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The Development of Temporal Metamemory

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In two studies of knowledge about the properties and processes of memory for the times of past events, 178 children from 5 through 13 years of age and 40 adults answered questions about how they would remember times on different scales, how temporal memory is affected by retention interval, and the usefulness of different methods. The adults showed quite accurate knowledge about the main properties of memory for time and the processes that underlie it. Different properties and processes were first understood at ages ranging from 8 years to 12 years or later. Knowledge of the roles of reconstruction and impressions of temporal distances appear well after children use them to remember the times of events.

Among the many domains of human knowledge that have interested cognitive psychologists is our understanding of our own mental processes. Researchers have attempted to learn about the nature of adults' understanding of cognitive processes and how this knowledge develops. One part of this domain has received particular attention from developmental psychologists: metamemory. Metamemory refers to knowledge about the processes of information storage and retrieval (Kreutzer, Leonard, & Flavell, 1975). Research on the development of metamemory shows that knowledge of some basic facts about memory is available to young children but that there are substantial age increases during middle childhood in children's awareness of many of the workings of memory and in their understanding and use of strategies for improving memory (Flavell, Miller, & Miller, 2002; Flavell & Wellman, 1977; Kuhn, 1999; Schneider, 1999; Schneider & Bjorklund, 1997). For example, during this time children learn that it is easier to remember content that has meaningful connections and easier to remember the gist of a story than the exact wording.

Although there is a substantial literature on knowledge about the storage and recall of content, knowledge of how we remember the times of past events, or "temporal metamemory," has received scant attention. Temporal metamemory can be conceived as a body of knowledge within the broader domain of metamemory. Accurate temporal metamemory would include an understanding of the properties and processes that are shared with memory for content and those that are specific to recalling the times of events.

Research on temporal metamemory could enrich our understanding of a number of aspects of cognitive development and children's abilities, including the development of autobiographical memory in general (Nelson, 1993) and of a chronological sense of the past (Friedman, 2003). This is because our confidence in assigning events to particular times in the past may depend on the evaluation of the kinds of information that led to the judgment, an ability that should become more accurate with the growth of knowledge about the processes underlying memory for time. For example, in forensic settings, where establishing the time of an alleged event is often of considerable legal significance, children who do not understand the processes and properties of memory for time may assign greater certainty to their testimony than is warranted, and they may not appreciate the benefits of using the kinds of reconstructive strategies that dominate adults' recall of the times of events (Friedman, 1993). For the same reason, the study of temporal metamemory may be relevant to our understanding of the development of source monitoring (Johnson, Hashtroudi, & Lindsay, 1993), because the time of anevent is considered to be an important type of information in establishing its origin (Johnson et al., 1993; Roberts, 2000). For example, someone who recognizes that memory for time is usually approximate

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rather than precise would realize that an event that cannot be exactly localized in time might still have really happened. In addition, findings on the development of an understanding of temporal reconstruction could add to our knowledge about children's understanding of mental processes, including the body of research on the interpretive nature of minds (e.g., Flavell, 1988; Lalonde & Chandler, 2002).

Research on temporal metamemory may also enrich our appreciation of the variety of humans' knowledge about memory processes. The development of metamemory may involve coming to understand memory processes that are specific to particular kinds of information (such as when an event occurred). For example, in contrast to memory for content, where prospective strategies such as organization have been widely studied, the processes that contribute to memory for time are hardly ever prospective ones (because we seldom know in advance that we will want to remember the time of an event). In addition, children may need to learn that recall of some kinds of information is usually relatively direct, whereas others, such as the time of an event, usually need to be reconstructed. Finally, research on temporal metamemory may contribute to our understanding of aspects of metamemory that develop in late middle childhood and later (Schneider & Bjorklund, 1997).

The past findings most relevant to temporal metamemory in adults are reports of the strategies they use in arriving at their judgments on specific tasks, reports that include inferring the times of events from other information that is recalled, using impressions of the vividness of memories to gauge how long ago the events occurred, and directly retrieving the time (Friedman, 1993, 2001; Thompson, Skowronski, Larsen, & Betz, 1996). There do not appear to be investigations that have focused on adults' knowledge of how, in general, people remember the times of past events. (A search of *PsychInfo* combining "metamemory" with "time" or "temporal" produced no studies on the topic.) However, there is a developmental study that provides some information about this kind of knowledge. One of the questions Kreutzer et al. (1975) posed to kindergarteners through fifth graders in their pioneering study of metamemory development was how someone could remember the particular Christmas he got his dog. The relevance of their findings to temporal metamemory is limited somewhat by the use of coding categories that were developed for other purposes. However, the authors did find clear age increases in awareness that nontemporal information can sometimes provide a retrieval cue to the date of an event. They also found that many children at all ages mentioned general-purpose strategies, especially asking another person for help and using external records.

The paucity of research on temporal metamemory means that we have very little information available to tell researchers and legal and other professionals what children and adults know about the processes underlying memory for when past events occurred. We do not know whether adults have an accurate understanding of the properties of memory for time or the processes underlying the ability, and we have very little indication of whether children's understanding differs from adults' or when knowledge about this kind of memory develops.

To begin the study of the intuitive understanding of a phenomenon such as memory for time, it is useful to consider the scientific description of that phenomenon. In contrast to the very limited literature on humans' knowledge about temporal memory, it is possible to draw on a substantial body of theory and research on the processes that underlie actual recall of the times of past events. In a recent review of the research on adults' and children's memory for time, Friedman (2004; see also Friedman, 1993; Thompson et al., 1996) identified 10 main properties of humans' memory for time (Table 1). These properties led to the conclusion that memory for time depends on a number of distinct processes. The most important is reconstruction, combining remembered content about an event with one's general knowledge of personal, natural, and conventional time patterns to infer when the event must have happened. Evidence for the use of this process includes reports of methods of recall, correlations between temporal accuracy and the amount remembered about an event, and a phenomenon called "scale effects": the finding that judgments on fine timescales (e.g., time of day) are sometimes more accurate than those on grosser scales (e.g., month) (Friedman, 2001). Other studies support the conclusion that adults have access to impressions of the distances of events in the past—most likely based on the vividness of memories—which bear a partial correspondence to how long ago the events occurred. The evidence includes methods of recall and findings that adults can make partially veridical judgments about how long ago an event occurred even in conditions in which reconstruction is unlikely (Friedman, 2001; Friedman & Huttenlocher, 1997).

Two other processes, direct retrieval of dates and automatically storing the order of two events when one reminds us of an earlier one, seem to play a very limited role. Direct retrieval is used rarely (for the

Table 1
Ten Main Properties of Memory for Time (Friedman, 2004)

1. Memory for time is usually approximate in nature.
2. Judgments become less accurate with the passage of time.
3. The better an event is remembered, the more accurately its time can be estimated.
4. The times of events are sometimes judged more accurately on fine timescales than on grosser timescales.
5. The temporal contiguity of unrelated events is often poorly remembered.
6. The times of events are judged more accurately when they occur near temporal "landmarks."
7. The order of related events is judged more accurately than the order of unrelated events.
8. Information about distances of events in the past is available even when reconstructing their times is precluded.
9. The ability to use distance information depends on the ages of the memories.
10. The dates of a small minority of events can be directly retrieved.

small minority of events where rehearsal of the time is likely), but it is associated with considerable accuracy (Thompson et al., 1996). Automatically storing the order of pairs of events (Tzeng & Cotton, 1980) appears to be of even more limited applicability to autobiographical memory (Friedman, 2007). There is no evidence to support other theories (e.g., Hasher & Zacks, 1979; Yntema & Trask, 1963) that memories are uniformly assigned "time-tags" or that memory is intrinsically organized by the times that events occurred (e.g., Murdock, 1974).

In addition to the findings from studies with adults, there is evidence that children can distinguish the times of events on the basis of impressions of distances in the past by 4 years of age and that 4- to 6-year-olds can reconstruct the times of events on some timescales under some circumstances (Friedman, 2001, 2003, 2005; Friedman & Kemp, 1998; Friedman & Lyon, 2005). Evidence for the early use of distance-based processes includes the finding that 4-year-old children can discriminate the recency of two class events from the previous 2 months, even though they cannot localize them in conventional time patterns longer than a day (Friedman, 1991). However, the 4-year-olds did remember the approximate part of the day that an event occurred, a finding that can only be explained by their reconstruction of time of day.

The goal of this study was to determine the ages at which these properties and processes of memory for time are understood. An initial question is whether even adults have an accurate grasp of the properties and processes of temporal memory. The fact that theorists have disagreed about the processes underlying memory for time (Friedman, 1993, 1996) raises the possibility that adults are unaware of the nature and bases of these abilities. On the other hand, that adults have had repeated experience trying to recall the times of events, including both successes and failures, may lead us to expect a generally accurate intuitive understanding of the properties of and the processes underlying these abilities.

