

Learning From Others: The Effects of Agency on Event Memory in Young Children

Lauren H. Howard 
Franklin & Marshall College

Tracy Riggins
University of Maryland

Amanda L. Woodward
University of Chicago

Little is known about the influence of social context on children's event memory. Across four studies, we examined whether learning that could occur in the absence of a person was more robust when a person was present. Three-year-old children ($N = 125$) viewed sequential events that either included or excluded an acting agent. In Experiment 1, children who viewed an agent recalled more than children who did not. Experiments 2a and 2b utilized an eye tracker to demonstrate this effect was not due to differences in attention. Experiment 3 used a combined behavioral and event-related potential paradigm to show that condition effects were present in memory-related components. These converging results indicate a particular role for social knowledge in supporting memory for events.

From early in life, the people in our environment shape the way we view our world. Even young infants have a set of cognitive responses that are specialized for reacting to and understanding other people: They are sensitive to the perceptual features that signal that a person is present in a scene (Farroni, Johnson, Brockbank, & Simion, 2000; Fox & McDaniel, 1982; Simion, Regolin, & Bulf, 2008), they shift their attention adaptively in response to others' actions (Cannon & Woodward, 2012; Csibra, 2003), and they interpret others' actions in terms of their meaningful, intentional structure (Baldwin & Baird, 2001; Woodward, Sommerville, Gerson, Henderson, & Buresh, 2009). This "social cognitive toolkit" sets children up to attend to and make

sense of the critical in-the-moment information that is provided by other people.

The early emergence and robustness of these social cognitive responses suggest that they may have broad effects not just on in the moment perception and reasoning, but also on children's learning and memory over time. In fact, the transfer of certain types of social information is inherently dependent on communication between social partners. For example, learning to use and understand language, cultural conventions, and social values would be nearly impossible without a social model (e.g., Hoff, 2006; Kenward, Karlsson, & Persson, 2011; Tomasello, 1999). Children's social cognitive responses lay the foundation for these aspects of learning; for example, children's ability to follow an informant's referential behaviors supports their learning about novel words (Frank, Goodman, & Tenenbaum, 2009) and guides their understanding of an informant's emotional expression (Egyed, Király, & Gergely, 2013; Liszkowski, Carpenter, Henning, Striano, & Tomasello, 2004). Beyond these situations, however, little is known about the broader effects of social contexts on children's learning and memory. In the current studies we ask whether learning that could, in principle, occur in

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Correspondence concerning this article should be addressed to Lauren H. Howard, Psychology Department, Franklin and Marshall College, 415 Harrisburg Ave, Lancaster, PA 17604. Electronic mail may be sent to lauren.howard@fandm.edu.

the absence of a person in the scene is nevertheless more robust when a person is present.

In particular, we consider the problem of encoding and remembering information from a sequence of events. A fundamental challenge for young learners is to take up information as events unfold, to integrate and maintain this information in memory, and to use it to guide future actions and decisions. This task is pervasive in children's lives. As examples, learning about common routines (Nelson, 1988), understanding the chain of events that generates important causal outcomes (Legare & Clegg, 2014), integrating new pieces of domain knowledge that are acquired over time (Bauer, King, Larkina, Varga, & White, 2012; Pathman & Bauer, 2013), tracking the identity, history and ownership of objects (Gelman, Noles, & Stilwell, 2014), and developing coherent autobiographical memories (Reese et al., 2011), all depend on the ability to encode, integrate and maintain information about sequential events. In the current studies we test the possibility that this kind of learning may happen most effectively when the events can be understood as the intentional behavior of a person.

One reason we believe agents might be particularly conducive for early learning is due to the structure that the presence of people and their goals provide. This structure may be learned over time, coinciding with the predictable patterns that agents demonstrate when completing intentional actions (Baldwin, Baird, Saylor, & Clark, 2001; Stahl, Romberg, Roseberry, Golinkoff, & Hirsh-Pasek, 2014), and research shows that even infants utilize these structures when understanding action as it unfolds. For example, infants reliably predict (Cannon & Woodward, 2012; Monroy, Gerson, & Hunnius, 2017) and parse (Baldwin & Baird, 2001) complex action events in accordance with an agent's goals, though they do not do so for similarly moving inanimate objects (e.g., claws; Cannon & Woodward, 2012; Falck-Ytter, Gredebäck, & von Hofsten, 2006). These effects are evident not just in behavior, but on neural levels as well, as infants demonstrate predictive neural activity to learned goal-directed actions via electroencephalography rhythms (Monroy, Gerson, Domínguez-Martínez, et al., 2017) and event-related potentials (Maffongelli, Antognini, & Daum, 2018; Monroy, Gerson, Domínguez-Martínez, et al., 2017). As such, converging evidence using a number of methods has found that, in the moment, infants recruit goal structures to comprehend and segment events.

Recent studies have found that the goal structure of events can influence preschoolers' nonverbal

memory, though the comprehension and utilization of this structure may mature with age (e.g., Bauer, Wenner, Dropik, Wewerka, & Howe, 2000; Freier, Cooper, & Mareschal, 2015). In a series of studies by Loucks and colleagues (e.g., Loucks & Meltzoff, 2013; Loucks, Mutschler, & Meltzoff, 2017), 3-year-old children watched demonstrators completing multistep actions to achieve a goal on two sets of objects (e.g., feeding a baby doll). These actions were either demonstrated in grouped chronological order (completing all the actions for one set before moving to the next) or the actions were interleaved across the sets, such that the demonstrator switched back and forth between stimuli to complete the goals. After a delay, children were given the stimuli objects and were asked to recreate the sequence. Interestingly, children in the interleaved condition privileged the goals of the demonstrator as opposed to the chronological order, suggesting that even in nonverbal event encoding, goals play a primary organizational role.

In addition to nonverbal memory, research on children's narratives provide further evidence early event memory is supported by an understanding of others' actions and intentions. Preschool children focus on the goals and desires of agentive characters when telling stories or recalling a narrative (e.g., Bower & Rinck, 1999; Hudson, 1988; Trabasso, Stein, Rodkin, Park Munger, & Baughn, 1992), 4- to 7-year-old children are more likely to verbally recall the goal rather than the starting point of a person in an event (Lakusta & Landau, 2005), and school-age children are more likely to comment on everyday events that include actions pertaining to goals (Anderson & Conway, 1997). Indeed, aspects of an event that do not relate to a goal are often excluded altogether from children's narratives (Lakusta & Landau, 2005; Travis, 1997). There is even evidence that word and sentence pairings associated with agency or animacy are remembered more robustly by 4- to 5-year-old children than similar pairings denoting inanimate objects (Aslan & John, 2016). Although these results highlight an agentive focus in children's narrative memory, it remains unclear whether the goal structure used in the verbal communication of an event is indicative of learned narrative form for representing events (i.e. how to tell a good story), or whether it reflects something deeper about the importance of human actions for memory processes. Young preschoolers have difficulty constructing coherent narratives, and they also show limited event memory, but, because studies in this area have relied on verbal measures of recall, it is difficult to distinguish limitations in

verbal abilities from limitations in memory per se (see Bauer, 2007).

