Journal of Cognition and Development

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/hjcd20

Examining Temporal Memory and Flexible Retrieval of Conventional Time Knowledge across Middle to Late Childhood

Thanujeni Pathman, Lina Deker, Christine Coughlin & Simona Ghetti

To cite this article: Thanujeni Pathman, Lina Deker, Christine Coughlin & Simona Ghetti (2022) Examining Temporal Memory and Flexible Retrieval of Conventional Time Knowledge across Middle to Late Childhood, Journal of Cognition and Development, 23:4, 571-589, DOI: 10.1080/15248372.2022.2072846

To link to this article: https://doi.org/10.1080/15248372.2022.2072846

JOURNAL OF COGNITION AND DEVELOPMENT
2022, VOL. 23, NO. 4, 571–589
https://doi.org/10.1080/15248372.2022.2072846

Routledge
Taylor & Francis Group

Examining Temporal Memory and Flexible Retrieval of Conventional Time Knowledge across Middle to Late Childhood

Thanujeni Pathman[a], Lina Deker[a], Christine Coughlin[b], and Simona Ghetti[b]

[a]Department of Psychology and Center for Mind and Brain, York University, Toronto, Ontario, Canada; [b]UC Davis, Davis, California, USA

ABSTRACT

Memory for the time associated with past events is critical for our understanding of episodic memory and its development. Relatively little is known about the factors that influence temporal memory development. One such factor examined in the literature is semantic knowledge for time (conventional time knowledge; CTK). Other possible factors include domain general skills (e.g., working memory). The goals of this study were to a) assess temporal memory for past events in middle to late childhood using a naturalistic, yet controlled task, b) examine the relation between temporal memory performance and CTK, c) examine the factors that support the development of conventional time knowledge, and d) test which factors best predict temporal memory performance. Participants included 7-year-olds, 9-year-olds, 11-year-olds and young adults (*N* = 140). They engaged in naturalistic events in unique locations in the lab over a span of 2–3 hours. One week later, participants were asked to place the events on an arbitrary timeline, and we measured deviations from the precise time that each event took place. Performance on the CTK task, but not age, contributed unique variance to accuracy in the timeline task, replicating findings from previous work. Further, vocabulary and working memory but not inhibitory control or age, were unique predictors of performance on the CTK task. Finally, vocabulary surpassed CTK task performance as a significant predictor of temporal memory. The implications of this work to our understanding of temporal memory, semantic knowledge for time and episodic memory development are discussed.

Episodic memory refers to memory for specific past events including details about when and where the event occurred (Tulving, 1972). The "temporal organization of otherwise unrelated events" (Tulving, 1993, p. 67) is an important feature of episodic memory, and understanding the development of temporal memory informs our understanding of episodic memory and its development. Further, the ability to understand temporal concepts and place past events in time are integrated into theoretical papers about autobiographical memory development (e.g., Nelson & Fivush, 2004; see also, 2020). Although there are age-related improvements in temporal memory in childhood, the factors that drive those improvements are relatively poorly understood, and much of the past work on this topic has focused on early to middle childhood (e.g., Deker & Pathman, 2021; Friedman, 1991,

CONTACT Thanujeni Pathman tpathman@yorku.ca Department of Psychology, York University, Behavioural Science Building Room 101, 4700 Keele Street, Toronto, Ontario M3J 1P3, Canada
Supplemental data for this article can be accessed online at https://doi.org/10.1080/15248372.2022.2072846

1992; Scales & Pathman, 2021; see Pathman & St. Jacques, 2014 for review). The purpose of this study was to examine the development of temporal memory in middle to late childhood, using naturalistic events, and to examine the factors that influence temporal memory development.

One such factor examined in past literature is semantic knowledge about time, which has been referred to as conventional time knowledge. This knowledge refers to an understanding of such temporal concepts as days, weeks, and months (Friedman, 1986, 1989). Friedman (1986) developed a task to assess the development of conventional time knowledge (CTK) by probing knowledge about days of the week and months of the year in children aged 7–15 years and college students and found age-related improvements. Friedman, Reese, and Dai (2011) modeled their CTK task from the original Friedman (1986; Experiment 2) questions which required a flexibility demand. Specifically, 8- to 12-year-old participants were asked to flexibly progress through the months of the year in backward order. For example, they were asked: "If you're going backward and you start in August, which would you come to first, December or April?" Friedman et al. (2011) found age-related increases in accuracy; they additionally found that performance on the CTK task was positively correlated with the ability of children to accurately report when past autobiographical events had occurred (based on parent report). The temporal memory test in this study explicitly required conventional time knowledge, because participants had to determine which month, season, or year past autobiographical events occurred, raising the question of whether this aspect of the task alone accounted for the correlation. However, one other study found that CTK performance was related to accuracy on a task of arbitrary object sequences that required no representation of conventional time scales (Pathman & Ghetti, 2014). Specifically, 7-year-olds, 10-year-olds and young adults viewed series of four objects on a computer screen, presented one at a time. At test, participants were shown one of the objects from the study phase (probe) and then asked to select from an array the object that had immediately followed the probe object during the study phase. Researchers found that accuracy on this arbitrary temporal order memory task was positively correlated to accuracy on the "months backward" CTK task used by Friedman et al. (2011). A recent study in which this task was adapted for use with younger children (4- and 6-year-olds) also found that the flexible retrieval of conventional time knowledge was a significant predictor of accuracy in a separate temporal memory task using arbitrary events (Scales & Pathman, 2021). Therefore, based on the current literature, the CTK task may capture processes that could contribute to the more episodic aspect of temporal memory development and should be investigated further. At the same time, we note that in these past studies other possible contributing factors to CTK performance and temporal memory performance (including domain general cognitive skills) were not fully examined.

