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RESEARCH ARTICLE

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With support, children can accurately sequence within-event components

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Summary

Accurate event sequencing can add critical detail to a child's account. However, our knowledge of sequencing in childhood to date primarily centers on distinct events separated by time. Sequencing a single event's components is also important, perhaps particularly in a forensic context. In two experiments, we explored children's ability to recall the sequence of a past event using a variety of prompts. In Experiment 1, 124 children (6–8 years) and Experiment 2, 96 children (6–8 years) attended a 45-min workshop with four (Exp. 1) or five (Exp. 2) distinct components. Children were asked to sequence the components using different retrieval strategies (Exp. 1 within-subjects; Exp. 2 between-subjects). Children had difficulty reporting within-event sequential order in response to open-ended prompts but with sufficient visual supports, children were able to provide accurate information about the sequencing of within-event components.

KEYWORDS
children, event sequencing, memory, temporal order, visual aids

Children's references to temporal attributes of an event can comprise critical information for forensic investigators. Accurately reporting whether an entire event occurred before or after another event, or whether a component of an event occurred first, last, or before or after another event component, can add critical detail to a child's account. Sequencing information may provide detail that can be corroborated and thus, lend credibility to a complainant's account, or it may lead to the discovery of evidence that can reveal new investigative directions. In contrast, inconsistencies or errors in sequencing can diminish a child's credibility and create difficulties for corroborating their report. Despite the vast practical importance of obtaining reliable event sequencing information, relatively little is known about children's ability to sequence and how to elicit such information from children. In the present experiments, we explored the effectiveness of different prompt types in eliciting children's recall of the sequence of within-event components.

There are two broad types of event sequencing, or temporal ordering, that are relevant to children's reports of past experiences. First, one might wish to sequence two events which are separated in time (e.g., Halloween happened first, then my birthday). Children as young as 4 years are able to report events that happened at a specific past time point (e.g., Fivush, 1984; Friedman, 1991) and to accurately order two past events that were separated in time by several weeks (Friedman et al., 1995; but see McWilliams et al., 2019 for important challenges with ordering past events). Further, Friedman and Lyon (2005) had children sequence two distinct events and found that children as young as 6-years could accurately recall the order of the unrelated events after three months (see also Pathman et al., 2013). The ability to sequence events separated in time improves with development (e.g., from 5–7 to 8–10 years; Moore et al., 2014) and this development is ongoing until at least until age 8 or 9 (Friedman, 1992).

Second, one might wish to sequence components within a single event (e.g., on my birthday we ate cake first, then opened presents). A rich body of literature has examined children's ability to sequence within-event components at a young age, with a substantial focus on infancy (e.g., using deferred or elicited imitation paradigms; see Bauer, 1996; Bauer & Mandler, 1992). This work has demonstrated that even very young infants are adept at re-creating two-to-three step event sequences, with increasing retention intervals and sequence difficulty ability as children age. Importantly, in this work there are often causal links, or enabling relations, between components that dictate the appropriate order and which facilitate ordered recall (Bauer, 1992). Not surprisingly, children are better able to sequence within an event when logical connections between event components can be made (Fivush & Mandler, 1985).

Like children's ability to sequence distinct events separated in time, children's ability to sequence within-event components is a skill that appears to develop over childhood. In one example of developmental change, Hudson and Nelson (1983) demonstrated that in response to open-ended recall prompts after a one-day delay, 6-year-old children were generally more accurate in their within-event sequencing than were 4-year-old children. Notably, however, the 4-year-olds were still able to sequence story elements, especially for more temporally structured events (baking cookies vs. birthday party). Relatedly, though it was not the primary focus of the study, Roberts et al. (2015) observed a similar pattern with children sequencing within-event components of individual instances of repeated events. Children experienced one activity session per day on each of 4 days, and each activity session included several components (e.g., read a different story each day). Roberts et al. found that when children were asked to sequence photographs of the repeated components across the days (e.g., when a story was read on each of 4 days, which story was read each day), children correctly ordered fewer than half of the components, but that older (6–8 years) children were significantly better than younger (4–5 years) children.

Both types of sequencing (distinct events and within-event) have the potential to play a critical role in children's recollections, however, each may involve unique cognitive processes (see Pathman & Ghetti, 2014). Thus, we cannot assume that children who can sequence distinct events will also be able to sequence within-event components. Further, though sequencing of distinct events and sequencing of within-event components both have the potential to provide critical information to a child's account of a prior experience, reconstruction of the order of actions or components within a single event will provide much needed detail about a particular instance of a child's experience and contribute to the coherence of the recollection. In many jurisdictions, children who experience repeated abuse are required to recall the details of a single instance of abuse (e.g., R. v. B.G., 1990). As a result, an accurate and detailed description of a single occurrence is a common legal need. In the present study, we focus on children's ability to accurately sequence the components within a single event.

