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Development of Temporal-Reconstructive Abilities

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In a study of the ability to reconstruct the times of past events, 86 children from 4 to 13 years recalled the times of 2 in-class demonstrations that had occurred 3 months earlier and judged the times of hypothetical events. Many of the abilities needed to reconstruct the times of events were present by 6 years, including the capacity to interpret many temporally relevant cues, but there were substantial changes well into middle childhood in the availability of temporally useful episodic information. Children were poor at remembering the events' proximity or order with respect to a major holiday, but the order of the 2 target events was well recalled by 6 years.

Temporal information is an important, and for some theorists defining, feature of autobiographical memory. Remembered life events seem to belong to specific times in our past, even if we cannot always determine the times with precision. Cognitive psychologists have posited a number of ways in which remembered events can be related to time and have conducted a substantial number of studies to test these theories. In a review of this literature, Friedman (1993) distinguished three main types of information that could be used to remember the times of past events. First, the times could be gauged as temporal *distances* from the present, as in theories that appeal to the strength or vividness of memory traces. Changes that occur to memories with the passage of time provide clues to the ages of the memories. Second, remembered events could be linked to *locations* in natural, personal, or conventional time patterns, such as parts of a day or year or the period of time when one was in college. For example, in reconstructive theories the times of past events are judged by retrieving whatever information is associated with the event in memory and, where possible, making temporal inferences based on one's general knowledge about time patterns. A third, logically independent, type of temporal information in memory is the *order* of two or more remembered events. According to order-code theories, the order of some pairs of events is stored if the earlier event is retrieved at the time when the later one occurs.

The 1993 review revealed considerable support for the importance of location-based processes in adults' memory for the times of past events (e.g., Friedman, 1987; Friedman & Wilkins, 1985; see also Thompson, Skowronski, Larsen, & Betz, 1996). In contrast, there was little evidence for distance-based theories, and a number of findings contradict their predictions. However, subsequent research (Friedman, 1996, 2001) has shown that information about distances also plays some role in humans' sense of the times of past events. Adults use impressions of the ages of memories when location information is unavailable (e.g., Friedman & Huttenlocher, 1997) or when judgments must be made very rapidly (Friedman, 2001). Children who do not yet represent time patterns can sometimes distinguish the ages of memories using impressions of their distances (Friedman, 1991). The contribution of the third type of temporal information, order, is supported by a small set of laboratory studies that show that, as predicted, adults are more accurate in judging the order of semantically related than unrelated pairs of items (e.g., Tzeng & Cotton, 1980; Winograd & Soloway, 1985). However, it is not yet known what part these processes play in the longtime scales of autobiographical memory.

In adults the most common method for remembering the times of past events is the reconstruction of their locations in time patterns (Friedman, 1993). The best available evidence to support this conclusion comes from method reports. For example, when

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adults were asked to remember the time of an earthquake that had occurred about 9 months earlier, a large proportion reported judging the time of day by recalling its contiguity to a routine event, such as lunch (Friedman, 1987). The other principal reported method is the use of some remembered aspect of the event itself, such as the weather, to infer the time (e.g., Friedman & Wilkins, 1985). These two approaches suggest that adults reconstruct past times by relating information in episodic memories to general knowledge of time patterns.

Although there is a substantial literature on children's memory for the order of parts of an event (e.g., Bauer, 1996; Nelson, 1986), there are few studies on children's memory for when events occurred (Friedman, 2003). Even less research has been conducted on children's ability to reconstruct the times of past events. Two experiments provide some relevant information (Friedman, 1991). In the first experiment, preschool children and first and third graders were asked to remember the time of an unusual event that had occurred 7 weeks earlier in the first half of the school year and to judge the plausibility of times when it might have occurred. The results showed that first and third graders, but not the preschool group, were able to use their knowledge of temporal patterns to make inferences about when the event could have taken place. In another experiment children in the nursery group were able to use the information provided by the testers to judge the time of day but not location on longer time scales. First graders, and especially third graders, brought to bear considerable knowledge of days of the week, months, and seasons in interpreting the clues.

These experiments and the studies of adults' method reports suggest that at least three components are necessary for reconstructing the times of past events: episodic memories that contain temporally relevant information, general knowledge about time, and executive processes that control the search for, and integration of, these two kinds of information. Each of these, in turn, must be made up of additional components, components that may be acquired at different ages. Temporally relevant information in episodic memory takes at least two forms: remembered aspects of the event that constrain the time and contiguity to other events whose time is stored or can, in turn, be reconstructed. General knowledge about time refers to a rich body of information, including several different conventional time patterns (and multiple ways of representing each; Friedman, 1977, 1986, 1990), autobiographical sequences (e.g., places where one has lived), the dates of important events, and the characteristics of particular times (e.g., the weather in different seasons). The presence of relevant episodic and semantic information in memory is not sufficient, however, for temporal reconstruction to take place. Executive processes must be available to control the search for information associated with events, the evaluation of that information, and its interpretation in light of general temporal knowledge. The involvement of executive processes in reconstruction is supported indirectly by recent evidence showing links to activity in the prefrontal cortex (Bastin, Van der Linden, Michel, & Friedman, 2004; Curran & Friedman, 2003).

Temporally relevant information, like other details about autobiographical events, may be available in episodic memory by early childhood, and the ability to store the temporal contiguity and order of events may develop early (although no research has investigated these issues). In contrast, there is considerable development in general knowledge of time patterns during middle childhood (e.g., Friedman, 1986), and awareness of autobiographical sequences may well increase during these ages and later (although, again, this has not been studied). Finally, based on the age trends found in research on strategic processes in memory (e.g., Kuhn, 1999) and the limited evidence on temporal reconstruction in children, substantial changes might be expected in the executive processes that control temporal reconstruction. At present, little is known about these components or how they develop. This study is designed to provide information about age changes in the components.

