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Children's Use of a 'Time Line' to Indicate When Events Occurred

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Abstract Children who allege abuse are often asked to provide temporal information such as when the events occurred. Yet, young children often have difficulty recalling temporal information due to their limited knowledge of temporal patterns and linguistic capabilities. As time is an abstract concept (we cannot see it), some investigators have begun to use 'time-lines' or pictorial representations of time to aid children. Yet, there is no published research testing whether children are able to use time-lines and whether they can provide adequate temporal information using them. We tested whether children could indicate the time-of-day of events using a pictorial time-line and then compared their responses to their parents'. Seven- to 8-year-olds were most consistent with parental estimates while 4-year-olds were least consistent. Responses from the 5- to 6-year-olds depended on the temporal task. Guessing and using general knowledge to estimate the time-of-day were ruled out, and so children were genuinely drawing on episodic memory when making time-line judgments. Thus, there was a developmental progression in children's use of physical representations to communicate abstract information. These results are promising for the use of the time-line in forensic settings but much more research is needed.

Keywords Child witnesses · Investigative interviewing · Forensic investigations · Child abuse · Temporal recall

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Introduction

In several countries, it is common for child victim-witnesses who allege repeated abuse to be required to particularize, or discuss specific instances of an event with an adequate degree of precision in reference to time, place, or other unique contextual detail, in order for an investigation to proceed (S v. R, 1989; see also Powell et al. 2007, for a review). Children may be asked to make judgments about whether an event happened one or more than one time (see Lamb et al. 2007), to report how many times an event occurred (Guadagno and Powell 2009), to make temporal judgements about the events in question based on personal temporally-relevant information, such as indicating how old they were or who their teacher was at the time of the events in question (US vs. Tsinhnahijinnie 1997), or when the events occurred with respect to temporal *landmarks* such as holidays (as in the matter of KAW, 1986; cited by Friedman and Lyon 2005). Children's ability to provide specific, temporal information only emerges around ages 8–10 (Friedman 2003; Friedman and Lyon 2005), however.

To help children report temporal information, many investigators use 'time-lines' comprising of a line with temporal markers at each end (e.g., breakfast, going to bed) so that children have a physical representation to aid in their identification of when events occurred (Debra A. Poole, personal communication, April 3, 2005). In theory, time-lines are a valuable resource because it gives children a chance to use physical representations to communicate the abstract concept of time. Yet there is currently no published research specifically investigating whether time-lines can elicit reliable information. As they are used in criminal investigations where inaccuracies or lack of precision in identifying the time of events can have drastic consequences (Powell et al. 2007), it is essential to investigate how children use time-lines. This is the first study to directly study the time-line as a technique to elicit reliable and precise temporal information from young children.

Most contemporary knowledge of the development of temporal memory in children comes from a large body of research completed by Friedman and colleagues (e.g., Friedman 1991, 1993; Friedman and Kemp 1998). Friedman's work has elucidated that the location (exact time) of events is *reconstructed* in conventional time patterns (Friedman 1993). There are three components that are necessary to reconstruct the time of events (Friedman and Lyon 2005): the retrieval of episodic, temporal information; general knowledge of time patterns; and an executive process that integrates temporal information with time patterns. For example, the times that events occurred are often inferred from retrieved information such as remembering lunch, knowing that the event occurred close to lunch, and thus inferring that the event happened around lunch-time (Friedman 1987). Reconstruction can also occur with more non-specific information such as remembering wearing shorts and inferring (from knowledge of weather at different times in the year) that the event must have happened in summer (Friedman and Wilkins 1985).

Research with children has shown clear developmental differences in the ability to provide temporal information (e.g., Bauer and Mandler 1992; Fivush 1984; Friedman 1991, 1992; McCormack and Russell 1997; Orbach and Lamb 2007). It is now well understood that children even as young as 4-years-old are able to retrieve memories of events that happened at specific locations in the past (Fivush 1984; Friedman 1991, 1992, 2003), but are less able to order or sequence events until age 8 or 9 (Bauer et al. 2007; Friedman 1992). When explicitly asked for temporal information, however, children's limitations become clear as in the observation that children can answer 'When?' questions as if they were being asked 'Where?' questions (Clark 1973; see examples in Poole and Lamb 1998). Unlike adults who have the semantic knowledge of conventional temporal patterns (e.g., days of the week, months, seasons) and can place retrieved contextual details in these patterns, children see events as happening in 'islands of time' (Friedman 1992) and do not connect events well with one another on larger time scales (Friedman). Once children have developed knowledge of temporal patterns, they still may have difficulty reconstructing their memories due to the difficulty of recalling contextual information and holding it in memory at the same time as the relevant temporal patterns (Friedman). Thus, different aspects of temporal understanding develop at different rates.