The second question is when children acquire this knowledge. As the previous discussion shows, some of the relevant time-memory abilities are present by 6 years of age. However, children may not be aware of these processes at the ages at which they are first used. The literature on metamemory has often revealed weak correlations between strategy knowledge and strategy use (Schneider, 1985), and children sometimes use strategies without being aware that they did so (e.g., Fabricius & Hagen, 1984). Furthermore, because occasions when children attempt to remember the times of past events are much less frequent than those in which they try to remember the content of those events, it might take years to develop an explicit awareness of the properties and processes involved in memory for time. These considerations led to three expectations about the development of temporal metamemory. The first is that children's initial ideas about memory for time are generalizations of their understanding of memory for content. Second, it was predicted that only at substantially later ages than generalizations appear will children understand the properties that are specific to memory for time. The third expectation is that there is a substantial delay between the age at which children first use a particular process and the age at which the process comes to be explicitly recognized.

An example of the first prediction about generalization from memory for content to memory for time would be recognizing that time judgments become less accurate as the retention interval increases (Property 2, Table 1). In light of past findings that even preschool children are aware that memory becomes poorer with the passage of time (Lyon & Flavell, 1993; Kreutzer et al., 1975), this generalization might be present by 6 years of age. However, generalization from memory for content will not explain all of the properties of memory for time and may even stand in the way of recognizing properties that are specific to this kind of memory. An example relevant to the second prediction is Property 4 (scale effects): that the time on fine timescales is sometimes remembered more accurately than on longer timescales. This knowledge cannot be generalized from what is known about memory for content because, unlike many other dimensions (e.g., how tall someone is), time is not experienced in an integral way. For example, we sometimes recall information that allows the reconstruction of time of day but not cues to day of the week. Properties like Property 4 that are specific to memory for time might not be recognized until late middle childhood or later. Similarly, following the third prediction, it is expected that children are not aware of the roles that processes such as reconstruction and impressions of distances play in memory for time until late middle childhood or adolescence, long after they are actually used to remember the times of past events.

The method of the first study was to ask participants a series of questions about how they would remember the times of events and the conditions that facilitate and impede memory for time. Some of the questions were used to elicit ideas about the processes that underlie memory for time. These ideas can be compared to processes such as reconstruction that have been identified in research. Other questions entailed predicting the likelihood of remembering the time of an event at each of several distances in the future and on several different timescales (to assess knowledge of Properties 1, 2, and 4, Table 1). Still other questions related to the usefulness and accuracy of different methods for remembering times (Properties 6, 8, 9, and 10) and the factors that make it easy or difficult to remember times (to assess awareness of Property 3). (Knowledge of two properties, 5 and 7, was not tested, because it is very unlikely that people have intuitions about them; they relate to phenomena that probably require formal study to detect. Indeed, even among researchers, there are disputes about the significance of these phenomena; for conflicting views about property 5, see, e.g., Aimone, Wiles, & Gage, 2006; Friedman, 2007.) In the second study, participants were again asked open-ended questions about how we remember the times of events, but these questions were supplemented by other, recognition tasks that did not require participants to generate methods and that included nonverbal judgments.

Study 1

Method

Participants

Participants included 91 children from public schools (two elementary schools and one middle school) in a small Midwestern town and the surrounding area. Participants were those whose parents granted written consent in response to letters sent home by the school. Children were not selected by any other criteria, but all were proficient in English. In addition, 20 undergraduates at Oberlin College were paid $10 for their participation. The overall population in the public schools was 52% white, 32% African American, 11% multiracial, and 5% other; 41% met the schools' criteria for being economically disadvantaged. There were 29 kindergarteners, 19 boys and 10 girls (M age = 5.87, SD = 0.26, range 5.4 – 6.3), 24 second graders, 11 boys and 13 girls (M = 7.87, SD = 0.29, range 7.4 – 8.3), 22 fourth graders, 10 boys and 12 girls (M = 10.02, SD = 0.39, range 9.4 – 10.7), and 16 sixth graders, 6 boys and 10 girls (M = 12.23, SD = 0.50, range 11.6 – 13.1). The undergraduates were evenly divided by sex and had a mean age of 21.18 (SD = 1.03, range 18.9 – 22.5).

Procedure

Each participant was tested in a single session of about 15 min or less. Children were tested individually in a quiet area of their school by one of two research assistants (RAs). The RA explained that he or she was going to ask some questions about how people remember when things happened. The RA then asked the series of questions presented in Appendix A in that order. The questions were ordered such that the RA did not introduce particular methods for remembering times until late in the interview (on Questions 7, 9, 10, and 11); through Question 6 participants were asked to generate methods themselves or predict whether or not a kind of temporal information would be remembered. The open-ended questions were designed to elicit participants' ideas about the processes underlying memory for time. The focused questions were selected to tap important properties of memory for time (e.g., how memory for time on different scales is affected by retention interval [RI]) or processes underlying temporal memory (e.g., using direct impressions of how long ago an event occurred).

If a child's response indicated a misunderstanding of a question, the RA repeated or paraphrased it. The phrases in parentheses in Appendix A could be used if a child seemed to require them. Answers were transcribed during the testing. At the end of the interview, children were thanked and asked not to talk about the interview with other children until everyone had been tested.

Undergraduates were tested individually in one of a number of quiet locations around their campus. The interview was the same as for the children, except for minor changes in wording and examples (e.g., a trip to a museum rather than the zoo; omission of paraphrases and examples of time units).

Scoring

Two RAs independently scored all of the participants' answers to all of the questions except the yes/no questions (e.g., Question 3a, Appendix A), which only the first RA scored. The RAs were instructed to score the answer to a particular question that was the clearest match to a category and to score the first response if multiple responses were equally good matches. For those answers scored by both RAs, they resolved disagreements by discussion. There were eight (partly overlapping) sets of scoring categories for different questions, and in the interest of space, these are not presented in detail. Instead, the most frequent and/or theoretically important categories are reported as relevant in the Results section. Interobserver agreement values are also reported in the Results section. Kappas were computed from tables in which individual participants' responses to a question were cross-classified according to the category assignments of the two RAs.

Results

Methods for Remembering Times

In the first series of questions (Question 1, Appendix A), participants were asked, for each of six timescales, how they could remember the time of a hypothetical event that they had experienced. Responses were assigned to one of 13 categories (averaging across the six scales, kappa = .83, range .79 – .87). The response category most frequent for adults was citing information that is differentiated on the timescale in question and thus could be used to reconstruct the time (e.g., percepts [such as the weather, or whether it was light or dark outside], activities, or events that would constrain the time on the scale in question, or proximity to another event whose time is known). Proportions of participants in each age group who produced responses assigned to this reconstruction-related category are presented in the first column for each grade in Table 2. A preliminary analysis of the frequency of use of this category, summed across the seven items in the table, failed to show significant sex differences in any group. (Few sex differences were found in later analyses in this study or in Study 2, and they are not further reported.) However, the age differences for each row were significant by chi-square tests (ps < .001). The proportions indicate that it is not until some time after 10 years of age that most children have a general understanding of the importance of remembering information that could be used to reconstruct the time. However, even 10-year-olds cite the utility of remembering differentiated information for the season scale. The low values for year are largely due to the frequent occurrence in the three older groups of a separately coded category of response that remembering one's age would help one know the year (a response that is also consistent with reconstruction). The most common remaining explanations fell in the categories "don't know," unclear, or giving a time with no real explanation, followed by doing something at the time of the event (e.g., recording the time) that would be useful for later remembering it (especially for children of about 8 and 10 years), directly retrieving the time (e.g., just know), using an impression of how long ago it was, asking parents or others, and general mental activity (e.g., think). (Several of these kinds of responses were also common in Kreutzer

Table 2
Proportion of Participants in Each Age Group Citing Temporally Differentiated Information as a Method for Remembering the Time for Each Timescale in Studies 1 and 2

Grade	K		2		4		6		College	
Study	1	2	1	2	1	2	1	2	1	2
Question 1										
Time of day	.14	0	.17	.13	.23	.48	.63	.68	.85	.95
Day of week	.10	0	.37	.13	.18	.26	.50	.53	.85	1.00
Month	.14	.04	.17	.37	.41	.46	.56	.74	.80	.85
Season	.27	.19	.33	.31	.77	.75	.94	.74	.85	.80
Year	.07	.04	.13	.07	.14	.17	0	.21	.50	.50
Age	.14	0	.30	.07	.09	.27	.31	.32	.70	.70
Question 2										
General question	0	.08	.09	.07	.10	.25	.25	.27	.75	.75

et al.'s 1975 study; see their Tables 22 and 23.) Responses suggesting direct retrieval of the time, which might be consistent with the theory that events are consistently assigned time-tags, only occurred on about 5% of answers. Those that might be consistent with chronological-organization theory—thinking backward through time (a type also found in Kreutzer et al.'s study)—were even rarer, 2%.