Whether and at what age children can reliably date events is also of practical importance, particularly when child witnesses are questioned about alleged experiences. Legal practitioners are concerned about the potential dangers of asking children leading questions (Lyon, 2002). Prior research has examined children's memory for temporal information using specific questions (e.g., Friedman, 1991), which memory researchers have found tend to be less accurate than information provided in response to free recall (e.g., Ornstein, Gordon, & Larus, 1992). However, memory researchers have not measured whether children produce temporal information (or temporally relevant information) in free recall, obviating the need for more specific questions. Second, legal practitioners often question children about their temporal understanding in order to determine whether children are competent to make temporal judgments, or whether their memory in general is likely to be accurate (In the matter of dependency of AEP, 1998). However, research has not examined whether individual children's abilities to date events

can be predicted by assessing their recall of the events, their knowledge of conventional time patterns, or their ability to draw temporal inferences based on temporally relevant episodic information. Conversely, it is unknown whether a child's failure to provide temporal information about an event suggests that the child's memory for other event details is poor. Finally, legal practitioners often assume that children should be capable of dating events with respect to personal time intervals, such as the child's age or the child's teacher at the time of the event (U.S. v. Tsinhnahijinnie, 1997), or landmark events, such as major holidays (In the matter of KAW, 1986). The first assumption has never been tested, to our knowledge, and the latter assumption has very limited support. In a German-speaking sample, Strube and Weber (1988) found that second graders (but not kindergartners) were better at sequencing events occurring over the past year when landmark events (such as Christmas) were provided.

The method was to stage two events just before or just after Halloween and to plant temporal clues in one of the events that might later be used to reconstruct the time. Children ranging in age from about 4 to 13 years were tested 3 months later for their memory of the events. General memory for the staged events was assessed in a free-recall task. We correlated the amount of information produced with measures of temporal accuracy to address some of our questions relevant to children's testimony. Most of the remaining tasks were designed to help us understand the development of the components of temporal reconstruction. We studied age trends in children's memory for temporally relevant information in a number of ways, including recall of the planted cues, the production of other temporally relevant information supplied in explanations of their time judgments, and memory for the contiguity and order of the staged events to one another and to Halloween. Information about children's ability to judge when the staged events had occurred came from the free-recall tasks and from direct questions about the time on scales including the time of day, month, and season. To examine the development of some of the executive processes involved in reconstruction, we asked children to interpret cues to the times of hypothetical events and to judge whether or not particular cues are useful in judging the times of such events. Measures of the growth of general knowledge of time came from children's explanations of their judgments of when the staged events had occurred and their explanations of their responses to the questions about the hypothetical events.

Method

Participants

Participants included 86 children from a small midwestern town. Of these, 26 were drawn from two private, racially mixed preschools serving mainly middle-class families. They had a mean age of 4.66 years ($SD = 0.31$, min = 4.04, max = 5.28; half female). The remaining children came from public schools in the same town. The public school population is 52% White, 32% African American, 11% mixed race, and 4% other; 41% are economically disadvantaged. There were 15 first graders, 8 boys and 7 girls ($M = 6.92$, $SD = 0.23$, min = 6.49, max = 7.32); 19 third graders, 8 boys and 11 girls ($M = 8.90$, $SD = 0.34$, min = 8.31, max = 9.58); 12 fifth graders, 4 boys and 8 girls ($M = 11.12$, $SD = 0.43$, min = 10.54, max = 11.97); and 14 seventh graders, 8 boys and 6 girls ($M = 13.34$, $SD = 0.61$, min = 12.54, max = 14.28).

Materials

One of the two staged events, the box demonstration, used a specially constructed, silver-painted box (28 × 31 × 57 cm), with a closeable section in which objects could be placed and a built-in pump handle that, when pushed down, seemed to pump air out of the box. There was also a sliding wooden device for measuring the child's forearm. Other materials for this event were a sheet of paper for each child with a line for his or her name and arm measurement, scotch tape, an autumn leaf for each child, a backpack, straws for each child, a small pack of dried fruit, a medium-weight jacket, a mask, a pair of sunglasses, a pen, and a notepad.

The other event, the egg demonstration, used a half-gallon juice jar, a large, peeled, hard-boiled egg, and a 1,500 W hair drier.

Procedure

Demonstrations. At each grade level, one class received the two demonstrations in the days before and the other in the days after Halloween (October 31). The box demonstration always took place between the egg demonstration and Halloween. Therefore, the two possible orders of the events were egg demonstration – box demonstration – Halloween and Halloween – box demonstration – egg demonstration. For all but the seventh graders, the pre-Halloween demonstrations were October 28 and 30. For the seventh graders, they were October 28 and 31. The

Table 1
Main Components of the Demonstrations

Box event	Egg Event
Taping leaves	Egg in bottle mouth
Measuring arms	Bottle heated
Sheets placed in box	Egg pulled in
Objects placed in box	Bottle inverted
Box sealed	Bottle heated
Children pump air	Egg expelled

post-Halloween demonstrations were November 4 and 6. All demonstrations took place between 9:30 and 11:50 a.m., always before the class's lunch time (or the end of nursery school). At each grade, a particular female undergraduate research assistant (RA), who was supposedly "practice teaching," conducted both demonstrations.

The box demonstration included a series of actions and objects connected with a "mystery box" (see Table 1). It was contrived to include some objects that could be clues to the time of the demonstration. Three objects (sunglasses, straws, and dried fruit) were intended as clues to the time of day, and another three (the leaves, the Halloween mask, and the jacket) were intended as clues to the time of year. Other aspects of the procedure were designed to allow the RA to touch each child twice. (No child reported these touches during the later testing, probably because they were innocuous and integrated with other actions.) The demonstration made little sense overall and was thus unlikely to be recalled with the help of schematic knowledge that only children in some age groups possessed. The following script was used.

The RA began by explaining that, "today we are going to be collecting some things in this mystery box to use at another time. When we're done, we'll seal the box up tight, and you'll help me pump out the air. First I'm going to give you each a sheet of paper. Please write your name on it. (For the nursery and first-grade children, the RA gave them instead the sheets with their names already written in the appropriate space.) Now I want you to take one of these leaves (the leaves were distributed) and tape it on your sheet. . .While you are doing that, I'm going to go around and measure the distance between each person's elbow and their fingertips."

When everyone had finished taping the leaves and everyone had been measured, children were asked to bring their sheets up, and the RA helped them place the sheets neatly in the bottom of the box. Children returned to their seats, and the RA continued, "Now I'm going to put some other things from my backpack into the mystery box. First I'm going to put this mask in the box. It's an extra Halloween mask. Next I'll put this special gel pen in the box. I thought I might need these sunglasses coming over (trying them on.) This pair is extra, so I'll put them in the box. Now I'll put this pad of paper in the box. I brought these straws along. I'll put one in the box. The rest are extras. I'll give them out, so you can each have one to use when you have lunch. (The RA distributes the straws.) I wore this jacket when I came over today. But I brought another one along, so I'm going to put this one in the box. I brought dried fruit packages for my lunch today. I have an extra, so I'm going to put it in the mystery box."