Friedman (1991) gave children a time-line of a day with pictures of waking, eating lunch, dinner and going to bed, as well as a time-line of the seasons with pictures depicting the four seasons. The nursery school and first grade children were able to judge the correct time of a target event using the time-of-day scale, while the third grade children were not (even though they did so verbally in a separate experiment; Friedman 1991, Table 4 and page 151). In addition, none of the children were able to judge the correct season using the seasons time-line. There is no clear explanation why the older children were less accurate than the younger children, but the results show some promise for the technique. The focus of Friedman's research was on children's ability to recall the location and sequence of events and not on investigating the time-line per se, and we could find no other study that systematically tested children's use of the time-line. Further, we do not know at what ages we can expect children to report/indicate time information after long delays and when recalling potentially stressful events with serious consequences, as in the case of child abuse.

Tversky et al. (1991) used a task somewhat similar to a time-line where children and adults were asked to place stickers to indicate breakfast, lunch, and dinner. These authors concluded that older children were better able than younger children to represent ordinal and interval information than younger children when using a pictorial time-line. Their results also demonstrated that children's ability to represent interval information using a time-line was related to how abstract the information was they were being asked to represent – with more abstract information such as preference for an item (e.g., a type of candy) being more difficult to represent than concrete information (e.g., the number of candies present) (Tversky et al. 1991).

Friedman and Lyon (2005) showed that ordering two novel events was achieved only after age 6, even though children younger than this could retrieve some temporally-relevant information. Thus, children attain competence in some time scales (e.g., when in the day an event occurred) before others (e.g., when in the year). Despite the early emergence of location processes on the smaller scale of a day (vs. the larger scale of a year), young children still show limitations in their retrieval and reconstruction processes, with further developments occurring until late childhood (Friedman and Lyon 2005).

Young children's difficulty in providing temporal information about events is clearly not simply a retrieval issue. The need to integrate retrieved information with time patterns is one difficulty (Friedman 1993), and the ability to explicitly describe retrieved temporal information is another. It is well known that the relationship between language and cognitive development is correlated in everyday settings (e.g., Tamis-LeMonda et al. 2004). With respect to time, children must at the very least acquire a temporal lexicon to verbally describe time, although children understand and respond appropriately to temporal words before they are able to reproduce them (Harner 1975). Further, word production often lags behind true conceptual understanding. For example, the word *yesterday* is present in the lexicon of most 3-year-olds yet it is used to refer to any time in the past. It is not until age 4 that 'yesterday' is used in the same, specific way as in adult usage (Harner 1975). Descriptions of time become more specific as children age, for example, at 36 months children will spontaneously use the phrase *this morning*, whereas at 48 months children can indicate *early in the morning* (Ames 1946). This evidence on children's linguistic markers of temporal information raises the possibility that verbal elicitation techniques may underestimate children's ability to retrieve and report temporal information (because they clearly are able to implicitly respond to conversations about time). Thus, the pictorial time-line has been considered an attractive alternative to elicit temporal information because it removes the need for children to verbally disclose such information.

