



Children’s Representation and Imitation of Events: How Goal Organization Influences 3-Year-Old Children’s Memory for Action Sequences

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Abstract

Children’s imitation of adults plays a prominent role in human cognitive development. However, few studies have investigated how children represent the complex structure of observed actions which underlies their imitation. We integrate theories of action segmentation, memory, and imitation to investigate whether children’s event representation is organized according to veridical serial order or a higher level goal structure. Children were randomly assigned to learn novel event sequences either through interactive hands-on experience (Study 1) or via storybook (Study 2). Results demonstrate that children’s representation of observed actions is organized according to higher level goals, even at the cost of representing the veridical temporal ordering of the sequence. We argue that prioritizing goal structure enhances event memory, and that this mental organization is a key mechanism of social-cognitive development in real-world, dynamic environments. It supports cultural learning and imitation in ecologically valid settings when social agents are multitasking and not demonstrating one isolated goal at a time.

Keywords: Cognitive development; Social cognition; Human action; Representation; Goals; Imitation; Hierarchical structure; Memory

1. Introduction

A fundamental developmental task for children is to learn about the objects, causal relations, and customs of their culture and to acquire competency with associated skills. A great deal of this is achieved through observation and imitation of more knowledgeable others (e.g., Hunnius & Bekkering, 2014; Meltzoff, Kuhl, Movellan, & Sejnowski, 2009).

By 3 to 4 years of age, children can imitate cognitive, rule-based events based on social observation (e.g., Subiaul, Anderson, Brandt, & Elkins, 2012; Wang, Williamson, & Meltzoff, 2015; Williamson, Jaswal, & Meltzoff, 2010), and they can imitate hierarchical structure in action (Whiten, Flynn, Brown, & Lee, 2006). Children's imitative prowess is one hallmark of human cognition in comparison to other primates (Tomasello, 1999; Whiten, 2005).

Children's imitative prowess suggests that they must possess a particular set of perceptual and cognitive mechanisms for action processing. Developmental research is concerned with uncovering the origins and early development of children's action processing (Greddebäck, Stasiewicz, Falck-Ytter, Rosander, & von Hofsten, 2009; Loucks & Sommerville, 2012; Marshall & Meltzoff, 2014; Paulus et al., 2011; Saylor, Baldwin, Baird, & LaBounty, 2007; Woodward, 2009). However, the behavioral streams that have typically been used in studying children's imitation and action representation are more simplified than those observed in ecologically valid, dynamic settings. Here we seek to close this gap.

One neglected aspect of children's action processing involves *multiple interwoven goals*, as commonly occurs during the observation of adult multitasking. Imagine a preschool girl observing her father preparing dinner (one goal). The father first fills a pot with water, turns on the stove, and retrieves pasta. But then he remembers he also has to prepare his daughter's lunch (a separate goal), so he takes bread from the drawer and jam from the refrigerator. Following this, he continues preparing dinner. Crucial theoretical questions arise as to how the child might mentally represent her father's interwoven actions. What information is represented—the veridical serial order of discrete actions or two differentiable higher level goals? How does the representational structure influence the child's imitative re-enactments at a later point in time?

1.1. Action segmentation and goals

Observers of human action tend to prioritize the actor's goals and intentions over surface characteristics of the behavioral stream (Heider, 1958; Malle, Moses, & Baldwin, 2001). This use of the term *goal* refers to the agent's psychological aim to achieve a particular outcome. Goals and intentions are not directly observable and must be inferred. One goal could be fulfilled via many specific actions (e.g., holding a door for a stranger with a hand or a foot); the same specific action can be executed into achieve multiple goals (e.g., opening a window to get fresh air vs. to let a bee out). (For a further analysis of goals versus intentions in ontogeny, see Meltzoff, 1995, p. 847).

Infants and young children are sensitive to an agent's goals. Five-month-old infants selectively encode information about an actor's goals (Woodward, 1998), and 18-month-old infants re-enact the inferred goals and intentions of an actor rather than duplicating the surface movements of his actual behavior (Meltzoff, 1995). Preschool children prioritize goal-relevant acts in their imitation of others (Williamson & Markman, 2006) and encode other people's actions in terms of the hierarchical importance in achieving the goal (e.g., Bekkering, Wohlschläger, & Gattis, 2000; Gleissner, Meltzoff, & Bekkering, 2000). The phenomena of emulation and overimitation (e.g., Lyons, Young, & Keil,

2007) also suggest that preschool children sometimes interpret the specific means used to achieve an end state as part of the actor's goal (e.g., McGuigan & Whiten, 2009).

Human sensitivity to goals is illustrated by how observers segment event streams. In explicit segmentation tasks, adults segment according to the "breakpoints" of action—moments marking the initiation and completion of goals (Newtson & Engquist, 1976). Both adults and infants also segment action at breakpoints online, in an implicit manner, as it unfolds (Baldwin, Baird, Saylor, & Clark, 2001; Zacks, Kurby, Eisenberg, & Haroutunian, 2011). Adults segment action according to a "partonomic hierarchy," that is, into coarse units (e.g., making a bed), smaller units that compose the coarse units (e.g., putting on the pillows), and fine units that compose these smaller units (e.g., grasping a pillowcase). Thus, goals are inferred at multiple levels, with higher level goals involving the coordination of multiple subgoals over time (Zacks, Tversky, & Iyer, 2001).

Higher level goals vary in physical outcomes and internal structure. Some result in an observable end state, but the execution of others does not (e.g., consider the difference between building a block tower vs. reading a book). The temporal ordering of subactions is also variable. For example, playing pat-a-cake involves a specific hand action sequence, but playing house involves certain actions in a multitude of orders. However, in all cases, a representational structure that encapsulates individual subactions can be inferred.

Segmentation also impacts observers' event memory. For adults, memory for action at breakpoints is more robust than memory for action between breakpoints (Newtson & Engquist, 1976), and inserting a visual disrupter to action sequences at breakpoints is more disruptive to memory encoding than such insertions at non-breakpoints (Boltz, 1992). Segmentation is impacted by an observer's top-down expectations (Ratcliff & Laster, 2007) and his or her semantic knowledge (Zacks, Speer, Vettel, & Jacoby, 2006), which has implications for what information is stored in memory. Finally, Hard, Recchia, and Tversky (2011) found that observers who engaged in more online hierarchical processing of action events had a more organized and robust memory for the events.

1.2. *Two ways to organize action representations*

When dealing with action sequences that involve multiple goals, there are at least two ways that observers could organize their mental representation of the event. One is that action representations could be organized according to goals. As actions unfold over time, they could be segmented at breakpoints and inferences about higher level goals (coarse units) can be generated by linking lower level goals in the sequence. This organization groups together lower level goals in such a way as to represent their service to and connection with higher level goals. We will hereafter refer to this type of representational organization as *goal organization*.

An alternative is that actions are organized according to the veridical serial order of events. Temporal order plays a role in action processing in adults and infants (e.g., Avrami & Kareev, 1994; Baldwin, Andersson, Saffran, & Meyer, 2008; Bauer & Mandler, 1992; Swallow & Zacks, 2008). The order in which actions are executed is often causally relevant (e.g., plugging in a machine before using it); and even when violations of order

are causally neutral, they often have implications for an observers' interpretation (e.g., observing someone eating dessert before dinner). This organization represents events in the order in which they occur, as a faithful recording of the action stream. We will refer to this type of representational organization as *sequential organization*. Of course, hybrid models and other models are also possible.

For many but not all action sequences, goal organization is redundant with sequential organization. This redundancy arises when an actor executes two higher level goals in sequence, finishing one before starting the other (e.g., mowing the lawn before weeding the garden). This does not, however, reflect the full scope of action that children observe in the real world. Observers in most ecologically valid settings witness action events in which *multiple goals are interleaved together*, as in the foregoing scenario of the preschooler and her father (see also Offer & Schneider, 2011). In such cases, the goal organization and sequential organization provide different representations (Fig. 1). Sequential organization reflects the veridical action flow; goal organization involves *reorganization* of the subactions to reflect higher level goal structure. There are cognitive trade-offs. Sequential organization prioritizes temporal order at the cost of representing higher level goals, whereas goal organization prioritizes goal structure at the cost of representing accurate sequential information.