"Now it's time to seal up the box. I'll put the lid on, and snap it shut. Now I want you to line up and take turns helping me pump all the air out. I'm going to put my hands over yours to make sure you don't pump too hard. (Each child pressed the pump down five times. The RA placed her hands over the child's while he/she pumped.) OK, we're all done for today. Thanks very much for your help."

The egg demonstration (see Table 1) was similar to that described by Adcock (1998). The RA placed the egg in the mouth of the bottle and heated the bottle with the hair drier. As the air in the bottle cools, the egg is sucked into the bottle. Next the bottle is inverted, with the egg lodged inside the mouth, the bottle is reheated, and the expanding air pushes out the egg. The RA then conducted a brief discussion of heat and air pressure, with wording adapted somewhat to ages of the children. She was careful not to mention eating the egg, so that she did not provide information linking the demonstration to lunch.

Testing. Children were tested individually about 3 months later, between February 2 and 6, by an RA who was different from the one who had conducted the demonstrations. Children were initially asked a series of questions about the present time and their class and teacher last year, questions that are omitted from this article. The remainder of the interview procedure is presented in the Appendix.

Scoring. Scoring categories are reported as relevant in the Results section. One RA scored the data of all of the children. To measure interobserver agreement on items where judgments were required, 2 children from each of the five grades were randomly selected and their responses scored by a second RA. For counts of information reported, the mean correlation was $r = .91$ (range .59–1.0). For items where responses were assigned to categories, the overall Cohen's κ was 0.77. This was computed conjointly for all 30 such items (using the mean

number of categories), because some, optional items had too few subjects for the individual κs to be meaningful.

Results

General Memory for the Demonstrations

Children in the nursery group showed great difficulty remembering the box demonstration; 9 out of 26 reported that they did not remember it, and only 7 of the 26 children supplied any correct information in response to the free-recall questions. However, older children reported a substantial number of pieces of information about the event. Including all children, the sums of correct objects, actions, and attributes for the five age groups (*SD*s in parentheses) are 0.69 (1.35), 2.73 (2.37), 3.95 (2.82), 7.00 (2.73), and 5.71 (4.38). These totals exclude information presented in the question but include gistlike responses (such as mentioning candy instead of the fruit bar).

A large majority of children at each age, including the youngest group, remembered the egg demonstration. Twenty-one out of the 26 children in the nursery group were able to supply at least one piece of correct information (compared to 7 for the box demonstration), and only 1 child reported that she did not remember the event. The mean sums of information recalled for the five groups are 2.96 (2.28), 5.87 (1.73), 4.84 (2.19), 5.17 (4.11), and 5.86 (2.41).

Memory for Temporal Information

Memory for planted cues. The first measures of children's memory for temporal information come from their recall of the planted temporal cues to the time of the box demonstration (e.g., straws, sunglasses, leaves, mask) in the free-recall and prompted-recall tasks. Table 2 shows the relevant means. An ANOVA was performed on these data, with free versus prompted recall as a within-subject factor and grade as a between-subject factor. The results revealed that more cues were recalled by older children, $F(4, 81) = 11.37$, $p < .001$, partial eta squared (η_p^2) = .36, and that participants reported more of the cues in the prompted than free-recall condition, $F(1, 81) = 11.23$, $p < .002$, $\eta_p^2 = .12$. The interaction was not significant. Overall, recall of the planted temporal cues was poor, with only the leaves being remembered by more than one third of the sample. Of course, incidental contextual cues can also serve temporal reconstruction, and this will be seen in the analyses of temporal judgments.

Table 2
Recall of the Planted Temporal Cues

	Grade				
	N	1	3	5	7
Box free recall					
M	.15	.40	0.79	1.42	0.86
(*SD*)	(.37)	(.63)	(0.63)	(0.51)	(0.77)
Box prompted recall					
M	.31	.80	1.26	1.33	1.36
(*SD*)	(.62)	(.94)	(0.65)	(0.89)	(1.01)

Note. The maximum for each measure is 6.

We also examined whether children mentioned the leaves in response to the follow-up questions about knowing the month or season of the box demonstration, a task reported in a later section. Eleven children did so, all of them third, fifth, or seventh graders.

Spontaneous reference to time. Children almost never produced statements about when the demonstration occurred in response to the open-ended questions in the free-recall task. One fifth-grader volunteered the information that she didn't "really remember because that was a long time ago," and another child from this group said, "It was around October, and it was around Halloween." The rarity of such responses tells us that whatever virtues free-recall procedures have for eliciting unbiased information, focused questions are needed if specific temporal information is sought. In this study, such questions immediately followed free recall and are reported in the next section.

Accuracy of temporal judgments. A number of findings are relevant to our questions about whether, and at what ages, children can make accurate judgments about the times of past events. On the first time scale considered, time of day, we computed the deviation of estimates from the true time in minutes for those children who responded with clock times. Table 3 shows the means for each age group for the box and egg demonstrations. An ANOVA with box versus egg demonstrations as a within-subject variable and grade as a between-subject variable showed no significant difference between the two demonstrations but a significant grade effect, $F(4, 36) = 6.99$, $p < .001$, $\eta_p^2 = .44$. (The sample size in this analysis is reduced by the numbers of participants who, for one task or the other, responded "don't know" or gave no answer, and by those who either were not present for the egg demonstration or reported not remembering it.) The grade effect is consistent with the

Table 3
Accuracy of Judgments of Times of the Demonstrations

	Grade				
	N	1	3	5	7
Deviation from correct					
Time of day (min)					
Box					
M	169.28	207.14	70.50	37.00	17.69
SD	(155.15)	(87.36)	(64.05)	(43.15)	(19.86)
Egg					
M	228.00	124.63	92.08	41.67	18.75
SD	(191.02)	(66.09)	(77.59)	(54.92)	(28.21)
October or November					
Box	0.23	0.40	0.74	0.58	0.43
Egg	0.17	0.53	0.53	0.62	0.69
Correct season					
Box	0.36	0.47	0.63	0.82	0.93
Egg	0.67	0.67	0.68	0.75	0.85

Note. For month and season judgments, the values are proportions of children in the group, excluding those who did not give an answer.

large increases in accuracy shown in the table. Those children in the two youngest groups who responded "don't know" to the clock-time question were also mostly inaccurate in judging whether the demonstrations had occurred in the morning, afternoon, or night. The children in the two youngest groups, who mainly gave inaccurate answers to the questions about time of day, only responded "don't know" on an average of .14 and .23 of the questions for the nursery and first grades, respectively (collapsing across events and questions). This indicates that the children usually attempted to answer the direct questions, even when they did not remember when the events had occurred.

