *6*, 568–584. doi:10.1111/1467-7687.00313

Feigenson, L., & Carey, S. (2005). On the limits of infants' quantification of small object arrays. *Cognition*, *97*, 295–313. doi:10.1016/j.cognition.2004.09.010

Feigenson, L., Carey, S., & Hauser, M. (2002). The representations underlying infants' choice of more: Object files versus analog magnitudes. *Psychological Science*, *13*, 150–156. doi:10.1111/1467-9280.00427

Feigenson, L., & Halberda, J. (2004). Infants chunk object arrays into sets of individuals. *Cognition*, *91*, 173–190. doi:10.1016/j.cognition.2003.09.003

Feigenson, L., & Halberda, J. (2008). Conceptual knowledge increases infants' memory capacity. *Proceedings of the National Academy of Sciences USA*, *105*, 9926–9930. doi:10.1073/pnas.0709884105

Gergely, G., Nádasdy, Z., Csibra, G., & Biró, S. (1995). Taking the intentional stance at 12 months of age. *Cognition*, *56*, 165–193. doi:10.1016/0010-0277(95)00661-H

Gobet, F., & Clarkson, G. (2004). Chunks in expert memory: Evidence for the magical number fouror is it two? *Memory*, *12*, 732–747. doi:10.1080/09658210344000530

Gobet, F., & Simon, H. A. (1998). Expert chess memory: Revisiting the chunking hypothesis. *Memory*, *6*, 225–255. doi:10.1080/741942359

Hamlin, J. K., Hallinan, E. V., & Woodward, A. L. (2008). Do as I do: 7-month-old infants selectively reproduce others' goals. *Developmental Science*, *11*, 487–494. doi:10.1111/j.1467-7687.2008.00694.x

Hamlin, J. K., Wynn, K., & Bloom, P. (2007). Social evaluation by preverbal infants. *Nature*, *450*, 557–559. doi:10.1038/nature06288

Johnson, S., Slaughter, V., & Carey, S. (1998). Whose gaze would infants follow? The elicitation of gaze following in 12-month-olds. *Developmental Science*, *1*, 233–238. doi:10.1111/1467-7687.00036

Kibbe, M. M., & Feigenson, L. (2013). *Infants use statistical regularities to chunk objects in working memory*. Manuscript submitted for publication.

Kinzler, K. D., Dupoux, E., & Spelke, E. S. (2007). The native language of social cognition. *Proceedings of the National Academy of Sciences USA*, *104*, 12577–12580. doi:10.1073/pnas.0705345104

Libertus, K. (2011). Preferential Looking Coder (Version 1.3.3) [Computer software]. Baltimore, MD: Johns Hopkins University

Luck, S. J., & Vogel, E. K. (1997). The capacity of visual working memory for features and conjunctions. *Nature*, *390*, 279–281. doi:10.1038/36846

Mathy, F., & Feldman, J. (2012). What's magic about magic numbers? Chunking and data compression in short-term memory. *Cognition*, *122*, 346–362. doi:10.1016/j.cognition.2011.11.003

Meltzoff, A. N. (1995). Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology*, *31*, 838–850. doi:10.1037/0012-1649.31.5.838

Miller, G. M. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, *63*, 81–97. doi:10.1037/h0043158

Moher, M., Tuerk, A. S., & Feigenson, L. (2012). Seven-month-old infants chunk items in working memory. *Journal of Experimental Child Psychology*, *112*, 361–377. doi:10.1016/j.jecp.2012.03.007

Over, H., & Carpenter, M. (2009). Eighteen-month-old infants show increased helping following priming with affiliation. *Psychological Science*, *20*, 1189–1193. doi:10.1111/j.1467-9280.2009.02419.x

Rosenberg, R. D., & Feigenson, L. (2013). Infants hierarchically organize memory representations. *Developmental Science*, *16*, 610–621. doi:10.1111/desc.12055

Ross-Sheehy, S., Oakes, L. M., & Luck, S. J. (2003). The development of visual short-term memory capacity in infants. *Child Development*, *74*, 1807–1822. doi:10.1046/j.1467-8624.2003.00639.x

Scolari, M., Vogel, E. K., & Awh, E. (2008). Perceptual expertise enhances the resolution but not the number of items that can be maintained in visual working memory. *Psychonomic Bulletin and Review*, *15*, 215–222. doi:10.3758/PBR.15.1.215

Simon, H. (1974). How big is a chunk? *Science*, *183*, 482. doi:10.1126/science.183.4124.482

Sperling, G. (1960). The information available in brief visual presentations. *Psychological Monographs*, *74*, 1–29. doi:10.1037/h0093759

Thomsen, L., Frankenhuis, W., Ingold-Smith, M., & Carey, S. (2011). Big and mighty: Preverbal infants represent social dominance. *Science*, *331*, 477–480. doi:10.1126/science.1199198

Van de Walle, G. A., Carey, S., & Prevor, M. (2000). Bases for object individuation in infancy: Evidence from manual search. *Journal of Cognition and Development*, *1*, 249–280. doi:10.1207/S15327647JCD0103_1

Wong, J. H., Peterson, M. S., & Thompson, J. C. (2008). Visual working memory capacity for objects from different categories: A face-specific maintenance effect. *Cognition*, *108*, 719–731. doi:10.1016/j.cognition.2008.06.006

Woodward, A. L. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition*, *69*, 1–34. doi:10.1016/S0010-0277(98)00058-4

Wu, R., & Kirkham, N. Z. (2010). No two cues are alike: Depth of learning during infancy is dependent on what orients attention. *Journal of Experimental Child Psychology*, *107*, 118–136. doi:10.1016/j.jecp.2010.04.014

Yoon, J. M., Johnson, M. H., & Csibra, G. (2008). Communication-induced memory biases in preverbal infants. *Proceedings of the National Academy of Sciences*, *105*, 13690–13695. doi:10.1073/pnas.0804388105

Zosh, J. M., & Feigenson, L. (2012). Memory load affects object individuation in 18-month old infants. *Journal of Experimental Child Psychology*, *113*, 322–336. doi:10.1016/j.jecp.2012.07.005