1.3. Evidence for the prioritization of goal organization

Goal structure is often prioritized over veridical serial order in adults and children. One line of support comes from research on adults' verbal processing of action sequences. Lichtenstein and Brewer (1980) found that adults' verbal recall of action

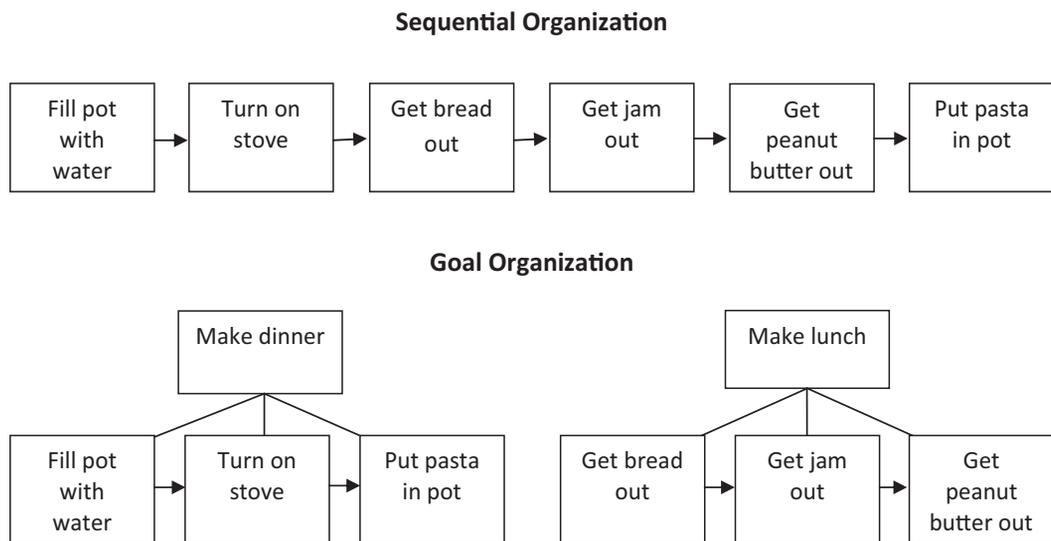


Fig. 1. Two ways to represent an action sequence. Sequential organization is a veridical memory for the actual order of event. Goal organization transforms the actual events into subactions under higher order inferred goals.

events reflected the hierarchical relations of goals and subgoals. Zacks et al. (2001) also found that partonomic hierarchies structure adults' verbal descriptions of action. However, verbal measures may reflect transformed or distinct representations relative to the underlying memory representation.

A second line of support comes from investigations into toddlers' representation of "enabling relations" (Bauer & Mandler, 1989, 1992; Bauer & Shore, 1987). For example, putting an object on a toy catapult *enables* the object to be launched. Bauer (1992) found that when children observed an enabling relation disrupted by a causally irrelevant action, most children displaced the irrelevant action before or after the relation when duplicating the event. This suggests the prioritization of goal over sequential organization in action memory.

However, based on these data alone, a critic might argue that children simply find the enabling relations more interesting or familiar than the causally irrelevant actions. Another critique might be that the representation reflects sequential order, but, because of poor inhibitory control, children cannot stop themselves from executing the enabling relations as a prepotent response—particularly because in these studies the children are typically given motor experience with the event before testing. In addition, this research does not address the representation of action sequences for which there are no constraints on temporal order. For many customs, rituals, habits, and culturally determined behavior patterns, the actual order is not constrained by physics.

Loucks and Meltzoff (2013) advanced prior work on children's goal organization by examining children's memory for complex, interleaved action sequences. They designed an imitation from memory task with 3-year-olds in which children observed an adult execute two familiar higher level goals with a set of toys, each involving three subactions. The subactions were not physically constrained and could occur in any order. To illustrate the logic of the study, we can symbolize one goal as ordered subactions "1, 2 and 3," and another goal as ordered subactions "A, B, and C." Children in the "grouped condition" saw sequences in which these were grouped together (1,2,3,A,B,C), and children in the "interleaved condition" saw sequences in which subactions of a goal were displaced over time and thus one goal was not fully achieved before the other one began (1,2,A,3, B,C)—the action stream was interwoven (bold underline indicates displacements). Children were then given a chance to imitate after a delay. The logic was that if children's memory for interleaved sequences prioritizes goal organization, then they should reorganize the subactions in their recall and group them according to the higher level goal—that is, execute 1, 2, and 3 together, and A, B, and C together.

The results indicated that children prioritized goal organization over veridical sequential organization: Children in the interleaved condition grouped the subactions together according to higher level goals. Although compelling, this study used goals that were highly familiar and over-learned. Even though the results from control conditions indicated that scripts could not explain the full pattern of data, prior practice with the higher level goals may have facilitated children's encoding and retrieval of these complex sequences. Indeed, prior knowledge of the higher level goal is a prerequisite for goal organization: Without such knowledge, subactions would be otherwise unconnected.

In sum, Loucks and Meltzoff (2013) provided evidence that children organize highly familiar actions according to higher level goals, but stronger evidence for goal organization would come from children's memory for novel actions. If goal organization is a fundamental property of action representation, then it should be observed early in development, when children are acquiring higher level goal knowledge.

1.4. Rationale for the current studies

Higher level goals come in many forms. Some culminate in a salient end state; children may gain semantic knowledge about the purpose of end state, which then organizes the preceding subactions. But what about goals that lack a salient, physical end state? Brushing one's teeth is an example: Young children maybe unaware of the deeper purpose behind tooth-brushing, and for them there is likely no salient end state to notice. Yet even young Western children can tell you the steps in brushing one's teeth. This is where language plays a key role in cultural learning: Adults label these events with verb phrases (e.g., "I'm brushing my teeth"), which over time binds the subactions together as a higher level goal. Verbal narratives by cultural experts occur for many higher level customs, rituals, and goals, even those that lack salient end states. Thus, the child does not need to be aware of the purpose of the higher level goal to abstract the relevant event structure. Language may help structure the event.

We took advantage of these aspects of social teaching and language to give children structural knowledge of a novel goal that lacked a salient end state and would otherwise be a sequence of arbitrary actions. We used a novel (nonsense) linguistic label in conjunction with multiple exemplars of the event sequence (variations in color, texture, size of the specific objects involved), while leaving the event structure the same, to communicate the abstract underlying structure of the event. Given the prior literature, we hypothesized that goal information would be inferred and prioritized over veridical sequential information in children's memory.

In two studies, we used a 2-day design. Children acquired information about one novel goal on Day 1, and then observed sequences of actions involving *two interleaved goals* on Day 2. They subsequently had an opportunity to imitate. Children's acquisition of goal knowledge for one of the two Day 2 goals was manipulated through random assignment of children to different experimental groups on Day 1. The experimental group learned about one of the goals that would be encountered on Day 2, whereas the control group learned an unrelated goal that would not be encountered on Day 2. On Day 2 both groups were treated the same.

We had three hypotheses. First, we hypothesized that only children who are provided with goal knowledge would reorganize their memory of the interleaved events according to goal structure, even if this comes at the cost of representing sequential information. Second, we hypothesized that this goal organization would result in children being able to learn more subactions overall—including subactions for the entirely novel goal on Day 2. Third, we hypothesized that the goal knowledge that children would acquire on Day 1 is abstract in nature. Thus, in Study 2 we examined the effect of gaining this goal

information through a pictorial storybook, which precluded direct, hands-on motor experience on Day 1.

The two studies offer three novel contributions to the cognitive science literature. First, they draw attention to an unexplored learning problem: How children come to understand and represent nonlinear executions of multiple higher level goals. Such action sequences and events occur in the real world outside the laboratory, because adults do not always complete one goal before initiating another—as in the case of multitasking. Second, we designed experimental tests of the importance of goal inference on action processing in a way which has not heretofore been examined in children. Specifically, we test whether a goal organization is privileged over veridical serial information in children’s imitation from memory. Third, Study 2 bears on a theoretical debate about the necessity of hands-on motor experience in event learning.

2. Study 1: Learning from observing other people’s actions

To test whether 3-year-old children’s memory for action prioritizes goal organization over sequential organization, children on Day 1 were randomly assigned to one of two groups. One group learned a goal that would be re-encountered again on Day 2 (experimental group); the other group learned a different goal (control group). On Day 2 both groups were treated the same. Both groups were further subdivided by demonstration organization on Day 2. More specifically, half of the children in each group saw an interleaved sequence involving two goals (the subactions interwoven with each other), termed the “interleaved demonstration”; and the other half saw these two goals enacted sequentially, such that all the subactions of one goal was completed before the next goal started, termed the “grouped demonstration.” After a short delay, all children were given a chance to imitate. Thus, by experimental design, children in the experimental group could apply the higher level goal they learned on Day 1 to the new materials on Day 2, and the children in the control condition could not.