There is a clear and strong literature supporting primacy and recency effects in recall. That is, when recalling components of a sequence, the first and last components are typically best recalled, relative to components embedded within the middle of the sequence. Some scholars have proposed a relative distinctiveness mechanism for this phenomenon—there are fewer competitors that are adjacent to the first and last items, thus enhancing the distinctiveness of these items (e.g., Kelley et al., 2015). Aside from this clear prediction of superior primacy and recency recall across events experienced in a temporal order, there are only a few clues that can provide guidance about how to anticipate children's ability to accurately recall the sequence of within-event components.

The extant literature suggests that there are developmental differences to be expected in children's ability to sequence events when requested to do so by an adult and that this skill continues to develop throughout the early school years, at least. Given children's developing understanding of temporal concepts, it is not surprising then that spontaneous reports of temporal information also increase with age, as does responsiveness to temporal questions (Orbach & Lamb, 2007). It has been argued that temporal references within a child's narrative recounting of an experience can enhance a child's ability to provide more event detail, in addition to enhancing narrative contextualization (Orbach & Lamb, 2007). Thus, establishing reasonable expectations and strategies for the provision of event sequencing information may be critical to understanding children's accounts.

The observation of children's spontaneous temporal reports and of children's ability to sequence upon the request of an adult support the notion that there are important developmental gains in temporal understanding. What is not yet understood is the role that interviewers can play in assisting children with recalling accurate sequencing information. In the context of investigative interviewing, open-ended questions and a focus on free-recall forms the basis for evidence-based best practice (see Lamb et al., 2007). However, given that younger children may struggle to provide such information spontaneously (Orbach & Lamb, 2007), perhaps particular types of non-suggestive interviewer prompts can assist children in accurately recalling sequence information. Interviewers might be able to enhance the accuracy of children's reports of such information by using particular types of prompts.

In prior work, researchers have used visual cues (photographs) to elicit sequence information (Roberts et al., 2015) or relied on more open-ended prompts (e.g., “what happened next?”; Hudson & Nelson, 1983) to assess children's ability to sequence within-event components. In one recent and clever example, Klemfuss et al., had 100 2.5-to-5-year old children select and view five image cards which were then arranged into a story (without enabling relations; Klemfuss et al., 2020). Klemfuss et al. observed that children were more accurate in their responses to open-ended first/last questions (e.g., what did he do first?) than before/after (e.g., what did he do before X?) questions and that they were more accurate for first (82%) than last (56%) and after (56%) than before (46%) prompts. However, to our knowledge, no study has examined the effectiveness of different types of retrieval prompts to elicit within-event sequencing information about a personally experienced, interactive event from school-aged children. Such laboratory work that evaluates multiple retrieval strategies can help provide a slate of options for exploration in an applied setting, and the present work takes an initial experimental step toward this broader aim. Further, the exploration of different retrieval strategies may provide insight into children's capabilities with varying levels of support and prompt types, which can contribute to a broader understanding of how to enhance recall of sequential information.

1 | THE PRESENT RESEARCH

In the present study, 6-to-8-year-old children provided free recall of within-event components and then responded to two additional sequence recall techniques which relied on visual cues. Specifically, we investigated use of event-component images in children's responses to forced-choice before/after questions (e.g., Did picture A come before or after picture B?) and to their ability to place the images in the order that was experienced. Evidence using pictorial timelines suggests that by the age of 5 years, children can use visual aids to assist in the reconstruction of time-related concepts (Gosse & Roberts, 2014). We opted for visual cues of each event component because it allowed us to explore children's ability to sequence event details without confounding this ability with their reproductive recall of those details (i.e., event details). Further, we opted for visual over written cues to avoid reliance on the large range in reading skill within this age group. We incorporated free recall of the events to explore children's ability to naturally recall within-event components in particular serial positions, as might often be the case in a forensic interview.

In two experiments, children attending a summer science camp experienced a 45-minute special guest-led event focused around a particular science topic, which comprised several distinct activities. Children were then interviewed about the order in which the activities were experienced using three different retrieval cue types. The aim of the present research was to explore children's underlying ability to sequence within-event components. Our ultimate goal was to work toward an understanding of how to effectively ask children about the order in which activities within an event have occurred in an applied setting. We explored these questions under optimal recall conditions (shortly after the event), as well as after a one-day delay. We anticipated that testing children at the very short delay would allow us to better understand children's basic ability to sequence events, and the one-day delay would allow us to explore children's ability to retain and relay sequence information. Finally, the extant research indicates that the early school years are a time for change and development in children's understanding of temporal constructs. Thus, in the present study, we focused on 6-to-8-year old children.