Why might the time-line be a useful way to support children's recall of temporal information? First, as it is a nonverbal technique requiring children to point on a pictorial representation, it removes the need to ask a series of direct questions that might elicit inaccurate responses (e.g., *Was it in the morning or the afternoon?* when it could have actually happened after bedtime; *Did that happen immediately or a while after?*). Such direct and focused questions are often used because children might not understand the detail that is required of them in forensic investigations (Roberts et al. 2011). Children often respond uninformatively, however, when given questions with options (Lamb et al. 2003). Second, as it is a visual representation, it may remove some of the cognitive demands of the reconstruction process. According to reconstruction theories of temporal memory, episodic temporal information must be retrieved and integrated with knowledge of temporal patterns to infer the time of an event. Such executive processing places a high demand on working memory (e.g., Mäntylä et al. 2007) and this may in itself explain why children struggle to accurately reconstruct events (even though they can remember episodic temporal information and time patterns). As the time-line depicts the entire time scale in question, it removes the need for continuous long-term retrieval of items to working memory and thus reduces the cognitive load. Third, research on children's understanding of symbolic representations such as models and photographs (e.g., Blades and Cooke 1994; DeLoache et al. 2003) suggests that pictorial representations like the time-line can provide useful information to children aged 3 and above. Indeed, nonverbal aids have been used successfully to help children recall event details such as color and some aspects of time (Friedman 2000; Friedman and Kemp 1998; Ling and Blades 2000; McCormack and Russell 1997; Silverman 1997). Finally, children's errors – such as responding to temporal questions with spatial information – suggest a close correspondence between spatial and temporal concepts (Clark 1973).

In sum, the extant research shows that the development of children's ability to report temporal information develops from age 3 to about age 9 or 10. Although children are able to use and retrieve temporal information at early ages, their knowledge of time patterns, their ability to reconstruct events within time patterns, and linguistic development that enables children to communicate temporal information from memory is more limited. Although some researchers have successfully used other memory aids such as photographs to elicit temporally-explicit memories (Bauer et al. 2007), these aids are not suitable in a criminal context because of their suggestive nature (e.g., Strange et al. 2008; Wade et al. 2002). Yet, despite the widespread use of time-lines in applied settings to compensate for children's limitations, there is very little scientific research on the effectiveness of time-line recall.

In this study, we tracked the development of temporal understanding for time-of-day information using the time-line technique. Most experimental research on children's eyewitness memory has been conducted on children's memories for staged events, but we focused here on children's autobiographical memories because they may be richer than contrived events, contain more meaningful cues to the time of events, and be more readily applied to actual child abuse investigations. Accurate recall of familiar events (e.g., the routine of a day) emerges before accurate recall of novel events (Fivush 1984), and so it is possible that children's temporal understanding has been underestimated in studies using novel, unfamiliar events.

Experiment 1

Design and Participants

Three age groups were recruited to examine developmental differences in the ability to recall temporal information about an autobiographical event using a time-line. Parents nominated three events (e.g., going to the park, riding a bike, going for a swim) involving their children and temporally located them using a time-line of a day. Children were then asked, using the time-line, to temporally locate the same events.

Children were recruited from local daycares and a mailing list in [Kitchener/Waterloo]. A total of 49 children participated initially, but three 4-year-olds did not complete the session, and one 8-year-old was removed because he had previously participated in a similar experiment, leaving a total of 45 (predominantly Caucasian) children in the sample, comprising 24 females and 21 males. This final sample included 15 4-year-olds (M=53.93 months, SD=3.88), 15 5- to 6-year-olds

(M=68.87 months, SD=7.68), and 15 7- to 8-year-olds (M=92.47 months, SD=7.05). Parents gave informed consent and children gave verbal assent.

Materials

A horizontal line measuring 56 cms was drawn on a piece of card to represent a time-line of a day. Picture anchors (4× 3 cm) were placed to mark the start of the day (picture of breakfast on the far left), the middle of the day (picture of eating lunch, in the middle), and the end of the day (picture of child going to bed on far right). There were 21 short vertical lines (tick marks) on each side of the middle anchor and these were evenly spaced at 1 cm intervals. Children were encouraged to show the researcher when events happened during the day by placing the tip of a red arrow on the time-line, without actually pointing to an anchor.

The total size of the time-line was large enough that there would be distance to discriminate the beginning of the day from the end, but it was small enough the children were able to see the entire time-line in their visual field while making time-of-day decisions. No further temporal information (e.g., the hours in the day) was provided on the time-line.

Procedure

Before each session, parents and children were escorted to an observation room where the parents would wait for the duration of the session. Parents were asked to write down four events (numbered 1 to 4) from their children's lives during the past week. Each event was to have occurred at a distinct time during the day (so it could not be an event that took place over the entire day), to be unique, enjoyable, memorable and to not have occurred as part of a regular schedule. For this part of the session, children played with toys in a different area and were not able to see their parents' responses.