We predicted that (a) children in the experimental group would reorganize the interleaved demonstration in memory by grouping subgoals together in their imitation, and that children in the control group would not, (b) performance in the experimental group would be similar whether they see the interleaved or grouped demonstration (highlighting a common goal representation), and (c) children in the experimental group would remember more subactions than children in the control group.

For theoretical reasons we also measured children’s executive functioning (EF) in Study 1, to address whether imitation and grouping of these events could be explained by poor inhibition of practiced, prepotent responses. This issue was also tested directly through experimental manipulation in Study 2, so the details of the EF tasks from Study 1 are reported in the Supplemental Material.

Three key features of the design are noteworthy. First, we ensured that the higher level goals did not result in salient physical end states (e.g., constructing a tower or a novel object). This was avoided to rule out the possibility that children’s imitation was based

on recalling the final end state or the physical causality. Thus, the subactions did not result in a salient end state and they were not constrained by physics to unfold in a certain order. Second, we ensured that the ordering of the subactions was a critical feature of the higher level goal, much like a game of pat-a-cake or a ritual, in which there are certain critical steps and an overall structure involved, but without a salient physical endpoint achieved by the action sequence. Third, the subactions were bound together as a higher level goal through the use of a novel linguistic label (*zavving*). The role of language in event representation, and a more detailed analysis of the nature of this higher level goal, will be examined further in the General Discussion.

2.1. Method

2.1.1. Participants

Participants were forty-eight 3-year-old children (27 boys). The mean age of children was 3.33 years ($SD = 2.8$ months). All children were typically developing and from the area surrounding Regina, Saskatchewan. Participants were recruited from a computerized database maintained by the first author. Based on parental report, 36 children self-classified as White, seven as mixed ethnicity, four as Asian, and one as Black. An additional nine children were tested but excluded from the final sample: Shy or poor compliance during warm-up, ($N = 3$), loss of video data ($N = 2$), and experimenter error ($N = 4$). Parents were compensated with \$10 at each visit, and children with a small toy.

2.1.2. Stimuli

2.1.2.1. Day 1 stimuli: Three sets of materials were used in the experimental group. Each set contained the following materials (see Fig. 2A): (a) a small wooden block (the platform) that had a hole drilled through it and cardboard flap attached to the bottom, (b) a wooden dowel that could fit inside the platform's hole, and (c) a bead. The materials in the three sets were similar in shape but differed from each other in color, texture, and size, to provide multiple exemplars of achieving the same goal. The use of multiple exemplars was one strategy used to promote children to abstract a higher order structure that united the event. As shown in Fig. 2A, the three steps were as follows: (a) place the bead on top of the platform, (b) thread the dowel into the platform and remove it, and (c) place the bead on top of the flap. In principle, these could be done in any order. There was no physical constraint that linked the subactions and no transformative end state.

The stimuli used in the control group involved three sets of the following materials (Fig. 2B): a small rectangular block, a small sheet of fabric, and a bottle cap. The subactions for carrying out this goal were (a) orient the block vertically (the block was always presented horizontally), (b) rub the block with the fabric, and (c) jump the bottle cap over the block. Again, the three sets differed from each other in color, texture, and size and again there was no causal dependency between subactions. Different sets of materials were used in the control group so that these children would have no exposure to the objects or actions that children in the experimental group saw on Day 1; thus, all actions were novel to control children on Day 2.

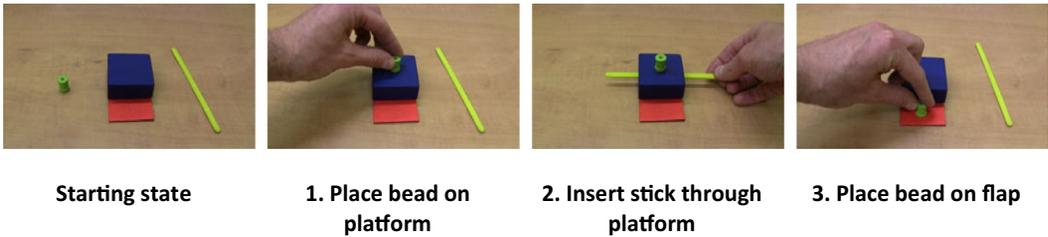
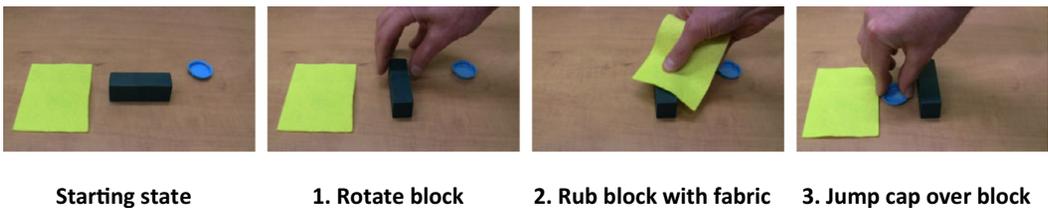
(A) Experimental Stimuli**(B) Control Stimuli**

Fig. 2. Example goal stimuli for Day 1 used in Study 1.

2.1.2.2. Day 2 test stimuli: Day 2 took place in a new room, so as to test generalization across contexts as often occurs in everyday life (Klein & Meltzoff, 1999). It involved two warm-up sets and the test set. The warm-up sets are described in the Supplemental Materials. Fig. 3 shows the Day 2 test set. It consisted of a fourth set of experimental materials, as well the “other goal” materials (i.e., the goal that was novel to all children on Day 2).

The two sets were spatially intermixed on a black foam tray (Fig. 3). The subactions associated with the experimental goal were identical to those described on Day 1 (place red bead on platform, thread stick through hole, place bead on flap). The subactions for executing the other goal were as follows: (a) draw a circle around the yellow disk with blue and black stick, (b) flip over the disk (there was green felt on the backside), and (c) stamp the arc block onto the felted disk.

2.1.3. Design

Fig. 4 provides an overview of the design and procedure. Participants visited the lab on two consecutive days, separated by 24 h. On Day 1, children were randomly assigned to either the Experimental or Control group. The Experimental group learned a relevant goal on the Day 1 (relevant because it would be seen again on Day 2) and the Control group did not (see Procedure and Figs. 2 through 4 for details). Then on Day 2 the children were further divided by demonstration organization. Half of the children in both the Experimental and the Control groups saw a *grouped* demonstration of the target event and half saw an *interleaved* demonstration (see Procedure below). Thus, across the 2 days

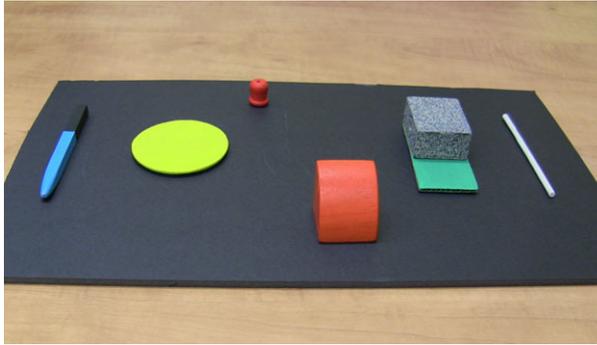


Fig. 3. The materials for the test on Day 2 (from the child's perspective) in Study 1. These same materials were used for children in both experimental and control groups.

children were randomly assigned to each of the four groups ($n = 12$ per group): experimental grouped, experimental interleaved, control grouped, or control interleaved. The higher level goal that the experimenter initiated the test demonstration with on Day 2 was also fully counterbalanced across children.

2.1.4. Procedure

2.1.4.1. *Day 1:* For both experimental and control groups, children were seated at a table across from the experimenter. The experimenter used the same language in both groups and linguistically coded both action sequences (Fig. 2) with the same nonce verb, “zav-ing.”