The evidence from preschoolers' imitative and verbal memory suggests that intentional action understanding is helpful for parsing and encoding events that include other people. However, it remains unknown whether an understanding of other's intentions supports memory in a more general manner. Does thinking about events in terms of human actions make them inherently more memorable? One hint comes from findings on infant memory: the strongest evidence for early long-term event memory comes from studies that tap infants' recall of human actions. Deferred imitation, a procedure which involves the presentation of an action on a novel object, a delay, and a test period where the child is able to act on the objects (e.g., Bauer & Mandler, 1989; Meltzoff, 1985), has been widely used in the infant literature to examine early memory. This method has elicited robust memory in early childhood, demonstrating recall in infants as young as 6-months of age (e.g., Barr, Dowden, & Hayne, 1996), after as few as one or two demonstrations (e.g., Bauer, 1992; Mandler & McDonough, 1995), and with memory maintenance of up to 1 year (Carver & Bauer, 1999). As in event segmentation, these abilities are predicted by underlying neural mechanisms; event-related potential (ERP) measures of infant memory after observing an action event predict behavioral recall up to 1 month later (Bauer, San Souci, & Pathman, 2010; Bauer, Wiebe, Carver, Waters, & Nelson, 2003). Deferred imitation procedures, by their very nature, require a human model that the child views acting in an intentional manner. Furthermore, infants selectively remember and imitate a person's intended goal and not necessarily the specific movements he or she undertakes (Meltzoff, 1995), suggesting that the inclusion of a person in an event not only makes it memorable, but may also influence young children to think in terms of a goal-based structure.

The robust effects found using deferred imitation paradigms, coupled with the prevalence of agents and their actions in the verbal recall of older children, suggests that the presence of an agent influences the way that young children not only perceive events, but also encode them in memory. However, no work to date has directly compared memory for agentive actions to memory for similar, nonsocial events. In an effort to parse out different types of social learning mechanisms, some studies have attempted to assess children's imitation of modeled actions in relation to a "ghost condition" where objects appear to magically move on their

own (see Hopper, Flynn, Wood, & Whiten, 2010; Subiaul, Vonk, & Rutherford, 2011; Thompson & Russell, 2004). However, the findings have been inconsistent across studies, and interpreting the findings is complicated by the fact that the ghost stimuli involve presenting participants with apparently impossible events. Therefore, the question of whether or not agentive events are more memorable than nonagentive events remains open.

In order to examine the influence of a person on childhood memory, we sought to create a paradigm that could directly contrast agentive versus nonagentive events within the same mode of presentation, and in which stimuli that could plausibly demonstrate a sequential event as the actions of a human actor or as occurring without a human present. In the studies reported here, we showed children a series of still snapshots from an event in which an object was sequentially created from parts. What varied across the conditions was whether a person was present in the scene (Agent condition) or not (Nonagent condition). After a delay, children's memory was assessed. In all experiments, event memory was measured via children's ability to reconstruct the sequence from memory. In some experiments, this behavioral measure was explored in the context of children's attention during encoding, or their electrophysiological indexes of recall (e.g., Riggins, Miller, Bauer, Georgieff, & Nelson, 2009; Riggins & Rollins, 2015).

We tested 3-year-old children because participants of this age have demonstrated poor verbal recall for events (see Brown, 1975) and yet impressive imitative social memory (see Bauer, 2007). Examining memory using nonverbal paradigms with preschool children will allow us to tie together the bodies of research on verbal recall and deferred imitation to better understand whether children preferentially recall events including an agent. In Experiment 1, we examined whether agentive versus nonagentive picture sequences have differential effects on children's memory, as evidenced by children's ability to reconstruct the depicted object. In Experiment 2a, we presented demonstrations on an eye-tracking computer in order to investigate attentional mediators of this social memory effect, and in Experiment 2b we explored attention and memory for events unaccompanied by verbal mention of the agent. In Experiment 3, we utilized ERP procedures to gain more insight into the nature of the memory effects that were observed using behavioral measures. Thus, we used converging evidence from a number of methodologies to probe the influence of social context on early event memory.

Experiment 1

Method

Participants

Fifty-four 3-year-old children ($M = 36.0$ months, range = 33.9–38.8 months, 26 females) participated in Experiment 1. All participants came from English speaking homes. Eighteen children saw a series of still pictures in which a person sat behind an object that was progressively constructed from parts (*Agent condition*: $M = 36.1$ months, range = 33.9–38.8 months; 9 females), whereas 18 saw still pictures demonstrating the same object construction with no person present (*Nonagent condition*: $M = 36.0$ months, range = 34.30–38.0 months; 8 females). A separate group of 18 children (*Baseline*; $M = 35.9$ months, range = 34.0–38.0 months; 9 females) did not view any picture demonstration and proceeded directly to the test phase (see following). Parents reported that 70% of participants were Caucasian, 7% were African American, 4% were Hispanic, 2 were Asian, and 7% were more than one race. An additional 9% of parents chose not to answer questions concerning their child's race or ethnicity. Six children were tested but were not included in the final sample due camera recording errors ($N = 3$) or parents interfering and telling the child where to place the objects ($N = 3$).

Procedure

Setup. Upon entering the testing room, children sat at a table next to the experimenter. Parents sat in a chair at the opposite side of the room, facing the table, and were asked to read a magazine

and to not intervene in the task or guide children's responses. Sessions were video-recorded for later coding, with one camera located at an angle behind the table (focused on the child's hands) and one directly in front of the table (focused on the front of the child and experimenter).

Demonstration phase. During the demonstration phase, each child read two picture books with an experimenter that depicted a six-step sequence culminating in the assembly of objects (a bunny and a tree). These stimuli were loosely based on multistep sequences that have been utilized to test nonverbal memory in young children (e.g., see Barr, Muentener, Garcia, Fujimoti, & Chávez, 2007; Herbert & Hayne, 2000). The first picture showed the object pieces spread on a table, and each subsequent picture showed the object with one new piece added (see Figure 1). The final picture showed the fully constructed object. In the Agent condition, the picture sequence included a person seated behind the objects, with her hands holding each new piece in its place on the object. In the Nonagent condition, there was no person present in the pictures.

The order of book presentation was counterbalanced so that half the children saw the bunny book first and the other half viewed the tree book first. These picture books varied in two respects, a visually perceivable agent and the accompanying language. In the Agent condition, children viewed an agent (Sally) at the beginning of the story and saw her hands assembling the pieces throughout the sequence. The children in the Agent condition also heard sentences accompanying the sequence such as "Look, this is Sally! I wonder what Sally is going to make!" In the Nonagent condition, children viewed pictures without an agent perceivably

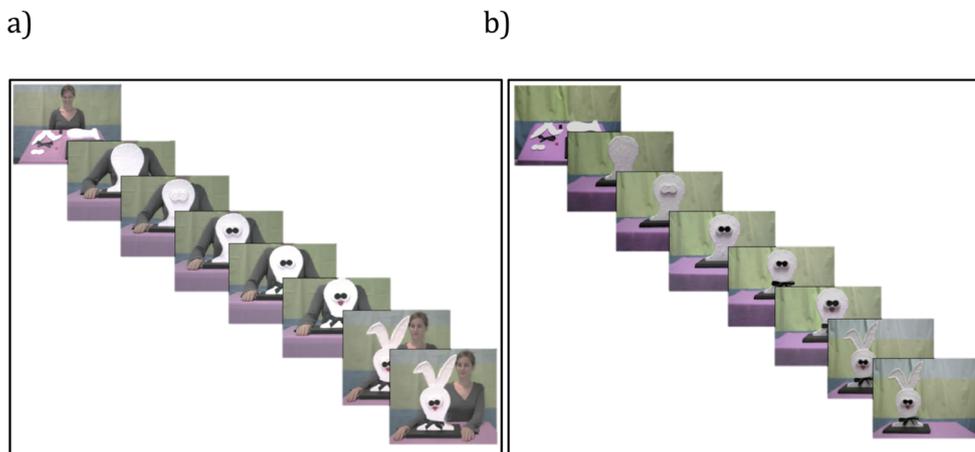


Figure 1. Example of still picture stimuli presented in the Agent (a) and Nonagent (b) conditions.

present, such that the mechanism behind the object construction was unknown though not implausible. The sentences accompanying the Nonagent condition described the object construction process but did not reference an agent (e.g., "Look at these things! I wonder what these things are going to make!"). Sentences across conditions were matched for approximate length and content. Furthermore, appropriate cues concerning the end state (that the objects go together to make something) and the sequential nature of the pictures ("first," "now," "then," "finally") were consistent in both the Agent and Nonagent conditions (see Appendix A for full narratives).

