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RESEARCH ARTICLE

Kindergarten children's event memory: the role of action prediction in remembering

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Abstract

In two studies, kindergarteners participated in a series of staged events immediately preceded by pre-event interactions that were designed to identify factors relevant to improving recall. The events were based on preschool science-related activities and the experimental pre-event involved predicting actions to occur during a target event, manipulating types of cues available to support these predictive inferences. Action prediction did improve free recall, and effects may have influenced attentional processes evoked by actions generated and enacted. Although children effectively used outcome cues to predict actions, a one-to-one relation between pre-event action prediction patterns and recall did not occur. In combination with other findings, this result may suggest that increased attention during the target event may have supported the pre-event effect rather than integration of information between the pre-event and target event. Early childhood teachers engaging children in science activities should provide explicit cues to enhance usefulness of preparatory activities for recall.

Keywords Kindergarteners · Event memory · Pre-event · Prediction · Objects · Science education

Introduction

Young children learn and remember in a variety of formal and informal contexts at home, in play, and in early childhood education and care sites (Bell et al. 2009; Leinhardt 2002), and are at times called upon to report detailed or distressing information in legal (Johnson et al. 2016) and medical settings (Baker-Ward et al. 2015). Considerable theoretical and applied focus (e.g., Miller 2014) has been given to identifying factors, both facilitative and disruptive (Hudson and Grysman 2014; Salmon and Reese 2015), that influence encoding and retrieval of information from events related to these contexts.

A common approach has been to create or "stage" an event (Bauer 2006) and then vary event or context attributes as the event unfolds (Bauer 1992; Haden et al. 2001), after the event occurs (Leichtman et al. 2017; Warren and Peterson 2014), or during remembering of the event (Gee and Pipe 1995) to detect features that raise or reduce performance. Most often the cues examined are those that occur during and after events, but expectations and prior knowledge are also known to influence event encoding and retrieval (Fivush et al. 1992; Nelson 1986). Indeed, in a few studies, the impact on memory of "pre-event" or preparatory activities for a target event has been investigated. Most notably, Salmon, Pipe, and their colleagues (McGuigan and Salmon 2005; Salmon et al. 2008; Salmon et al. 2011; Salmon et al. 2007; Sutherland et al. 2003) have explored the effect of engaging children in conversations with adults under a variety of conditions prior to the staged event to determine whether these interactions help children remember the target event better.

Child-directed and event-related *wh*-questions during conversation (Boland et al. 2003), the availability of objects or photographs (McGuigan and Salmon 2005; Salmon et al. 2007), cues that connect preparatory and target event

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activities (Jant et al. 2014), and child contributions to the pre-event (McGuigan and Salmon 2005) are among the features that have been investigated. Memory benefits resulting from pre-event factors appear mixed, and when effects do occur, they have been described as "modest" (Salmon et al. 2011). Results related to child contributions are particularly unclear. Children's participation in parent-directed and elaborated pre-event conversations have led to better target memory (Salmon et al. 2011), transfer of information, and joint memory talk about target events during a delay (Jant et al. 2014); however, neither McGuigan and Salmon (2005) nor Salmon et al. (2011) found that greater child-generated information during these pre-event conversations facilitated memory for the target event. This is surprising given evidence of the generation or enactment effect in which children's self-generated information or actions are better remembered than those produced by others (Baker-Ward et al. 1990; Foley and Ratner 2001). However, features of the experimental context, what the child was asked to talk about and the timing of the pre- and target events, might have contributed to these null effects when they occur.

First, in studies testing conversational pre-event effects, most child-contributed information seems to have involved repetition of information provided by the adult or related to past contexts involving the objects or actions within the event to come (McGuigan and Salmon 2005; Salmon et al. 2011). Salmon et al. (2011) did find, however, that in discussions with a parent, children generated more "contextual" information that involved statements about what the child would "get to do," a type of future-oriented prediction. An extensive literature for adults does show that making predictions is effective in enhancing learning (Brod et al. 2018) and mothers' questions about future events have been found to be positively related to very young children's memory (e.g., Ratner 1984), but the child statements made in the Salmon et al. study did not increase recall. Perhaps a recall effect failed to occur not because child-contributed and future-oriented pre-event information does not support memory but because the information children added to the conversation reflected what they were told rather than what they generated themselves.

In the present studies, kindergarteners generated predictions about events in which they would then participate. Their predictions were guided by perceptual cues from visible products that they would bring about during the target event. Prediction is common in children's everyday reasoning and begins at a very young age (e.g., Atance and Hanson 2011), suggesting that making event-related predictions is well within kindergarteners' capabilities. This process is also similar to what occurs in using everyday scripts (e.g., Nelson 1986), but the predictions here were applied to a particular learning context, science-related activities. As a key aspect of the scientific method, prediction has been identified as an important skill and included in preschool and kindergarten science curricula (e.g., Gopnik et al. 2010).

A second characteristic of the experimental context that may have influenced results in past research involves the timing of the pre-event, target event, and recall. In most studies, although not all (e.g., Jant et al. 2014), preparatory activities have occurred at least a day before the target event, and recall, often a week or more after (e.g., Salmon et al. 2007, 2011). Perhaps the apparent fragility of pre-event effects reflects forgetting because of these delays (McGuigan and Salmon 2005; Sutherland et al. 2003) rather than the linguistic complexity of future-oriented conversations or children's understanding of the relation between the future and the past (McGuigan and Salmon 2005; Naito and Suzuki 2011). It is also possible that the delay between preparation and the target event increases the likelihood that children interpret the two as separate occurrences reducing activation or integration between them. If so, eliminating delays between the pre-and target event and between the target event and recall might enhance the pre-event effect. For many kinds of events studied, particularly those reflecting legal or medical settings, preparation immediately before a target event might not be meaningful in a real-world environment. But brief preparation immediately before kindergarten science-related activities, which are often event-based (e.g., Dejonckheere et al. 2016; Tuttle et al. 2017), would be ecologically valid for the classroom.

The purpose of the two studies reported here is to look again at the features of pre-event child contributions that may facilitate memory for target events when children are guided to make predictions about the events in which they are to participate and when the target event immediately follows the pre-event. The events in which children participated were science-related activities, organized by actions and objects into causal relations that led to observable transformations and outcomes. These actions, objects, and outcomes provided cues for the pre-event predictions. The activities were appropriate for kindergarteners, the age of children typically involved in studies of pre-event memory effects. We chose these activities and this age group so that our findings might have applicability not only to the classroom but also could be compared to others' in the field.