The experimenter first explained to the children that he would be showing them some “neat stuff” today. The experimenter then brought out the first set of items and told the children, “With these things here, I think we can zav. Here, watch closely, and I’ll show you how to zav.” The experimenter then demonstrated the actions, with narration: “First we do this, then we do this, and then, we do this. There, I did it! I zavved! That’s called zavving!” Immediately following this demonstration, the experimenter pushed the objects over to the child and asked the child if he or she could “zav.” If the child needed help, the experimenter provided verbal support (such as “It’s your turn,” or “Yes, that goes there”). Then the second set was brought out (which differed in color, texture, and size), and demonstration and imitation proceeded identically to the first trial, with the exception that explicit assistance was only given if necessary. Following this, the third set was brought out, and the experimenter said, “With these things here, I think we can zav too. Here [child’s name] can you show me how to zav with these?” The objects were then passed to the children to test whether children would “zav.” The purpose of this third trial was to see if children had learned the goal event and could execute it without a further demonstration with this particular set. Results showed that 100% of the children performed correctly with no demonstration or help in both experimental and control groups (i.e., for both of the stimuli shown in Fig. 2).

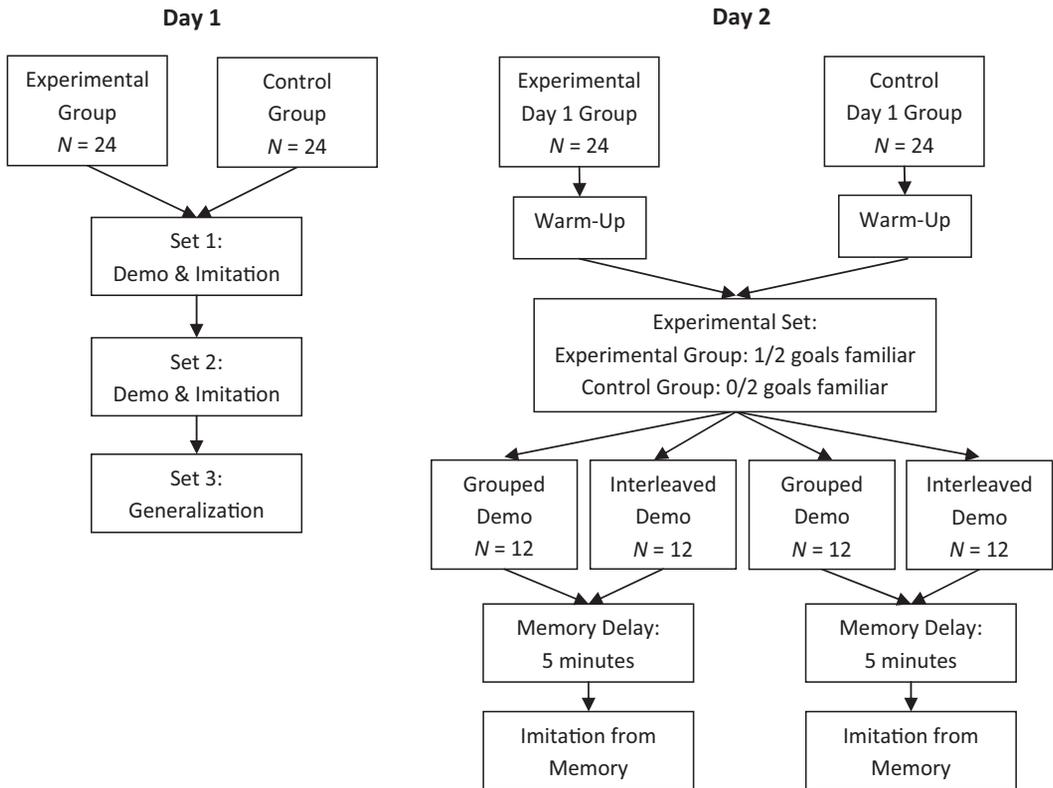


Fig. 4. The procedure for Study 1. The materials used for the Day 2 test of imitation from memory are shown in Fig. 3.

2.1.4.2. *Day 2:* To test generalization, testing for Day 2 occurred in a different room, at a different test table, and the test objects differed in color, size, and texture from Day 1. On Day 2 all the children followed the same protocol; thus, any difference in their behavior had to be due to their memory of Day 1. Equal numbers of children in both groups saw a grouped or interleaved test demonstration (see Fig. 4).

Children first completed the two warm-up tasks that were completely different from the test items. For each warm-up set, the experimenter brought out the set and demonstrated the actions, maintaining a neutral expression, and using no language, and upon completion exclaimed, “There, I did it!” The experimenter then put the set away and told the child they would have their turn in a moment, after doing something else for a little while. Children then engaged in a 1-min coloring activity with the experimenter. Following this, the set was brought back to the table, arranged as it was prior to the demonstration, and the experimenter prompted children with “Now it’s your turn!”

After the warm-ups, the test stimuli were brought out, and the experimenter provided one of two demonstrations, either the interleaved or grouped demonstration (counterbalanced across participants); see Fig. 4. No linguistic narration was used during the test. In

the descriptions below, the subactions for each goal are indicated with a Z for the “zav” goal and an O for the other goal, and a numeral denotes the serial position of the subaction in the goal (not in the demonstrated sequence). For the *interleaved demonstration*, two subactions for one goal were first executed, then two subactions for the other goal, then the final step for the first goal, and then the final step for the second goal (i.e., Z1, Z2, O1, O2, Z3, O3 or O1, O2, Z1, Z2, O3, Z3). For the *grouped demonstration*, the experimenter carried out all three steps of one goal in an immediate sequence before proceeding to execute the three steps for the second goal (i.e., Z1, Z2, Z3, O1, O2, O3 or O1, O2, O3, Z1, Z2, Z3). Crucially, on Day 2 no language was used during to narrate the events, and the experimenter maintained a neutral expression during the demonstration. Items were returned to their original location on the tray once they were used (with the exception of the “zav” bead).

Following the demonstration, the test set was put away, and children were given a 5-min memory delay during which they engaged in picture-book activity with the experimenter. The test set was then brought back (rearranged) and presented to the children, and they were given a chance to play. If the children asked questions about the objects or the subactions, the experimenter provided a neutral response (e.g., “I don’t know” or “It’s your turn”). If the children had interacted with all of the objects, and indicated behaviorally that they were finished, the experimenter removed the test set. If the children indicated that they were finished, but had not interacted with all of the objects, the experimenter encouraged the children only once with “It’s still your turn.” If the children indicated they were finished again, regardless of whether they interacted with more objects, the experimenter removed the test set and the response period was terminated.

2.1.5. Coding

All the object-directed behavior of children’s Day 2 response was first coded from video as elemental behaviors. Most children executed target subactions faithfully, but minor deviations from the demonstrated action were permitted (e.g., if the child circled most of the disk but did not complete a full circuit). All participants were scored by one coder, and a subset of 25% of the participants was scored by a second coder, blind to group assignment, for the purposes of evaluating agreement (detailed below). Any scoring discrepancies were resolved through discussion.

2.1.5.1. Target action score: Independent of children’s organization of actions, this score reflected how many unique subactions the child recalled correctly from both goals. Since there were two goals with three subactions each, scores on this measure could range from 0 to 6. Coders disagreed only once on this measure.

2.1.5.2. Goal grouping score: This score reflected how organized the child’s imitation was with respect to goal structure. A goal was considered grouped if all three subactions for a goal were executed in sequence: for example, executing Z1, Z2, and Z3, in order. Importantly, a goal was not considered grouped if the child omitted a subaction, performed the three subactions in an alternate order, or performed any interleaving actions.

Children received a score of 1 for each higher level goal that they grouped. Scores on this measure could thus range from 0 to 2 for each child. Coders did not disagree on this measure.

2.1.5.3. First goal match: This score reflected whether children's first action did or did not involve materials from the first goal the experimenter initiated the demonstration with. This score served as a measure of children's memory for the initial sequencing of the event, independent of grouping behavior. Children were considered matched if they performed a target subaction with an object involved in the same goal. For example, if the experimenter began with placing the bead on the platform (zav), and the child began by threading the stick into the platform (also zav), the child received a score of 1. Thus, scores on this measure could range from 0 to 1. Coders disagreed twice on this measure.

2.2. Results

Preliminary analyses revealed no effects of gender or order on any of the other variables. Thus, those were collapsed in subsequent analyses. Analyses regarding EF tasks can be found in the Supplemental Materials.