When reading the books, the experimenter pointed to each of the key objects on each page. For example, when looking at a picture of the ears going on the bunny head, the experimenter would first point to the ears and then the top of the head to indicate the object ("Sally puts this piece . . .") and its location ("like this!"). The experimenter kept movement consistent across participants, helping to restrict attention to the key features of the step and ensuring that the child focused on the relevant details. A page of the book was flipped only when it was clear that the child had attended to the relevant picture for approximately three seconds (equivalent to the duration of the sentence on the page). The total time for the demonstration phase was approximately 5 min.

Children assigned to the Baseline condition did not participate in the demonstration phase.

Delay phase. During this phase, a delay period of 10 min was imposed and participants were given the option to either play a matching game or complete a puzzle.

Test phase. During this phase, the experimenter produced a tray that contained the pieces previously seen in the picture books. The order of test sets was the same as that of the books during demonstration. Once the experimenter placed the tray on the table, she asked "What do you think you can make with these?" and allowed the child to freely complete the sequence in whichever way they saw fit. If the child questioned the experimenter about object placement, the experimenter expressed ignorance and asked the child where he or she thought it should go. If the child placed a piece in the correct location but could not fully complete the step (e.g., put the bunny ears in the slot on the top of the head but could not reach high enough to get the angle correct), the experimenter aided in step completion and the child received credit for the step. If the child incorrectly placed

any piece in the wrong location twice (e.g., tried to put the bunny ears underneath the object base) or asked for help at least two times, the experimenter moved the piece to the correct location, but the child did not receive credit for completing the step. In this way, each child saw the objects completed in the correct manner, whether by their own devices or with help from the experimenter.

Coding

Test trials were coded from video by a research assistant blind to experimental condition using Interact coding software (Mangold, 1998). A second independent assistant coded 30% of the participants, with the two coders agreeing on 97% of total behavioral scores. When there was a coding disagreement, the primary coder's score was used. Sessions were coded for the number of correct steps completed by the child (of a possible six for each object, 12 total). Child completion credit was given in instances where the child correctly placed a piece or placed a piece in the correct location but needed slight assistance from the experimenter (as outlined earlier). No credit was given when the experimenter or parent significantly intervened or provided help in object placement.

Results and Discussion

Preliminary analyses revealed that there were no effects of gender, age, or stimulus set for either condition, therefore subsequent analyses were collapsed across these factors. A one-way analysis of variance (ANOVA) was run to test the effect of condition (Agent, Nonagent, Baseline) on reconstruction scores. Results revealed a significant main effect of condition on test scores, $F(2, 51) = 40.90, p < .001$. Specifically, children who viewed the event with a person present were able to reproduce significantly more of the assembly steps at test ($M = 10.83, SD = 1.46$) than those that did not see a person in the pictures, $M = 8.39, SD = 3.38$; two-tailed t -test; $t(34) = 2.815, p < .05$; see Figure 2, and participants in both the Agent and Nonagent conditions completed significantly more steps than those in the Baseline condition ($M = 3.89, SD = 1.74$; all $ps < .001$).

These results demonstrate that the inclusion of a person in an event improves memory in young children. Reconstruction scores across conditions were significantly different 10 min after children first encoded the event, despite the fact that the same construction information was provided in both picture sequences. Why might this be the case? We know

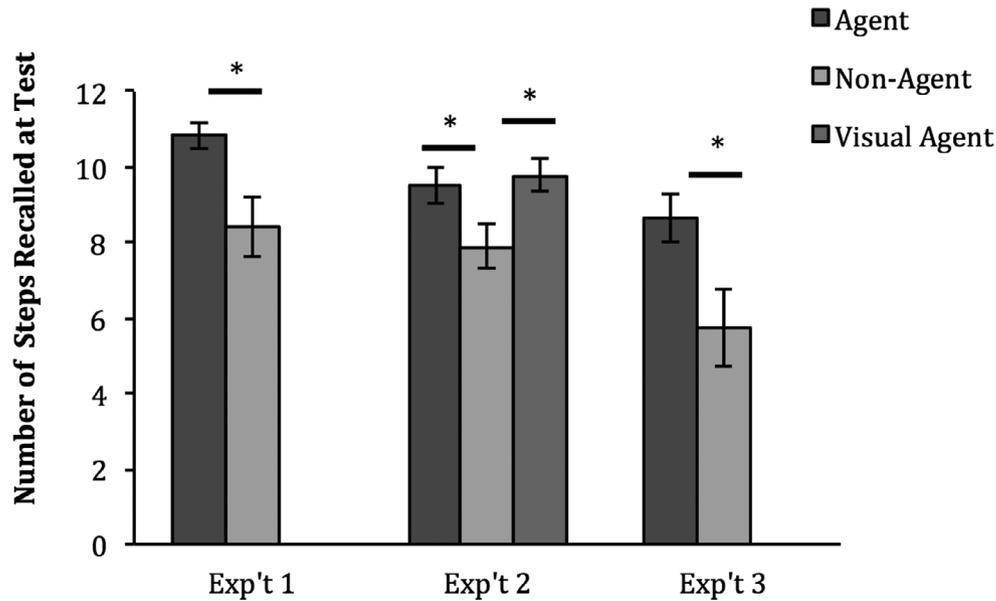


Figure 2. The number of steps recalled and recreated at test (of a possible 12) for children in the Agent, Nonagent, and Visual Agent conditions in Experiments 1–3. $*p < .05$ and denotes differences between the number of steps recalled.

that attention to a stimulus is a requirement for adequate encoding and later recall (Chun & Turk-Browne, 2007). Therefore, if significant differences in attention are evident across conditions, this might be a mechanism underlying a memory difference. It is possible that events including people are generally more salient than events without people in them, leading to increased global attention and better memory for the event. In addition, local shifts in attention, for example, attention to each part directed by the character's hands, may have drawn children's attention to most relevant aspect of each page.

On the other hand, if just *thinking* about an agent creating an object is enough to increase recall, we might expect increased memory in the agent condition even if children attend equally to the picture sequence during demonstration and even if the character's hands did not highlight the relevant pieces. In fact, it is possible that the presence of an agent would be enough to elicit this memory boost even in the absence of a verbal narrative referring to her actions. In Experiments 2a and 2b we investigated these possibilities by examining the ways in which attention and memory might intertwine while recalling agentive and nonagentive events. Specifically, in Experiment 2a, we utilized an eye-tracking methodology to explore whether children's patterns of attention to the picture stimuli differed between the Agent and Nonagent conditions in ways that might lead to differences in memory. In Experiment 2b, we used this paradigm to examine attention and memory when children viewed an agentive picture sequence without a

matched agentive narrative. Together, these experiments allowed us to tease apart ways in which agency might influence early memory.

Experiment 2a

In Experiment 2a, we examined whether memory differences in Experiment 1 reflected differences between the Agent and Nonagent conditions in terms of how children's attention was directed during encoding. The procedure was the same as Experiment 1, with the following exceptions. First, in order to gain evaluate children's pattern of attention to the stimulus during, all sequential pictures were presented on a 24-in. Tobii eye tracking monitor as opposed to a picture book. Second, the character in the Agent condition pictures was presented with her hands resting on the table, as opposed to touching the object, controlling for any extra information the hand placement in Experiment 1 may have provided. Finally, a third stimulus set (a bug) was created so that all children could participate in a within-subjects baseline condition.