The next analyses were of the accuracy of the estimates of the months that the demonstrations had taken place. Mean distances from the correct months were misleading, because many in the youngest group responded with the first (January) or last (December) month mentioned, and this inflated their accuracy. Instead, analyses were based on the proportions of children reporting the correct or near-correct months October or November. (Both demonstrations occurred at the end of October or the beginning of November.) These are shown for each of the demonstrations in Table 3. With 2 out of a possible 12 months correct by chance alone, the null expectation is 0.17. This value was significantly exceeded in one-tailed binomial tests ($ps < .03$) for both the box and egg demonstration for all groups except the youngest. The proportions of children who were accurate in their month judgments of the box and egg demonstrations were very similar, again suggesting that the temporal cues planted in the box demonstration did not affect children's accuracy. The box demonstration was always closer in time to Halloween; therefore, these results show that this did not increase children's accuracy either.

Analyses of season judgments also provide information about children's memory of when within the year the demonstrations had occurred. The proportions of children correctly reporting the demonstrations to have been in the fall (Table 3) can be compared with the null expectation of 0.25 in binomial tests. Season accuracy was greater than would be expected by chance for all group-demonstration combinations, one-tailed $ps < .01$, except for the nursery and first graders on the box demonstration; the latter group approached significance ($p = .057$). Overall accuracy for the egg demonstration was slightly greater than for the box demonstration; therefore again there is no evidence that children benefited from the planted cues or the greater proximity of the box demonstration to Halloween.

The remaining questions about the times of the demonstrations concerned the child's grade and teacher. For the two questions and two demonstrations, between 0 and 2 children in the youngest group responded incorrectly or "don't know"; all of the remaining children were correct.

Finally, we examined whether free recall or prompted recall of the planted temporal cues in the box demonstration was associated with greater accuracy on the corresponding scale (e.g., leaves, jacket, and mask for the month and season judgments). Partial correlations were conducted, controlling for age. None of the correlations were significant, suggesting once again that memory for the planted cues played little part in reaching accurate judgments.

Explanations of temporal judgments. For each of the time judgments reported in the preceding section, children were asked to explain how they knew the answer. These explanations can reveal whether or not they had access to two kinds of information that could have been used to reconstruct the correct times: relevant episodic memories and semantic knowledge about the properties of particular temporal locations. In a first analysis, we counted cases where children supplied specific information that was definitely correct and relevant to the scale in questions (e.g., the leaf for the season question or which class they had been in for the time-of-day question) or possibly correct (e.g., weather that was

possible for the season) for the time of an event. We excluded responses for which it was implausible that the information was noticed at the time. (For example, we did not include cases where the child claimed to remember looking at the calendar during a demonstration.) Averaging across the two demonstrations and across time of day, month, and season, the proportions reporting such memories for the five age groups were 0.13, 0.29, 0.68, 0.79, and 0.76. It is clear that there were large age increases between about 6 and 8 years in children's reports of information that could have been remembered and used to reconstruct the times of the demonstrations.

We also examined how frequently children reported memories that are relevant to the scale in question (e.g., the time of day), whether the memories were correct (as in the previous measure) or incorrect (e.g., mentioning an activity that clearly takes place at a different time of day or year but would be useful for constraining the time). Such reports could lead a questioner who does not know the true time of an event to accept a judgment of the time, whether or not it is correct, because the justification is plausible.

Averaging across the two demonstrations and across time of day, month, and season, the proportions reporting information relevant to the scale in question were 0.37, 0.74, 0.81, 0.91, and 0.84. (For the youngest children, such reports were substantially more common for time of day than for the month or season.) These data show that from about age 4 onward, many children are aware of and report types of information that would be useful for remembering the time of an event. However, a comparison with the proportions in the preceding analysis shows that through about 6 years, much of the information reported to justify time judgments is incorrect. A test of the developmental sequence of producing useful cues versus accurate cues was conducted on the whole sample's cross-classification on these two variables for each of three time scales (time of day, season, and month) and for each of the two demonstrations (box and egg). Binomial tests comparing the off-diagonals showed that cue usefulness preceded cue accuracy for five of the six combinations, two-tailed binomial $ps < .03$, and the remaining comparison approached significance ($p < .06$).

It should be noted that many of the explanations for month and season judgments that we credited as being possibly remembered were really only marginally credible. (Such marginal responses were uncommon for explanations of time-of-day judgments.) For example, there were many reports that the leaves were off the trees or the weather was beginning to turn cold, things that were probably not noticed at the time of the demonstration, because most children's attention would have been focused on the demonstrations, which occurred indoors. Averaging across the two demonstrations, 87% of the explanations for month and 73% for season that were "possible" responses fell in the subcategory in which it was unclear whether the information was really likely to have been noticed or to be remembered. This suggests that an even greater proportion of participants reported relevant cues to the time of year that were not really remembered. Together with the findings concerning the accuracy of temporal judgments, these results show that direct questions lead children to produce a considerable amount of incorrect information.

Finally, we investigated whether reporting memories of temporal cues that could have been correct was related to the accuracy of temporal judgments. Partial correlations, controlling for age, were computed for each demonstration on the scales time of day, month, and season. Of the six correlations, only two were significant, and these were very weak: $r(N = 73) = .29$, $p = .011$ for the month of the box demonstration and $r(N = 71) = .30$, $p = .011$ for the month of the egg demonstration. The partial correlation for the time of day of the egg demonstration approached significance, $r(N = 45) = -.27$, $p = .066$. (This correlation is negative because greater accuracy is reflected in smaller deviation scores.) Together, these results provide limited evidence for a relation between recalling temporally relevant aspects of events and the accuracy of judgments of the month or time of day that they occurred. Season judgments showed no such relation, perhaps because accurate judgments were based on other processes.