2.2.1. Target action scores

Because children in the experimental group could use their experience from Day 1 and children in the control group could not, we hypothesized that children in the experimental group would recall more target actions than children in the control group, and that the type of demonstration (goal vs. interleaved) would have no impact on target action recall. Fig. 5 displays the mean target action scores. As expected, a 2 (group: experimental vs. control) \times 2 (demonstration organization) ANOVA revealed a significant main effect of group, $F(1, 44) = 6.96, p < .02$, partial $\eta^2 = 0.14$, with children in the experimental group ($M = 5.21, SD = 1.14$) recalling significantly more target actions than children in the control group ($M = 4.21, SD = 1.59$). Also as expected, the main effect of demonstration organization was not significant, $F(1, 44) = 3.10, p > .08$. The interaction between group and demonstration organization was not significant, $F(1, 44) = 3.94, p > .05$.

2.2.2. Grouping scores

Because children in the experimental group had encountered one of the goals on Day 1, and control children did not, we hypothesized that children in the experimental condition would group the goals more often than children in the control condition, and that the type of demonstration would not impact grouping scores in either condition. Fig. 6 displays the mean grouping scores. A 2 (group) \times 2 (demonstration organization) ANOVA revealed a significant main effect of group, as expected, $F(1, 44) = 14.38, p < .001$, partial $\eta^2 = .25$, with experimental children obtaining significantly higher goal grouping scores ($M = 1.13, SD = 0.80$) than control children ($M = 0.29, SD = 0.69$). As expected,

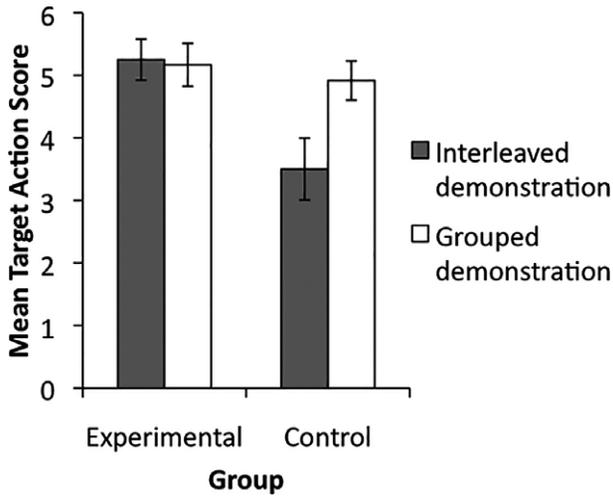


Fig. 5. Mean target action scores by group and demonstration in Study 1. Error bars indicate ± 1 SE.

neither the main effect of demonstration organization, $F(1, 44) = 0.14, p > .70$, nor the interaction between group and demonstration organization, $F(1, 44) < 1, p > .99$, was significant. As expected, a planned independent samples t test revealed that there was no significant difference in grouping scores between experimental interleaved and experimental grouped children, $t(22) = 0.25, p > .80$.

We also compared children's grouping scores for the two individual goals (zav vs. other goal, range 0–1 for each). It is possible that children's significantly higher grouping scores in the experimental group were primarily due to children grouping the zav goal they learned on Day 1, even if they were not grouping the new, other goal. Such a result would not count as strong evidence that the children reorganized the subactions from both goals in the memory representation. Paired t tests indicated that experimental interleaved children grouped the zav goal ($M = 0.50, SD = 0.52$) as frequently as they grouped the other goal ($M = 0.58, SD = 0.51$), $t(11) = 0.43, p > .67$; experimental grouped children also grouped the zav goal ($M = 0.67, SD = 0.49$) as frequently as they grouped the other goal ($M = 0.50, SD = 0.52$), $t(11) = 1.00, p > .33$. This pattern of data is in line with the idea that experimental interleaved children chunked the zav goal in memory, which allowed them to also group the other goal in memory.

2.2.3. First goal match

We thought that all children's imitation, regardless of group, would accurately reflect which goal the experimenter started the sequence with, due to a primacy effect. A 2 (group) \times 2 (demonstration organization) ANOVA revealed no significant main effect of group, $F(1, 44) = 0.91, p > .34$, or demonstration organization, $F(1, 44) = 0.10, p > .75$, nor any significant interaction between group and demonstration organization, $F(1, 44) = 0.91, p > .34$. Thus, children in all groups remembered well which goal the experimenter initiated first ($Grand M = 0.73, SD = 0.44$).

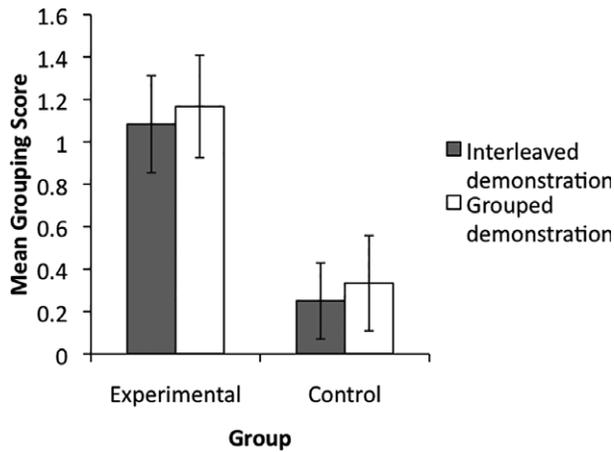


Fig. 6. Mean grouping scores by group and type of demonstration in Study 1. Error bars indicate ± 1 SE.

2.3. Discussion

Study 1 provides evidence that goal organization is prioritized over sequential organization in children's memory for action. Children in the experimental group had a relatively small amount of linguistic and motor experience with the structure of one of the goals the day before. Yet experimental children who viewed interleaved demonstrations on Day 2 used this prior experience to reorganize their memory for the subactions according to the higher level goal structure of the actions. In fact, they did this to the same extent as experimental children who viewed a grouped demonstration on Day 2. It seems that the stored representations for the action events of these two groups were indistinguishable and that both were organized according to the higher level goals. The current results show memory for an action sequence across a 24-h delay and changes in context (i.e., different room on Day 1 vs. 2, and variations in color, size, and texture of the test objects).

Crucially for theory, children in the experimental condition were not just remembering the individual actions from the day before; in both the grouped and the interleaved conditions, they bound "zavving" actions together, and equally often they bound the other novel other goal actions together as well. This suggests that they segregated the two goals and considered the order of subactions within each as an important aspect of the two events.

Children in the control group serve as a benchmark. For the control children, both of the goals viewed on Day 2 were novel. Thus, they have no goal knowledge that they can use to organize their memory representation. In the case of control children who saw an interleaved demonstration, this explains why they did not engage in a systematic reorganization of the subactions. In fact, the sequential order of the recalled subactions was haphazard and idiosyncratic for each child, with no systematic pattern discernible. Data from control children who viewed the grouped demonstrations are also relevant: They

also displayed poorly organized and idiosyncratic orders of the subactions. If they had been able to organize the subactions in memory sequentially, then they would also, by default, have grouped the goals together just by virtue of duplicating the veridical sequential order—but they did not. Thus, it seems as though sequential organization may break down as an organizational strategy in memory for novel six-step sequences over a delay.

We also hypothesized that children in the experimental group would recall more subactions from the sequence overall, and this was borne out in the data. We think that goal organization allows subactions to be chunked in memory (cf. Bauer, 1992). This unitization then allows children to encode more subactions, which in our case involved subactions from an entirely novel other goal. This idea works especially well to explain the difference between target action scores between the experimental and control children who viewed interleaved demonstrations: Experimental interleaved children recalled significantly more subactions than control interleaved children. (Additional discussion of the behavior in the control group can be found in Supplemental Materials.)

Study 1 shows that goal organization is prioritized when children have prior knowledge about a higher level goal. This immediately raises another question: Does the manner in which this prior knowledge is obtained make a difference? Some have argued that direct motor experience provides a privileged form of learning experience (e.g., Sommerville, Hildebrand, & Crane, 2008). We hypothesize that it is the *goal information itself, and not the particular experiences through which that information was acquired*, that plays a key role in the mnemonic re-organizational process (e.g., Meltzoff & Brooks, 2008). Support for this hypothesis would come from evidence that children reorganize their memory for an interleaved action sequence even if they acquired that goal knowledge in a more abstract fashion that completely precludes direct motor involvement. Study 2 provided a critical test.