Experiment 1 was divided into two parts, and each part was conducted not only to investigate the experimental questions of interest but also to develop different aspects of the methodology used in Experiment 2. The same action prediction pre-event was used as the experimental task across studies but control conditions varied. In Experiment 1a, we compared recall of the target event after a pre-event that did or did not include a prediction task. Because of the modest recall effects of pre-event tasks observed in the literature, our first question was simply whether a pre-event involving the child's own predictions about an event would lead to better recall than an activity that involved no focus on the future event at all. Then in Experiment 1b, we tested the pre-event task against another that involved prediction but was focused more on the event objects rather than its action–object relations. In Experiment 2, further methodological modifications were made in response to the findings of Experiment 1b.

Experiment 1a

Cues available to guide pre-event predictions children made varied in two event types, Preserved and Transformed. For Preserved events, action results were maintained during the event and were perceptually available in the activity's end product. For example, assembling a tossed salad made from lettuce, tomatoes, carrots, and cucumbers would be a Preserved event. The salad retains the individual elements that compose it, and how it was made can be inferred by looking at it because cues are perceptually present or "preserved" in the outcome. In contrast, Transformed events produce action results that "disappear" from view, no longer looking like they once did during the event. For example, when a cake is made the flour, eggs, sugar, butter, and baking powder are transformed by mixing the ingredients together and baking them. The cake no longer resembles most of the ingredients used to make it, and looking at it reveals fewer clues about what was done to produce it. Thus, if nothing is known or remembered about how salads or cakes are made, the resulting salad provides visible clues to its origins that can be deduced and used to predict how it was or could be made. The cake offers fewer of these cues.

In previous research (Ratner et al. 2001), kindergarteners recalling events in which they participated were found to benefit from the perceptual information available in outcomes. More actions were reported from Preserved than Transformed events, especially when the outcomes children made were present during recall. Can children also use these outcome cues to generate predictions about the event and do these predictions improve memory for the target event? If children use the outcome to make predictions, they should generate a greater number of actions overall or more actions that are correct for Preserved than Transformed events. A greater number of actions should then lead to higher recall and recall differences between Preserved and Transformed events should be greater under instructions to make predictions than when no predictions are made. An assumption that is shared among various explanations for why a pre-event effect occurs is that the pre-event is conceptualized as a first instantiation of the target and is then thought to be elaborated (McGuigan and Salmon 2004), activated (Murachver et al. 1996; Sutherland et al. 2003), updated by, or integrated with the representation of the target event (Bauer 2013). For ease of reference, we will refer to this as the integration hypothesis.

Method

Participants

Twenty-two girls and 22 boys were included in this study ($M = 6.0$, range = 5.5–7.1). Children were drawn from kindergarten classrooms in public and parochial schools in suburban areas of a large US Midwestern city. Sample size in each of the three studies reported in this manuscript were informed and guided by prior research (e.g., Ratner et al. 2001). This first study, as the two experiments to follow, were approved by the Behavioral Institutional Review Board, a committee of the university's Institutional Review Board. Parental consent was provided for children's participation.

Materials

Each child participated in four staged events. Two of the events were Preserved, and two were Transformed. Each event consisted of eight actions that resulted in an outcome. These actions were guided by the experimenter and performed by the child. The four Preserved events were: make a bird feeder, make a boat, make a kazoo, and make a hat. The four Transformed events were: make a fingerprint, make a bookmark, make clay, and make a balloon blow up. Events were selected from science-related activity books for preschool and kindergarten children. An example of each event type appears in "Appendix 1." Events were counterbalanced so that across all participants each event appeared an equal number of times across conditions. The order of event presentation was similarly counterbalanced. Additional details can also be found in Ratner et al. (2001).

Procedure

Children were accompanied from their classroom by the experimenter to a small quiet room in their school and invited to sit at a table with the experimenter positioned across the table from the child. All sessions were videotaped. Materials used for implementing the events, along with a prototypic example of the outcome to be produced, were set up behind the work table for child and experimenter. After the child was comfortable, the experimenter began to place the materials and the outcome example for the first event on the table. While doing so, children were provided the following instructions: "We're going to make some little toys that you can take home when we're done. Doesn't that sound like fun? The first thing that we're going to make is a(n) (outcome). Then you can (function). These are all the things we need to make the (outcome).” As each item was placed on the table, the experimenter encouraged the child to name the items with her and repeat the names of items that were unfamiliar. For example, if the event was make the ***kazoo***, the child was told, “The first thing that we’re going to make is a kazoo. Then you can make noise with it. These are all the things we need to make the kazoo.” Then the experimenter would place tissue paper, tape, waxed paper, a staple remover, a rubber band, a pencil, and a tissue tube on the table. If she presented an item, such as the staple remover, which the child did not name with her, she asked the child to repeat the name. If children provided idiosyncratic labels (e.g., “puncher” for staple remover), these names were used by the experimenter.

After the event items were placed on the table, one of two pre-event conditions, Prediction or No Prediction, was initiated. In the Prediction condition, the experimenter asked while pointing first to the outcome and then the materials, “How do you think we will make this (outcome) using these things?” If a child could not generate an action, a prompt was given to pick one item, and then another, and tell how it could be used to make the (outcome). In the No Prediction condition, children were asked questions unrelated to the target event: “Do you like school?” “What is your favorite thing to do at school?” “Do you have brothers or sisters?” “Do they go to school?” “What don’t you like to do at school?”

After the Prediction or No Prediction questions were answered, each child was guided through the specific actions involved in each event. When the outcome was achieved, the materials for that event, as well as the item produced, were placed out of view. When all four events were completed, recall began. For each event in the order in which it had been presented, children were asked to recall verbally everything they had done to produce the event outcome. When the prompt, “Is there anything else you can remember?” was answered “no,” the outcome produced was presented and children were asked whether the (outcome) helped them remember anything else.

Pre-event actions generated in the Prediction condition were coded as either matching or mismatching an actual event action. To be coded as a match, both the object action predicted and its outcome needed to be consistent with what would occur during the target event. Mismatches included, and often were, object uses that were typical but not enacted during the event. For example, one child predicted that she would use the pencil in the kazoo event to write her name rather than to punch a hole in the tissue tube.