In both experiments, we assessed children's sequencing ability with different retrieval techniques. In Experiment 1 we also tested whether providing within-event sequencing practice prior to the target recall task would enhance children's ability to sequence the novel events. We anticipated that providing sequencing practice may help children who were on the cusp of being able to provide accurate sequencing information. This research was approved by the institutional ethics board and all children had parental consent and also assented themselves.

2 | EXPERIMENT 1

2.1 | Method

2.1.1 | Participants and design

One hundred twenty-four children (aged 6–8 years, M_{age} = 7.04 years; n = 66 males) were recruited from a summer science camp. Children were quasi randomly assigned to a 2 (Delay to interview: same day, one day later) × 2 (Sequencing practice: yes, no) between-subjects design. Data are available on the Open Science Framework (osf.io/ahjtg).

2.2 | Procedure

A research assistant attended the children's science camp and presented a 45-min workshop about magnets to groups of 10–20 children. The workshop involved four distinct interactive magnet-themed activities and two random orders of activities were created (half of the children were in each order; no difference between orders were observed, so data are collapsed across order). Given the lack of focus in prior work on within-event components, we explored events without enabling relations. We expect that most forensically relevant events will have both features (enabling relations and no enabling relations), but that evaluating reports of event components without causal connections was likely to be the more difficult assessment to make. Finally, either immediately or 1 day after the workshop, children were interviewed by trained research assistants.

2.2.1 | Practice

To begin the interview, half of the children were randomly assigned to receive sequencing practice (the other half were controls and did not practice), which took place prior to administration of the interview protocol. Practiced children were presented with the classic story of the tortoise and the hare. During the telling of the story, six pictures were presented to represent six key stages of the story, each of which was not obviously placed in a particular order if one was unfamiliar with the story. Immediately following the story, the interviewer shuffled the cards and then asked children to correctly sequence the photos (guided by interviewer prompts; for example, "which activity was first?"). After children ordered the photos (95% did so correctly), they were asked two forced-choice 'before/after' questions (e.g., "Did the tortoise pass the hare before or after the hare fell asleep?"), with pictures used as cues. Feedback was provided to ensure children understood the task.

2.2.2 | Interview

Following best-practice guidelines for interviewing children, interviews moved from open-ended to more specific questions about the target event (i.e., magnet games). Interviews began with an open-ended prompt to report everything they could remember about the magnet activities. Note that children were not specifically asked to sequence during the open-ended recall phase and no visual cues were provided (as visual cues would interfere with independent recall of components). Next, children were prompted to describe the first activity, then the last activity, and then any other games that were referenced in the initial free recall description (using children's labels). The final prompt about "other" games resulted in no new sequential information and is thus not discussed further.

Following the open-ended portion of the interview, children were presented with one of two random orders of six 'before/after' questions (e.g., "Did activity X happen before or after activity Y?"). Finally, children completed a photo sequencing task in which they were presented with a photograph of each of the four activities and asked to sequence the photos in the order they were experienced (guided by interviewer prompts; e.g., "Which activity was first? Then what?").

2.3 | Coding

2.3.1 | Open-ended free recall

Recall that in response to the open-ended prompt, children were not asked to recall the order in which each activity occurred, but rather they were simply asked to report what happened. From these reports, we coded which activities were reported by children and the order in which those reported activities were experienced. Thus, first, we coded for whether or not each activity was mentioned in response to the initial open-ended prompt (present or absent). To be coded as present, the child had to either provide the name of the activity (as provided by the workshop leader) or the central material used to execute each activity (e.g., paperclips). Second, we noted the serial position in which that activity was experienced within the event. We also counted the overall number of distinct activities described in response to the initial open-ended prompt. Finally, in response to the directive prompt to recall the first and then the last activity, children's accuracy of identifying and describing each activity was coded as correct or incorrect for each question, using the same criteria as for the initial open-ended prompt (i.e., activity name or material used).

2.3.2 | Before/after questions

For responses to the before/after questions, we recorded the overall number of responses that were correct. We then explored the relative position within the sequence of activity pairs queried in each before/after question. We coded each question as one of the following:

1. First activity compared with an adjacent (i.e., second) activity.
2. First activity compared with a nonadjacent (i.e., third) activity.
3. Last activity compared with adjacent (i.e., third) activity.
4. Last activity compared with nonadjacent (i.e., second) activity.
5. Exterior activities compared with each other (i.e., first and last).
6. Middle adjacent activities (i.e., second and third).

2.3.3 | Photo sequencing

For the photo sequencing task, we recorded how many of the photos (of 4) were placed in the correct sequential position. However, given that misplacing one photograph necessarily means that another will also be misplaced, we also coded a *partial order score*. Children were given a 3 if they placed all photos in the correct sequential order, a 2 if they placed a triplet correctly (123 or 234), a 1 if they placed a pair of photos correctly (12, 23, 34, or 14) and a 0 if no photo was correctly adjacent to any pair.