RAs next asked the closely related general question, ''What are some good ways of remembering when something happened?'' The proportions of participants who cited remembering temporally differentiated information, using the same criteria as in the previous questions, are presented in the last row of Table 2 (kappa = .85). The most common other response was doing something at the time of the event that would be useful in later remembering the time. The category was used most by fourth graders (25% of the group) and sixth graders (50%). This kind of response, here and in the earlier questions, suggests that children are generalizing what they know about how prospective measures help one remember something later (Kreutzer et al., 1975).

Two other questions, Questions 9 and 10, are relevant to awareness of the utility of information that can aid reconstruction. In Question 9 participants were asked whether an event's contiguity to one's birthday would help in remembering the month or season. Here and for later yes/no questions, responses were collapsed into two categories: affirmative (yes or probably) and other (no, probably not, maybe, don't know, or another response). The null expectation for these questions is .50 responding affirmatively. The proportions responding affirmatively were .62, .83, .91, 1.00, and .80 for the five age groups respectively, $\chi^2(4, N = 111) = 12.05, p < .02$. The proportion of participants giving an affirmative response was significantly greater than .50 for each age group except the youngest by binomial tests, $ps < .02$. The following proportions of the five age groups gave responses to the follow-up question (kappa = .68): .67, .91, .95, 1.00, and .95. Out of these participants, few kindergarteners and only one quarter of the second graders, but half or more of the older participants, gave a reasonable explanation of why the information is useful (e.g., knowing when one's birthday is, remembering the contiguity). These data provide some evidence of awareness of Property 6 (Table 1) by about 8 years of age, although only a minority of children at this age can explain why remembering contiguity to a datable landmark event would be useful in constraining the time.

In the other reconstruction-related question (Question 10), participants were asked whether remembering what the weather was like could help in remembering when an event happened. The proportions responding affirmatively were .76, .71, .77, .37, and .90, $\chi^2(4, N = 111) = 13.22, p < .02$. There is no clear developmental pattern in these findings, and responses to the follow-up question proved to be difficult to code reliably.

Effects of Retention Interval

Questions 3 through 6 test knowledge of the effects of the RI on remembering the time on different scales (e.g., time of day, day of the week, month). As noted previously, studies with children and adults have demonstrated such scale effects, and the phenomenon has been interpreted as evidence that people use remembered contextual information to infer when an event must have occurred (on whichever timescales the information constrains; Friedman, 2001). By examining the pattern of responses to these yes/no questions, we can consider three possible relations between timescale and RI that may underlie participants' answers. The first is an equal decline in memory for time on all scales. The second is more rapid loss of information on finer timescales (e.g., time of day) than grosser timescales (e.g., month). This can be described as the decay of precise temporal information to approximate temporal information (as if time were remembered as a unitary, continuous dimension like height). The third is principled violations of the second relation: Information relevant to the time on a fine timescale may be preserved whereas information relevant to a grosser scale is lost. This is consistent with separate memory for information about each scale.

The first nine data rows in Table 3 show the proportions of participants who responded affirmatively to the questions of whether they would remember the time tomorrow, 1 month from now, and 6 months from now. Analyses were conducted to answer three separate questions. The first is whether there are age differences in responses on each timescale and RI. The results of chi-square tests are indicated in the table. The data in Table 3 were subjected to Cochran's Q tests to answer two other sets of questions. One was whether children of a given age differentiated a given timescale by RI (e.g., whether proportions for the time-of-day scale differed between tomorrow, 1 month, and 6 months). The youngest group did not show significant RI differences for time of day, day of the week, or month, but all of the older groups did for all three scales ($ps < .05$). In nearly all of these cases, the proportion of affirmative responses declined continuously with increases in RI (consistent with Property 2,

Table 3
Proportion of Participants in Each Age Group Answering That They Would Remember the Time for Each Timescale and Each Retention Interval in Study 1

	Grade				
	K	2	4	6	College
Tomorrow (Question 3)					
Time of day**	.55	.75	.77	.87	1.00
Day of week*	.72	.88	1.00	.94	.95
Month	.83	.92	.95	.94	1.00
1 month from now (Question 4)					
Time of day*	.52	.54	.41	.50	.90
Day of week*	.69	.75	.64	.31	.40
Month	.72	.87	.95	.81	.90
6 months from now (Question 5)					
Time of day***	.62	.50	.18	.12	.65
Day of week***	.72	.54	.36	.19	.15
Month	.79	.65	.59	.50	.40
6 months ago (Question 6)					
Time of day**	.52	.50	.09	.19	.80
Day of week**	.62	.39	.36	.25	.10
Month	.59	.74	.64	.56	.40
Season	.69	.63	.77	.75	.85
Grade	.90	.87	1.00	1.00	1.00
Age	.93	.92	.91	.87	.95

*$p < .05$, **$p < .01$, ***$p < .001$ in chi-square tests for group differences.

Table 1). Kindergarteners' relative insensitivity to the effects of RI on the loss of information, most notably for day of the week, is reminiscent of the common finding in the metamemory literature of overestimating the number of items that will be remembered later (Flavell & Wellman, 1977; Schneider, 1999).

The remaining question was whether children of a given age differentiated the different scales for each RI (e.g., whether time of day, day of the week, and month differed in the "tomorrow" question). For tomorrow, the kindergarten and fourth-grade groups appeared to predict poorer memory for the time of day than the other timescales ($ps < .03$), whereas the other groups did not show significant scale differences. For the longer RIs—1 month and 6 months—all groups showed significant differences among the three scales ($ps < .03$), except the youngest group (for both of the longer RIs) and the second graders (for the 6-month RI).

The foregoing analyses, coupled with an examination of the data in Table 3, support the following description. Kindergarteners showed no evidence of awareness of any of the three relations between timescale and RI. Second graders understand that information is lost with the passage of time, but there is no clear indication that they expect more rapid loss of information on finer timescales. Fourth and sixth graders' data seem to reflect the second relation: Memory for time of day and day of the week decline more rapidly with increasing RI than memory of the month. This suggests that by about 10 years, children think that with increasing RI, precise temporal information decays to approximate temporal information. Only the undergraduates show a clear awareness that the time on fine timescales is sometimes remembered even when memory for the time on grosser scales is poor: After a 6-month RI, they predict that memory for time of day will be greater than for day of the week, a difference significant by sign test, $p = .004$. Adults appear to recognize that time is not integral and that what is remembered about an event can constrain the time on a fine but not grosser scales.

The last six rows of Table 3 show the answers to the questions about remembering the time of an event that happened 6 months ago (which essentially repeated the preceding three questions but added the scales season, grade, and age). Differences between the six scales are significant at each age by Cochran's tests, $ps < .001$. Kindergarteners predict the best memory for age and grade, perhaps because these are the scales most meaningful to them, and the older groups also have the greatest proportions of affirmative responses for the two annual scales. Second through sixth graders also predict better memory of season and month than day of the week and time of day, and fourth and sixth graders and adults appear to expect greater accuracy for season than month (all consistent with Property 1). However, the adults again show an exception to the pattern, present in most of the younger groups, of predicting poorer accuracy the finer the scale: They believe that time-of-day information will be better preserved over 6 months than day of the week ($p = .001$, by sign test) and month ($p = .021$). This expectation, shown here and in the preceding questions about RI, is consistent with the finding of scale effects in research on memory for time (Property 4). In addition, the questions about RI show that adults expect especially poor memory for day of the week. This also corresponds to findings in studies of children's and adults' memory for time that memory for day of the week is generally poor (e.g., Friedman, 1991; Friedman & Wilkins, 1985 [unless an event occurs on the weekend; Huttenlocher, Hedges, & Prohaska, 1992; Thompson, Skowronski, & Betz, 1993]).

Distance-Based Processes

Under favorable circumstances, children of about 4 years of age and older (and adults) are able to use direct impressions of amounts of elapsed time to judge how long ago a remembered event occurred (Property 8). Several questions in this study provide information about knowledge of the contribution of these distance-based processes to memory for time. In Question 7 participants were asked whether one could readily remember which was a longer time ago, a movie seen yesterday or one seen a year ago. The proportions responding affirmatively were .66, .54, .45, .63, and .95, for the five age groups respectively, $\chi^2(4, N = 111) = 12.67, p < .02$. Only the adults show a strong tendency to respond affirmatively to this question, $p < .001$ by binomial test; for the remaining groups, binomial tests were not significant. Answers to the follow-up question were given by .66, .54, .54, .63, and .95 of the participants in the five age groups, respectively. Of those participants, the following proportions responded with an explanation consistent with distance-based processes (e.g., differences in clarity, vividness, or amount recalled): 0, .08, .17, .60, and .84. (The kappa for the open-ended question was only .70, but, when responses were dichotomized according to whether or not the critical distance-based category was used, the kappa was .91.) In this dichotomous tabulation, group differences were significant, $\chi^2(4, N = 73) = 39.62$, $p < .001$. These results indicate that before about 12 years of age, few children understand how qualities of memories that change with passage of time contribute to a sense of when the events occurred.