Recall actions that described the outcome achieved and the process used to achieve it were scored as accurate. Recalled actions that mismatched event actions, including those generated during the pre-event, or intruded in recall from another event, either as part of the experiment or an unrelated event, were identified as inaccurate; however, these occurred only twice and were not analyzed. Two recall scores were created: Free Recall and Total Recall. Free Recall was the number of unique actions reported before the outcome prompt. Only new actions reported after the outcome cue were added to Free Recall to create Total Recall. This focus on unique actions in the Total Recall measure reflected the instructions children were given to recall “anything else” after the outcome was presented. Additional details regarding coding are provided in “Appendix 1.”

Results

Pre-event action predictions

Actions generated in the Prediction condition were entered into a 2 (Event Type: Preserved, Transformed) × 2 (Response Type: Match, Mismatch) ANOVA. Means and standard deviations are given in Table 1. The highest possible score was eight. Children generated more actions for Preserved ($M = 2.15$) than for Transformed ($M = .86$) events, F (1, 43) = 69.54, $p < .0001$, partial eta^2 = .62. This main effect was moderated by an interaction between Event Type and Response Type, F (1, 43) = 4.90, $p < .05$, partial eta^2 = .10. The number of mismatches children produced for Preserved ($M = 1.84$) and Transformed ($M = 1.05$) events did not differ; however, children gave more match responses for

Table 1 Mean (SD) pre-event action prediction types for preserved and transformed events in the action prediction conditions across experiments

Event type	Outcome present				Outcome absent (experiment 1b only)			
	Preserved		Transformed		Preserved		Transformed	
Response type	Match	Mismatch	Match	Mismatch	Match	Mismatch	Match	Mismatch
Experiment 1a	2.45 (1.78)	1.84 (1.58)	.66 (0.83)	1.05 (.89)				
Experiment 1b	2.75 (1.28)	.38 (.74)	1.25 (1.49)	.88 (.84)	1.25 (1.39)	1.00 (.93)	.75 (0.89)	1.00 (1.41)
Experiment 2	3.81 (1.97)	.69 (.79)	2.19 (1.22)	1.25 (1.13)				

In Experiment 1a the condition was called “Prediction”; however, Action Prediction accurately describes the pre-event activity. In Experiments 1a and 1b, interaction with the objects occurred during the pre-event. In Experiment 2, enactment was prevented

Preserved ($M = 2.45$) than for Transformed events ($M = .66$), $t\,(43) = 6.15$, $p < .0001$.

Recall

Free and Total Recall means and standard deviations are given in Table 2. The number of actions reported during Free Recall was entered into a 2 (Pre-Event: Prediction, No Prediction) × 2 (Event Type: Preserved, Transformed) ANOVA. Only the main effect of Pre-event condition was significant, $F\,(1, 43) = 4.41$, $p < .05$, partial $\text{eta}^2 = .09$. Children reported more actions in the Prediction ($M = 4.22$) than the No Prediction condition ($M = 3.61$). The number of actions reported for Total Recall was also entered into a 2 (Pre-Event: Prediction, No Prediction) × 2 (Event Type: Preserved, Transformed) ANOVA. Again children reported more actions under Prediction ($M = 4.97$) than No Prediction ($M = 4.55$) instructions; however, this effect was only marginally significant $F\,(1, 43) = 3.31$, $p = .076$, partial $\text{eta}^2 = .07$. The main effect for Event Type, however, was significant, $F\,(1, 43) = 35.1$, $p < .0001$, partial $\text{eta}^2 = .449$. After the outcome prompt, children recalled more actions for the Preserved ($M = 5.37$) than Transformed ($M = 4.15$) events.

Correlations between prediction and recall

Pearson correlations were calculated between prediction and recall measures. Action matches and mismatches were combined across the Preserved and Transformed events. Prediction and No Prediction Free and Total Recall were also combined across Preserved and Transformed events and served as the recall measures. Because the two recall measures within both the Prediction and No Prediction conditions were highly correlated with one another ($r = .885$, $p < .0001$; $r = .840$, $p < .0001$, respectively) and patterns were identical for both measures, only the correlations for Free Recall are reported across studies. Within the Prediction condition, matches were positively and significantly correlated with Free Recall, $r = .30$, $p = .034$, whereas there was no significant relation with mismatches ($r = -.019$). Prediction matches, however, were also significantly related to No Prediction Free Recall, $r = .315$, $p = .037$, and mismatches, not ($r = .050$). Prediction matches and mismatches were significantly and negatively correlated with one another, $r = -.297$, $p = .050$.

Discussion

Children did free recall more event actions when the pre-event activity involved generating their own, and not someone else's, predictions about actions composing a future event. In comparison with conversing with the experimenter about topics unrelated to the target event, children who identified actions they expected to carry out reported more actions correctly after they participated in the event. The timing of the pre-event immediately prior to the target may have also been important but does indicate that even if the precursory activity is relatively brief, recall can improve, at least when compared to a no prediction task. A brief pre-event activity that involves a science skill, improves memory for science-related activities, and is practical for classroom implementation may be helpful to early childhood educators.

As expected, children did generate more actions during the pre-event for Preserved than Transformed events. Thus, children did appear to use the outcome cues to derive these inferences and benefited from them. *More* actions generated during the pre-event, however, did not necessarily translate into *more* actions recalled. For instance, the recall advantage that the Preserved events afforded was not differentially greater under Prediction than No Prediction instructions and only occurred after the presentation of the outcome cue, even though children generated more Preserved actions during the pre-event. The integration hypothesis would seem to predict that recall should be higher when more information during the pre-event was generated. The representation of the pre-event would include more information initially and then

Table 2 Mean (SD) correct actions reported during free and total recall across experiments as a function of condition and event type with the outcome present during the pre-event

Condition	Free recall				Total recall			
	Action Prediction		No or object Prediction[a]		Action Prediction		No or object Prediction[a]	
Event type	Preserved	Transformed	Preserved	Transformed	Preserved	Transformed	Preserved	Transformed
Experiment 1a	4.34 (1.95)	4.09 (2.18)	3.82 (2.29)	3.39 (2.21)	5.50 (1.69)	4.43 (2.04)	5.23 (1.90)	3.86 (1.98)
Experiment 1b	4.00 (1.51)	4.13 (1.73)	3.25 (1.67)	3.75 (2.05)	4.88 (1.13)	4.50 (1.20)	4.50 (1.60)	4.25 (1.98)
Experiment 2	4.44 (1.46)	4.31 (1.70)	4.00 (1.93)	2.81 (2.20)	5.25 (1.66)	4.88 (1.59)	5.19 (1.94)	3.19 (2.07)