Memory for contiguity and order. Several questions were relevant to children's ability to remember the contiguity and order of events, abilities that are often assumed in forensic interviews and which are among those that allow adults to reconstruct the times of events. We first examined children's memory for the contiguity and order of other events in the box free-recall task and the questions about the time of this event. (We did not analyze these for the egg demonstration, because Halloween had already been mentioned by that point in the procedure.) Only 1 child referred to the contiguity of Halloween or Thanksgiving in the free-recall portion of the box demonstration, and the proximity of Halloween and/or Thanksgiving was mentioned in only 8 of the 133 justifications of season or month judgments of the time of the box demonstration.

In addition to these opportunities to mention the proximity of other events, children were directly

asked to recall other events that had occurred at about the same time as the box event and to judge the order of the box demonstration and Halloween and the box demonstration and the egg demonstration. In response to questions about what else happened at about the same time as the box demonstration, only 17 children recalled the proximity of Halloween (0, 4, 5, 5, and 3 for the five age groups). Even fewer reported the egg demonstration (12) and Thanksgiving (10). These findings show that children throughout this age range cannot be counted on to recall the contiguity of other events to a target event, even other events as important to children as Halloween. They also show that the holidays were probably not important sources of children's accuracy on the time-of-year questions.

The questions about order also revealed that children were very poor at remembering whether the box demonstration had occurred before or after Halloween. The question was asked in two ways, and both produced the same low levels of accuracy. In addition, there was no significant difference in accuracy between children experiencing the box demonstration before and those experiencing it after Halloween. The proportions correct for the five age groups were .50, .60, .37, .25, and .36. In marked contrast, children from first grade onward were quite accurate in remembering the order of the box and egg demonstrations. The proportions correct on each question for the five groups were .46, .79, .95, .89, and .77. Group differences were significant, $\chi^2(1, N = 79) = 17.19$, $p < .03$, and one-tailed binomial tests showed that accuracy was significantly greater than .50 for each age group from first through seventh grade, $ps < .05$. We had little sensitivity to detect the ability to order the two demonstrations in the youngest group, because only 7 children were able to remember the events well enough to supply at least one item of correct information for both of them. (Of these 7, only 3 correctly judged their order.) As the proportions show, there is no evidence that accuracy in ordering the two demonstrations increased after first grade, and chi-square tests excluding the youngest group were not significant.

The relatedness of the two demonstrations may have contributed to accurate memory for the order of the two demonstrations in first-grade and older groups. The attempt in the demonstration procedure to create a link between the box event and Halloween was unsuccessful: Only 2 children in each of the free-recall and prompted-recall tasks remembered the Halloween mask. Clearly, temporal contiguity in itself was not sufficient for the creation and retention of a temporal relation between the two events.

Finally, we examined the relation between accuracy in ordering the two demonstrations or in ordering the box demonstration with respect to Halloween and accuracy of the month and season judgments of the two demonstrations. In order to control for age, chi-square analyses were conducted separately for the two younger groups combined and the three older groups combined on sixteen 2×2 tables, in which month or season accuracy was one dimension and accuracy of order judgments (box-Halloween or box-egg) was another. (There are 16 combinations, because there are two box-Halloween order questions and two box-egg order questions.) Of these 32 analyses, only one produced a significant result: For the older three groups combined there was a tendency for children who judged the order of the two demonstrations correctly to also be more accurate in judging the month of the box event, $\chi^2(1, N = 41) = 4.44$, $p = .035$. In general, these results are consistent with the independence of psychological processes that underlie memory for order and memory for locations or distances (Friedman, 1993), and they show that under the present conditions success in ordering the two demonstrations was usually of little help in reconstructing the locations of the events.

Relation Between Temporal and Nontemporal Accuracy

Several analyses were designed to test whether children who were accurate in judging the time of an event were also more accurate in producing nontemporal information. These analyses are relevant for legal practitioners who test child witnesses' event memory by asking questions about when an alleged event occurred. A first analysis was a partial correlation between the sum of correct information reported in the free-recall tasks and the deviation from the correct time in clock-time estimates. This analysis includes only those participants who produced a clock time. Controlling for age, there was no relation between the two variables, $r(N = 48) = -0.03$, in the box task and only a weak tendency for children who reported more nontemporal information to be more accurate for the egg demonstration, $r(N = 49) = -0.36$, $p < .01$. For those children who did not give a clock time but went on to give a part of the day, more correct nontemporal information was actually supplied by children who believed that the box demonstration had taken place in the afternoon than those who correctly recalled it as having taken place in the morning, and the corresponding differences were very small for the egg task.

To test the relation between time-of-year accuracy and the amount of correct information reported by

participants, we conducted ANOVAs for each of the box and egg tasks on each of the month and season scales. In each case, being correct versus incorrect on the relevant scale and grade were between-subject factors, and the sum of correct information recalled was the dependent variable. None of the analyses resulted in a significant effect of temporal accuracy, nor did the effects interact with grade. Accuracy in judging the order of the box demonstration and Halloween was also unrelated to the amount of correct information reported about the box demonstration in a similar ANOVA, and again temporal accuracy did not interact with grade. In general, these results show that children can recall a considerable amount about what happened in the demonstrations without being able to report accurately when they occurred.

Table 4
Proportion of Children Correct on the Questions About the Times of Hypothetical Events

	Grade				
	N	1	3	5	7
Cue interpretation					
Season or month 1	.27	.87	1.00	1.00	0.93
Season or month 2	.16	.53	0.89	1.00	1.00
Time of day	.58	.73	0.89	1.00	1.00
Day of the week	.28	.53	0.84	1.00	0.86
Cue evaluation					
Time of year—relevant	.58	.87	1.00	1.00	1.00
Time of year—irrelevant	.58	.73	0.89	0.92	0.77
Time of day—relevant	.43	.73	0.58	0.92	0.86
Time of day—irrelevant	.61	.60	0.84	0.92	0.93

Reconstruction from Hypothetical Information

Cue interpretation. The last two tasks provide information about the availability of temporally useful semantic information and the capacity to use it to infer the times of events. First, in four questions children were presented with a clue about the time that someone lost a book and asked to interpret the clue. The first clue was that it was hot outside. As the first data row in Table 4 shows, children from first grade onward were very accurate (in responding "summer" or giving a summer month). On this and the remaining questions, the most common wrong answers were on the correct time scale (e.g., an incorrect month for the first question). Another question was based on the clue that the protagonist had seen fireworks that night. The second row of Table 4 shows the proportion of children who responded "July (4th)" or "summer." The next row displays the proportion responding to the cereal question with "morning" or a time between 6:00 and noon. The fourth row is the proportion who referred to the weekend or a weekend day when told that the character had been watching cartoons. All four questions resulted in significant age improvement by chi-square tests, $ps < .01$. These results show that the children in the youngest group had difficulty interpreting clues other than the one relevant to the time of day. First graders were relatively poor at interpreting the clues relevant to the time of year of Independence Day celebrations and the day of the week when cartoons are usually watched.