Method

Participants

Thirty-six 3-year-old children ($M = 35.8$ months, range = 34.2–37.9 months; 15 females) participated in Experiment 2a. All participants came from

English speaking households. Eighteen children saw a series of still pictures with a person present (*Agent condition*: $M = 35.8$ months, range = 34.4–37.9 months; 8 females), whereas 18 saw still pictures demonstrating the same object construction with no person present (*Nonagent condition*: $M = 35.8$ months, range = 34.2–37.9 months; 7 females). Parents reported that 64% of participants were Caucasian, 17% were African American, 3% were Hispanic, and 11% were more than one race. An additional 6% of parents chose not to answer questions concerning their child's ethnicity. Six additional children were tested but not included in the final sample because of camera recording errors ($N = 5$) and refusal to play ($N = 1$).

Procedure

Upon entering the experimental room, children were seated on their parent's lap in front of a 24 in. computer monitor. Parents were asked to gaze at the floor during the demonstration phase to minimize parental influence. The demonstration and test phases were video-recorded for later coding.

During demonstration, children viewed two object construction sequences in picture format. The picture sequences were presented on a 24 in. TFT monitor integrated into the Tobii eye-tracking system (Model T60XL), which records participant gaze direction using corneal reflection technique at a rate of 60 hz with an average accuracy of 0.5 degrees visual angle. Tobii's standard nine-point infant calibration technique was utilized for initial setup.

As in Experiment 1, each sequence depicted a six-step process, culminating in the assembly of an object (e.g., see Figure 1). Pictures remained on the screen for 8 s before moving to the next. An attention-getter with a small moving photo and bell sound effect marked the transition between sequences. Two object sequences were shown during the demonstration and test and the third was used as a within-subjects baseline measure. The order of sequence presentation and which object set was used at baseline was counterbalanced to account for order effects.

As in Experiment 1, the demonstration sequences varied across condition in two respects, both visual and auditory. However, unlike Experiment 1, the agent in Experiment 2a kept her hands on the table without drawing attention to specific pieces (see Figure 1). Furthermore, minor modifications to the stimuli were made for Experiment 2a in order to facilitate the coding of separate steps in children's responses (see Appendix B).

A delay period of 10 min was imposed after the demonstration, and participants were allowed to freely play in a waiting room across the hall. Participants then re-entered the testing room and sat on their parent's lap, directly across a table from the experimenter for the test phase (conducted as outlined in Experiment 1). Finally, the experimenter produced a third object set to be used as a within-subjects baseline, and followed the same protocol as for the first two sets. Unlike the two test sets, children had no prior information about the baseline object set. Each child was taught on two of the three sets and received the third as a baseline. The assignment of sets to taught versus baseline presentation was counterbalanced across children within each condition.

Coding

Attention during encoding. Overall attention to the picture stimuli and specific areas of interest (AOIs) within the stimuli were processed using Tobii Studio software (Tobii Technology, Danderyd, Sweden). All attention measures were exported as fixation durations. For the Agent condition, AOIs consisted of the agent, the new piece (piece was added to the object in each photo), and the overall object (any part of the object that was not the new piece). In the Nonagent condition AOIs were restricted to the current new piece and the overall object. Exported eye-tracking measures included the percent of time attending to the screen stimuli (number of seconds staring at the screen divided by the total number of seconds the stimuli was presented) and the percent of time spent on each AOI (number of seconds staring at each AOI divided by the number of seconds staring at the screen stimuli), as quantified by a standard Tobii fixation filter.

Object reconstruction. Test trials were coded from video recordings by a research assistant blind to experimental condition, using the Interact coding software (Mangold, 1998). A second independent assistant coded 30% of the participants, with the two coders agreeing on 95% of total behavioral scores. When there was a coding disagreement the primary coder's scores were used. Participants were coded as in Experiment 1.

Results and Discussion

Preliminary analyses revealed that there were no effects of gender, age, or stimulus set for either condition, therefore subsequent analyses were collapsed across these factors. A two-tailed

independent *t*-test was run to test the effect of condition (Agent, Nonagent) on reconstruction scores at test. As in Experiment 1, the results demonstrate that children in the Agent condition were able to complete significantly more of the steps ($M = 9.50$, $SD = 2.00$) than those in the Nonagent condition, $M = 7.89$, $SD = 2.52$; $t(34) = 2.12$, $p < .05$, see Figure 2. There was no difference between conditions on baseline scores, *Agent condition*: $M = 2.11$, $SD = 1.84$; *Nonagent condition*: $M = 1.50$, $SD = 1.42$; two-tailed *t*-test: $t(34) = 1.13$, $p = .27$.

Overall attention to the stimuli did not statistically vary across conditions, *Agent condition*: $M = 79.17\%$, $SD = 16.4\%$; *Nonagent condition*: $M = 80.55\%$, $SD = 13.56\%$; two-tailed *t*-test: $t(34) = 0.27$, $p = .79$, highlighting the fact that the Agent condition did not capture more global attention than the Nonagent condition. However, since there was more information presented on the screen in the Agent condition (the agent in addition to the objects), we also explored whether attention to the discrete AOIs varied across condition and influenced subsequent memory. Within the Agent condition, the distribution of attention was 53.25% to the overall object, 28.08% to the new piece, 15.55% to the agent, and 3.12% to “other” (areas on the screen

outside the AOIs, see Figure 3). In the Nonagent condition, the distribution of attention was 72.78% to the overall object, and 27.22% to the new piece, and 0% looking to “other.” Therefore, attention to the overall object was greater in the Nonagent condition ($M = 72.78\%$, $SD = 11.54\%$) than in the Agent condition, $M = 53.25\%$, $SD = 7.88\%$; two-tailed *t*-test: $t(34) = 6.45$, $p < .001$, though no such difference was found for the new piece, Nonagent: $M = 27.22\%$, $SD = 8.05\%$; Agent: $M = 28.08\%$, $SD = 7.52\%$; two-tailed *t*-test: $t(34) = 0.33$, $p = .74$. Importantly, there was no significant correlation between attention to either the overall object or the new piece and later reconstruction scores (all $ps > .14$), suggesting that any differences in attention facilitated by the inclusion or exclusion of an agent did not influence memory.

The findings reported earlier demonstrate that memory differences across the Agent and Nonagent conditions did not result from children attending more to events involving a person. Although memory was more robust in the Agent condition, children’s overall attention to the pictures during encoding was similar. If anything, children in the Nonagent condition looked more to the object than those in the Agent condition, even though they