Free Recall is the number of unique actions reported before presentation of the outcome retrieval cue, and Total Recall is the total number of unique actions reported both before and after the outcome retrieval cue

[a]The control conditions were No Prediction in Experiment 1a and Object Prediction in Experiments 1b and 2

would be added to in some way by the target event. Without retrieval cues during free recall, this pattern occurred overall in the Prediction condition but did not occur for Preserved events under prediction instructions. The fact that actions were predicted, rather than how many, seemed to be more relevant. Although the number of matches was correlated with recall in the Prediction condition, consistent with the integration hypothesis, these matches were also correlated with recall in the No Prediction condition. This suggests that a third factor, such as cognitive ability may have contributed to the relation, rather than reflecting processes connecting the representations of the pre- and target events. Thus, collectively these findings suggest that greater elaboration of or integration with the target event by the pre-event might not have occurred.

Perhaps the pre-event representations for Preserved events were more greatly elaborated than for Transformed events, but were not activated or integrated with those of the target event. If this were true, however, it is not clear why integration would occur less often for Preserved than Transformed events. Given that mismatches were the same for the two event types, perhaps inaccurate information compromised the representations, but if so, mismatches should have been negatively correlated with recall and they were not. Mismatches were less frequent than matches, and perhaps there was no correlation because there was little variance in the measure, but a significant negative correlation between matches and mismatches was observed, suggesting otherwise. It is also possible that the outcome helped children generate the actions but did not function as an effective retrieval cue. Consistent with earlier research, however, the event effect did occur for Total Recall when the outcome was available to provide a visible reminder to its action origins, demonstrating the effectiveness of the outcome for retrieval.

Another possibility is that prediction did lead to greater elaboration of the representation for the target event but not for the pre-event. As a result, both event types would have benefited. Prediction may have directed greater attention to the actions and/or objects used during the events. Sutherland et al. (2003) suggest that pre-event activities direct children's attention to particular aspects of events, and if so, this reallocation of attention may have occurred here independent of event type. Perhaps children attended more to the event actions in the Prediction condition because they were more curious or interested in what was going to happen (Inagaki and Hatano 1977, as cited in Brod et al. 2018) or surprised by what they did see happen in relation to their predictions (Brod et al. 2018).

Although prediction did improve recall, the effect was only compared to a pre-event in which event-relevant objects were not acted upon. The outcome and the materials to bring it about were available to children in the No Prediction condition, but these objects were not manipulated or discussed, except during their naming. It is possible that any event-related activity involving prediction or any interaction with the event props might have had the same effect. In the control condition in Experiment 1b, children were asked to make predictions about the objects to be used in the events. Children generated predictions involving the event objects, but their focus was on the perceptual characteristics of the to-be-used materials and their spatial configuration rather than on the event outcome or the actions composing it.

In addition, the apparent absence of interference from pre-event action mismatches with the target event contributed to the idea that children might not have been integrating pre- and target event representations, but rather increasing their attention to the actions in the target event. But the number of mismatches was relatively low and often consistent with typical uses for the event objects. In an attempt to increase mismatches, we also manipulated whether the outcome was present or absent during the pre-event. Without the outcome present, children might generate more actions that did not match the target event, and if so, interference might increase, indicating that children were attempting to make connections between the pre- and target event. Of course, it is also possible that matches would simply decline. Or perhaps if children were not actually using the outcome cues at all, no differences might occur. The difference in actions predicted between Preserved and Transformed events may have been related to some other possible difference between them, so manipulating the presence of the outcome during the pre-event also allowed us to confirm that outcome cues did guide children's predictions.

Experiment 1b

Method

Participants

Sixteen kindergartners were included in this study ($M = 6.1$, range = 6.7–5.7). Equal numbers of boys and girls were drawn from kindergarten classrooms in public and parochial schools in suburban areas of a large US Midwestern city.

Materials

As in Experiment 1a, each child participated in four staged events; however, in this experiment, children were randomly assigned to a Preserved or Transformed condition so that all four of the events were either one type or the other. To be consistent with earlier research and to ensure that children did not become fatigued during the experimental session, only four events could be presented to each child. By manipulating three factors (prediction condition, outcome, and event type), one factor needed to be between subjects. Because earlier research (Ratner et al. 2001) provided more information about event type effects and established that varying event type either between or within subject has similar effects, children participated in only one type of event in this experiment.

The particular event instances of each type were the same as in Experiment 1a. Two of the four events in which children participated were in the Action Prediction condition and the other two were in the Object Prediction condition. In the Object Prediction condition, children predicted which objects would fit into a white box measuring 4.5 inches long, 4.75 inches wide, and 6.0 inches deep and then had the opportunity to place the items in the box. In one event within the Action Prediction condition and one event within the Object Prediction condition, the outcome to be produced during the event was present, and in the other, it was absent. Thus, each child within the Preserved and Transformed Conditions participated in four events: Action Prediction Outcome Present, Action Prediction Outcome Absent, Object Prediction Outcome Present, and Object Prediction Outcome Absent. Events were counterbalanced across participants appearing as often across conditions and in order of presentation.

Procedure

The procedures for Experiment 1a were followed here with two exceptions. First, in the Action Prediction and Object Prediction Outcome Absent conditions, when children were told, “These are all the things we need to make the (outcome),” the to-be-used items were placed on the table, but the outcome was not included. When the outcome was available in the Outcome Present conditions, the experimenter pointed to the outcome as children were told what they were going to make. Second, in the Object Prediction condition instead of engaging children in conversation, the experimenter told them, “I want you to look at all these things and pick two of them that you think will fit in this box.” Next children were asked, “Do you see any other things that you think would fit in the box?” They then had the opportunity to put the items in the box. In the Action Prediction Condition, the experimenter, as in Experiment 1, said, “I want you to look at all these things and pick two of them. Then I want you to tell me how you think we make the (outcome) using those two things. “After the child described the actions, the experimenter asked, “Do you have any ideas about how any of these other things might be used to make the (outcome)?” pointing to the outcome if it was present.

After children participated in each of the four events, the recall phase was initiated just as in Experiment 1a. For all events, the outcome was presented as a retrieval prompt. Before the prompt, the number of actions reported was scored as Free Recall. After the prompt, any new actions reported were added to Free Recall to create the Total Recall score.