As reviewed by McCormack and Hoerl (2017), expertise in conventional time scales (e.g., calendar system) is slow to develop and there may be a qualitative shift in how conventional time knowledge is processed in late childhood (see Friedman, 1986, 1989, 2000). Friedman (1986) asked participants how they determined the answers to the CTK questions. Specifically, participants were asked whether they "said the months or thought about a picture or did it some other way." Friedman found that most third and fifth graders said they recited the months, whereas most tenth graders and college students were classified as using imagery (e.g., referring to a continuum, cycle, or calendar) based on their responses. Although this study provides some evidence that younger children, older children, and young adults can report their impressions of using different types of strategies, it is not clear what cognitive factors are involved in performance. Semantic knowledge and language could be involved, given the content of and verbal nature of the questions. Working memory could also be involved, given that the flexible retrieval of the months of the year involves keeping the months in mind and manipulating their order in mind. And aspects of executive function, particularly inhibitory control, could be involved given that participants have to inhibit certain months as they move backwards through the months of the year. No study has tested whether factors such as these may relate to performance on the CTK task and so it is not yet clear what contributes to age-related improvements in this task. Further, it is not clear whether or not the CTK is related to temporal memory performance in episodic memory tasks because the CTK is tapping something unique or whether the relations found in previous research can be explained by more domain general abilities like working memory and language. Filling this gap in knowledge would have theoretical implications.

Time and temporal memory are integral to episodic and autobiographical memory and as such are featured in theoretical frameworks of memory development (e.g., Bauer, 2015; Nelson & Fivush, 2004). Data on children's temporal memory performance can be used to extend memory development models; models can be refined, for example, by specifying age ranges under which temporal memory shows continued developments, or how temporal memory compares with other featured constructs. Further, studies that can inform our understanding of mechanisms and what constructs or processes contribute to developmental change help to expand theoretical models as well. As discussed earlier, several studies have found that CTK task performance relates to temporal memory accuracy for both autobiographical events and lab-based events in middle to late childhood. Thus, a vital next step is to better understand why this is the case -*why* does CTK task performance relate to temporal memory accuracy, and what constructs or processes could be involved? Answers can help further refine theoretical models of memory development and contribute to our understanding of the factors driving the protracted development of temporal memory.

The goal of this study was to assess temporal memory for past events in middle to late childhood. First, we aimed to extend past work by providing additional evidence about whether there is a relation between memory for past events and the development of conventional time knowledge via the CTK task. In other words, we sought to replicate past research showing performance in CTK is predictive of temporal memory accuracy (using a different temporal memory task). Second, we aimed to investigate the factors that contribute to accuracy on the CTK task. Third, we aimed to test whether CTK or other factors best predicted temporal memory performance. We approached our goal using a naturalistic yet controlled temporal memory measure in which accuracy could be objectively verified. The paradigm is based on investigations in which children engaged in age-appropriate activities in the lab and were then tested on their memory for the location of the events (Bauer et al., 2012; Bauer, Stewart, White, & Larkina, 2015). We used a similar approach but tested children's memory for the times of past events by asking participants to place the events on a spatially based arbitrary timeline. Past studies reviewed above have measured temporal memory by testing children's accuracy when ordering arbitrary object sequences (Pathman & Ghetti, 2014; see also Pathman, Coughlin, & Ghetti, 2018) and placing events on conventional time scales (e.g., school year, month, season; Friedman et al., 2011). No study has tested the relation between the CTK task and temporal memory involving an arbitrary timeline, although timeline studies are useful in understanding how children represent past and future events (e.g., Friedman & Kemp, 1998; Friedman, 2000; Tillman, Marghetis, Barner, & Srinivasan, 2017; see Friedman, 2014; Pathman & St. Jacques, 2014; McCormack & Hoerl, 2017 for reviews). As discussed by Friedman and Kemp (1998), young children can use spatial arrangements, like timelines, to represent the temporal organization of events. We predicted that we would see age-related improvements in temporal memory accuracy and that performance on the CTK task would be a unique predictor of temporal memory, replicating previous findings. However, unlike past studies, the present study included additional measures to help us understand why CTK performance may be predictive of temporal memory performance and whether other factors are relevant. Previous literature has not provided firm ground to make precise predictions about which factors would predict accuracy on the CTK task and potentially contribute to its relation with temporal memory performance. We assessed several candidate constructs: i) working memory, which involves manipulating stored information in mind, ii) vocabulary, a proxy for language/semantic knowledge, and iii) inhibitory control, which allows one to control a prepotent response. Together this work can give us insight into the development of temporal memory, while also informing work on the development of episodic memory and temporal cognition more broadly.