2.4 | Hypotheses

We deliberately did not prompt children to provide sequence information in free recall, as our interest was in children's natural tendency to do so. As we address in the discussion—and to presage the results—however, children only infrequently spontaneously reported sequence information and, retrospectively, eliciting some specific free recall sequencing information would have been useful. Nonetheless, our prediction was that children would more frequently recall the first and last event component (consistent with primacy and recency effects) and that they would be less adept at providing sequencing information in free recall than when provided additional structure for recalling such information, as in the cued tasks. It was also hypothesized that sequence practice would improve children's ability to order events by providing hands-on experience with the interviewer request and by highlighting the interviewer's desire for such information in recall of the science event, akin to the effects of narrative practice during rapport building (see Roberts et al., 2011). Furthermore, performance was predicted to be better at shorter, relative to longer delays to recall. Finally, the before/after questions and the photo sequencing task were exploratory and we did not develop specific hypotheses about which would produce superior sequencing. We anticipated that the relatively smaller task of comparing only two activities at a time in the before/after questions might enhance children's ability to sequence, but also considered the possibility that the ability to physically order all activities and make relative comparisons between activities in the photo sequencing task might provide the structure needed to succeed on the task.

3 | RESULTS

To explore the impact of delay to interview and sequencing practice on children's responses, we initially conducted analyzes with the full 2 (Delay to interview: same day, one day later) × 2 (Sequencing practice: yes, no) model. However, there was no effect of sequencing practice on any dependent variable, so for parsimony, we report all analyzes collapsed across sequencing practice conditions.

3.1 | Free recall

To examine the likelihood of recalling each serial position at each delay to recall in response to the free-recall prompt, a Generalized Estimating Equation (GEE) was performed on the number of children who reported the activity in each serial position (see Tables 1–3 for free recall descriptives). A binary logistic GEE model was used with children's responses (yes = 1, no = 0 to recalling position 1, 2, 3, 4) as the dependent variable and delay as the predictor. Child participant was identified as the repeated factor in the model. The main effect of delay was not significant, Wald $\chi^2(1) = 0.71$, $p = .40$, nor was the interaction between delay and position, Wald $\chi^2(3) = 2.13$, $p = .55$. However, the main effect of position was significant, Wald $\chi^2(3) = 57.78$, $p < .001$. As can be seen in Table 2, children most frequently reported the activity in the 2nd serial position, followed by the 4th, 3rd and the 1st. All comparisons differed statistically, $zs > 3.35$, $ps < .01$, except for the difference between the 1st and 3rd position, $z = 1.25$, $p = .21$.

3.2 | First and last activity prompts

Next, we explored children's responses when they were asked specifically which activities were first and last (see Table 3). A binary logistic GEE was performed with children's responses (correct = 1, incorrect = 0) to the first and last activity prompts as the dependent variable and delay as the predictor. Child participant was again identified as the repeated factor. The main effect of delay was not significant, Wald $\chi^2(1) = 2.57$, $p = .11$, nor was the interaction between delay and position, Wald $\chi^2(1) = 1.98$, $p = .16$. However, the main effect of first/last recall was significant, Wald $\chi^2(1) = 10.20$, $p < .01$. Children were more likely to accurately recall the last activity (0.72) than the first activity (0.51).

3.3 | Sequencing within-event activities with guided retrieval techniques

Two different retrieval strategies were implemented to explore children's structured sequencing ability: before/after questions and photo sequencing. Table 4 provides descriptive data for both photo sequencing and before/after tasks.

TABLE 1 Mean proportion of children describing each activity in free recall

Number of activities recalled	Delay	Experiment 1	Experiment 2
0	None	0	0.20
	1-Day	0	0.17
	Total	0	0.19
1	None	0.07	0.10
	1-Day	0.10	0.00
	Total	0.08	0.06
2	None	0.27	0.05
	1-Day	0.33	0.25
	Total	0.30	0.13
3	None	0.53	0.30
	1-Day	0.45	0.17
	Total	0.49	0.25
4	None	0.13	0.30
	1-Day	0.12	0.33
	Total	0.12	0.31
5	None	—	0.05
	1-Day	—	0.08
	Total	—	0.06

3.3.1 | Before/after questions

For before/after questions, 55% of children accurately responded to all six questions (i.e., perfect accuracy). Children's average before/after question accuracy was also quite high, with a mean of 5.17 ($SD = 1.09$) correct. Children were more accurate after a short than long delay, $F(1, 120) = 4.51$, $p = .04$, $\eta^2 = 0.04$.