Results

Pre-event performance

In order to evaluate pre-event performance in the two prediction conditions, the number of objects named and/or manipulated was compared. The number of objects was entered into a 2 (Pre-event: Action Prediction, Object Prediction) × 2 (Outcome: Present, Absent) × 2 (Event Type: Preserved, Transformed) ANOVA. There was a significant interaction between Pre-event and Event Type, $F\,(1, 14) = 5.98$, $p < .03$, partial eta$^2 = .30$. Children interacted with more objects in the Object Prediction ($M = 4.69$, SD = 1.31) than the Action Prediction ($M = 3.88$, SD = 1.09) condition for Preserved events, $t\,(7) = 2.88$, $p < .05$; however, there was no significant difference between the number manipulated and/or named in the two conditions for Transformed events (Action Prediction, $M = 3.25$, SD = 1.49; Object Prediction, $M = 2.63$, SD = .69), $p > .25$.

The number of actions predicted was entered into a 2 (Outcome: Present, Absent) × 2 (Response Type: Match, Mismatch) × 2 (Event Type: Preserved, Transformed) ANOVA. Means and standard deviations appear in Table 1. There was a main effect of Response Type, $F\,(1, 14) = 7.74$, $p < .02$, partial eta$^2 = .36$. Children made more matches ($M = 1.50$) than mismatches ($M = .82$); however, as in Experiment 1a, there was also a significant interaction between Response Type and Event Type, $F\,(1, 14) = 6.39$, $p < .05$, partial eta$^2 = .31$. For Preserved events, children reported more Match ($M = 2.00$) than Mismatch actions ($M = .69$); however, for Transformed events, the number of Match ($M = 1.00$) and Mismatch ($M = .94$) actions did not differ. When the outcome was present, children also made significantly more matches ($M = 2.00$) than mismatches ($M = .63$), $t\,(15) = 2.11$, $p = .05$, but when the outcome was absent the number of matches ($M = 1.00$) and mismatches ($M = 1.00$) was exactly the same. Similarly, when the outcome was present action matches were significantly higher for Preserved ($M = 2.75$) than Transformed events ($M = 1.25$), t (14), $p < .05$; however, the three-way interaction involving outcome, event type, and response type was not significant ($p > .25$) because all other means did not differ from one another. In a one-sample t test, we compared the No Outcome Preserved and Transformed matches and mismatches to the mean value of their Outcome counterpart measures in Experiment 1a. We had suggested that removing the outcome might increase the number of mismatches; however, the only difference in the mean values between experiments was for Preserved Matches. In Experiment 1b, matches were significantly lower than in Experiment 1a, $t\ (7) = -2.44$, $p < .05$.

Recall

The number of actions reported during Free Recall was entered into a 2 (Pre-Event: Action Prediction, Object Prediction) × 2 (Outcome: Present, Absent) × 2 (Event Type: Preserved, Transformed) ANOVA. No significant effects emerged. Outcome Present Recall means and standard deviations are provided in Table 2 to allow comparisons across experiments; however, the Outcome Absent means and standard deviations appear in "Appendix 2". Combining performance across the Outcome and No Outcome conditions, Free Recall was the same for Action Prediction Preserved ($M = 4.13$) and Transformed ($M = 3.86$) events, as well as Preserved ($M = 4.07$) and Transformed ($M = 3.88$) Object Prediction events. The same analysis was conducted for Total Recall, and again no significant effects emerged. Overall, Total recall was the same for Action Prediction Preserved ($M = 4.88$) and Transformed ($M = 4.25$) events, as well as Preserved ($M = 5.13$) and Transformed ($M = 4.38$) Object Prediction events.

Correlations between pre-event and recall measures

As in Experiment 1a, we correlated the pre-event and recall measures. Both sets of measures were averaged across Outcome and No Outcome conditions and then collapsed across Preserved and Transformed events. The n for all analyses was 16. The pattern for the Action Prediction condition was similar to that found in Experiment 1a. The mean number of matching actions was positively and significantly correlated with Free Recall for the Action Prediction ($r = .54$, $p < .05$) and Object Prediction ($r = .55$, $p < .05$) conditions, whereas mismatches were not related to Free Recall for either ($r = .12$, $r = .13$ for the Action and Object Prediction conditions, respectively). In contrast to Experiment 1a, matches and mismatches were unrelated ($r = .15$). Free Recall and the number of objects placed in the box in the Object Prediction condition were also unrelated ($r = .16$). Objects manipulated were also not significantly related to matches ($r = .35$, $p > .15$) or mismatches ($r = .12$, $p > .65$).

Discussion

The test of the Object Prediction condition as a control for the Action Prediction condition led to mixed findings. In contrast to Experiment 1a, there were no differences in Free or Total recall between the two pre-event conditions; however, children actually manipulated more objects in this task than they did in the Action Prediction task, at least for the Preserved events. It is possible that this greater engagement during the task masked the effects of Action Prediction. Indeed, in other studies, children have been prevented from manipulating the objects to reduce the inclination to play with them (Salmon et al. 2007), which may have occurred here.

As in Experiment 1a, the number of predicted action matches was positively correlated with recall in both the Action and Object Prediction conditions, whereas the number of mismatches was related to neither. Similarly, the number of objects placed in the box was also not related to recall. The presence of the outcome during the pre-event was manipulated in part to attempt to influence the number of mismatches to test predictions from the integration hypothesis. We thought that not presenting the outcome might increase mismatches which might increase recall intrusions, but the only difference was that matches were reduced. The manipulation of pre-event outcome presence did confirm that children used the outcome cues to predict how they thought the events would unfold. They produced more action matches than mismatches when the outcome was present, and more matches for Preserved than Transformed events. When the outcome was unavailable, children's matches and mismatches were the same for both event types.

In Experiment 2, we looked again at the contrast between performance in the Action and Object Prediction conditions; however, in this experiment, we prevented children from acting on the objects. Children pointed to and described the actions predicted, either for the ensuing event or object task. If predicting object properties during the pre-event boosts memory for the target event then performance in the two conditions should be the same, as in Experiment 1b. But if prediction of actions or their results in which the objects are embedded is critical, then performance should be better under Action Prediction than Object Prediction instructions, as in Experiment 1a. In addition, we presented the outcome during the pre-event tasks to provide children with as effective support as possible to guide their predictions.