The parents were simply given the following instruction: *Using the time-line show me when in the day ________ happened.* The nearest tick to the arrow placement was recorded. Parents provided events that occurred at different times in the day but most (73 %) nominated events happened in the afternoon and evening.

The children were then escorted into a separate room and the parents were able to view the entire session through a one-way mirror. The sessions were video and audio recorded for coding purposes. First, children were provided with two relevant practice recalls. A researcher described each anchor and explained how the distance from one anchor to another represents the entire day. The researcher provided an example of a time she went to the park in the morning after breakfast and she demonstrated the time by placing the arrow on the time-line after, but close to, breakfast. Then the researcher asked the children to show on the time-line when the researcher went to the park. The children were asked to repeat the information and then provide an explanation as to why they reported the event happening when they did. Children were given feedback on their responses. All of the children that were included in the study appeared to understand the time-line before they began the testing portion of the interview.

After practice, children were asked to recall the three parent-provided events that best fit the nomination criteria. Children recalled the events in the same order as their parents recalled them. Children were first asked *Do you remember _______?* (no temporal information was included). Following a 'yes' response, children were then given the same time-line instruction as the parents were given (see above). If children could not recall an event, the alternate was used. The procedure was repeated for the two other events.

Coding

Inter-rater reliability (percent agreement for each of the placements – location, order, and duration) between coders was high (at least 99 % for each of the measures below) and all errors were corrected before analysis.

a) *Recall of Temporal Location (when the event occurred).* Difference scores were calculated by subtracting the children's placements on the time-line from their parents' placements (using the cm marks where the arrows were placed); larger scores indicated greater disagreement. The average difference scores ranged from 0.67 to 27.83 cm; the maximum difference could have been 56 cm.
b) *Recall of Temporal Order (which half of the day).* Children's placements on the time-line were coded as '1' if they located the event in the same half of the day as their parents did, or '0' if not. That is, the time-line provides information about which half of the day the event occurred in, although the children were not explicitly asked "What half of the day did ______ happen?" Scores were summed and ranged from 0 to 3, with higher scores representing greater consistency with parental estimates.
c) *Recall of Temporal Duration (a short or long duration before/after).* Short or long duration estimates were coded by dividing the time line into quarters and recording the quarter of the time-line the events were placed in. Placements were considered to be 'close' to lunch only if they were within the quarter of the time-line before or after lunch, as appropriate (i.e., simply placing the event within the correct half of the day was not deemed 'close'). Using this definition, children's placements were thus coded as '1' if they agreed with their parents or '0' if they did not. Scores were summed and could range from 0 to 3 with higher scores representing greater agreement with parents.

Results

a) *Recall of Temporal Location (when in the day)*. The difference scores were analyzed using a one-way analysis of variance (ANOVA), with age as the independent variable. There was a significant effect, $F(2, 42)=12.51$, $p=.000$ $\eta_p^2=.37$, because all three age groups were significantly different from each other (*LSD*, $p<.02$). Mean difference scores decreased as children aged. The means (and standard deviations) for the 4-year-olds, 5–6 year-olds, and,7-8 year-olds respectively, were 13.38 (4.98), $CI_{.95}=10.77\text{-}15.51$; 9.00 (5.48), $CI_{.95}=6.63\text{-}11.36$; and 4.82 (3.24), $CI_{.95}=2.48\text{-}7.21$. As the time-line was 56 cm long, these scores show that the oldest children placed events within 5 cm (or less than 10 % of the time-line; approximately an hour) of their parents, whereas the youngest children diverged more.

b) *Recall of Temporal Order (which half of the day)*. A between subjects ANOVA was run to examine developmental differences in children's ability to recall if the events happened before or after lunch when using a time-line. There was a significant effect of age, $F(2, 42)=4.01$, $p=.03$, $\eta_p^2=.26$ Overall, the 7- to 8-year-olds ($M=2.53$, $SD=0.64$, $CI_{.95}=2.16\text{-}2.90$), agreed with their parents more than did the 5–6 year olds ($M=2.47$, $SD=0.64$, $CI_{.95}=2.10\text{-}2.91$), and 4-year-olds ($M=1.87$, $SD=.83.$, $CI_{.95}=1.50\text{-}2.24$). In contrast to the location scores, however, 5–6 year olds agreed with their parents significantly more than did the 4-year-olds, (*LSD*, $p<.05$).