We also explored which before/after questions were answered most accurately. As described in the coding section, before/after questions were divided into six different segment types, based on which serial positions were compared. As can be seen in Table 5, children were most accurate for first/last comparisons, followed by first/nonadjacent comparisons, then last/ nonadjacent, middle/adjacent, last/adjacent, and finally, first/adjacent. Interestingly, the clear pattern was of superior recall for nonadjacent pairs (0.88), relative to adjacent pairs (0.71), $z = 5.60$, $p < .001$, 95% CI (0.109 to 0.225).

3.3.2 | Photo sequencing

For photo sequencing, 59% of children were able to perfectly order the four activity photos as they were experienced. There was no effect of delay on children's photo ordering scores, $F(1, 121) = 2.42$, $p = .12$, $\eta^2 = 0.02$. There was also no difference in partial order scores between the short and longer delay, $F(1, 121) = 1.75$, $p = .19$, $\eta^2 = 0.01$.

TABLE 2 Proportion of children who freely recalled each component in response to "what happened" prompt

Activity position	Delay	Experiment 1	Experiment 2
1	None	0.45	0.50
	1-Day	0.52	0.68
	Total	0.48	0.56
2	None	0.92	0.55
	1-Day	0.92	0.58
	Total	0.92	0.56
3	None	0.57	0.60
	1-Day	0.45	0.33
	Total	0.51	0.50
4	None	0.77	0.60
	1-Day	0.70	0.58
	Total	0.74	0.59
5	None	—	0.30
	1-Day	—	0.58
	Total	—	0.41

TABLE 3 Descriptive data for open-ended prompts

Open-ended recall				
Exp. 1	**Delay**	**# Activities accurately reported/4**	**First activity prompt accuracy (prop)**	**Last activity prompt accuracy (prop)**
	None	2.76 (0.86)	0.51	0.81
	1-Day	2.58 (0.83)	0.51	0.61
	Total	2.67 (0.85)	0.51	0.71
Exp. 2	**Delay**	**# Activities accurately reported /5**	**First activity prompt accuracy (prop)**	**Last activity prompt accuracy (prop)**
	None	4.27 (1.01)	0.56	0.44
	1-Day	2.52 (1.63)	0.46	0.46
	Total	3.13 (1.66)	0.52	0.45

TABLE 4 Descriptive data for before/after and photo sequencing prompts

		Before/ after		Photo sequencing		
	Delay	**Before/after score/6**	**Perfect score**	**Photo sequencing/4**	**Perfect score (prop)**	**Partial order**
Exp. 1	None	5.38 (1.03)	0.68	3.21 (1.56)	0.66	2.25 (1.08)
	1-Day	4.97 (1.12)	0.43	2.87 (1.28)	0.53	1.98 (1.12)
	Total	5.17 (1.09)	0.55	3.04 (1.23)	0.59	2.11 (1.10)
		Before/after score /8	**Perfect score**	**Photo sequencing/5**	**Perfect score (prop)**	**Partial order**
Exp. 2	None	6.88 (1.15)	0.31	4.27 (1.01)	0.64	3.64 (1.91)
	1-Day	5.73 (1.39)	0.07	2.52 (1.63)	0.24	2.05 (1.86)
	Total	6.32 (1.38)	0.19	3.13 (1.66)	0.38	2.59 (2.00)

TABLE 5 Before/after sequencing responses by sequence

	Delay	First/ last	First/ nonadjacent	Last/ adjacent	Last/ nonadjacent	First/ adjacent	Middle/ adjacent	Middle/ nonadjacent
Exp. 1	None	0.90	0.85	0.75	0.86	0.86	0.86	—
	1-Day	0.97	0.90	0.75	0.80	0.77	0.75	—
	Total	0.93	0.87	0.75	0.83	0.59	0.80	—
Exp. 2	None	0.83	0.61	0.78	1.00	0.94	0.76	0.94
	1-Day	0.95	0.94	0.43	0.33	0.60	0.73	0.71
	Total	0.90	0.87	0.63	0.59	0.77	0.75	0.82

3.3.3 | Relative performance on guided retrieval techniques

Because each child completed all memory tasks, we were able to compare children's relative performance across tasks. It is important to note, however, that tasks were always completed in the same order, and performance on one task may have influenced performance on subsequent tasks. There was a significant correlation between children's photo sequencing score and the proportion of accurate responses to before/after questions, Spearman's rho = 0.504, $p < .001$. However, of the children who were completely accurate on the photo sequencing task ($n = 71$; i.e., correctly ordered photos of all four activities) only 76.1% were completely accurate in response to before/after questions. Of the children who were completely accurate on the before/after questions ($n = 67$), 80.6% were completely accurate in response to the photo sequencing task. The difference between perfect performance on the before/after questions and the photo sequencing questions was not significant, $z = 0.63$, $p = .53$.