Experiment 2

Method

Participants

Sixteen kindergartners were included in this study ($M = 6.0$, range = 5.5–6.10). Eleven boys and five girls were drawn from kindergarten classrooms in public schools in suburban areas of a large US Midwestern city.

Materials

As in Experiment 1, each child participated in two Preserved and two Transformed events. Within each event type, one was presented in the Action Prediction condition and the other in the Object Prediction condition. The two Preserved events were: make a birdfeeder and make a boat. The two Transformed events were: make a balloon blow up and make clay. As in the other two experiments, event instance and order were counterbalanced so that each was experienced as often across the two prediction conditions.

Procedure

The procedures followed here were similar to those in Experiment 1b, but instead of allowing children to pick up objects, they were asked to point to them. In the Action Prediction Condition, the experimenter said, “I want you to look at all these things and point to two of them. Then I want you to tell me how you think we make the (outcome) using those two things.” When events were presented in the Object Prediction condition, the experimenter said, “I want you to look at all these things and point to two of them that you think I could put in this box.” For all events, the outcome was present.

Results

Pre-event performance

In order to evaluate pre-event performance, the number of objects named and/or pointed to was compared in a 2 (Pre-event: Action Prediction, Object Prediction) × 2 (Event Type: Preserved, Transformed) ANOVA. There were no significant effects. When children participated in the Preserved Action Prediction ($M = 5.62$, SD = 1.31) and Object Prediction ($M = 5.56$, SD = 1.79) pre-events, they named and/or pointed to an equal number of objects as in the Transformed Action Prediction ($M = 5.38$, SD = 1.20) and Object Prediction ($M = 5.63$, SD = 1.67) conditions.

The numbers of Action Prediction pre-event actions reported were entered into 2 (Event: Preserved, Transformed) × 2 (Response Type: Match, Mismatch) ANOVA. Means and standard deviations appear in Table 1. There were significant main effects for Event, F (1, 15) = 9.36, $p < .01$, partial eta$^2 = .38$, and Response Type, F (1, 15) = 18.43, $p = .001$, partial eta$^2 = .55$ and an interaction between the two, F (1, 15) = 10.04, $p < .01$, partial eta$^2 = .40$. The main effects showed that more actions were generated for Preserved ($M = 2.25$) than Transformed ($M = 1.72$) events and that there were more Matches ($M = 3.00$) than Mismatches ($M = .97$); however, these patterns differed for the two event types. For Preserved ($M = 3.81$) events, there were more matches than for Transformed events ($M = 2.19$), t (15) = 3.72, $p < .01$, but for Mismatches, the two event types were the same (Ms = .69 and 1.25, for Preserved and Transformed events, respectively). For Transformed events, matches ($M = 2.19$) were marginally significantly more frequent than mismatches ($M = 1.25$), t (15) = 1.78, $p < .10$.

Recall

The number of actions reported during Free Recall was entered into a 2 (Pre-Event: Action Prediction, Object Prediction) × 2 (Event Type: Preserved, Transformed) ANOVA. There was a significant main effect of Pre-event, F (1, 15) = 5.67, $p < .05$, partial eta$^2 = .28$. When recalling events experienced in the Action Prediction condition, children reported more actions ($M = 4.38$) than when participating in the Object Action Prediction condition ($M = 3.41$), consistent with Experiment 1a. No other effect was significant. Means and standard deviations appear in Table 2.

Total Recall was also examined in a 2 (Pre-Event: Action Prediction, Object Prediction) × 2 (Event Type: Preserved, Transformed) ANOVA. As in Experiment 1a, there was a marginally significant main effect for Pre-event condition, F (1, 15) = 3.73, $p = .073$, partial eta$^2 = .20$, and a significant effect for Event Type, F (1, 15) = 6.64, $p < .05$, partial eta$^2 = .31$; however, the interaction between Pre-event condition and Event Type was also significant, F (1, 15) = 4.96, p < .05, partial eta$^2 = .25$. Under Action Prediction condition instructions, children recalled as many Preserved ($M = 5.25$) as Transformed ($M = 4.89$) actions; however, under Object Prediction instructions, more Preserved ($M = 5.19$) than Transformed ($M = 3.19$) actions were reported, t (15) = 3.27, $p < .01$. In addition, Transformed Action Prediction recall ($M = 4.89$) was higher than Transformed Object Prediction recall ($M = 3.19$), t (15) = 3.39, $p < .01$.

Correlations between pre-event and recall measures

Pre-event matching actions were combined across Preserved and Transformed events and were found to be positively correlated with Free Recall within the Action Prediction condition ($r = .37$, but negatively correlated with Free Recall within the Object Prediction condition ($r = -.29$). Neither correlation, however, was significant ($.15 < ps < .30$). Mismatches were also not significantly corrected with Free Recall in the Action Prediction condition ($r = -.01$), but unexpectedly were positively and marginally correlated with Object Prediction recall ($r = .49$, $p = .054$). Match and mismatch actions were negatively and significantly correlated with one another, $r = -.57$, $p = .022$. The number of objects pointed to or named in the Object Prediction condition was not significantly related to Free Recall in the Object

Prediction ($r = .37$, $p > .15$) or Action Prediction ($r = -.26$, $p > .30$) conditions.

Discussion

In Experiment 2, when children recalled the events under Action Prediction instructions, they reported more items during Free Recall, and marginally more during Total Recall, than under Object Prediction instructions, just as in Experiment 1a. Children performing under instructions in both conditions were prevented from manipulating event objects during the pre-event activity, only pointing to or naming them. These findings demonstrate that under certain conditions pre-event activities involving child-generated predictions of to-be-enacted actions do lead to better recall performance than if children only have access to object cues. Visual or object information provided by props or photographs (e.g., Salmon et al. 2007; Jant et al. 2014) has been identified as important memory supports; however, our findings also indicate that the actions the objects afford or evoke are likely more useful cues. Moreover, if object manipulation contributed to the effects of Action Prediction in Experiment 1a and led to equivalent performance in the two conditions in Experiment 1b, the results of Experiment 2 suggest that the contribution of actor–object interactions to pre-event effects reside in the cognitions evoked by enactment rather than enactment itself (e.g., Badinlou et al. 2017).