3. Study 2: Learning goals from picture books

This study investigated whether children's memory prioritizes goal organization even when goal knowledge is more abstract, in the form of a pictorial storybook with no motor experience on the task. Evidence indicates that children can learn actions from storybooks. By 24 months of age, children can faithfully imitate a demonstrated three-step action in the face of changes to materials and context (Simcock & DeLoache, 2008; Simcock & Dooley, 2007; Simcock, Garrity, & Barr, 2011). Thus, we felt confident that 3-year-old children would have the capacity to learn and imitate a multi-step novel action from a picture book. Our question did not concern children's recognition of the pictures (which we assume they can by this age). Instead, we investigated whether children would be able to abstract an event structure without prior motor experience. Specifically, we tested whether 3-year-olds utilize abstract, information depicted in the 2-D events *to reorganize a complex, interleaved sequence of actions in memory*. This is a more stringent test of the hypothesis that goal organization is an abstract principle of action representation, because it allows us to exclude motor involvement and practice by the child (see below).

Study 2 compared children's grouping behavior for the same interleaved sequences used in Study 1 in three groups: (a) the experimental hands-on group, which was identical to the experimental group of Study 1 (replication), (b) the experimental storybook group, in which children learned about one of the goals via a storybook and without touching or handling the 3-D test objects, and (c) the control storybook group, in which children learned an unrelated goal via the storybook. If direct motor experience is the driving factor, the children in the experimental hands-on group should obtain significantly higher goal grouping scores than the other two groups. However, we predicted that (a) goal grouping will be similar between both experimental groups, and (b) children in both experimental groups would remember more subactions overall than those in the control group.

3.1. Method

3.1.1. Participants

Participants were thirty-six 3-year-old children (15 boys). The mean age of children was 3.5 years ($SD = 3.7$ months). Participants were recruited from daycares. Based on parental report of race/ethnicity, 18 children were self-classified as White, three as Aboriginal, three as Black, one as Asian, and seven as mixed race/ethnicity. An additional 13 children were tested but excluded from the final sample: poor attention during storybook ($N = 3$), too shy ($N = 4$), and absence on Day 2 ($N = 6$). Children were given a small toy for participating on both days. Equal numbers of children were assigned to one of three independent groups: control storybook, experimental storybook, or experimental hands-on group.

3.1.2. Stimuli

Two picture books (33 pages, saddle-stitched, pages approximately 21.5×28 cm) were constructed for the experimental and control storybook groups, using digital illustrating software. The books were titled *Tommy Learns to Zav* and contained color illustrations which depicted three different instances of different animal characters learning how to perform a three-step goal sequence. The book was bound such that there was an image on the right page that faced a blank page on the left. The storybook in the experimental group illustrated three sets of materials that were the same objects used in the Study 1 experimental group. The objects were drawn to represent three dimensions in perspective and shading to resemble those in the experimental hands-on group as vividly as possible (see Fig. S1 in the Supplemental Material).

A narration of the storybook appeared on each picture page. The narration generally transcribed the script used in Study 1 and was identical between experimental and control groups. The book told the story of a lion named Tommy who was taught by a fairy how to zav, and who then taught two other animal friends how to zav. Each step of the sequence was illustrated close-up in the storybook for both the teaching character and the learning character for the first two learning events, and then only for the learning character for the final learning event (to match generalization).

For the control storybook group, pilot testing indicated that a different control sequence from the one used in Study 1 was needed because that sequence was difficult to represent faithfully in storybook illustrations. The control storybook thus illustrated three sets of materials that included a cardboard tube, a thin square of cardboard, and a bottle cap. The subactions for carrying out the this goal were (a) stand the tube up vertically (the tube was always presented horizontally), (b) place the bottle cap in the tube, and (c) put the tube on top of the cardboard piece.

For both books, each set of items shown in the book was unique relative to the other sets in terms of color. After the presentation of the storybook, children in the experimental and control storybook groups were also shown a set of materials that were identical to the ones seen in the storybook, to test for recall of the goal subactions.

The experimental hands-on group involved the same 3-D objects used in the experimental group of Study 1. The warm-up sets and the test set used for the Day 2 testing procedure for all children were also identical to those used in Study 1.

3.1.3. Design

Children were visited by the experimenter at their daycare on two consecutive days, separated by 24 h. All Day-1 groups (experimental storybook, control storybook, experimental hands-on) were independent groups, with equal numbers of children ($N = 12$) randomly assigned to each. As in Study 1, on Day 2, the order with which the experimenter initiated the test demonstration (i.e., zav first or other goal first) was fully counterbalanced between subjects.

3.1.4. Procedure

3.1.4.1. Day 1: For both experimental and control storybook groups, children were seated at a table perpendicular to the experimenter. The experimenter said to the child, "I have something to show you today. Today we are going to read this book. This book is called *Tommy Learns How to Zav*, and today we are going to learn how to zav." The experimenter then proceeded to read the storybook and called the action sequences in both books zavving. The experimenter attempted to maintain children's attention on the book, and if a child was distracted by something else in the room, the child's attention was guided back to the book. When finished reading, the experimenter said, "We're all finished with this book now, but I have some more things to show you." The book was then put away and the experimenter brought out one unique set of zav materials that were identical to the ones seen in the storybook. The experimenter asked the child, "I think that I can zav with these things, but I need your help. Can you tell me how to zav?" Children were not permitted to manipulate the objects, but they could vocalize or use gesture to direct the experimenter to perform the subactions of the novel goal from the storybook. The purpose was to make sure that children had paid attention to the story and understood the zav sequence. Results showed that 100% of the children from both groups were able to do so.

In the experimental hands-on group, children were seated across the table from the experimenter. This group followed the identical script as the experimental group of Study 1, with demonstrations and imitation periods.

3.1.4.2. *Day 2*: The Day 2 testing procedure followed that in Study 1 for all groups in all aspects, with two exceptions: (a) children were only shown an interleaved demonstration, and (b) children were tested in the same room as Day 1.

3.1.5. *Coding*

All of children's Day 1 and Day 2 behavior was coded from video. Day 2 coding was the same as in Study 1. One coder scored all participants, and a subset of 25% of the participants was scored by a second coder, blind to group, to assess inter-coder agreement. Coders did not disagree on grouping or first action scores, and they disagreed on only one target action score (resolved through discussion).

3.2. *Results*

Preliminary analyses revealed no effects of gender or order on any other variables, and thus these variables were collapsed in subsequent analyses.

3.2.1. *Target action scores*

As in Study 1, because the two experimental groups (storybook and hands-on) had experience with one of the goals on Day 1, and the control group did not, we hypothesized that children in both experimental groups would recall significantly more target actions than children in the control group. Fig. 7 displays the mean target action scores. As expected, a one-way ANOVA revealed a significant difference among the test groups, $F(2, 33) = 5.11, p < .02, \eta^2 = 0.24$. Follow-up tests determined that children in both the experimental storybook group and the experimental hands-on group remembered significantly more target actions than those in the control storybook group, respectively, $t(22) = 2.74, p < .02, d = 1.11$, and $t(22) = 2.67, p < .02, d = 1.09$. As hypothesized, there was no difference in target action scores between the experimental groups, $t(22) = 0.21, p = 0.83$.

3.2.2. *Grouping scores*

Because both experimental groups had been familiarized with one of the goals on Day 1, and the control group had not, we hypothesized that children in the experimental groups would group the goals more often than children in the control group, and would not differ from each other in this respect. Fig. 8 displays the goal grouping scores. As expected, a one-way ANOVA revealed a significant difference between the three groups, $F(2, 33) = 5.76, p < .007, \eta^2 = .26$. Follow-up tests determined that grouping scores in both the experimental storybook group and the experimental hands-on group were significantly higher than in the control storybook group, respectively, $t(22) = 3.26, p < .004, d = 1.23$, and $t(22) = 3.46, p < .003, d = 1.41$, with no significant difference between the experimental storybook and experimental hands-on groups, $t(22) = 0.81, p > .43$.

Children's grouping scores for the two individual goals (zav vs. other goal) were also compared. As expected, paired t tests indicated that experimental storybook children grouped the zav goal ($M = 0.25, SD = 0.45$) as frequently as they grouped the other goal

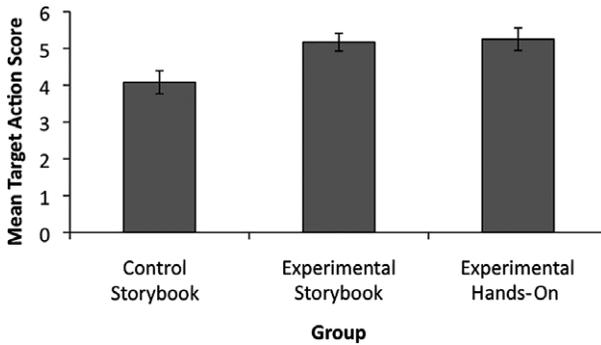


Fig. 7. Mean target action scores by group in Study 2. Error bars indicate $\pm 1 SE$.