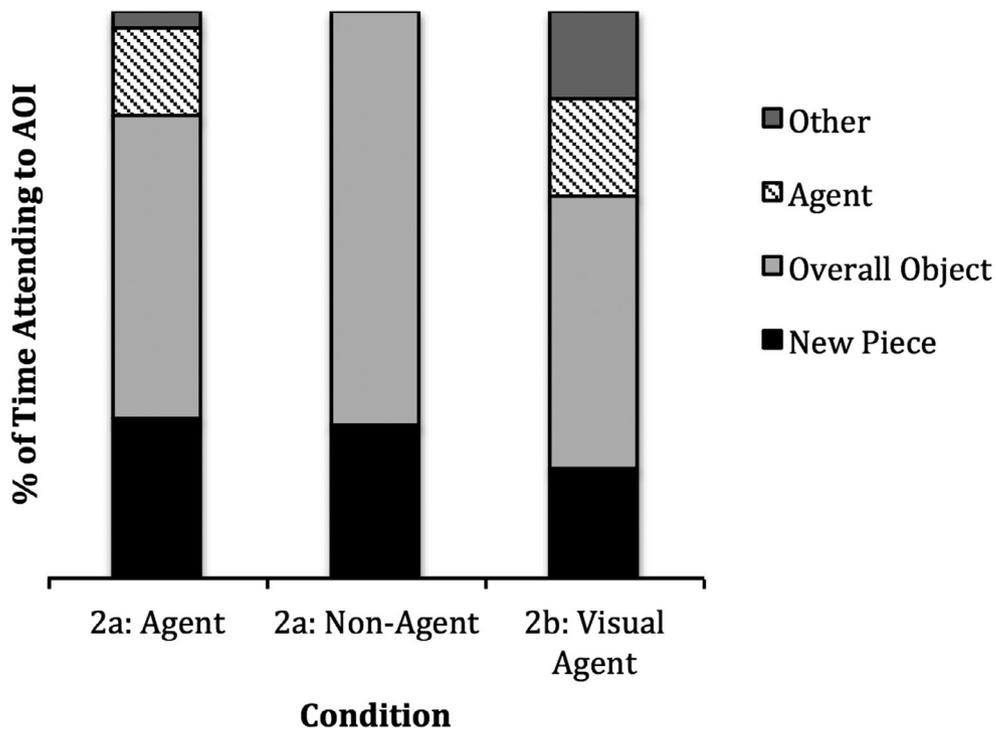


Figure 3. Percent of time that children in Experiments 2a (Agent and Nonagent conditions) and 2b (Visual Agent condition) attended to the specified Areas of Interest (AOIs). Note that children in the 2a Nonagent condition were not presented with the Agent and therefore could not attend to her hands or face.

were less likely to remember the steps to construct it at test. Furthermore, this effect persisted even without children viewing the agent's hands on the pieces (as per Experiment 1), suggesting that that particular visual cue provided little in the way of a memory boost.

Experiments 1 and 2a provided evidence that the presence of an agent improves nonverbal event memory in preschool children. However, it is still unclear what specific aspects of the agentive events were most influential for subsequent memory. Although language was not used as our measure of memory, it is still possible that linguistic cues contributed to this "social memory boost." In both conditions, the demonstration sequences were accompanied by matched agentive or nonagentive verbal descriptions of the events ("Sally puts this piece like this" and "This piece goes like this"). Therefore, though children's memory was not measured using verbal assessments, the provided verbal narratives may have contributed to the memory effect. To evaluate this possibility, in Experiment 2b we presented the agent pictures from Experiment 2a with the nonagentive verbal descriptions. If the presence of the agent was the critical factor, children's memory for these events should remain robust.

Experiment 2b

Method

Participants

Eighteen 3-year-old children ($M = 35.9$ months, range = 34.1–38.0 months, 10 females) participated in Experiment 2b. All participants came from English speaking homes. Parents reported that 50% of participants were Caucasian, 33% were African American, and 11% were more than one race. An additional 6% of parents chose not to answer questions concerning their child's race or ethnicity. Three children were tested but were not included in the final sample due to refusal to participate in the test session ($N = 2$) or camera recording errors ($N = 1$).

Procedure

The procedure and subsequent coding were the same as Experiment 2a with the following changes: During the demonstration phase, children viewed the picture stimuli from the Experiment 2a Agent condition, but heard the verbal narrative from the

Nonagent condition. Therefore, though children saw an agent visually present in the pictures, the accompanying narrative did not mention Sally or her actions. No within-subjects baseline was conducted.

Results and Discussion

As in Experiments 1 and 2a, preliminary analyses revealed that there were no effects of gender, age, or stimulus set. Therefore, subsequent analyses were collapsed across these factors.

Data from Experiment 2b were analyzed along with those from Experiment 2a. A one-way ANOVA was run to explore the effects of condition (Agent, Nonagent, Visual Agent) on children's test scores. This analysis revealed a main effect of condition on test scores, $F(2, 52) = 4.60$; $p = .01$. Post hoc comparisons revealed that children in the Visual Agent condition ($M = 9.94$, $SD = 1.83$) remembered significantly more than children in the Nonagent condition, $M = 7.89$, $SD = 2.52$; $t(34) = 2.80$, $p < .01$; see Figure 2. There was no difference between children's memory scores in the Visual Agent ($M = 9.94$, $SD = 1.83$) and Agent conditions, $M = 9.61$, $SD = 1.85$; $t(34) = 0.69$, $p = .49$.

A one-way ANOVA examining the effects of condition (Agent, Nonagent, Visual Agent) on global attention to the stimuli revealed no significant effects, $F(2, 52) = 1.24$, $p = .30$, suggesting that children attended equally to the demonstration regardless of agency. Fine-grained analyses across conditions revealed a significant difference in the percent of time looking to the overall object, one-way ANOVA; $F(2, 46) = 23.49$, $p < .001$, and to the new piece, one-way ANOVA; $F(2, 46) = 4.27$, $p = .02$; Figure 3. Post hoc analyses demonstrate that children in the Nonagent condition ($M = 72.78\%$, $SD = 11.54\%$) attended to the overall object significantly more than children in the Visual Agent condition, $M = 48.00\%$, $SD = 15.36\%$; $t(1, 29) = 5.18$, $p < .001$, though no such difference existed between the Agent condition ($M = 53.25\%$, $SD = 7.88\%$) and the Visual Agent condition, $M = 48.00\%$, $SD = 15.36\%$; $t(1, 29) = 1.20$, $p = .24$. Contrastingly, children in the Visual Agent condition were significantly less likely to attend to the new piece ($M = 19.33\%$, $SD = 8.05\%$) than those in both the Nonagent, $M = 27.22\%$, $SD = 8.05\%$; $t(1, 29) = 2.77$, $p = .01$, and Agent conditions, $M = 28.08\%$, $SD = 7.52\%$; $t(1, 29) = 4.27$, $p = .02$.

The results of Experiments 2a and 2b strongly suggest that the presence of a person produces robust memory representations in childhood. As in

Experiment 1, children who viewed a picture sequence with a visible agent (Agent and Visual Agent conditions) were able to recall significantly more of the steps than those in the Nonagent condition. This was not due to the fact that the person inherently drew more attention to the sequence than an event without a person, as children attended equally to both demonstrations. Furthermore, the combination of a visual and verbal agent was not necessary for increasing event memory. Memory was equally robust in the Agent and the Visual Agent conditions (where the verbal mention of the agent was removed, but she remained in the pictures, see Experiment 2b), though significantly lower in the Nonagent condition.

These findings provide clear evidence for the effects of people in supporting event memory in childhood. However, there is still an open question regarding the nature of the agentive memory benefit. The agentive events may have resulted in a stronger general memory trace regardless of testing procedures, or it may be that the agentive events were more easily relatable to child's own actions at test. For example, children may be relying on their own experience with objects when observing the Agent condition, stimulating a "like me" mindset (i.e., "I could do that too!", e.g., Meltzoff, 2007) that may activate their motor systems (Marshall & Meltzoff, 2014) and facilitate reconstruction actions. In other words, the inclusion of an agent may have facilitated performance for a reconstruction test, as opposed to improving memory per se. Although both of these possibilities are interesting, the former implies a more foundational effect than the latter. In order to determine if there are significant differences in the general memory representation across conditions, as opposed to a difference only in the ease with which children could perform the construction sequences, a passive measure of memory is needed.

In Experiment 3, we examined the neural signature of children's event memory during passive picture-viewing of the sequence after encoding. This allowed us to distinguish between the agentive effects on children's memory representations versus enactive performance during the test phase.