Cue evaluation. In the final part of the interview, children were asked whether each of a number of clues would be useful in constraining the time on a particular time scale. The bottom half of Table 4 shows the accuracy of children's answers to the yes–no questions concerning the adequacy of the clues. Chi-square tests showed significant age increases in the accuracy of answering the two questions where the correct answer was "yes," $ps < .02$. The group effect was of borderline significance for rejecting the irrelevant cue to time of day, $p = .05$, and not significant for rejecting cartoons as a clue to time of year. If children judged a clue to be helpful, they were asked to explain how it could help to know the time. Most children who were correct on the "relevant" items went on to provide the intended explanation or at least draw a correct inference (e.g., it was fall). The exception was that children in the youngest group could not explain how spoiling one's appetite was a clue to time of day. Overall, children in the youngest group fell at about chance levels in evaluating the cues. With only two exceptions, about three-fourths or more of children in each age group from first through seventh grade produced differentiated and correct judgments of the utility of cues in constraining the time.

Relation to temporal accuracy. We examined whether performance on the cue interpretation and evaluation questions was related to accuracy in judging the times of the demonstrations. Controlling for age, a composite score for the cue interpretation and evaluation tasks was weakly related to accuracy of month judgments of the box demonstration, partial $r(N = 72) = .34$, $p = .003$, and marginally related to month accuracy on the egg task, $r(N = 72) = .22$, $p = .064$. None of the partial correlations for time of day or season were significant.

Discussion

The findings of this study provide information about the development of temporal reconstruction and

about several issues related to children's accuracy in remembering the times of past events. We suggested earlier that temporal reconstruction depends on three kinds of abilities: the capacity to remember information about events that is useful in constraining the time, general knowledge of time patterns, and executive processes that control the integration of the two kinds of information. In the following sections, we discuss evidence relevant to the nature and development of each of these abilities and to the accuracy of children's memory for the times of past events.

Memory for Temporally Relevant Information

Information that constrains the temporal location. First we consider whether incidental and planted cues to the times of demonstrations were remembered 3 months after the demonstrations. All age groups had difficulty remembering the planted temporal cues (Table 2). By this measure, only children in the three oldest groups were likely to remember at least one specific detail of the events that could constrain the time. Most commonly it was the leaf, with which they had interacted directly.

Evidence relevant to memory for nonplanted, contextual clues to the times of the demonstrations could be found in children's explanations of how they knew the times and in the weak correlations between reporting cues that could be correct and the accuracy of month judgments. It was not until third grade, though, that half of the children reported memories for the context of the demonstrations that could have been correct and that constrained the time of day. There were similar age trends in children's explanations of their month and season judgments, with third graders being the first group in which about half of the children cited memories that were possibly or probably correct. However, in most of these cases judgments probably were not based on true memories. Overall, it seems likely that fifth and seventh graders were able to remember contextual cues to the time of day, a conclusion further bolstered by their extreme accuracy in judging the time on this scale. However, many or most of the explanations of time-of-year judgments, even in the oldest two groups, were probably constructed at the time of recall. In contrast to the age changes on the time-of-day and time-of-year scales, children of all ages appeared to recall enough of the context of the demonstrations to remember who their teacher was and, for those children asked, the grade they had been in. Here, however, their proficiency may be partly attributable to the fact that the to-be-remembered events occurred in the children's current school year and the test context overlaps with the encoding context. Moreover, questions about a child's age (or the name of the child's teacher) at the time of an event might be appropriate only when the event to be dated shares contextual features with the child's knowledge about his or her age or teacher.

The finding that children apparently seldom actually remembered information that could constrain the time of year raises the question of why the accuracy of month and season judgments was usually greater than would be expected by chance. No clear evidence is available to answer this question, but children often may have been using impressions of temporal distances in the past. Based on past findings (Friedman, 2003), general impressions of the distances of the demonstrations in the past would have been available to even those children in the youngest group who remembered the events. Impressions of distances could have been combined with another source of information, remembering that the event took place during the current academic year, information that was available to children in all age groups. In order to arrive at the correct month or season, children would still need some knowledge of the order of seasons and months, knowledge that should be available by third grade (Friedman, 1977, 1978). It remains unclear, however, exactly how younger children sometimes arrived at approximately correct judgments. Finally, if many children used impressions of distances in the past and the knowledge that the event had happened during the current school year to arrive at month and season judgments, it may be appropriate to view the weather and other details cited in their subsequent explanations as reconstructions rather than real memories. Just as an episodic memory can be given a temporal interpretation, an impression of the likely time can lead to the reconstruction of what the weather was probably like. Legal professionals who attempt to interpret children's judgments of the times of target events should be aware that the same abilities that can lead to successful reconstruction could also lead to the production of convincing incorrect information.

Contiguity and order. Adults often report using two other kinds of information to reconstruct the times of past events: the contiguity and order of target events to other dateable events (Friedman, 1993). We tested children's memory of the contiguity of the box demonstration to Halloween, Thanksgiving, and the egg demonstration, all of which happened within about 1 month of the box event. Fewer than 20% of children recalled that the box demonstration occurred near Halloween, and even smaller

percentages remembered the proximity of the other events. Whether or not children recalled the contiguity of the events, they were asked to judge whether the box demonstration was before or after Halloween, and at no age were children capable of answering correctly. Legal professionals often assume that reference to landmark events will enable children to make accurate judgments of the time of year of a target event. Our results show that this is a risky assumption, even when the to-be-dated event is relatively recent (3 months old) and proximal to the landmark event.