c) *Recall of Temporal Duration (short or long time)*. Inspection of the means shows that providing duration information was difficult for all children but there were similar developmental differences as was gleaned from the measures of temporal location and order. A between subjects ANOVA was used to examine developmental differences in using a time-line to identify if the events occurred a short or long time before/after lunch. There were significant effects of age, $F(2, 42)=3.20$, $p=.05$, $\eta_p^2=.19$, because the 7- to 8-year-olds ($M=2.00$, $SD=0.76$, $CI_{.95}=1.61\text{-}2.39$), agreed with their parents more than the 4-year-olds did ($M=1.4$, $SD=0.74$, $CI_{.95}=1.01\text{-}1.79$), (*LSD*, $p<.01$). In addition, the 5–6 year-olds ($M=2.00$, $SD=0.76$, $CI_{.95}=1.61\text{-}2.39$), were significantly more consistent with their parents than were the 4 year-olds, and their scores were similar to those of the 7–8 year-olds.

d) *Chance analysis on time-line scores*

Further analyses were performed to see whether children were merely guessing in their time-line judgments. As the children depicted the temporal location of three events using the time-line (hereafter referred to as events A, B, and C), two new difference scores (discrepancy between parental and child placements) were calculated by subtracting the child's placement of each of the events B and C from the parental placement of A. Thus, difference scores were calculated for completely unrelated events. If the children were simply guessing the location of A, then there should be no difference between the new A-B and A-C differences scores and the original A(child)-A(parent) scores. The procedure was repeated for all other combinations of the three events. The new difference scores were then compared to the original difference scores. A *t*-test showed that the original difference scores were, in fact, smaller than the new difference scores (average *M*s=9.79, 13.76, $CI_{.95}=7.95\text{-}11.63$, $CI_{.95}=11.96\text{-}15.56$ and *SD*s=5.92, 6.04, for the original and new difference scores, respectively), $t(86)=-3.116$, $p=.002$.

Discussion

The findings of Experiment 1 are consistent with previous literature using mostly verbal tasks that showed that temporal understanding is not well developed until age 7- to 8 years-old (Friedman and Lyon 2005). The 7–8 year olds were consistently more similar to adults than the 4-year-olds in indicating when events had occurred. In fact the 7- to 8-year-olds placed the events within 10 % (roughly equivalent to an hour) of their parents' estimates. This provides external validity to the use of the time-line with this age group given that it is consistent with other markers of temporal understanding.

Initially we had hoped that the time-line aided especially the youngest children given their developing ability to articulate temporal information. Unfortunately, and just like other representational devices designed to aid young children such as anatomically detailed dolls (Poole et al. 2011), the time line augmentation did not help the 4-year-olds to behave like older children or adults. What is especially noteworthy, however, is that the 5- to 6-year-olds sometimes used the time-line just like the 7- to 8-year-olds and adults did. When we used the time-line to determine whether the event happened a 'short or long' time after lunch, there were no differences in the estimates from the 5–6 year-olds and the 7- to 8-year-olds. Thus, not only were the 5–6 year-olds more consistent about when events happened than were the 4-year-olds (difference scores), they were also more precise with respect to an anchor (lunch). Although coding of the time-line placements was somewhat arbitrary (albeit conservative), the coding included both the parents' and children's estimates. We cannot claim that children placed the arrows absolutely 'close to' or 'far from' the parents' placements, as these are abstract concepts highly dependent on context. But we do know that the 7–8 year-olds, and sometimes the 5–6 year-olds, were interpreting and using the time-line in more similar ways to their parents than were the 4-year-olds.

Before accepting these results, however, we opted to further empirically test whether children in Experiment 1 were genuinely drawing on episodic memory and using the pictorial representation of their mental representations appropriately, or whether they were using general knowledge to infer time-of-day. Thus, in Experiment 2, we asked children who had no knowledge of the events that were nominated in Experiment 1 to provide their best judgment of when those events happened, using the time-line. As this new sample of children had no knowledge of the events, they could only answer by guessing and/or inferring time-of-day. We compared placements by children in Experiment 1 with those of children in Experiment 2. If the children in Experiment 1 were guessing or inferring, there would be no difference between their difference scores and those of the children in Experiment 2. On the other hand, if the children in Experiment 1 were genuinely using the time line to indicate time-of-day information, we would expect them to be more consistent with the parental placements than children in Experiment 2.