4 | DISCUSSION

There were several clear patterns that emerged from Experiment 1. First, practice had no impact on children's ability to sequence in subsequent tasks. This lack of difference, of course, may have been a result of our particular sequencing practice—a possibility we did not explore further in Experiment 2, but is worthy of future consideration. Second, where differences existed, children's sequencing was generally better at short than long delays. This finding is not surprising given that memory is known to fade with time, but it does indicate that recall of sequence information may be subject to similar forgetting processes as other types of memory. Third, there was evidence that children had relatively stronger memory for the last activity than the first activity, in response to free recall questions. Fourth, comparisons between nonadjacent activities appeared to be easier for children than comparisons of adjacent activities, indicating that distance between activities may enhance perception of distinctiveness. Finally, children generally performed very well on the visually-cued sequencing tasks. We discuss these findings in more detail in the General Discussion.

Children's sequencing performance in Experiment 1 was strong and provided evidence that sequencing activities from a recently experienced event could be completed accurately with supports. Given the relatively successful performance of children on the sequencing tasks in Experiment 1, in Experiment 2, we increased the difficulty of the task from 4 to 5 activities to explore the boundaries of children's sequencing ability, and the usefulness of various prompts to retrieve sequencing information. Further, children in Experiment 1 responded to all retrieval types, all in the same order—a procedure that did not allow us to examine their performance without the influence of prior questions about the event. Thus, instead of a within-subjects manipulation of retrieval technique, in Experiment 2, we examined their performance on these prompts in isolation with a between-subjects design. Finally, as noted earlier, given the lack of an effect of practice on children's sequencing, we did not include a practice manipulation in Experiment 2.

5 | EXPERIMENT 2

5.1 | Method

5.1.1 | Participants and design

Ninety-six children (aged 6–8 years, M_{age} = 7.15 years; *n* = 48 males) were quasi randomly assigned to a 2 (Delay to interview: same day, one day later) × 3 (Retrieval conditions: Open-ended, before/after sequencing, photo sequencing) between-subjects design.

Memory retrieval conditions from Experiment 1 were replicated in Experiment 2, but in a between-subjects manipulation rather than within-subjects. Three interview conditions were created: open-ended (*n* = 26), before/after sequencing questions (*n* = 31), and photo sequencing (*n* = 32). To increase the external validity of the research, we designed a new series of five (rather than four, as in Exp. 1) science activities themed around climate change, with approximately the same overall total time duration (45 min).

5.2 | Coding

Coding was the same as in Experiment 1, with some modifications made due to the increase in the number of activities (i.e., 5 vs. 4 in Exp. 1). Specifically, coding of before/after questions (*n* = 8) was modified, as below:

1. First activity compared with an adjacent (i.e., second) activity.
2. First activity compared to a nonadjacent (i.e., third or fourth) activity.
3. Last activity compared to adjacent (i.e., fourth) activity.
4. Last activity compared to nonadjacent (i.e., second or third) activity.
5. Exterior activities compared to each other (i.e., first and last).
6. Middle activities, adjacent (i.e., second/third or third/fourth).
7. Middle activities, nonadjacent. (i.e., second and fourth).

Partial order score coding was also adapted. Children were given a 5 if they sequenced all photos in the correct order, a 4 if they placed a quadruplet (1234 or 2345), a 3 if they sequenced two correct pairs of photos that were not recalled in the correct order (e.g., 1245×, 12 × 34) a 2 if they placed a triplet correctly (123, 234, 345), a 1 if they sequenced one pair of photos correctly (12, 23, 34, or 45) and a 0 if no photo was correctly adjacent to any other photo.

6 | EXPERIMENT 2

6.1 | Results

6.1.1 | Free recall

To examine the likelihood of recalling each serial position at each delay to recall in response to the free-recall prompt, a binary logistic GEE was performed with children's responses (yes = 1, no = 0 to recalling position 1, 2, 3, 4, 5) as the dependent variable and delay as the predictor. Child participant was identified as the repeated factor in the model. The main effect of delay was not significant, Wald $\chi^2(1)$ = 0.1,2 *p* = .73, nor was the main effect of position, Wald $\chi^2(4)$ = 4.21, *p* = .38, or the interaction between delay and position, Wald $\chi^2(4)$ = 5.43, *p* = .25. See Tables 1–3 for free recall descriptives.

6.1.2 | First and last activity prompts

Next, we explored children's responses when they were asked specifically which activities were first and last (see Table 3). A binary logistic GEE was performed with children's responses (correct = 1, incorrect = 0) to the first and last activity prompts as the dependent variable and delay as the predictor. Child participant was again identified as the repeated factor. The main effect of delay was not significant, Wald $\chi^2(1)$ = 0.09, *p* = .77, nor was the main effect of first/last, $\chi^2(1)$ = 0.24, *p* = .62, or was the interaction between delay and position, $\chi^2(1)$ = 0.24, *p* = .62.