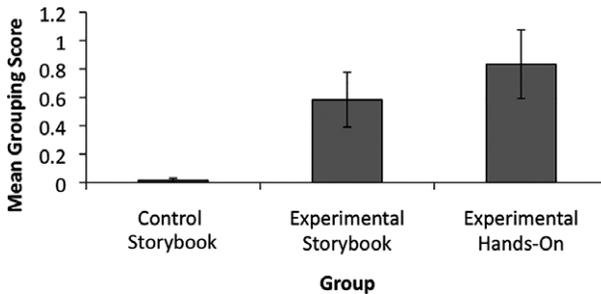


Fig. 8. Mean grouping scores by group in Study 2. Error bars indicate $\pm 1 SE$. Note that the mean for the control storybook group is actually zero.

($M = 0.33, SD = 0.49$), $t(11) = 0.43, p > .67$, and experimental hands-on children also grouped the zav goal ($M = 0.41, SD = 0.51$) as frequently as they grouped the other goal ($M = 0.41, SD = 0.51$), $t(11) = 0, p = 1.00$, replicating Study 1.

3.2.3. First goal match

We thought that all children, regardless of group, would correctly recall which goal the experimenter initiated the sequence with, due to a primacy effect. A one-way ANOVA revealed no significant differences between the groups in first goal scores, $F(2, 33) = 1.22, p > .30$. Scores in the experimental storybook group ($M = 0.83, SD = 0.39$), the experimental hands-on action group ($M = 0.92, SD = 0.29$), and the control storybook group ($M = 0.83, SD = 0.49$) were similar.

3.3. Discussion

Study 2 establishes that knowledge of higher level goals can organize children’s memory for action even without direct motor experience with those goals. Children who learned about zavving from a storybook, and who had no opportunity to physically enact

this goal, were just as likely to reorganize an interleaved action sequence involving zavving as children who had first-hand motor experience with zavving. They also reaped the same cognitive benefits of goal organization: They were able to remember more subactions for the entire sequence, including entirely new actions from the other novel goal. This suggests that goal organization does not require direct motor experience or habits and is based on more abstract information (see General Discussion).

Study 2 also supports the inference that children's goal grouping behavior is not the result of poor inhibitory control in suppressing a prepotent motor response. A critic might argue that in Study 1 experimental children's motor practice with zavving on Day 1 built up a prepotent tendency to execute the subactions in order. Then on Day 2, perhaps experimental children's representation of the interleaved demonstration was organized sequentially, but because of poor inhibitory control children could not help but execute all three zavving actions in order. In Study 2, however, children in the experimental storybook group had *no prior motor experience* with zavving, and thus there was no overlearned motor habit that they would have had to suppress on Day 2. These results are best explained by a process of active reorganization of memory, based on relatively abstract knowledge of goal structure (see Supplemental Material for further discussion on representation).

4. General discussion

Children learn about the causal structure of event sequences from observing adult goal-directed behavior, and also learn about the canonical structure of other cultural-specific customs and rituals in this way (Legare & Nielsen, 2015; Meltzoff, Waismeyer, & Gopnik, 2012; Meltzoff et al., 2009; Tomasello, 1999). However, in everyday life, the adult action stream is notably different and more complex than that used in most developmental psychology laboratories. In ecologically valid settings, young children observe a fast-paced stream of human action which sometimes involves the execution of multiple goals in a nonlinear fashion. Adult actions can be interrupted on the way to achieving a goal, and adults switch back and forth from achieving one goal to another as they multitask. The present results demonstrate that children possess a cognitive system that can handle nonlinearity in action observation. Provided children have knowledge about the higher level goals that bind certain subactions together, they can organize the observation into two or more goals, rather than a jumble of individual actions.

These results replicate and extend the phenomenon that Loucks and Meltzoff (2013) reported for highly familiar acts. They reported that 3-year-old children group familiar activities (e.g., going to bed) according to goals in their imitation of an adult. Children in the current work reorganized across a longer temporal span than Loucks and Meltzoff used. This establishes that the mental representation of the action can operate across a significant gap in space and time. In order for children to succeed in the way they did, they needed to organize their Day-2 actions (a) based on information acquired originally 24-h before, (b) in a different physical context (Study 1 involved a new test room on

Day 2), and (c) across three steps of a sequence spread over approximately 8 s. Because the current studies used novel, arbitrary goals, they suggest the existence of goal organization after very brief exposure on Day 1.

Study 1 demonstrates the fundamental power of the memory reorganization phenomenon: Despite seeing *different* sequences (different stimulus displays), children in the experimental grouped and the interleaved conditions *recalled the same number of actions in the same order*. This supports the hypothesis that the memory representation of these two different behavioral streams was organized in a similar manner according to higher level goals. The children were able to use their prior experience to parse the action stream and recognize that two distinct higher level goals were being enacted (even if these goals were intermixed in the actual observed event); and this goal organization was prioritized over sequential information for the purposes of long-term storage and imitative re-enactment of the scene.

Study 2 extends this line of work by demonstrating that children can learn about the structure of a novel, three-step goal from a storybook, and can and use this 2-D symbolic information to structure their memory for 3-D novel actions. These findings add to a growing literature that indicates that preschool children can learn conceptual information from picture books (Fecica & O'Neill, 2010; Ganea, Ma, & DeLoache, 2011; Kelemen, Emmons, Schillaci, & Ganea, 2014). The procedure strictly ensured that children could not directly interact with the *zavving* objects on Day 1, yet they still grouped according to goals at the same level that they had when they learned via first-hand motor experience. This indicates that the representational system can work with abstract information to structure memory for the observed actions of other agents.

4.1. Higher level goals, cultural learning, and social understanding

What, then, was the goal that children inferred? The stimuli were designed so that the action sequence the children learned did not result in a salient physical end state. We believe that during the observation of the adult's action stream (Day 1), children inferred a higher level goal of the series of (arbitrary) actions that we linguistically labeled with the verb "*zavving*." In this sense, *zavving* is executing particular subactions in a specific order, similar to a game or ritual. Does this mean that our results only bear on the representation of causally opaque, novel action sequences? We do not think so, because our results are identical to those of Loucks and Meltzoff (2013) for more familiar, causally transparent goals.

We hypothesize that young children's cognitive representation and organization of action sequences helps them parse the social world and learn about conventional goals, norms, and customs. We assume, for instance, that young children see no deep purpose in brushing their teeth, yet they learn the steps and seem to represent and unitize this event. Even for goals that result in a salient end state, such as making a bed, the ultimate purpose may not be fully grasped by children initially; they may treat it more like a social custom. Higher level goals are often defined within a specific culture and marked by linguistic labels. Young children have to learn the organization of the higher level

goals for their local culture even if they have no salient end state, as for example, a practice of “doing things a certain way” or a cultural ritual (Legare, Wen, Herrmann, & Whitehouse, 2015; Nielsen, Kapitány, & Elkins, 2015). Finding purpose in these actions may come at a later age, and the cognitive organization used to represent action streams may support this development (for additional theoretical analysis, see also Wang et al., 2015; Williamson et al., 2010).

4.1.1. *The role of language*

Language may be crucial in this developmental process. We think that our use of a novel verb played a role in children’s goal organization, and that language is also a relevant factor in children’s construction of partonomic goal hierarchies in the real world. Research on children’s categorization of natural kinds indicates that language helps children to go beyond the perceptual appearance of an entity and represent it as a member of a conceptual category (Gelman, 2003; Gelman & Markman, 1986). Novel verbs also invite young children to interpret ambiguous actions as goal-directed and important to imitate (Chen & Waxman, 2013). In a similar fashion, we believe language invites children to conceive of a sequence of seemingly arbitrary units as a higher level event.

Language is ubiquitous in children’s learning of cultural actions, customs, and rituals. Indeed, it is possible that experimental children in this study would not have grouped the interleaved sequence if the linguistic narrative and novel verb had not been used on the first day, or that younger children need the linguistic input to bind sequences of subactions whereas older children can do without this linguistic support. This is a key issue in developmental cognitive science which we are currently investigating.