Experiment 2

Method

Children were recruited from a summer day camp and matched according to the ages of children in Experiment 1. In total, 42 children participated in one 15-minute session with a research assistant at the camp during regular camp hours. All of the events that were provided by parents for the time-line in Experiment 1 were used, such that each child was asked about three events provided by the parent of an age-matched child.

Children were told they were going to play a game with the researcher. The researcher taught the child to use the time-line following the same training procedure as in Experiment 1. The children were then provided with an event (e.g., made a cake) and asked to indicate, using the same time-line from Experiment 1, when a girl/boy the same age as them made a cake. The procedure was repeated for the two other events.

Placements from these children were scored in the same way as in Experiment 1 (i.e., given a ‘1’ if they fell within 5 cm of the parents’ placement). Each child had three opportunities to use the time-line, and, therefore, received a total score out of three.

Results & Discussion

The scores were entered into a 3 (age in years: 4 vs. 5–6 vs. 7–8)×2 (Experiment: 1 vs. 2) ANOVA, and we report any main effects of or interactions with Experiment. As expected, children in Experiment 1 were more consistent with parental time-line placements (M=1.50, SD=.96, CI_{95}=1.25-1.75), than were children in Experiment 2 (M=.64, SD=.69, CI_{95}=.40-.89), $F(1, 76)$=23.98, p=.000, η_p^2=.24. There was no Age x Experiment interaction. Thus, children in Experiment 1 regardless of age were more consistent with parental temporal recall than a group of children who were asked to recall the same events but had no prior knowledge of when the events occurred. Given that the children in Experiment 2 must have been guessing or inferring time-of-day (because they had no knowledge of the events), it is likely that children in Experiment 1 were genuinely using the time-line to retrieve temporal information.

General Discussion

It is well known that children do not develop adult-like recall of temporal information until about age 8 to 10 (Friedman and Lyon 2005), even though they begin using words denoting temporal concepts from very early (Ames 1946). Time is abstract concept, we cannot see it, but we are able to hold mental representations of time. Preschoolers (aged 3–6) undergo profound development in their understanding of mental representations, largely made possible by developments in the frontal lobe where executive processing takes place (Newcombe et al. 2007). Thus, professionals such as teachers and detectives have been using pictorial representations of time to enable young children to provide temporal information. Despite the common sense logic of this approach, it cannot be assumed that the transformation of abstract mental representation to concrete physical representation is within the grasp of young children with respect to temporal concepts. While developmental increases in adult-like judgments using the time-line might be predictable, it was previously unknown whether and at what age children might benefit from using a pictorial time-line to provide temporal information.

The examination of children’s temporal memory in this study using a pictorial time-line shows that there is, indeed, a developmental progression in the translation of temporal representations to a physical depiction of time, at least when describing time-of-day. The 7- to 8-year-olds were consistently closer to parental time-of-day estimates than the younger children. In fact, the 7- to 8-year-olds were considered to be within an hour of their parents’ estimates. In other words, the time-line provided a way of eliciting temporal information from these children that is largely as accurate as an adult would be. The 4-year-olds were just as consistent in their divergence from their parents’ estimates. These young children consistently placed the arrows on the time-line further away from their parents’ placements than any of the older children. Finally, the 5–6 year-olds were consistent in terms of relative distance to their parents’ estimates but were less in agreement than were the 7- to 8-year-olds when deciding the order of events relative to an anchor. Thus, the ability to provide pictorial representations of time seems to also co-occur with the development of the abstract representation of time. We cannot infer any causality from the current data, but perhaps one needs to be able to at least entertain the concept of time, before being able to benefit from experience with physical representations (which in turn can lead to more sensitive understanding of time).

In support of this argument, many of the 3-year-olds we tested (and excluded from the study) did not seem to grasp the idea of what the time line represented. While the 4-year-olds did grasp the concept of the time line, they were still more discrepant with their parents' estimates than the older children. In other research, children as young as 4-years-old have benefited from using visual representations of their environment, such as the spatial layout of a room (Blades and Cooke 1994; DeLoache et al. 2003). Indeed, spatial and temporal understanding is correlated in adults and children (e.g., Casasanto et al. 2010). The concept of 'time', however, cannot be mirrored in a concrete representation as easily as room items can. Visual representations of time do not have one-to-one correspondence with actual time. This may be partly why only the older children in the current study who are familiar to varying degrees with abstract representations (e.g., the mind) were supported by the visual representation of time offered by the time-line, but the youngest children (3-year-olds who are still learning about abstract concepts) were not.