Unlike Experiment 1a, Preserved and Transformed Total Recall was equivalent in Experiment 2 under Action Prediction instructions. The event type differences only emerged in the Object Prediction task. In contrast to the other experiment, children did tend to generate more action matches than mismatches for the Transformed events, suggesting children might have been better able to use the Transformed outcomes to predict forthcoming actions. Perhaps unable to manipulate the objects, children focused more attention on the event outcomes or on the objects themselves and were better able to use them to derive the predictive inferences. Transformed outcomes are not completely opaque with respect to the action results that give rise to them (e.g., make clay into a ball), and because some action results relevant to the events were suggested by the characteristics or combinations of the objects (e.g., fill bottle with water, pour salt into bowl), some prospective cues may have been available for these kinds of events.

In this experiment, no significant correlations between recall and matches emerged. Although in both studies within Experiment 1, we did find that matches were related with Action Prediction recall, they were also correlated with Object or No Prediction recall, suggesting the contribution of a third factor to the relation. The absence of a correlation here reinforces the idea that the number of actions predicted during the pre-event may not have been the important factor in the pre-event effect. Mismatches also were not related to recall in the Action Prediction condition, as in the other experiments; however, they were positively correlated with Object Prediction recall. It is not clear why this relation would have occurred, but again casts doubt on a causal relation between the amount of pre-event activity and recall. In addition, no significant relation between the number of objects identified for placement in the box and either type of recall in the Object Prediction condition emerged, just as in Experiment 1b. It is interesting that once again mismatches did not interfere with or intrude in recall (Macleod et al. 2016; Principe et al. 2013).

General discussion

In two experiments, children participated in a series of staged events immediately preceded by a pre-event. The pre-event was structured to determine whether child contributions to a pre-event could improve recall of the target event when children were the source of the information generated and whether the pre-event immediately preceded the target event. The events were based on preschool science-related activities and the key pre-event involved child predictions about the event actions. Different types of perceptual and enactment cues were available to organize and guide the predictive inferences. Children in Experiments 1a and 2 reported more actions from the target event during free recall if they had experienced an action-based and future-focused pre-event in comparison to two other types of activities.

Because Action Prediction led to better recall than Object Prediction when children did not manipulate the objects, the benefits of the pre-event were not dependent on physical components of enactment (Badinlou et al. 2017; Kormi-Nouri 2000) or the visual cues objects provided (e.g., Salmon et al. 2007; Salmon et al. 2011). Action Prediction may have enhanced attention to the way objects were used or functioned together rather than the way they were configured as in the Object Prediction condition. In addition, whatever the benefit of the Action Prediction activities were, they seemed particularly useful for free recall when no other external retrieval cues were available. Objects would have been more causally related to one another in the Action than Object Prediction condition by virtue of the described actions upon them and perhaps garnered more attention during the target event. Children then may have been better able to use these relations in recalling the information (Bauer 2006). When the outcome cues were available the pre-event effect was attenuated and the event effect emerged. Preserved events were recalled better than Transformed because the outcome in these events provided more visual hints for the actions composing them.

These interpretations become more nuanced, however, when the results of Experiment 1b and 2 are considered together. Although pre-event enactment appears unnecessary for action prediction to improve target event recall (Experiment 2), action prediction may also be unnecessary (Experiment 1b). Experiment 1b suggests that the more frequent manipulation of objects in the Object Prediction Task may have improved memory, as found in other research (Foley and Ratner 2001) and, if so, may have masked or reduced the effects of Action Prediction. If the Object Prediction task emphasized the spatial configuration of the objects to be used in the target event, perhaps the act of putting the objects in the box was sufficient to heighten attention to the objects' features or their use during the target event. Enactment does increase children's recall of poorly integrated objects more than the recall of objects that are well-integrated (Badinlou et al. 2018), so enactment might have been particularly helpful in the Object Prediction condition. The unanticipated result, the small sample size, and the difficulty in interpreting null results all represent limitations in the study. As a result, it will be critical in future research to replicate these findings and tease apart the pre-event effects of object relations, enactment, and their interaction. Nevertheless, child-predicted pre-event actions do appear important in bringing about memory benefits for a target event, regardless of the particular mechanism that leads to the effect.

One explanation given for weak pre-event effects in past research is that the future is more complex for children to understand than the past (e.g., Salmon et al. 2011). In the current studies, however, cognitive demands involving the future were reduced. First, there was no delay between the pre- and target events, lessening both conceptual difficulty and forgetting. Second, children were not called upon to make decisions regarding future plans (e.g., Prabhakar and Hudson 2014) or to remember to do something in the future (Mahy et al. 2014). Children were, however, asked to make predictions, and although event talk involving hypothetical references, including predictions, has been found in past work to be associated with reductions in recall (Salmon et al. 2011), children show early competence in making causal inductive inferences, especially in the physical domain (Ricco 2015).

Indeed, children in our study were clearly able to generate the predictive inferences, making use of the outcome cues presented to them. When the outcome was available across experiments, children produced more matching actions for the Preserved than Transformed events presumably because more cues to the outcome's origins were present for the Preserved events. Moreover, when the outcome was not available (Experiment 1b), children's matches and mismatches were the same for both event types, with matches apparently declining in comparison with the number produced in Experiment 1a. The information provided by the outcomes may have helped to constrain the information that children were likely to generate and this focus may have been helpful for recall. In other research, when pre-event information highlights what actually is going to happen recall benefits are more likely. For instance, contrary to expectations, Salmon et al. (2011) found that during the pre-event when parents informed their children rather than discussed what would happen during the target event, recall improved. The discussion may have introduced extraneous information and may have led to less focused attention on the target event itself. In fact, children's contributions to the discussion were greater than in informational conversations, but these contributions were not necessarily target related and did not lead to any higher recall than in a control condition. It is possible, then, even here that child contributions in and of themselves were less important than the focus on key target event information that these contributions provided.

We did suggest that the pre-event action predictions may have heightened attention to all or some of the actions experienced during the target event. Research with both infants (Stahl and Feigenson 2015) and preschool children (Stahl and Feigenson 2017) provides strong evidence that expectations, a type of prediction, increase attention to the relevant elements of the event and support learning. They point out that research with animals also highlights the role of attention in the relation between prediction and learning (Pearce and Hall 1980). In the Stahl and Feigenson research, however, only violation of predictions related to "core knowledge" (laws that govern the physical world) led to learning; predictions validated by the ensuing event did not. Stahl and Feigenson suggest that violations of different kinds of knowledge may provide different learning patterns and opportunities. Our results may be consistent with this suggestion in that mismatches (violations) did not intrude in recall and were unrelated to it. If anything, it was matches that seemed more relevant to the relation, although the small sample size limits interpretation of the correlational results. Still, the differences between the two sets of findings may lie in the fact that the violations these mismatches provided did not involve violated expectations of how the physical world actually works.