6.2 | Sequencing within-event activities with guided retrieval techniques

Table 4 provides descriptive data for photo sequencing and before/after questions.

6.2.1 | Before/after questions

For before/after questions, only 19% of children were completely accurate, however, children's average accuracy was quite high, with a mean of 6.35 (SD = 1.38) of eight possible correct responses. Children were more accurate after a shorter than longer delay, $F(1, 30) = 6.27$, $p = .02$, $\eta^2 = 0.02$.

As with Experiment 1, we explored which of the type of before/after questions were more accurately answered by children (see Table 5). Children were again most accurate for first/last comparisons, followed by first/nonadjacent comparisons. Middle activities that were nonadjacent was the next most accurate segment, followed by first/adjacent, middle/adjacent, last/adjacent, and finally, last/nonadjacent. As with Experiment 1, the general pattern was higher accuracy for nonadjacent (0.81) relative to adjacent (0.73) pairs, $z = 1.40$, $p = .16$, 95% CI (−0.03 to 0.183), though the pattern was nonsignificant and not as consistent as with Experiment 1.

6.2.2 | Photo sequencing

For photo sequencing, 38% of children were able to perfectly order the five photos of the activities as they were experienced. There was a significant difference in children's photo ordering score at the short and long delays, $F(1, 31) = 10.45$, $p < .01$, $\eta^2 = 0.26$, with children much more accurate at the short delay. Children's partial order scores were also significantly better after the short than long delay, $F(1, 31) = 5.18$, $p = .03$, $\eta^2 = 0.15$.

6.2.3 | Relative performance on guided retrieval techniques

The difference between proportions of perfect performance on the before/after questions and the photo sequencing questions was not significant, $z = 1.68$, $p = .09$.

7 | GENERAL DISCUSSION

In the present experiments, we explored if specific retrieval cues could assist 6-to-8-year old children in recalling within-event sequence information. Given that best-practice interview recommendations consistently—and crucially—recommend that interviewers rely on open-ended prompts as much as possible (e.g., Lamb et al., 2007), we examined children's free recall of sequence information (including cued, open prompts for free recall of the first and last components), in addition to two more supportive visually-cued sequencing reconstruction tasks. The aim with the visually-cued tasks was not to mimic the type of strategy that might be available in a real investigative interview setting, but rather to assess whether or not children could provide sequencing information. The present data suggest that children can provide highly accurate within-event sequencing data, with retrieval support. This is an important finding that further places the onus on researchers and interviewers to identify strategies that can be used to elicit this detail that children are capable of providing.

Children averaged recall of just over half of all individual event components in free recall. However, children's responses to the recommended open-ended prompt showed that, consistent with Orbach and Lamb's (2007) observations, children did not often offer sequential information in free recall. This challenge in obtaining free recall sequential information complicates the ability to use optimal questioning practices to obtain this information and, as a result, additional and more focused probes are required to obtain enough information about event components in order to establish sequence. Even when more focused open-ended prompts were introduced, children still struggled to identify event components; In response to the specific request to describe the first and last event components, children hovered around 50% accuracy, with the exception of recall of the last activity in Experiment 1. However, with a high level of support in the form of photographs, children were quite accurate in providing sequential information using two different retrieval prompt types. This latter observation indicates that children have the ability to provide this information from memory, but may require interviewer assistance in doing so. Thus, a substantial focus of research should be on exploring non-suggestive methods of eliciting sequencing information in children's memory for personally experienced events. As a starting point, these data provide evidence that asking children to sequence within-event components with physical/visual cues may be more effective than asking children to respond to verbal queries about sequences.

In comparing the two photo-supported retrieval cues across both experiments, the only notable drop in performance was in Experiment 2 for the before/after questions: Increasing the task difficulty from four event components (Exp. 1) to five event components (Exp. 2) appeared to substantially affect children's ability to accurately respond to before/after questions, but a similar impact on photo sequencing was not observed. In the before/after task, only two photos were shown at a time, while the other photos remained out of view. Thus, children may have had to hold information about the additional, unseen event components in memory to be able to accurately sequence the two components presented in the before/after question. The working memory load in Experiment 2 (3 additional components) would then be larger than the working memory load in Experiment 1 (2 additional components). It is possible that the additional memory demands associated with the before/after questions in Experiment 2 negatively impacted children's ability to respond to before/after questions. Perhaps children actively seek to recall all event components when attempting to sequence a pair of components. This possibility requires empirical investigation. A second consideration is the ordering of the components in the before/after questions. The difficulty posed by before/after questions for children is compounded by questions that are asked with components presented nonchronologically (e.g., Pyykkönen & Järvikivi, 2012, see limitations for additional discussion). Thus, children show evidence consistent with the findings that forward-ordered listing benefits recall of temporal details (Anderson & Conway, 1993). The additional challenges associated with responding to some of the counter-ordered before/after questions may have been further exacerbated by the additional component in Experiment 2, relative to Experiment 1.