Experiment 3

Experiment 3 examined the neural basis of the agent versus nonagent memory differences. Furthermore, it investigated whether increased memory for social events was evident in both physical reconstruction and in passive-viewing methodologies.

Procedures and picture stimuli were the same as Experiment 1, except that children participated in an ERP paradigm during the delay period. As in Experiment 2a, children also participated in a within-subjects baseline phase. Therefore, the order of phases in Experiment 3 was demonstration (book reading), ERP, behavioral assessment, baseline.

Method

Participants

Seventeen 3-year-old children ($M = 36.2$ months, range = 33.8–38.5 months; 8 females) contributed usable data in Experiment 3. All participants came from English speaking households. Nine children saw a picture demonstration with an agent assembling the object pieces (*Agent condition*: $M = 36.4$ months, range = 33.9–38.03 months; 5 female), while eight saw the pieces assembling with no agent present (*Nonagent condition*: $M = 36.0$ months, range = 34.0–38.5 months; 3 female). Parents reported that 59% of children were Caucasian, 12% were African American, and 5% were more than one race. An additional 24% of parents chose not to answer questions concerning their child's ethnicity. Seventeen additional children were tested but were not included in the final sample due to refusal to wear the testing cap ($N = 8$), technological failures ($N = 6$), parental interference ($N = 1$), experimenter error ($N = 1$), or an insufficient number of usable ERP trials ($N = 1$).

Procedure

All participants proceeded through a demonstration phase that was identical to Experiment 1. After the demonstration, all children were moved in to a small table in the testing room where they could play while being fitted with a stretchy Lycra electrode cap appropriate for their head circumference.

During the ERP procedure, participants viewed 108 pictures on a computer screen. Half of these photos (54) were previously viewed in the picture books during demonstration (old pictures), and half of these pictures (54) were similar to the picture book stimuli but included new pieces (new pictures). Stimulus pictures included the six photos demonstrating object construction, and thus excluded the first picture showing the objects on the table and the last picture showing the fully completed object (see Figure 1). Old and new pictures were matched to condition, such that children in the Agent condition saw an agent both in the old and new photos, and those in the Nonagent condition did not see an agent in the old or new pictures.

On the basis of previous literature, we focused on two components that have previously been shown to differentiate between old and new stimuli: the negative central component (Nc) and the positive slow wave (PSW; e.g., Bauer et al., 2003; for review see de Haan, 2007, DeBoer, Scott, & Nelson, 2005). The Nc component is most prominent in front-central regions (Nelson, 1994), occurring at approximately 300–600 ms post stimulus onset in infant and child populations (see Moulson, Westerlund, Fox, Zeanah, & Nelson, 2009; Riggins & Rollins, 2015). This component is thought to reflect obligatory attention early in processing (e.g., Dawson et al., 2002; Nelson & Collins, 1991). The PSW, also maximal in fronto-central regions, appears later in the waveform than the Nc, at approximately 600–900 ms post stimulus onset. This component indicates the updating of previously encoded stimuli in working memory (Nelson, 1994; see de Haan, 2007; DeBoer, Scott, & Nelson, 2007 for review). In particular, a larger PSW amplitude has been associated with novel as opposed to familiar stimuli (e.g., de Haan & Nelson, 1997), and is greater to items recalled with contextual details (Riggins, Rollins, & Graham, 2013). Importantly, different slow wave responses to old versus new stimuli have also been associated with better event memory in infancy (Carver, Bauer, & Nelson, 2000). This suggests a connection between PSW amplitude and long-term behavioral memory early in development.

A combined a-priori and data-driven approach was utilized to determine where the Nc and PSW waveforms presented in this preschool population. On the basis of a combination of previous literature and a visual inspection of the data, we selected two time windows for ERP analysis: 350–550 and 750–1,500 ms. We used mean amplitude as the dependent measure as previous research suggests that it is more unbiased by trial number differences than peak amplitude (Keil et al., 2014; Luck, 2014). As Nc and PSW components are most prominent at fronto-central locations three leads (AFz, Fz, FCz) were chosen for analysis. Nc and PSW values were measured separately at each electrode site and then averaged together to give a single value for mean amplitude (Grice et al., 2003). All data were filtered and interpolated prior to analyses (see Appendix C),

Results and Discussion

Object Reconstruction

Preliminary analyses revealed that there were no effects of gender, age, or stimulus set for either

condition, therefore subsequent analyses were collapsed across these factors. As in Experiments 1 and 2, children in the Agent condition reconstructed significantly more steps at test ($M = 8.67$ steps, $SD = 1.94$) than those in the Nonagent condition, $M = 5.75$, $SD = 2.96$, $t(1, 15) = 2.43$, $p = .03$, see Figure 2. There was no difference between conditions on baseline scores, *Agent condition*: $M = 2.00$, $SD = 1.31$; *Nonagent condition*: $M = 1.75$, $SD = 1.70$; two-tailed *t*-test: $t(15) = 0.28$, $p = .78$. This pattern replicated the findings in the prior studies, despite the significantly longer delay between encoding and test, and with the addition of an intervening ERP task.

Event-Related Potentials

Repeated measures analyses of variance were conducted within each of the two windows for the averaged fronto-midline leads (Fz, Afz, Fcz) with the following factors: 2 Condition (Agent, NonAgent) \times 2 Stimulus Types (old picture, new picture). Participants provided an average of 49.65 usable trials for analysis ($SD = 6.10$). This number did not statistically vary across conditions, *Agent*: $M = 44.67$, $SD = 14.41$; *Nonagent*: $M = 55.25$, $SD = 16.95$; $t(1, 15) = 1.38$; $p = .19$.

In the Nc (350–550 ms poststimulus onset) time window, no significant main effects or interactions were observed (see Figures 4 and 5). Thus, 3-year-old children did not evidence neural differences within or across conditions in the component associated with early attention processes. In the PSW (750–1,500 ms poststimulus onset) time window, a main effect of stimulus type emerged such that, across conditions, the mean amplitude was greater for new pictures ($M = 2.25$, $SD = 2.46$) than old pictures, $M = 0.60$, $SD = 2.71$; $F(1, 15) = 7.57$, $p = .01$; see Figures 4 and 5. Furthermore, there was a marginal interaction between stimulus type and condition, $F(1, 15) = 3.31$, $p = .08$. Post hoc analyses indicate that participants in the Agent condition evidenced greater mean amplitudes for the new pictures ($M = 2.22$, $SD = 1.97$) relative to the old pictures, $M = -0.43$, $SD = 2.99$; $t(1, 8) = 2.72$, $p = .03$, whereas no such old–new distinction was present in the Nonagent condition, new pictures: $M = 2.29$, $SD = 3.06$; old pictures: $M = 1.75$, $SD = 1.92$; $t(1, 7) = 0.98$, $p = .36$.

These findings demonstrate a difference at the neural level between the Agent and Nonagent conditions, suggesting that agents may provide not just an event representation that is easy to relate to one's own actions, but a stronger memory trace.