In another two questions, 11a and 11b, participants were asked directly to evaluate the usefulness of the clarity of memories. When asked whether this would help someone remember how long ago an event had occurred, the following proportions responded affirmatively for the five age groups respectively: .57, .67, .36, .38, and .40. A chi-square test for age differences was not significant. A relatively large proportion of the fourth and sixth graders' and undergraduates' responses to this yes/no question were assigned to the subcategory "other:" .18, 0.13, and .40, respectively. The following proportions of the age groups gave responses to the open-ended follow-up question: .59, .73, .57, .63, and .90. These were combined with explanations that were spontaneously given in response to the yes/no question but proved difficult to code reliably (kappa = .61). However, a reason for the undergraduates' frequent "other" responses to the yes/no question is apparent. Seventy-eight percent of their responses (but only 20% of the sixth graders') were statements about the unreliability of the clarity of a memory for judging its age. (The kappa for whether or not this category was used was .88.) These included statements that an especially memorable old event might be remembered more clearly than a recent one, that beyond a certain RI, this information is less useful (Property 9), and that clarity does not provide sufficiently precise information. Together, the findings for Questions 7, 11a, and 11b show that some 12-year-olds and most adults are aware of the role that distance-based processes play in memory for the times of events, and adults are especially sensitive to the limitations of this kind of information.

Attributes of Memories

Research with adults shows that accuracy in judging the time of an event depends on how well the event is remembered (Property 3). Responses to Questions 8a and 8b provide information about participants' awareness of this relation. In Question 8a they were asked, "What helps us remember really well when something happened?" and the follow-up question, "What else?" The response category most relevant to Property 3 was describing qualities of events that make them especially memorable (e.g., their emotional valence, novelty, or personal importance). The following proportions of participants gave at least one response falling in this category (kappa = .93): .07, 0, .27, .63, and .75 for the five age groups, respectively, $\chi^2(4, N = 111) = 45.30, p < .001$. Question 8b concerns what makes it difficult to remember the time of an event. One response category was the lack of distinctiveness or importance of the event (e.g., routine, ordinary, boring, confusable with other events). The proportions of participants producing answers in this category once or twice (kappa = .91) were 0, .12, .09, .38, and .95, $\chi^2(4, N = 111) = 64.64, p <$ .001. These results suggest that adults and many or most children of about 12 years, but few younger children, are aware of the relation between how well an event is remembered and our accuracy in judging its time.

Discussion

This study was conducted to provide information about children's and adults' knowledge of the properties of memory for the times of past events and of the processes that underlie temporal-memorial abilities. Knowledge of the properties of memory for time can be compared with some of the main phenomena found in research on the topic (summarized in Table 1). The sample of adults tested in this study showed an awareness of all of those properties for which there are relevant data. Knowledge of the approximate nature of memory for the times of most events (Property 1) can be seen in the predictions of what will be remembered after 6 months (Question 6): Most undergraduates predicted that the season of the event will be remembered after this interval of time, but fewer than half believed the month would be remembered. Awareness of Properties 2 and 4 can also be inferred from answers to the questions about the effects of RI on temporal accuracy (Questions 3–6). The adults predicted a loss of temporal information with the passage of time, but they expected time of day to be remembered even after information relevant to the time on some longer scales is forgotten. Responses relevant to Property 3, the correlation between how well an event is remembered and accuracy in judging its time, are found in answers to Question 8. Most undergraduates articulated the view that it would be easier to remember the times of memorable events than those that were indistinct. The adults also agreed with the usefulness of an event occurring near a dateable landmark (Property 6). Responses to the questions relevant to Property 8 revealed an understanding that differences in the clarity of memories can help us determine how long ago they occurred. The undergraduates also recognized the limitations of such information, with some of them pointing out that differentiation is lost with the passage of time (Property 9). There are no clear findings relevant to Property 10—that direct retrieval of the temporal location is possible for only a small minority of events. No group contradicted the principle, for example by usually responding to Question 1 that "you just remember." But few, if any, participants responded to the open-ended questions by pointing out that direct retrieval is possible for a very limited number of events, and there was no relevant focused question.

The findings of this study also show that adults recognize the contributions of two of the processes that have been supported by research: reconstruction and distance-based processes. In response to questions about how they could remember the times of events, the undergraduates frequently cited remembering information that could be used to reconstruct the time. They also recognized that one would know immediately (on the basis of clarity, vividness, or the completeness of memories) which was a longer time ago, an event that was yesterday or one that happened last year. There was no evidence that adults believe that information about the times of all events is directly available, as might be expected if time-tagging theory or the theory that memory is chronologically organized were correct. In fact, many of their responses indicate that adults believe that it is difficult to judge the times of events unless one can remember enough about them.

Adults' belief in the necessity, in most cases, of reconstructing times is probably not a simple generalization of their beliefs about other kinds of memory. For example, adults probably view remembering the location of an event as a more direct process than remembering its time. To test this prediction, relevant questions were included in a separate survey of adults' experience of time. Thirty-eight undergraduates were asked to rate how they would remember, for some event, when it happened and where it happened. Each type of information was rated on a 7-point scale, with the value 1 labeled *remember directly* and the value 7 labeled *figure out from other remembered information*. The mean rating for "when" was 4.97 (SD = 1.65), and the mean for "where" was 2.66 (1.65), $t(37) = 6.66, p < .001$. These results show a substantial difference ($d = 1.40$), with location falling toward the direct-remembering end of the continuum and time falling toward the reconstruction end. Adults clearly understand that different processes underlie memory for time and memory for space. Together with a variety of findings from Study 1, these results show that adults possess considerable, and largely accurate, knowledge about the workings of memory for the times of past events.

The questions considered next are whether children's understanding of memory for time differs from adults' and, if so, in what ways. There is no evidence that children younger than 10 years understand that memory for time is usually approximate rather than precise (Property 1). This inference comes from the apparent pattern that it was not before this age that children predicted that after a 6-month RI, accuracy would be greater for month than day of the week or time of day (Question 5) or accuracy greater for season than month (Question 6). However, by 8 years of age children predicted a general loss of temporal information from 1-day to 1-month to 6-month RIs (Property 2). The relatively early awareness of the loss of temporal information with the passage of time can be explained as a generalization from children's knowledge about memory for content. Implicit knowledge of a more complex relation between RI and accuracy, that accuracy is sometimes greater on finer than grosser timescales (Property 4), appears to be uncommon in any of the age groups tested except for the adults. This is consistent with the prediction that properties that cannot be generalized from memory for content will first be understood in late middle childhood or adolescence. Awareness of the correlation between how well an event is remembered and temporal accuracy (Property 3) was not evident in children's answers before 12 years of age. Property 6 is that events can be judged more accurately if we remember that they occurred near dateable landmarks. By 8 years most children agreed with this proposition in a yes/no question (Question 9), and by 10 years most gave a reasonable explanation for why the information is useful.

Children do not seem to be aware of distance-based processes or their limitations (Properties 8 and 9) before 12 years, and even among the sixth graders such knowledge was not evident in the majority of children. However, an intuitive understanding of the other main process underlying humans' memory for time, reconstruction, appeared somewhat earlier. By 10 years in the case of seasons and 12 years for most other timescales, the majority of children indicated that remembering information that is differentiated on a particular scale could help one remember when it occurred. The age trends for reconstruction are comparable to those for Kreutzer et al.'s (1975) most closely related question (Retrieval: Event) and category (Indirect). Nearly half of their fifth graders but fewer than one third of children in younger age groups produced responses falling in this category.

Study 2

These conclusions about awareness of the processes underlying memory for time are based largely on answers to open-ended questions. However, it is possible that children recognize some of the processes at earlier ages than they can spontaneously think of them. For this reason a second study was conducted that included recognition measures. Another change was the introduction of tasks that included nonverbal judgments, which might also increase the chance of detecting knowledge at earlier ages than tasks requiring explanations. The three principal methods adults use to judge the times of past events—reconstruction, distance-based processes, and direct retrieval—were presented to participants, each represented in pictorial form, and participants were asked to evaluate them. In some of the evaluations, participants responded by pointing to one of several choices, thus avoiding the requirement that they explain their reasoning. The inclusion of open-ended questions as well made possible a comparison between production and recognition measures. The open-ended questions were presented first, so responses were not biased by prior presentation of specific methods for remembering the times of events. In addition, particular methods were presented in random order in the recognition tasks, so differences between them are not the result of order-related effects.