4.1.2. *Temporal order in memory*

Although the current paradigm pitted goal organization against sequential organization, these results should not be taken as evidence that temporal information is completely absent in young children’s memory. Temporal information is critical in the execution and interpretation of a number of goals that involve causal relations among objects. Temporal information can also be used as a means of action segmentation in some situations (Baldwin et al., 2008; Swallow & Zacks, 2008). Indeed, in the current work, children’s ability to learn the novel goals on Day 1 indicates sensitivity to temporal order, because the events we used were not “enabling” relations or mandated by strict causal necessity. Once children bound them together as “zavving” it allowed them to structure and simplify their memory for the complex interleaved demonstration. Because the current results show that children reorganized the interleaved demonstration, and this suggests, that a goal organization is *prioritized*, this does not mean that veridical temporal order is completely unrecoverable.

4.1.3. *Alternative considerations*

Although the current results indicate that children’s processing of other people’s action can handle issues of nonlinearity resulting from multitasking/interruptions, there are no precise quantifications of how often children experience such interwoven events in the

real world. It is reasonable to assume, however, that at least in North America, with its busy, multitasking caretakers (Offer & Schneider, 2011), children frequently observe adults interrupting themselves and multitasking. Indeed, there have been neuroscience studies of multitasking in adults as it is thought to be a significant part of everyday cognition that requires explanation (Burgess, Veitch, de Lacy Costello, & Shallice, 2000). We believe the present results showcase the power of young children's representational system: It can reorganize observed nonlinearity such that children can learn from complex, everyday action streams, restructure them in memory, and imitate at a subsequent time.

Because children imitated in the presence of the experimenter on Day 2, it is also useful to consider what role social "demand" factors might have played. Adherence to normativity has been raised in work on children's overimitation (Kenward, Karlsson, & Persson, 2011; Keupp, Behne, & Rakoczy, 2013). One possibility is that children in the experimental group may have been "repairing" the "mistake" the experimenter made in doing the interleaved demonstrations; that is, children may have noted the interleaving, and on their turn demonstrated the "correct" way to execute the sequence.

We do not favor this idea for two reasons. First, if children were simply correcting the experimenter, then they would have been more likely to "fix" the *zavving* goal, and not the other goal, but both goals had an equal probability of being grouped, and some children only grouped the other novel goal (both studies showed this pattern). Second, we reviewed the videotapes for behaviors that would suggest that children considered the event a violation of norms—such as quizzical looks or social referencing toward the adult at the time of the "error"—and found none.

We believe that the results highlight the effect of knowledge on children's representation of other people's actions, rather than social demand factors. However, we acknowledge that children can imitate for a variety of other social, affiliative, and motivational reasons (e.g., Meltzoff, 2007; Nielsen & Blank, 2011; Over & Carpenter, 2012; Shneidman & Woodward, 2016). Thus, it remains possible that by using the same experimenter on both days, we may have somehow encouraged grouping. Further designs could provide additional clarity on our interpretation (e.g., switching experimenters, requesting exact reproduction, or utilizing non-imitative dependent measures).

4.1.4. Benefits of goal organization: Mechanisms of developmental change

We now come to a key question about cognitive science and development: What benefit, if any, does a goal organization (see Fig. 1) provide for the developing mind? This is connected to the weight observers give to goals in interpreting other people's action (Baldwin & Baird, 2001; Csibra & Gergely, 2007; Meltzoff, 1995; Woodward, 2009; Zacks et al., 2001). We would argue that goal organization is likely the preferred organization for actions in memory because it reflects a deeper analysis of the event (e.g., Craik & Tulving, 1975). With subactions nested under a higher level goal, memory for both the subactions *and* the higher level goal itself is likely improved.

The present results also highlight another, less obvious, developmental benefit of goal organization: Children can recall more subactions in their imitative re-enactments when they have knowledge of goals, even when the subactions are entirely novel, as in the case

of the “other goal” demonstrated on Day 2. We hypothesize that this is due to the fact that goal organization allows subgoals to be chunked in memory.

This cognitive benefit has the potential to accelerate children’s sociocultural development. As the child’s representation binds units of a higher order goal together in memory, it also shifts subactions of new events together in memory. Instead of being a meaningless collection of new singleton actions, this “other event,” which may be entirely novel, can be grouped and remembered. This accelerates learning and memory of novel observed goals. The fact that children in the experimental condition significantly grouped the subactions of the “other goal” together lends support to this idea. In this way, knowing about one higher level goal of the social agent may improve categorization and learning for a new, different higher level goal, which then adds to children’s goal database. This in turn fuels further learning in a generative, ratchet-like fashion.

We tested 3-year-old children because this is a time of rapid uptake of cultural actions, social norms, and verb learning. However, we believe that goal organization is maintained across development. With older samples, the effects may be more subtle and manifest most strongly with more complex tasks, because increased working memory capacity would allow older children to retain more sequential information and/or retain it for longer periods. Another pressing issue concerns the developmental foundations for prioritizing goal organization over a veridical memory for serial order in the social behavioral stream. What are the precursors to the effects reported here? This is a topic we are currently exploring, as the finding that 18-month-old infants imitate intended over surface acts (e.g., Meltzoff, 1995) strongly suggests ontogenetic roots of this phenomenon.

4.1.5. Broader implications for theories of action representation

The present findings have broad implications regarding action perception and representation. First, they support the idea that the action stream is segmented during observation, a topic of interest in adult cognitive science (Kurby & Zacks, 2008; Newtson & Engquist, 1976; Saylor et al., 2007), and also fit with the notion of partonomic hierarchies (e.g., Hard et al., 2011; Zacks et al., 2001). Goal organization requires that subgoals are segmented out of the continuous flow and organized under the higher level goal that binds them together. The current work, along with Loucks and Meltzoff (2013), provides the first set of evidence that young children segment action with reference to higher level structure, in real-time. According to event segmentation theory (EST; Zacks, Speer, Swallow, Braver, & Reynolds, 2007), segmentation of the action stream occurs automatically in real time, as a result of the continual updating of event models. EST works well to describe the process of segmentation in this study, but it may need to be expanded to incorporate cognitive architecture that can handle nonlinearity in goal execution and/or reorganization in the long-term representation of human action.

Second, the current results suggest that preschoolers can process and represent human action in an abstract fashion. A growing literature has argued that some aspects of children’s action perception are mediated by the neural system linked to those used to execute actions (e.g., Marshall & Meltzoff, 2014; Rizzolatti & Craighero, 2004; Southgate, Johnson, El Karoui, & Csibra, 2010). In one variant of this argument (not shared by all),

action understanding can be achieved directly through motor resonance, and the motor system provides the essential grounding (e.g., Gallese, Rochat, Cossu, & Sinigaglia, 2009). The present findings, especially those from Study 2, require that observers make use of information that goes beyond the motor system per se, and thus join with other developmental work using both behavioral and neuroscience findings that distinguish between action representations that are motor versus those that are more abstract (see also Meltzoff & Brooks, 2008).

When an observer views someone shifting to a new goal, and then returning to the first goal, mirror neurons and motor resonance cannot help to the observer bind subgoals together across the temporal gap. This is accomplished by children's inferences about goals, which are used to reorganize the literal/actual motor behaviors into an organized form that differs from the actual stimulus. Literal motor resonance alone cannot do this job (and might lead to the opposite, veridical organization). Ultimately, for children to learn relevant cultural information by observing others in ecologically valid settings—including the adult penchant for multi-tasking and interweaving subactions from different goals into one long behavioral sequence—children must possess a flexible and abstract representational system that can handle the complex nonlinear stimulus that is other people's goal-directed action.

In summary, the current research documents that young learners utilize prior experiences and previously learned information to organize their memory for other people's action and, in doing so, can fuel social learning at an accelerated pace. By blending literatures on action segmentation, imitation, language, and memory, we are able to investigate the cognitive systems at play in children's parsing and representing other people's behavior. These in turn support young children's rapid cultural learning. We hope this work engenders future research on children's learning in richly complex social settings, and refinements of both psychological and computational models of action perception, representation, and understanding.

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Supporting Information

Additional Supporting Information may be found online in the supporting information tab for this article:

Data S1. Additional methods, data analysis, and discussion for Study 1, including measures of executive function.

Fig. S1. Example pages from the experimental storybook used in Study 2.