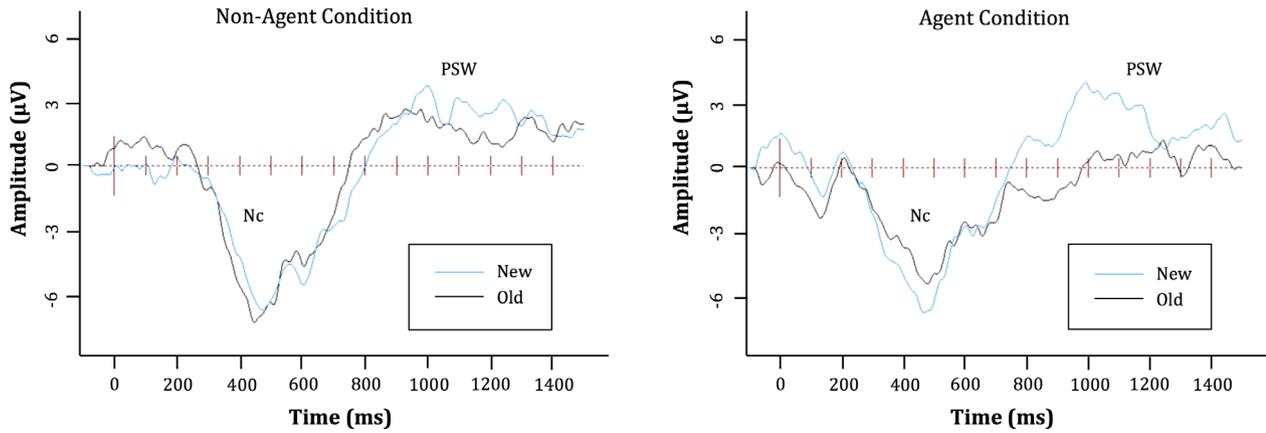


Figure 4. Average waveforms for new pictures and old pictures in both the Agent and Nonagent condition at the Fz lead. PSW = positive slow wave; Nc = negative central component.

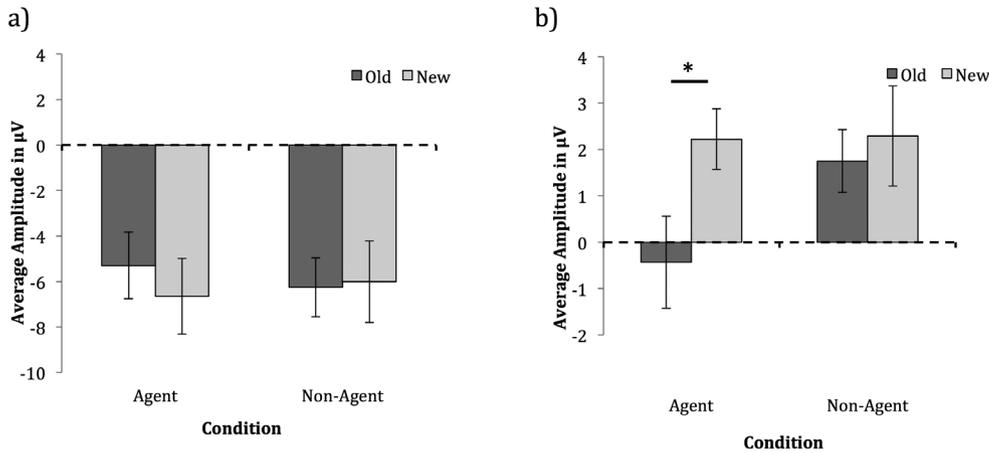


Figure 5. Average amplitude to old and new pictures in the Agent and Nonagent condition during the (a) negative central component time window (350–550 ms) and (b) positive slow wave time window (750–1,500 ms) at fronto-midline leads. Error bars denote standard error. * significance at $p < .05$.

PSW amplitude for children in the Agent condition differentiated between the old and new pictures, whereas PSW amplitude for children in the Nonagent condition did not. Research has shown that PSW amplitude reflects the degree to which the stimulus has been fully encoded (de Haan & Nelson, 1997; Nelson & Collins, 1991; Snyder, 2010; though see Riggins & Rollins, 2015; Riggins et al., 2013), suggesting that the effect of agency on memory may be related to memorial, not attentional, mechanisms. Although as this interaction effect did not reach conventional levels of statistical significance, future studies with larger sample sizes or matched photos across conditions may be beneficial for better elucidating this ERP effect.

Although children in the Nonagent condition do not evidence significant old–new distinctions in their ERP waveforms, they do seem to remember

some portion of the event during the reconstruction test. There are several possible explanations for why an effect was not observed in the Nonagent condition. Children could have attempted to solve the reconstruction test in the same way, relying on similar neural substrates to do so, though the memory representation was less robust. Therefore, differences were not observed at the neural level and behavioral performance was low. Alternatively, children may have been approaching the reconstruction test differently (e.g., relying on recall vs. in-the-moment problem solving) and engaging different neural substrates in accordance with these processes. Finally, since no research to date has explicitly examined agentic versus nonagentic memory in 3-year-old children, it is also possible that the components or windows selected for analysis did not fully capture the components or the

effect of interest. Future research with larger sample sizes may allow for more complex analyses to examine the temporal distribution of these effects and to distinguish between these (and other) possibilities.

General Discussion

Across four experiments, 3-year-old children remembered more sequential steps when the event was presented with a person present (Agent conditions) versus absent (Nonagent condition). The information needed to assemble the object was identical in these conditions, and in all conditions there was accompanying speech that directed children's attention to the sequence, the piece that was added at each step, and the end goal of creating something. Despite these similarities, the presence of the person enabled children to produce more of the presented steps.

Analyses of children's attention during encoding indicated that these memory effects did not result from children attending more to the pictures with the person in them. Children's levels of overall attention to the pictures did not differ across conditions, suggesting one sequence was not more salient than another. Furthermore, ERP measures indicated differential effects in memory components (PSW) between the Agent than the Nonagent condition. Thus, the presence of the person led to increased recall and recognition memory, not simply to differential attention allocation or more "task compatible" memory representations.

On the one hand, the fact that agents increase event recall in children may appear obvious. There is an abundance of evidence demonstrating that children are attuned to and prefer social stimuli from early in life (Johnson, Dziurawiec, Ellis, & Morton, 1991; Simion et al., 2008), and it is well known that items that capture attention often result in increased memory (Chun & Turk-Browne, 2007). On the other hand, events with people are also more complex than nonagentive events, as social events may include more surface-level information or involve the extra step of goal interpretation (Butler & Markman, 2016). This increased complexity might be expected to result in decreased recall for agentive versus nonagentive events. Interestingly, the current studies found more robust memory for the agentive event despite the additional information load the agent may have provided, and no differences in attention across condition.

Importantly, events that include people do not *always* produce optimal learning outcomes. For example, providing pedagogical cues to young children in a social event can constrain their discovery of object features (Bonawitz et al., 2011), and learning the function of an object in a social context may restrict children from flexibly learning to use this object in novel circumstances (Casler & Kelemen, 2005). It is therefore erroneous to assume that simply having a person present in a situation will always result in superior learning outcomes. Rather, it may be the combination of an agentive presence and goal interpretation that combines to facilitate adaptive learning.

Why is the presence of a person a potent catalyst for children's memory? As noted earlier, although linguistic representations of events, including narratives, productively incorporate information about agents' goals, linguistic representations are not likely to account for the findings of the current experiments. Children in the current studies were too young to be able to generate well-structured narratives on their own (Trabasso & Nickels, 1992), and we did not ask them to do so. Further, although there was verbal information in both conditions that directed children's attention to the pictures and related each step to the progression of events, the memory effect did not depend on goal information being present in this verbal framing. The results of Experiment 2b demonstrate having the agent visually present, though not mentioned in the accompanying narrative, boosted children's memory to the level seen in the "full" Agent condition.