In the second study, the stimulus event was one that had almost certainly never occurred to the participants. It could be argued that children's responses to the questions about ways of remembering the times of events in the first study were influenced by accessing cognitive scripts for going to the zoo and a movie. Reasoning about a nonschematic event may provide more accurate measures of general temporal metamemory, ones not affected by participants simply accessing script information in response to the questions.

Method

Participants

Participants were 87 children from the same schools as in Study 1 whose parents granted written consent and 20 Oberlin College undergraduates. The undergraduates were paid $5 for their participation. There were 28 kindergarteners, 13 boys and 15 girls (M age = 5.99, SD = 0.33, range 5.42–6.53), 16 second graders, 7 boys and 9 girls (M = 7.90, SD = 0.41, range 7.45–8.63), 24 fourth graders, 10 boys and 14 girls (M = 10.00, SD = 0.35, range 9.57–10.98), and 13 sixth graders and 6 other 12-year-olds from a developmental psychology laboratory pool, 12 boys and 7 girls (M = 12.20, SD = 0.42, range 11.44–13.00). Volunteer families from the laboratory pool supplemented the sixth graders, because relatively few families responded to a first and second distribution of recruiting letters. The two groups were comparable in the sum of reconstruction-related responses in Questions 1 and 2, $t(17)$ = 0.10. None of the children had participated in Study 1. The undergraduates were evenly divided by sex and had a mean age of 20.37 years (SD = 0.94, range 18.63–22.11).

Procedure

Children were tested individually in a quiet area of their school. One of the two RAs explained that she was going to ask some questions about how people remember when things happened. The interview procedure is presented in Appendix B. Other aspects of the interview were modeled after the methods used in Study 1.

Stimuli

Figure 1 shows the picture (21.5 × 28 cm) used for judgments of the quality of ways of remembering. Figure 2 shows the representations (21.5 × 21.5 cm each) of reconstruction, vividness, and direct retrieval.

Scoring

Two RAs independently scored all of the participants' answers to all of the questions except the yes/no questions and those where the child responded by pointing. For those answers scored by both RAs, they resolved disagreements by discussion. Scoring categories and interobserver agreement values are reported as relevant in the Results section.

Results

Open-Ended Questions

Responses to the questions about how one could remember the time of the stimulus event were coded using the same categories as in Study 1. The first six data rows of Table 2 show the proportions of participants whose responses fell in the same first category as in Study 1, citing information that is differentiated on the timescale in question and thus could be used to reconstruct the time. (The data for Study 2 are presented in the second column for each grade.) The mean kappa for these six questions is .89 (range .80–1.00). The last row is for the general question, Question 2 (kappa = .91). The age differences for each row were significant by chi-square tests (*p*s $< .002$). The pattern replicates the one found in the first study: References to temporally differentiated information were made mainly by participants older than 10 years. However, as in that study, most children of about 10 years produced answers consistent with an awareness of reconstruction for the season scale. Also as in Study 1, the low values for year are largely due to the frequent occurrence in the three older groups of another category of response: that remembering one's age would help one know the year (a category that is also consistent with reconstruction).

The most common remaining responses were giving a time with no real explanation, doing something at the time of the event that would be useful for later remembering it (mainly produced by fourth graders), and unclear or "don't know." Only about 2% of answers fell in the category most closely corresponding to direct retrieval of the time, and only about 1% suggested using information related to temporal distances in the past.

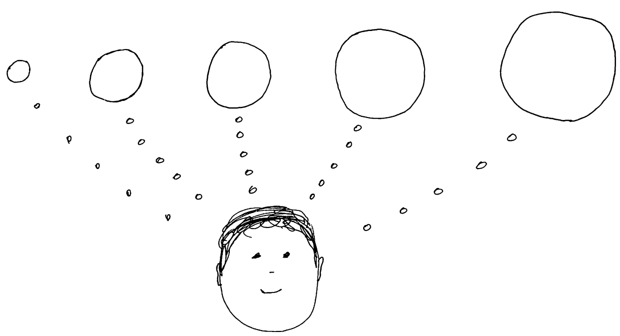

Figure 1. The representation used for metric ratings of the memory methods in Study 2.

Metric-Rating Task

During the training portion of the metric task, participants were introduced to a rating scale using an example of memory for content. They were asked to rate two methods for remembering a telephone number, repeating it and thinking about other things. Mean ratings are given in the first and third data rows of Table 4. (Ratings of 1 correspond to *not a good way*, 2 to *OK but not very good*, 3 to *in-between*, 4 to *a pretty good way*, and 5 to *a really good way* to remember.) To test whether children as young as 6 years can understand this task, kindergarteners' ratings on the two questions were compared. Repeating the telephone number was given a higher rating by the kindergarteners, $t(27) = 3.90$, $p = .001$. Age differences were also significant by ANOVAs (*p*s $< .001$) for both of the training the questions. While there is no clear developmental pattern for repeating the telephone number, ratings of thinking about other things showed a near monotonic decline.

Ratings of the three ways of remembering the time of the stimulus event are presented in the remaining rows of Table 4. An ANOVA was conducted with the three temporal methods as a within-subject factor and age group as a between-subjects factor. Both main effects and their interaction were significant: Method, $F(2, 204) = 12.59$, $p < .001$, partial eta squared (η^2) = .16, Age Group, $F(4, 102) = 4.92$, $p = .001$, $\eta^2 = .16$; and their interaction, $F(8, 204) = 6.87$, $p < .001$, $\eta^2 = .19$. In separate tests for age-group differences for each of the three methods, only vividness showed significant group differences, $F(4, 106) = 14.87$, $p < .001$, $\eta^2 = .37$. The pattern was a near monotonic decline with age. The three younger groups gave this method a positive rating, whereas the sixth graders and adults rated it below the neutral point of the scale. Reconstruction and direct retrieval were rated positively on average by each age group. Tests for the differences between the three methods within age groups were significant for each group, *p*s $< .05$, except the fourth graders.

Before participants made their ratings on each of the three depicted methods of remembering the time, they were asked if the method could help remember the time and how it could help. The proportions

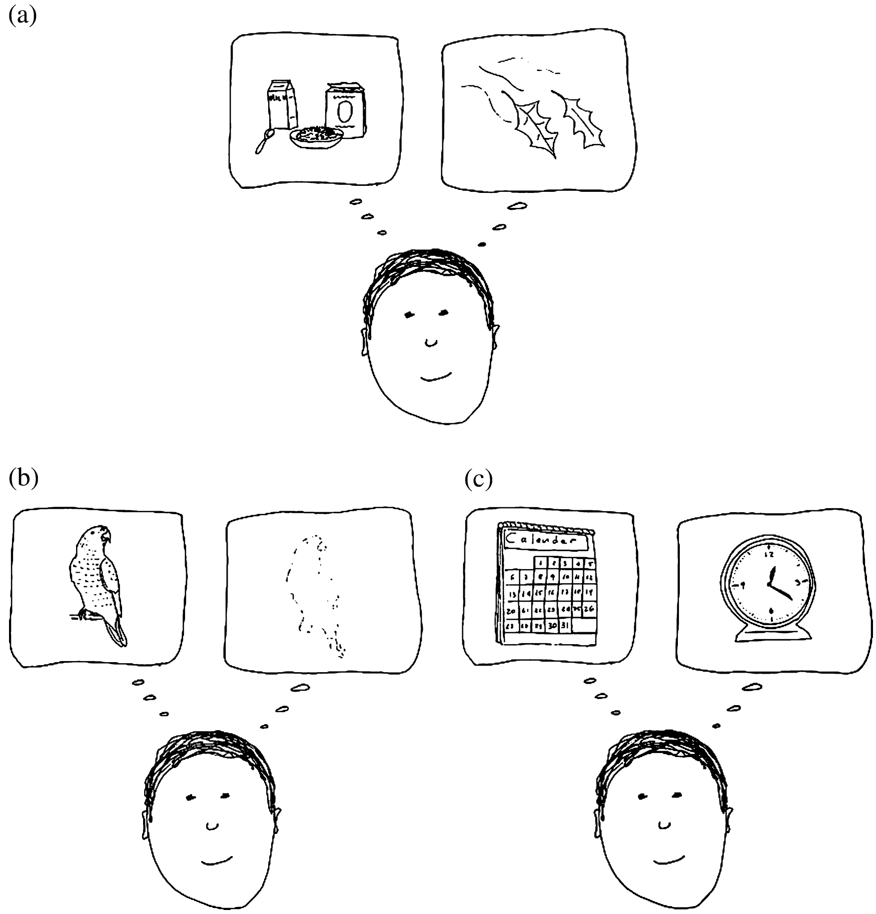

Figure 2. The representations used to depict reconstruction (top), vividness (bottom left), and direct retrieval (bottom right) in Study 2.

giving affirmative responses (yes or probably) to the yes/no question were generally consistent with the metric ratings. Between .73 and 1.00 of each age group gave positive responses to reconstruction, and between .88 and 1.00 did so for direct retrieval. For vividness, the proportions for the five age groups, respectively, were .81, .50, .75, .53, and .50. Age differences approached significance for vividness, $\chi^2(4, N = 106) = 8.99$, $p = .061$, and were not significant for the other measures. The failure to show a continuous decline in evaluations of vividness could be due to the second graders responding by chance on this question. In any case, sixth graders and undergraduates gave vividness substantially fewer positive responses than the other two methods (*p*s $< .04$ by sign tests), but the differences were not significant for the younger groups.