Interestingly, we argued that *because* pre-event mismatches did not intrude in recall and mismatches (violations of expectations) were unrelated to recall, the pre-event experience may have only heightened attention to target event actions. This suggestion was also consistent with the finding that more pre-event actions did not always translate into more target event recall. Action prediction may have supported stronger functional relations among the actions and objects *within* the target event, but may not have supported integration of information *across* the pre- and target events. Children may have conceptualized each as "different" in some way. The pre- and target events may have been understood to be unrelated because the pre-event did not enable the target event (e.g., Bauer 1992). In fact, even when preparatory actions do enable later actions in the same event, these preparatory actions are still less often recalled than those more causally related to an event goal (Ratner et al. 1990). In addition, we did not explicitly draw children's attention to the connection between the two phases. Children were told that we would "see" whether they were correct about the actions they generated; however, no direct comparisons were made for them. Without explicit direction, children may have been less likely to notice the correspondences, especially because intent of each activity could have been understood to be different (i.e., predicting and making something). Event segmentation is organized by goal hierarchies, even by very young children (e.g., Loucks et al. 2016) and, children may have considered each segment separate from the other.

The idea that segmentation is more likely or integration is less likely to occur for young children is consistent with findings from other studies. Holliday and Hayes (2002) found that children were less likely to incorporate misinformation provided during a pre-event if they were told to exclude pre-event suggestions. The fact that they could separate the pre-event from the target suggested that each was represented as individual segments of the sequence. Sutherland et al. (2003) also found that topic-related but general information provided during the pre-event did not intrude more general information into children's memory reports of the target event. In addition, Price and Goodman (1990) have found that younger children require more event exposures than older children to acquire a script, which suggests that the ability to integrate event occurrences across episodes develops with age. Finally, there is evidence that young children are less likely than older children to engage in binding (e.g., Bauer et al.2012), which involves the integration of features associated during encoding and the subsequent integration of features with those already represented (Howe 2015). Ghetti et al. (2012) suggest that binding, along with strategic processes and introspection regarding memory states, continues to develop during the school-age years. Of course, our interpretations are speculative, but do provide questions to explore in future research.

Finally, our findings have implications for early science education. Both the pre-event and the target events are brief and can easily be enacted in the classroom. Moreover, they are consistent with a science-as-practice approach to the development of scientific thinking in which particular scientific skills (e.g., generating predictions) are targeted (e.g., Lehrer and Schauble 2015). Our findings highlight the importance of structured guidance for the enhancement of these skills, just as for older children (e.g., Matlen and Klahr 2013), and provide suggestions for teaching and learning of these skills. Young children can accurately generate predictions and should be encouraged to do so (Early et al. 2010); however, strong perceptual cues to the causal structure of the activity, such as outcomes, assist in making these inferences. Children can benefit from these cues but need direction in using them and additional guidance may be necessary to make connections between making predictions and testing those predictions. In addition, children do need to be cognitively engaged with materials to remember, but direct hands-on activity might not always be necessary. This may be helpful in a classroom setting where manipulatives might not be available to every child at any one point in time.

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Compliance with ethical standards

Conflict of interest The authors declare that we have no conflicts of interest and have followed all ethical research practices.

Ethical approval All procedures performed in the studies involving human participants were in accordance with the ethical standards of the Behavioral Institutional Review Board, a committee of the university's Institutional Review Board and with the 1964 Helsinki Declaration and its later amendments.

Appendix 1

Examples of actions defining and materials used in a preserved and transformed event.

Preserved event

Outcome: make a kazoo

Materials: pencil, tissue tube, rubber band, wax paper, staple remover, cellophane tape, tissue paper

1. Tear off piece of tape.
2. Put tape on child's hand.
3. Wrap tube in tissue paper.
4. Tape the tissue paper.
5. Press staple remover into tube to make hole.
6. Push the pencil through the hole to make the hole bigger.
7. Put the wax paper on the end of the tube.
8. Put the rubber band around the tube.

Transformed event

Outcome: make a fingerprint

Materials: glass disk, strainer, glove, charcoal, Chapstick, paper plate

1. Rub the Chapstick on the end of the finger.
2. Rub the finger and thumb together.
3. Place the finger in the middle of the glass disk.
4. Put the glass disk on the paper plate.

5. Put the strainer over the glass disk.
6. Put on the glove.
7. Rub the charcoal over the strainer.
8. Blow away the charcoal dust.

Event action coding

Pre-event actions

To be coded as a match the predicted action needed to include a complete and specific action, the same process for a tool or object used in the actual action, and achieve the same outcome as an actual action. For the kazoo, for example, a match would be "put the wax paper on the end of the tube," but "put the tissue on the end of the tube" would be a mismatch. Or for the clay, "put the salt in the bowl," would be a match, but "mix the salt and flour in the cup," would be a mismatch. Nonspecific actions such as "you use the tissue" or object references, such as "the bowl" were not counted as a match or a mismatch and were not included. A second coder independently coded 25% of the protocols. Dividing the number of agreements by the sum of agreements and disagreements yielded a reliability score of 88%. Disagreements were resolved through discussion.

Recall

Event actions recalled that described the outcome achieved and the process used to achieve it were scored as accurate. Actions that were inaccurate were infrequent and dropped from the coding process. A second coder independently coded 40% of the recall protocols. The recall reliability measure, calculated in the same way as the Action Prediction pre-event score, was 91.5%.

Appendix 2

See Table 3.

Table 3 Mean (SD) correct actions reported during free and total recall in experiment 1b for the outcome absent condition

Condition	Outcome absent							
	Free recall				Total recall			
	Action Prediction		Object Prediction		Action Prediction		Object Prediction	
Event type	Preserved	Transformed	Preserved	Transformed	Preserved	Transformed	Preserved	Transformed
	4.25 (1.67)	3.63 (1.30)	4.88 (1.46)	4.00 (2.27)	4.88 (1.36)	4.00 (1.41)	5.75 (1.67)	4.50 (1.77)

Free Recall is the number of unique actions reported before presentation of the outcome retrieval cue and Total Recall is the total number of unique actions reported both before and after the outcome retrieval cue

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