In contrast to their inability to order the box demonstration and Halloween, children from first grade onward were quite accurate in recalling the order of the two demonstrations. We do not have evidence about the specific processes that led to accurate judgments of the order of the two demonstrations, but it is extremely unlikely that distance-based processes could be used to discriminate the ages of events with a temporal separation of about 2 days after a 3-month delay. In a study where a very large group of 5- to 7-year-olds compared unrelated events on similar time scales, but with even greater separation of the events relative to elapsed time, performance was at chance levels (Friedman & Kemp, 1998). Judging the order of the two demonstrations by reconstructing their temporal locations also seems unlikely, given the evidence that accuracy on this item was unrelated to month and season accuracy and children's inaccuracy in linking the box demonstration to Halloween. Instead, processes involving the relatedness of the two demonstrations were probably responsible. All children must have recalled the RA having conducted the first demonstration during the time that she was present to conduct the second one. If this information was stored in memory, as order-code theories presume, it could have been retrieved at the time of the test. Order-code theories correctly predict better memory for the order of the two related events (the two demonstrations) than the two unrelated events (the box demonstration and Halloween; these are considered unrelated because very few children recalled the Halloween mask).

To our knowledge these findings are the first demonstration of this effect in long-term memory in either the literature on adults' or children's memory for time. They suggest that order information, alongside distance and location information, is a potential contributor to humans' sense of the times of life events, even when there is no logical-causal link between events. Even if this conclusion is correct, however, important questions remain about the applicability of the order-code model in particular to autobiographical memory. Chief among these is whether this process is automatic, as the theories presuppose, or whether long-term memory for order requires active processing of the relation at the time of encoding.

It should also be acknowledged that another encoding-related process might account for children's ability to remember the order of the two demonstrations. If children remembered that a particular demonstration was the one in which they encountered the RA for the first time, they could have used this information to judge it to be the earlier event. Storing information about the novelty of an experience can explain not only these findings but that it is one possible mechanism that can account for "primacy" in memory for temporal position, a phenomenon that is present on relatively longtime scales by 6 years of age (Powell, Thompson, & Ceci, 2003). However, such primacy effects can also be explained by order codes: Later events can remind one of the first event, but the first event has no such order codes.

These results are also practically significant, particularly when one contrasts children's ability to order related and unrelated events. Child witnesses may be capable of testifying to the order of repeated events (if their number is small enough so that schematization has not taken place) but incapable of ordering those events with respect to landmarks, at least landmarks that do not share contextual features with the events.

Conclusion. Together, the findings on memory for temporally relevant information indicate that children throughout the age range from 4 to 13 years often lack memories for details that could be used to reconstruct the time of year. On the other hand, children throughout this age range recalled at least some contextual information. Under the conditions of this study, the contextual information was adequate to constrain the time to the current academic year and, for older children, who had highly differentiated school schedules, to a very specific time of day. Information about the order of related, but not unrelated, events was preserved over the 3-month retention interval.

General Knowledge of Time Patterns

A number of previous studies have provided information about the growth of children's knowledge of the order of parts of the day, days of the week, and months from early childhood through adolescence (Friedman, 1977, 1986, 1990). In the present study, the main kind of temporal knowledge that children

used was the characteristics and activities associated with particular times. This was shown in several tasks, including children's explanations of how they remembered the times of the demonstrations. When asked how they remembered the time of day, even in the youngest group most children reported information that would be useful in constraining the time on this scale (although most of this information and their actual judgments were usually incorrect for the times of the demonstrations). By first grade more than 75% of children reported information that would be useful in constraining the time of year (although much of the information probably was not based on actual memories). The finding that scale-relevant information is produced by 4 years of age for the time-of-day scale and by 6 years of age for the time-of-year scale shows that children have relatively early access to some facts about times that could, in principle, aid reconstruction of the temporal locations of events. Other evidence for early general temporal knowledge came from explanations of judgments about hypothetical events.

Relating Remembered Information to Time Patterns

In order to reconstruct the times of past events, episodic memories must be related to semantic knowledge about personal, natural, and conventional time patterns. Children's competence in integrating information about events with information about time patterns was measured apart from memory-based performance by presenting them with hypothetical events. The results of the interpretation task show that most children, even as young as 4 years, are able to draw correct inferences on a time scale about which they are knowledgeable, parts of the day. More than half of the children in the youngest group drew a correct inference from the clue that the protagonist was eating cereal. First graders were very accurate in inferring the time of year when given the clue that it was hot, but apparently were unfamiliar with the time of year of Independence Day, and many had difficulty using a clue to the day of the week. These findings, like those of Friedman (1991), reveal that the basic ability to interpret temporally relevant clues is present by early childhood. Competence is related to the presence or absence of specific temporal knowledge. Performance is also likely to be limited by more general memory abilities; we have seen that recall of both temporally relevant and nontemporal information about the demonstrations was poor in the youngest group.

Another component necessary for successful reconstruction is the ability to determine which information is useful in constraining the time. Children in this study showed this competence in that they usually reported scale-relevant information when queried about how they remembered the times. Further evidence for competence in evaluating the temporal relevance of information came from the cue-evaluation task. Although children in the youngest group performed at about chance levels, first graders and older children were mostly successful in judging which clues were and were not helpful in constraining the time on particular scales. These findings indicate that the competence to evaluate information for its temporal relevance is present by 6–7 years of age. As for interpretation, successful performance also requires knowledge about particular time patterns and memory for episodic information that can constrain the time.

Conclusions about the Development of Temporal Reconstruction

In our analysis of the components of reconstruction in the introduction, we speculated that children might have early access to temporally relevant episodic memories and memory for the contiguity and order of events. Strategic processes and semantic knowledge of time patterns were predicted to develop during middle childhood and to limit children's ability to reconstruct the times of past events. Our results paint a different picture of the development of reconstruction. Although even 4-year-olds could remember some aspects of the general context, substantially more information about what happened in the demonstrations was reported by 6- to 7-year-olds, and there were further age increases in the recall of details that could aid temporal reconstruction. We also saw that memory for contiguity was poor at all ages, and memory for the order of related events appeared to increase from about 4 to 6 years. These results indicate that there are substantial changes from early through middle childhood in the availability of temporally useful episodic information.

The second component is general knowledge about time patterns. Here, considerable competence in accessing relevant semantic information was found by about 8 or 9 years of age. Children of this age appear to possess much of the knowledge about parts of time patterns needed to reconstruct past times on the scales of the day, week, and year, and even younger children mentioned some useful information about particular times. Finally, we have seen that 6- to 7-year-olds have the general ability to evaluate the temporal relevance of clues and to interpret them, with performance being limited only

when appropriate semantic knowledge is unavailable. Important executive processes needed for reconstruction are evident at these ages.