We believe that the time-line enabled children to *reconstruct* temporal information in their memories. As temporal information is usually reconstructed (Friedman 1993), some executive processes must be implicated. In a recent study, school-aged children were asked to indicate the passing of 5 minutes. Those who attained high scores on executive tasks internally regulated the 5-minute intervals (specifically, those that assessed the ease with which children updated working memory representations and inhibited irrelevant information); children who had difficulty updating and inhibiting information compensated by frequently checking a clock to see when the 5 min had passed (Mäntylä et al. 2007). Such executive processes necessarily demand significant cognitive resources, especially in young children with developing frontal lobes. Working memory, reasoning, integration of information, and inhibition may all be implicated (Mäntylä et al. 2007). If children have a developing and/or vague knowledge of temporal patterns, it may be difficult for them to hold memories and knowledge in working memory long enough to make a precise time judgment *and* verbally report it. The time-line may have reduced some of the cognitive load because it provided a visual cue to the time-frame that could be seen in its entirety while children were recalling the contextual details of the event, further reducing their cognitive load. The visual representation of the day may also have allowed children to assess and reassess their judgments, moving the arrow (signifying the target event) until they were sure of their placement.

The current findings join the group of research showing advanced skills when developmentally-appropriate tasks are used. This does not belittle the findings, however. Investigators have tried, and continue to try, novel techniques to improve testimony such as the use of anatomical dolls and drawings. Systematic research testing these techniques is vital; it cannot be simply assumed that techniques that use concrete objects and fit well with common-sense notions are reliable. Indeed, the literature on eliciting reports using anatomical dolls, another aid presumed to be helpful, is quite critical of their effectiveness (Poole et al. 2011).

Can we be sure that the children were genuinely and accurately recalling temporal properties of memories? We provided two analyses that gave clear evidence that children were trying to accurately report when events occurred. Support came from comparing responses to chance and, even more convincingly, the children in Experiment 1 were significantly more consistent with their parents' temporal estimates than were a group of children who guessed/inferred when the events occurred (Experiment 2). Is it valid to compare children's responses to those of their parents considering that we can never measure objective accuracy when assessing autobiographical memory? We believe that the pattern of results is valid because a) it reflects other developmental patterns using measures of objective accuracy (e.g., Friedman 1991, 1992), b) we have other data using the time-line for memories of staged events and found highly similar results, and c) even when objective measures are used, children's behaviour is still assessed with respect to adult performance. For example, if a 6-year-old scores 7/10 on a test, is that good or average performance? To answer this, we would consider what an adult would get on the test. If it's 10/10, the child is OK-Good, if it is 7.5/10, the child is very good.

Applications and Future Research

In a general sense, using pictorial as well as verbal measurement tools might provide a richer sense of children's temporal understanding than verbal measures alone. Despite the highly encouraging results, however, we offer two caveats. First, we have provided evidence that children aged at least 5 and older can indicate when during the day an event happened using a time line. We need further research, however, to know whether time lines using other scales (e.g., the school year) can be used as effectively. It is also imperative to know what form time-lines should take and how this varies with culture. The children in the current studies all spoke English and, the older children at least, read English which visually is read left to right. In other cultures with dominance in a non-English language, scripts may be read right to left (e.g., Hebrew) or top to bottom (e.g., Mandarin) and this is matched by pictorial concepts of time (Tversky et al. 1991). Children from these cultures might not benefit from the left-to-right time line we used (as was appropriate to do in these studies), but may benefit when the pictorial representation more closely matches their dominant language. Another immediate direction for research would be to assess the impact of different anchors on temporal judgments. For example, lunch could be interpreted by one person as 'the middle of the day' but by another as 'the first third of the day'. Second, we are not recommending that time-lines replace verbal open-ended probing of temporal information. Rather, we suggest that the time line should be considered as something in an investigator's toolbox, to be used only when other developmentally-appropriate verbal techniques have been exhausted.

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