There were several other interesting observations in the present data. One of the most intriguing findings was that adjacent activities were more difficult to sequence than were items that were nonadjacent. There are at least two possible explanations for this observation. First, by definition, the first and last items in a sequence can only have one adjacent item. Adjacent items increase the competition for recall and reduce distinctiveness of an individual item (Kelley et al., 2015). Thus, it makes sense that in the present context, items which were adjacent to more than one item (i.e., were in the middle section of the sequence) were more difficult to sequence. However, there are additional explanations that might provide future avenues for investigation. The temporal distance between nonadjacent items is larger, which may make individual components that are more separated more distinct. This possibility could be studied by relying on research into the temporal distance between to-be-remembered items and the impact of that distance on recall. This 'spacing effect' describes a phenomenon in which information that is spaced temporally farther apart (i.e., distributed in time) is recalled more accurately than information that is presented in a temporally massed manner (e.g., Bellezza & Young, 1989). In our experiments, there was no temporal spacing between event components—components were experienced back-to-back. A compressed time frame may further exacerbate the challenges associated with massed presentation of information and make adjacent items even more difficult to recall than nonadjacent items due to their temporal proximity. This possibility raises the question of the two distinct literatures discussed in the introduction: sequencing within-event components versus sequencing distinct components. At what temporal spacing between event components does a single event become distinct events? If an event has four components, each with a 15-min break between, is it a single event? What about an hour break? Or four hours? This distinction matters not if the two types of event sequencing show the same pattern across similar experiences, events with different underlying meaning or connections, retrieval cues, and developmental stages. However, it is more likely that such distinctions will matter.

7.1 | Limitations and future directions

In our use of before/after questions, we did not explore the match between the order in which event components were experienced and the order in which event components appeared in the question. Some research suggests that children's ability to respond to before/after questions is influenced by their working memory capacity and that before/after question that are presented nonchronologically (i.e., not in the order in which the event was experienced) are difficult to answer (e.g., Klemfuss et al., 2020), and may be particularly so up until age 12 at least (e.g., Pyykkönen & Järvikivi, 2012). Further, research suggests that chronology, clause salience, recency of correct response in the question, and working memory are all likely to influence before/after accuracy (Karlsson et al., 2019; Pyykkönen & Järvikivi, 2012). However, the challenge with applying these findings to a forensic context is that an investigative interviewer seeks event sequencing information that only the child can provide and thus, there is little opportunity to design retrieval prompts that facilitate children's recall based on how the event was experienced. A second important limitation is the delay between the event and recall. Even our "longer delay" condition in the present experiments was quite short (one day) and longer—and more forensically realistic—delays are likely to increase confusion between instances (e.g., Price et al., 2006).

Because children must generate their own event components that are then subjected to sequencing questions during a forensic interview, researchers must begin to explore ways in which they can reduce the cognitive load of this request. One possibility is to use children's free reports to create visual cues that can then be subject to sequencing questions. For example, for children who are able to read, writing a key word on a card that can then be sequenced in relation to other labeled cards might assist some children when sequencing is a critical element of an investigation. This suggestion, and other possibilities, must of course first be subject to empirical scrutiny. In retrospect, free-recall generation of order in our experiments could have provided both an initial examination of this concept, as well as provided direct points of comparison between free recall and the two visual cue conditions. Alternatively, a modified directed recall component (e.g., "what happened before x?") could provide useful complementary information that could speak more clearly to recall of sequencing.

These experiments were an initial foray into exploring retrieval cues for children's sequencing of within-event components. It is clear that there are many avenues that could be explored. In our view, the most urgent directions include examining longer sequences of event components, with varying temporal spacing between components, and after varying delays to recall. Of course, we also strongly believe that relying on the groundwork provided by basic research, we must develop strategies that can be implemented in the field. As we work to establish the parameters of children's sequencing recall, we must remain focused on the development of practical strategies that investigative interviewers can implement.

8 | CONCLUSION

The present experiments provide clear evidence that 6-to-8-year old children can provide highly accurate within-event component sequencing information when provided with sufficient retrieval supports. However, it is also clear that much more work must be done to better understand the limitations of children's recall, the boundary conditions associated with children's strong performance, and how to translate this basic experimental work in the important forensic investigation context.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available on the Open Science Framework (osf.io/ahjtg).

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