Answers to the question "how could it help?" were assigned to separate coding categories for each of the three methods. For the reconstruction method, the kappa was only .74 for assignment to one of nine categories. However, when responses were dichotomized according to whether or not a response fell in one of the three categories that indicate an understanding of reconstruction (pointing out that the information tells the time of day and/or season, giving a correct temporal interpretation of one or more of the cues, or a general statement that the information would tell when the event had occurred), the kappa was .94. Only four participants (three kindergarteners and one second grader) did not answer this question. The proportions of the remaining participants giving responses in these categories, for the five age groups, respectively, were .04, .37, .61, .68, and .90. The age differences were significant, $\chi^2(4, N = 105) = 39.85$, $p < .001$. As for the initial open-ended questions, explicit references to reconstruction were not predominant before about 10 years of age. (In the initial questions, such references were only produced by the majority of children of about 10 years for the season question.)

Table 4
Metric Ratings of Ways of Remembering for Each Age Group in Study 2

	Grade				
	K	2	4	6	College
General memory					
Repeating telephone number					
M	4.42	3.13	3.87	3.16	3.65
SD	1.03	1.20	0.85	0.83	0.88
Thinking of other things					
M	2.89	2.56	1.75	1.92	1.05
SD	1.57	1.50	1.03	1.03	0.22
Temporal memory					
Reconstruction					
M	3.64	4.00	3.87	3.47	4.30
SD	1.50	0.82	0.99	1.12	0.66
Vividness					
M	4.57	3.38	3.42	2.84	2.15
SD	1.00	1.40	1.14	1.17	0.99
Direct retrieval					
M	4.18	4.37	3.71	4.05	3.55
SD	1.31	0.89	1.04	1.03	1.32

It also proved difficult to reliably assign responses to the question of how vividness could help to the original seven categories. However, if responses were dichotomized according to whether or not the participant mentioned that vividness tells the age of a memory, there was good agreement, .92. The proportions in each age group who answered this question were .79, .87, .92, .84, and .90. The following proportions of them produced a correct interpretation of vividness: 0, .07, .09, .19, and .50. Age differences were significant, $\chi^2(4, N = 93) = 21.17$, $p < .001$.

Responses for direct retrieval could be consistently categorized in one of seven categories, kappa = .85. Age differences were significant, $\chi^2(24, N = 107) = 54.95$, $p < .001$. The most common response category was giving an answer based on the assumption that the date and/or time information *would* be noticed and remembered (e.g., stating that this information would tell the month, day, or time of day). Responses falling in this category were given by .38, .88, .75, .89, and .30 of the five age groups, respectively (excluding the two kindergarteners who did not answer this question). Forty percent of the adults, but 12% or fewer of children in the younger age groups, expressed doubt that such information would actually be remembered. Apparently, relatively few adults used these questions as an occasion to express the view that direct retrieval is not a common way of remembering the times of past events, a view that was shown in the categorization task reported in the following section and in the separate study of undergraduates reported in the discussion of Study 1. In the latter, memory for time was rated toward the reconstruction end of the continuum rather than the end representing remembering directly. Probably, the positive ratings of direct retrieval by adults and most other age groups in the metric-rating task of Study 2 were based on judging how good the method would be *if* date and time information were remembered.

Categorization of Methods

In the final task participants were asked to choose among the pictures representing reconstruction, vividness, and direct retrieval when asked which way of remembering the time is best, used most often, worst, and not used much. Responses are presented in Table 5. Age differences were significant for each of the four questions by chi-square tests, *p*s $< .04$.

Adults' responses are consistent with the view that reconstruction is the most accurate and widely used method for remembering the times of past events. Vividness is judged to be inaccurate and seldom used. Adults believe that direct retrieval is used infrequently, but apparently they do not view it as inaccurate when it is employed.

The kindergarten group produced an inconsistent pattern. The most frequently selected choice for best method, vividness, was also the worst, and that for most often used, direct retrieval, was also the one most often chosen for "wouldn't use much." These inconsistent responses could be due to a failure to understand the three ways of remembering the times of events, the way they are represented, or the task.

Most children from Grades 2 through 6 judged direct retrieval to be the best method (and few judged it the worst method). In contrast to adults, direct retrieval was rated as a common method of judging the times of past events. However, second through sixth graders appeared to share adults' unfavorable evaluation of vividness and the view that it is not used frequently. Views of the accuracy of reconstruction and the extent to which it is used are less clear in these three groups. There is an indication that negative evaluations of reconstruction decline from second to sixth grade (although a chi-square tests for age differences for "worst" was not significant for these three age groups). However, even sixth graders do not seem to share adults' belief that reconstruction is the most common method of remembering the times of past events. Sixth graders and adults had significantly different distributions of choices for the method most often used, $\chi^2(2, N = 41) = 12.50$, $p = .002$.

Table 5
Proportion of Participants in Each Age Group Choosing Each Method in Study 2

	Grade				
	K	2	4	6	College
Best					
Reconstruction	.18	.19	.21	.21	.70
Vividness	.43	.12	.21	.10	.05
Direct retrieval	.39	.69	.58	.68	.25
Most often used					
Reconstruction	.26	.40	.33	.37	.90
Vividness	.18	.20	.17	.11	.05
Direct retrieval	.56	.40	.50	.53	.05
Worst					
Reconstruction	.32	.44	.29	.21	0
Vividness	.50	.56	.50	.74	.95
Direct retrieval	.18	0	.21	.05	.05
Wouldn't use much					
Reconstruction	.29	.44	.38	.16	0
Vividness	.28	.44	.33	.53	.65
Direct Retrieval	.43	.13	.29	.32	.35

Even though the second through sixth graders responded with some consistency, it is unclear whether their responses were based on the evaluation of the actual methods that the pictures were intended to represent. For example, their rejection of vividness may be due to a lack of understanding of how the vividness of a memory could convey information about its age. Unfortunately, the follow-up ''why'' questions did not clarify children's understanding of the representations and the methods. In answering these questions, children sometimes made points about methods other than the one they chose, by way of contrasting them, so advantages and disadvantages of each of the three methods were coded wherever they occurred. Despite this method of selecting responses, on average fewer than half of participants gave answers to each of the six combinations of methods and advantages or disadvantages, and these responses proved difficult to categorize consistently (mean kappa = .65, range .57 – .77).

Relation Between Categorization of Methods and Metric Ratings

Metric ratings of the three methods were examined as a function of which of the methods was selected as the best one in the categorization task. When participants were divided according to the best method they selected, this method also received the highest mean metric rating of the three. This pattern was supported by an ANOVA, with choice of best method as a between-subjects factor and metric rating of each of the three methods as a within-subject factor. The interaction was significant, $F(2,106) = 15.93$, $p < .001$, $\eta^2 = .23$, supporting the conclusion that judgments on the two tasks were related.

Discussion

The second study was conducted to provide additional information about children's understanding of the three main processes underlying adults' memory for the times of events: reconstruction, vividness, and direct retrieval. Participants were posed the same open-ended questions used in the Study 1, and they were then introduced to representations of the three methods and asked to evaluate them in two tasks involving both pointing and explanations. In Study 2 the stimulus event was chosen so that participants could not rely on schematic knowledge about the times at which a particular type of event could occur.

Even with the change in type of stimulus event, the results of the open-ended questions were quite similar to those of Study 1, supporting the generality of those findings. For most timescales, reconstruction-related explanations of how one could remember the time were predominant only after 10 years, but most children of about 10 years produced reconstruction-related explanations for the season scale. Other findings that repeat those of the first study were that participants very rarely referred to vividness or direct retrieval in response to the open-ended questions, and many responses appear to be generalizations from their knowledge about memory for content.

Together with the findings from the metric and categorization tasks, these results support a number of conclusions about the development of knowledge of the three methods. For the first method, reconstruction, the emergence at about 10 years of reconstruction-related responses to the initial open-ended questions was supported by age differences in explanations of the metric ratings. Here, a majority of participants in the fourth-grade and older groups produced responses consistent with an understanding of reconstruction. Knowledge that reconstruction is the most widely used method of remembering the times of events emerged later: Only the undergraduates chose reconstruction as the most frequent way of remembering the times of events (Table 5).