Even so, an insight from the literature on narrative memory may be useful for understanding the current findings: research with adults and children has shown that the goal structure of an explicit narrative can provide a framework for relating events across time and space, a representation that endures in memory (Trabasso & Magliano, 1996). It is possible that nonverbal representations of goals work the same way. Nonverbal action understanding could help children to encode and maintain information by providing a cognitive structure analogous to that expressed in narratives, one which chunks together sequential action steps by focusing on agents and their goals (e.g., Black & Bower, 1979). In fact, in adults, ERP studies have demonstrated that sequential picture stories and narratives are comprehended using similar neurocognitive mechanisms (Cohn, Jackendoff, Holcomb, & Kuperberg, 2014). Furthermore, Loucks and colleagues (Loucks & Meltzoff, 2013; Loucks et al.,

2017) found that 3-year-olds privileged goal structure above chronological order when recalling nonverbal actions, and recent looking-time studies with nonhuman primates (chimpanzees, gorillas, and capuchins) found better memory for a video event depicting goal-directed human action than one depicting the movements of a mechanical claw (Howard, Festa, & Lonsdorf, 2018; Howard, Wagner, Woodward, Ross, & Hopper, 2017). Combined with the impressive retention rates infants demonstrate in deferred imitation paradigms (e.g., Barr & Hayne, 1999; Carver & Bauer, 2001), these findings highlight the influence that goal-directed actions can have on memory when tested nonverbally or with nonlinguistic populations.

The current data cannot speak to exactly which aspects of an agent are most influential for later event recall. For example, though previous literature suggests that an agent's intentional goals may be helpful for memory, we did not explicitly examine whether altering goal-directedness subsequently altered children's memory. Future research may be helpful in this regard. To start, if early, implicit, understanding of actions provides a framework for young children's memory, then other manipulations that support children's interpretations of events in terms of an agent's goal may have similar effects on their memory. For example, hearing events described as the actions of a person, or seeing evidence that events are the result of a person's actions, even in the absence of a visible person, could support children's memory. Furthermore, even when a person is present in a scene, manipulations that vary whether he or she is acting in a goal-directed manner may have differential effects on children's event memory. For example, if a person were associated with a series of accidental events, or near to events that he or she could not perceive, then no memory "boost" should occur.

It is also possible that children in the Agent condition mentally simulated the character's actions when thinking about her constructing the object, increasing their mental engagement and depth of encoding for the event. Research has suggested that children mentally simulate certain aspects agent-based stories, such as the character's speed of movement or mental motivations (Fecica & O'Neill, 2010). This simulation is also evidenced via cortical motor activation when children observe others completing actions (e.g., Meyer, Hunnius, van Elk, van Ede, & Bekkering, 2011), and it may have consequences for later recall. In a study by Sommerville and Hammond (2007), 4-year-old children took turns completing steps with an experimenter in

order to build a novel object. At test, children were asked to reconstruct the object from memory and verbally recall who had completed the step during the initial building sequence (the child or the experimenter). Children who were more likely to take credit for steps they had not actually completed (e.g., saying "I did it") were also more likely to remember more of the steps after a delay, suggesting that falsely remembering the event in terms of their own actions was beneficial for later recall. As the current series of studies did not directly test any aspects relating to mental simulation, further research is needed to evaluate whether this process contributes to the memory benefit seen in the current experiments.

Finally, there is a possibility that the memory effects found in the current series of studies have more to do with engagement, and less to do with high-level goal understanding or simulation. Although our eye-tracking data provided information on where and how long children were attending to the events, more covert aspects of attention are not captured by these measures. For example, though children's eyes may have been equally directed toward the screen, they may have been more engaged or aroused by the agentive stimuli than the nonagentive stimuli, an effect not possible to detect in the current studies. Future research could examine this idea using physiological measures such as pupil dilation or heart rate as a proxy for arousal (e.g., Bradley, Miccoli, Escrig, & Lang, 2008). Recent work has suggested a relation between increased pupil dilation during encoding and later recognition memory for both infants and adults (e.g., Hellmer, Söderlund, & Gredebäck, 2018). However, to our knowledge no studies have explored whether pupil dilation is strongly correlated with, or separate from, other attention measures such as gaze duration.

Open questions aside, the current findings suggest that even a minimally social context, the presence of a person in an event, may have broad effects on how children learn and remember information. Our results indicate a particular role for social knowledge in supporting memory for sequential events, in this case, the separate pictures that, together, conveyed how to build the target object. Many instances in which young children are able to integrate information over time involve goal-directed actions (either the child's or those of a social partner), for example, learning about common routines, acquiring domain knowledge in school, and exploratory learning about the causal structure

of a problem. Children also privilege information about others' actions in tracking the identity of objects over time (Casler & Kelemen, 2005; Gelman et al., 2014). The current findings suggest that these diverse phenomena may all reflect a basic tendency for children to track and remember the actions of people.

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Appendix A

Table A1
Example of Verbal Narratives Across Conditions (Bunny Sequence)

Agent (Exp. 1, 2a, 3)	Nonagent (Exp. 1–3)	Visual agent (Exp. 2b)
1. This is Sally. Look at all these things on the table. I wonder what Sally can make with them.	1. This is a table. Look at all these things on the table. I wonder what they can make.	1. This is a table. Look at all these things on the table. I wonder what they can make.
2. First, Sally puts this piece like this.	2. First, this pieces goes like this.	2. First, this pieces goes like this.
3. Look, Sally put this piece on there.	3. Look, this piece went on there.	3. Look, this piece went on there.
4. Sally puts this piece on top of that one.	4. This piece goes on top of that one.	4. This piece goes on top of that one.
5. Then, Sally put this piece on top of that one.	5. Then, this piece went on top of that one.	5. Then, this piece went on top of that one.
6. Oh, Sally puts that piece on there.	6. Oh, that piece goes on there.	6. Oh, that piece goes on there.
7. Finally, Sally put this piece in here.	7. Finally, this piece went in here.	7. Finally, this piece went in here.
8. Look, Sally put all the pieces together and made something. What did she make?	8. Look, all the pieces went together and made something. What did they make?	8. Look, all the pieces went together and made something. What did they make?

Appendix B

Sequential Steps for Each of the Three Possible Object Sets

Bunny Sequence

1. Place bunny head form on black base
2. Place white eye base on the head

3. Place black pupils on top of eye base
4. Place bowtie on neck area under nose
5. Place nose on head under eyes
6. Put ears into hole on top of head

Tree Sequence

1. Place tree trunk into green base
2. Place branch through hole in tree trunk
3. Hang vine on one end of branch
4. Place leaves on top of tree trunk
5. Put second set of leaves onto end of opposite branch
6. Place raccoon on top of top leaves

Bug Sequence

1. Place bug body onto flower base
2. Place legs vertically onto white body
3. Put round head on top of white body
4. Place wings behind body
5. Put eyes on top of round head
6. Place antenna into hole on top of head

Appendix C

Event-Related Potential Data Cleaning Methods

Event-related potentials (ERPs) were recorded from 64 scalp locations, left and right mastoids, two

vertical electrooculogram (EOG) and two horizontal EOG channels using active Ag–AgCl electrodes while children viewed the stimuli. EEG was recorded at a sampling rate of 512 Hz. Stimuli were presented on the screen for 1,500 ms, followed by a fixation cross which varied in duration from 1,250 to 1,750 ms. Electrophysiological data were re-referenced offline to mathematically linked mastoids using Brain Electrical Source Analysis software (MEGIS Software GmbH, Gräfelfing, Germany). Missing data from individual channels were interpolated for a maximum of 10% of bad channels (i.e., six per participant; see DeBoer et al., 2002). Ocular artifacts were corrected by applying the Ille, Berg, and Scherg (2010) algorithm. Data were high pass filtered at 0.1 Hz and low pass filtered at 80 Hz. Movement-related artifacts were hand-edited and rejected prior to averaging. Trials were epoched with a 100 ms baseline and continued during stimulus presentation for 1,500 ms. ERPs were averaged based on whether the pictures were old or new to the participant. Participants with fewer than 10 trials per condition were excluded from analysis.