Production and Accuracy of Temporal Information

In the literature on children's testimony, important questions surround the costs and benefits of using open-ended versus direct questions (Lamb et al., 2003). Open-ended questions are generally believed to be better for minimizing biased and otherwise inaccurate information. On the other hand, direct questions may elicit information not otherwise recalled. This study is unusual in that it provides an opportunity to compare the effectiveness of open-ended and direct questions in eliciting temporal information in particular. A first kind of temporal information is mention of when the demonstrations occurred. At least for the form of the open-ended question used here (''Tell me everything that happened from beginning to end''; ''Tell me something else that happened''), children almost never provided temporal information. It could be that other common question forms (e.g., ''Tell me everything about...'') might elicit more temporal information, but free production of the times of events does not seem to be frequent in past studies (see Peterson, 1996, finding little production of temporal information in response to free recall or ''when'' questions).

The direct questions, of course, led to the production of a great deal of information, and the overwhelming majority of children gave responses to each question that were times on the appropriate scale. We have seen that accuracy varied by time scale and by age, and these data provide some indication of the likelihood of obtaining correct temporal information for each combination (see also Friedman, 1991). Accuracy in response to direct questions about time-of-day was poor before third grade. Although age groups from first grade onward exceeded chance levels in recalling the month, no age group produced high levels of accuracy; only about 60% of third, fifth, and seventh graders produced the correct month or the other one closest to the time of the demonstrations. Only among the fifth and seventh graders were about 80% or more of children correct in remembering the season. On the other hand, teacher and grade judgments were very accurate for all age groups who were asked these questions. For all but teacher and grade, we can see that direct questions about when the demonstrations had happened led to large increases in the amounts of correct and incorrect information produced.

Of course, all of these conclusions about children's accuracy must be limited to conditions comparable with those in this study: events that take place in school and retention intervals of about 3 months. Given the importance of general contextual memories in this study, it will be especially useful in future studies to examine events in home and other nonschool settings. These settings may provide contextual information that is more temporally differentiated, such as activities that vary from one time of year to another. It is also possible that children are more accurate in remembering the times of events that are of greater personal significance than those used in this study. Only by studying a broader range of events and encoding situations will we understand the development of children's competence and performance in reconstructing the times of past events.

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Appendix

The Box Event

Free Recall

I heard that a college student came in to do practice teaching and put things in a special box. I heard she did a bunch of things and had you do some things, too. Tell me everything that happened from the beginning to the end. What else happened? Tell me something else that happened. (Each child received the first follow-up question. If they supplied any other information in response to it, they received the second follow-up question.)

Questions about Temporal Locations

Now I'm going to ask you some questions about *when* the college student came in and put things in the special box. (The following time scales were presented in random order.)

Time of day. When the college student put things in the special box, about what time was it? (If the child did not mention a clock time) Was it morning, afternoon, or night? (On this and the follow-up questions for the other time scales, the next two questions were presented unless the answer was "don't know" to the preceding question(s). However, if participants gave a temporal answer, *both* of the follow-up questions were asked.) How do you know it was —— (their response, if a time)? Can you remember anything (else) that helps you know what —— (time, month, or season, etc.) it was?

Month. When the college student put things in the special box, what month was it? (If don't know) Was it January, February, March, April, May, June, July, August, September, October, November, or December?

Season. When the college student put things in the special box, what season was it? (If don't know) Was it spring, summer, fall, or winter?

Grade. (Omitted for preschoolers.) When the college student put things in the special box, what grade were you in?

Teacher. Who was your teacher when the college student put things in the special box?

Prompted Recall of Contents of the Box

Tell me everything that the college student put in the special silver box, the one that had the handle to pump out the air. (Each child received the first follow-up question. If they supplied any information in response to it, they received the second follow-up question.) What (else) did she put into the box? Anything else?

Contiguity and Order Questions

Do you remember anything else that happened at about the same time as the day the college student put things in the special box? (If only Halloween or the egg demonstration or neither mentioned by the child) Was there something (else) a few days before or a few days after? (If Halloween is still not mentioned) Was there a special day or holiday at about the same time? (If so, which one?) Think about the day that the college student put things in the special box. Was that before Halloween or after Halloween (order of mention counterbalanced)?

Which happened first? Think about the day that the college student put things in the special box, and think about the day she showed you something with an egg and a bottle. Was the box before the egg or after the egg (order of mention counterbalanced)? Which one happened first?

The Egg Event

Free recall (similar to free recall for the box event)

Questions about temporal locations (similar to those for the box demonstration)

Reconstruction from Hypothetical Information

Cue Interpretation

Now I'm going to ask a few questions about something that happened to another person. John/Jane (matching the child's gender) lost his/her book and is trying to remember when he/she last saw it.

He/she remembers that he/she had it when it was hot outside. What time of year or season do you think it was?

He/she remembers that he/she was eating cereal. What time of day do you think it was?

He/she remembers that it was a day when he/she had been watching cartoons in the morning. What day of the week do you think it was?

He/she remembers that he/she saw fireworks that night. What time of year or month or season do you think it was?

Cue Evaluation

Michelle/Mike is trying to remember the times when s/he played with her/his cousin.

Time of year. Michelle/Mike remembers some things about when they played. Tell me which memories can help her/him know what time of year it was when they played?

Michelle/Mike remembers that one time they played, s/he and the cousin jumped in a pile of leaves. Can that help her/him know what time of year it was? (If yes) How could that help her/him know what time of year it was?

Michelle/Mike remembers that another time they watched cartoons on TV. Can that help her/him know what time of year it was? (If the child responded with a day of the week or a time of day, attention was refocused on time of year.) (If yes) How could that help her/him know what time of year it was?

Time of day. Tell me which memories can help Michelle/Mike know what time of day it was when s/he played with the cousin?

Michelle/Mike remembers that one time they were playing on a green rug. Can that help her/him know what time of day it was? (If yes) How could that help her/him know what time of day it was?

Michelle/Mike remembers that another time they played her/his aunt said not to have cookies because it would spoil their appetite. Can that help her/him know what time of day it was? (If yes) How could that help her/him know what time of day it was?