The second method assessed in this study was using the vividness of memories to judge their ages. Other than the adults, very few participants explained their metric rating of vividness in terms of the correlation between the clarity and recency of memories. There was a decline with age in ratings of how good this method is for remembering times, and it was only in the two older groups that vividness received a high rate of ''worst'' judgments. However, it is likely that the more positive metric ratings (and the fewer ''worst'' judgments) in the kindergarteners and second and fourth graders were based on a misunderstanding of the method. In fact, the most common explanation in these age groups was simply an appreciation of the value of having a clear memory of an event. Together with the results of Study 1, these findings indicate that an awareness of the role that distance-based processes play in memory for the times of events is not present until some age after 10 years.

The third method of remembering times, direct retrieval, was evaluated positively throughout the age range. This was true for the metric ratings, answers to the question ''could it help?'' and low rates of assigning it to the ''worst'' category. However, adults were less likely than younger participants to consider this to be the best method, probably because they held a different view about how frequently information about the time of an event is directly available. In their choices of the method most often used, and in their explanations of their metric judgments, adults were much more likely than other age groups to reflect the belief that direct retrieval is not a common way of remembering the times of past events. These findings (and those of the separate study of adults presented in the discussion of Study 1) show that adults are aware that direct retrieval is used but only rarely (Property 10, Table 1). Children as old as 12 years do not seem to understand the exceptional nature of direct retrieval: About half of children of this age and younger judged it to be the method most often used to remember the times of events. Unfortunately, we cannot tell from the present findings exactly how children conceive of the method of direct retrieval (or their interpretation of the depiction and accompanying description of the method used in this study). Explanations of their metric ratings shed little light on the questions. The great majority of children from second through sixth grade simply explained that this information would tell one the time or date.

Despite the inclusion of nonverbal tasks and the use of ones where children did not need to generate methods themselves, there was no evidence that the processes underlying memory for time are understood at earlier ages than was suggested by the open-ended questions. For example, children first gave explanations showing an awareness of the method of reconstruction at about 10 years both in open-ended questions, where no particular methods were suggested by the tester, and those in which the method was introduced to them. In a review of research on metamemory for content, Schneider (1999) interpreted a number of studies as showing that interview and recognition measures lead to generally consistent findings. The use of nonverbal tasks also did not reveal an earlier awareness of the processes than the open-ended questions. Findings from the pointing part of the categorization task indicated that awareness of the importance of reconstruction emerged at at least as late an age as in the open-ended questions. This conclusion must be treated with caution, however, because of the difficulty of representing ways of remembering times and the fact that the nonverbal judgments in themselves do not tell us whether or how children understood the representations.

General Discussion

The findings of this study show that adults understand most of the main properties of memory for time. Study 1 provided evidence for their awareness of Properties 1, 2, 3, 4, 6, 8, and 9 (Table 1), and Study 2 revealed an understanding of the rarity of directly retrieving the times of events (Property 10). The two studies also showed adults' substantially accurate knowledge about the three main processes that contribute to humans' memory for time: reconstruction, using impressions of distance, and direct retrieval. They know that reconstruction is the dominant process, that distance-based processes provide limited temporal information, and that direct retrieval is only rarely used. The findings for the younger samples showed that in early middle childhood, children know little about the workings of memory for time and that their understanding increases substantially through late middle childhood and adolescence. In the following discussion, the developmental findings are related to the predictions and to related research.

The property of memory for time that is first recognized may be generalized from an understanding of memory for content, consistent with one of the predictions advanced in the introduction. The 8-year-olds tested in this study understood that memory for the time of an event declines with the passage of time, and even 6-year-olds or younger children might show this knowledge if questions did not require familiarity with conventional time units. As noted earlier, there is evidence that even preschool children are aware that memory becomes poorer with the passage of time (Kreutzer et al., 1975; Lyon & Flavell, 1993), so the understanding of the loss of temporal information with RI, by at least 8 years, may be a modest generalization from well-established knowledge about memory for content. Other evidence for such generalization was found in the tendency of some children from kindergarten through sixth grade to propose recording the time of an event when it occurs (or some other prospective measure) as a way of helping one remember the time. Prospective measures to aid memory for which Christmas an event occurred were mentioned even by kindergarteners in the Kreutzer et al. (1975) study, as were ''the use [of] other people as storage and retrieval devices'' (p. 51), another apparent generalization found in the present study. However, many of the prospective measures cited in the present study and, as they suggest, in the Kreutzer et al. study might be more accurately described as overgeneralization. We seldom record the times of trips to the zoo or going to movies in the expectation that this information will later be needed, and this seems even less likely if one saw a parrot at the window.

Another possible overgeneralization from metamemory for content to metamemory for time was found in older children in this study. From the time that children begin to distinguish memory for time on different timescales (at about 10 years of age) through at least 12 years, they assume greater forgetting on fine than grosser timescales. This is a quite reasonable extension of a view that adults appear to hold (Goldsmith, Koriat, & Pansky, 2005), and children might share by middle childhood, that with increasing RIs memory for gist remains even after memory for precise details is lost. In overextending it, the fourth and sixth graders in the present sample seem to assume that time, like many other things that can be measured, is integral. The undergraduates' predictions that accuracy will sometimes be greater on fine than grosser timescales show that adults, in contrast, do not regard memory for the time of an event as memory for an integral quantity. This example shows that important properties that are specific to memory for time are learned during adolescence.

It was also predicted that properties that are specific to memory for time will not be understood until substantially later ages than those that can be generalized from memory for content. Consistent with this prediction, much of the other knowledge that appears at about 10 years or later may also depend on learning properties and processes that are specific to memory for time. These include the usually approximate nature of this kind of memory, the correlation between memorability and temporal accuracy, and awareness of the roles of distance-based processes and reconstruction. The only evidence for time-memory-specific knowledge at earlier ages was evaluating positively the utility of remembering that a target event happened near a temporal landmark, and even for this property children did not produce adequate explanations before 10 years.

The late appearance of knowledge specific to memory for time that was observed in this study is not likely to be a consequence of the timing of formal instruction, because children probably do not receive such instruction. More plausible are accounts based on abstraction of knowledge from one's own experiences of remembering the times of events, perhaps in conjunction with adults' modeling and supporting such remembering (Flavell & Wellman, 1977). Some authors have argued that social interaction is critical in developing an understanding of a number of aspects of temporal knowledge that are acquired early, such as tense and the continuity of the self over time (Fivush & Nelson, 2006; Nelson, 1996; Nelson & Fivush, 2004), and observations show that parents use a considerable amount of time language even with young children (e.g., Hudson, 2002). We do not know whether parent–child conversations include information that could be used by children to learn about how one remembers the times of past events. Parents may well engage in overt reconstruction in arriving at a time, but young children might have little appreciation of what their parents are doing and, as has been noted, remembering the times of events is much less common than remembering content. For these reasons, it may take children a considerable period of time to accumulate a sufficient set of interactive or individual experiences from which to abstract knowledge that is specific to time.

Another issue raised by the present findings is the developmental relation between use and awareness of mental processes. According to the third hypothesis presented in the introduction, there is a substantial delay between the ages at which children use particular time-memory processes and their awareness of those processes. Distance-based processes are used to judge the times of past events in children as young as 4- and 5-year-olds (Friedman, 1991; Friedman, Gardner, & Zubin, 1995; Friedman & Kemp, 1998). But the results of this study show that it is not until much later, between about 10 and 12 years, that children become aware of how qualities of memories that change with the passage of time contribute to a chronological sense of the past. In the case of reconstruction, past research has shown that even 4-year-olds can use their memory that an event took place in nursery school to infer that it must have taken place in the morning (Friedman, 1991), and by 6 to 7 years of age, children can evaluate the usefulness of cues to the times of events, interpret them if they have sufficient knowledge about relevant time patterns, and use logical constraints in explaining their time judgments (Friedman, 1991; Friedman & Lyon, 2005). Yet it was not until about 10 years in the present study that most children revealed an awareness of reconstruction, and it is not until some time after 12 years that reconstruction is recognized as the most commonly used way to remember times.

The expectation of a delay between use and awareness in these cases was based on the relative rarity of remembering the times of events and on the findings in the general metamemory literature showing a weak relation between awareness of strategies and their use (Schneider, 1985). In the case of distance-based processes, another factor contributing to the delay may be the rapidity of the processes (Curran & Friedman, 2003; Friedman, 1996), which may make it difficult for children to recognize that they use them to judge the ages of events. Furthermore, previous research suggests that distance-based processes usually serve as a backup to reconstructing the times of events (when reconstruction is possible) and are therefore unlikely to be used much by children once both processes are available. There was some indication that children become aware of the role of reconstruction in memory for time (by about 10 years) before they recognize distance-based processes (by about 12 years). This could be explained by the fact that reconstruction is the primary process used (at least by adults) to remember the times of events (Friedman, 1993), and it is not as rapid as distance-based processes (Curran & Friedman, 2003). Even so, these findings suggest that there is a delay of several years between children's use of reconstruction and the presence of a general understanding of its role in their memory for time. To the extent that reconstruction is considered a strategic process, these results show that memory strategies are sometimes used at earlier ages than children become aware of their importance.

The findings of this study can also be related to those in the literature on children's understanding of mental processes. Research by Lalonde and Chandler (2002) has shown substantial changes between 5 and 7 years of age in children's understanding of the active, interpretive nature of minds. These changes are revealed in tasks in which children are tested on their ability to attribute two different false beliefs to two characters who are given inadequate information about a picture. The present study showed the much later development of the understanding of another kind of interpretation, that the times of past events must usually be reconstructed. Of course, recognizing that nontemporal information can be assessed for temporal relevance is more complex than recognizing that different people construct different interpretations when given partial information about a picture. A particular challenge is the need to consider the interaction between multiple kinds of knowledge. Another difficulty for understanding temporal reconstruction is that even within the realm of memory, some kinds of remembering are more direct than others. As was seen, adults view memory for the location of an event as a more direct process than memory for its time. Perhaps children need to learn to differentiate types of memory according to the direct or constructive nature of the underlying processes. Further research on children's understanding of the role of reconstruction in memory seems warranted.

Finally, the limitations demonstrated in this study in children's knowledge about how they remember the times of past events may have implications for forensic practice. It appears that we cannot count on children, even as old as 12 years of age, to understand the processes that underlie their judgments of times of events or to know whether their judgments are based on reliable or error-prone processes. It is probably only after this age that an understanding of the importance of reconstruction, the rarity of direct retrieval, the limitations of distance-based processes, and the correlation between amount remembered and temporal accuracy is achieved. Children's ability to evaluate the quality of information on which their memory for time is based may influence their willingness to respond to questions about the time of events. Children who do not understand the difficulties of making temporal judgments may be more likely to guess, and their unrealistic estimates may undermine their credibility. Because the accuracy of children's judgments of the times of events does not appear to be a good predictor of the accuracy of recall of content of the same events (Friedman & Lyon, 2005), pressuring children to make such judgments may lead to excessively skeptical assessments of their accuracy as witnesses.

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Appendix A

1. Let's say you remembered something that you did a while ago, like a trip to the zoo or going to a movie you really liked. Pretend that you want to remember when it happened. (a) How could you remember the time of day (like the time on the clock)? (A paraphrase for this and the following questions is "What are some ways that you could remember . . .?") (b) (How could you remember) the day of the week (like whether it was Sunday or Monday or one of the other days)? (c) (How could you remember) the month (like whether it was January or February or one of the other months)? (d) (How could you remember) the season (like whether it was spring or summer or fall or winter)? (e) (How could you remember) what year it was (like whether it was 2002 or 2003 or 2004)? (f) (How could you remember) how old you were?
2. What are some good ways of remembering when something happened?
3. Right now it's (tell the child the part of the day, e.g., morning; day of the week; month). Let's say I see you tomorrow and ask you to remember when we had this talk. (a) Do you think you'll remember the time of day we had this talk? (b) Will you remember the day of the week? (c) Will you remember the month?
4. What if I ask you one month from now? (a) Do you think you'll remember the time of day we had this talk? (b) Will you remember the day of the week? (c) Will you remember the month?
5. Now pretend that I ask you six months from now? (a) Do you think you'll remember the time of day we had this talk? (b) Will you remember the day of the week? (c) Will you remember the month?
6. Pretend that six months ago you saw a movie you really liked. (a) Do you think you would remember the day of the week that you saw the movie? (b) Would you remember the season? (c) Would you remember how old you were? (d) Would you remember the month? (e) Would you remember what grade you were in? (f) Would you remember the time of day?
7. Pretend that you saw one movie yesterday and another movie last year. (a) Would you be able to remember right away which movie you saw a longer time ago? (Paraphrase: If one thing happened yesterday and another thing happened a year ago, would you know right away which was a longer time ago?) (b) (If yes:) How can you tell which was a short time ago and which a long time ago?
8. Sometimes we remember when something happened really well, like we remember the time of day or day of the week or time of year really well. But sometimes we can't remember when it happened. (a) What helps us remember really well when something happened? What else? (b) What makes it really hard to remember when something happened? What else?
9. Pretend that you remember that something like seeing a special movie or going to the zoo happened right before your birthday. (a) Would that help you remember the month or season that you saw the special movie or went to the zoo? (b) (If yes:) How?
10. One student said that it helps if you can remember what the weather was like outside when you saw a special movie or went to the zoo. (a) Would that help you remember when it happened? (b) (If yes:) How?
11. Let's say you're trying to remember when something, like a trip to the zoo, happened. A student told me he/she tries to think about how clearly he/she remembers the trip to the zoo. He/she said that tells how long ago it was. (a) Would that help? (b) (If yes:) How?

Appendix B

Open-Ended Questions

1. I'm going to ask you to pretend you are trying to remember something that happened a while ago. We'll make up something that is really unusual, but pretend that it really happened to you: Let's say that somebody's parrot got loose, and you saw it when you were looking at the window. That would be pretty unusual, wouldn't it? Now pretend that you want to remember *when* it happened. (a) How could you remember the time of day? (b) The day of the week? (c) The month? (d) The season? (e) What year it was? (f) How old you were? (If the child's response to any of the questions indicates

a misunderstanding of the question, repeat or paraphrase it.)

2. What are some good ways of remembering *when* something happened?

Metric Ratings of Methods

Training. Now I want to show you a way to find out what you think about good and not so good ways to remember things. These are called "thought bubbles (Figure 1)." You sometimes see them in comics; they are supposed to show what a person is thinking. Now here we have a bunch of different thought bubbles (point to them). We're going to use this one here (the largest) to show that something is a really good way to remember something. We'll use this one (the smallest) to show that something is not a good way to remember. We can point to the others, too. This one (second largest) means a pretty good way to remember. This one (second smallest) means OK but not very good, and this one (middle bubble) means in between.

OK, let's try it out. Let's say a friend tells you their telephone number and you want to remember it. One thing you could do would be saying the telephone number over and over to yourself. Is that a good way to remember, not a good way, or in between? (Without waiting for an answer) Point to the bubble that shows how good a way to remember this is. Another thing you could do to remember the telephone number would be to think about other things, and just hope that you'll remember the phone number later. Point to the bubble that shows how good a way this is to remember.

Temporal memory. Now we're going to use this (pointing to the diagram of the five thought bubbles) to see what you think about some different ways that people could remember *when* things happened, like the time of day or the month when something happened. Let's look at a picture that shows the first way someone could try to remember the time when they saw a parrot at the window. (The three methods of remembering times were presented in random order.)

Reconstruction: This is a/another picture (Figure 2, top) of someone who is trying to remember when he saw the parrot. He tries to remember what he was doing and what he saw. He remembers that it was breakfast (point to the appropriate bubble) and that there were leaves falling (point to the appropriate bubble). Can this help him remember when it happened? He wants to remember *when* he saw the parrot. How could it help if he tries to think about what he did and what he saw? I want you to show me if you think this is a good way to remember *when* something happened. How good is it to try to remember what he did and what he saw? Point to the bubble that shows how good a way this is to remember *when* it happened.

Vividness: This is a/another picture (Figure 2, bottom left) of someone who is trying to remember when he saw the parrot. He tries to think about how clearly he remembers it. He thinks about whether he remembers it clearly (point to the clear bubble) or can't remember clearly (point to the faint bubble). Can this help him remember when it happened? He wants to remember *when* he saw the parrot. How could it help if he tries to think about how clear the memory is? I want you to show me if you think this is a good way to remember *when* something happened. How good is it to try to remember how clear the memory is? Point to the bubble that shows how good a way this is to remember *when* it happened.

Direct retrieval: This is a/another picture (Figure 2, bottom right) of someone who is trying to remember when he saw the parrot. He tries to just remember what month it said on the calendar (point to the bubble with the calendar) and to just remember what time it said on the clock (point to the picture of the clock). Can this help him remember when it happened? He wants to remember *when* he saw the parrot. How could it help if he just tries to think about what month it said on the calendar and what time it said on the clock? I want you to show me if you think this is a good way to remember *when* something happened. How good is it to just try to remember what month it said on the calendar and what time it said on the clock? Point to the bubble that shows how good a way this is to remember *when* it happened.

Categorization of Methods

The last thing I want you to do is to tell me which of these three ways of remembering (gesture to the three pictures presented in Figure 2) is the best way to remember when something happens. Which one is the best? (The three methods were mentioned in random order.) Is it (a) trying to remember what he did and what he saw, (b) trying to think about how clear the memory is, or (c) just think about what month it said on the calendar and what time it said on the clock? Why? Which one would you use most often to remember when something happened? Why? Which is the worst way of remembering when something happened? Why? Which one wouldn't you use much? Why?