Method

Participants

One-hundred fifty children and young adults participated in this study. Ten participants were not included in the final sample because they did not return for the second session (n = 7), the delay between Sessions 1 and 2 was over 2 weeks (n = 2) or because diagnosis of a neurodevelopmental disorder was disclosed (n = 1). The final sample included 140 participants: 36 7-year-olds (M = 7.60, SD = .28; 17 females, 19 males), 34 9-year-olds (M = 9.55, SD = .30; 18 females, 16 males), 35 11-year-olds (M = 11.38 years, SD = .60; 18 females, 17 males), and 35 young adults (M = 21.08, SD =2.07; 17 females, 18 males). The 11-year-old group included some 10- and 12-year-olds, but the majority of children were 11 years old. Demographics questionnaires revealed that participants were 62% Caucasian, 14% Asian, 12% Mixed Race, 6% did not specify race, and the remaining 6% selected other racial categories. The family income reported (percentage of participants in parentheses) was less than 25 K (13%), between 25 and 40 K (6%), between 40 and 60 K (16%), between 60 and 90 K (20%) and more than 90 K (42%); 3% of participants did not report family income. Children were recruited from a pool of families that volunteered to participate in research and were compensated with $10 per hour for participating. Young adults were recruited through an undergraduate participant pool and received course credit.

Participants completed two sessions separated by an approximately 1-week delay. Age groups did not differ in the precise delay between session 1 and session 2, $F(3, 136) = 0.02$, p = .995. During the first session, participants completed the Naturalistic Events Timeline Task (encoding phase), the Conventional Time Knowledge (CTK) task, and the Corsi Blocks task (Kessels, van den Berg, Ruis, & Brands, 2008; Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2000; Milner, 1971). During the second session, participants completed the Naturalistic Events Timeline Task (retrieval phase), the Happy-Sad task, and the WJII Picture Vocabulary task. Other tasks administered to participants are out of the scope of the present manuscript; they included child-friendly computer-based tasks or interviews with experimenters. Due to several factors (e.g., experimenter error, timing constraints), there was a small amount of missing data for particular tasks. These data are dealt with by pairwise (e.g., ANOVAs) or listwise deletions (regressions). The number of participants included in each analysis is listed in the relevant section. Sample size exceeds recommendations, including for the regression analyses with the greatest number of factors included (e.g., Harris, 1985).

Procedure

Naturalistic events timeline task

Encoding phase

Participants engaged in four naturalistic events that occurred in unique locations and unique times throughout an approximately 2.5-h session. The locations they visited for each of the events were particular areas within a playroom, student computer work room, testing room, and hallway (see Figure 1). The naturalistic events were a "help event" (an experimenter pretended to accidentally drop blocks on the floor and asked the participant whether they could help her clean it up), a "joke event" (an experimenter told the participant a child-appropriate joke about a mouse or a cow), a "draw event" (participants were asked to draw a picture of either a house or a boat), and "picture event" (participants were shown a funny picture of a dog wearing sunglasses, and asked whether they had seen anything like that before). Experimenters recorded the precise time of the beginning and

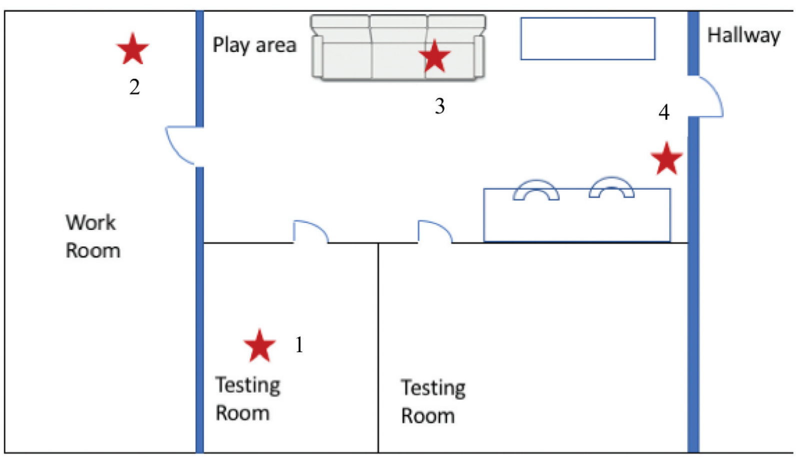

Figure 1. Diagram of the lab space.
The events for the Naturalistic Events Timeline task occurred in the locations marked with stars: in a small testing room, in a student work room, on the couch in a play area, and next to the lab entrance hallway. We are showing locations for the four task events in the schematic, however, participants engaged in other types of events throughout the session, and so they moved to multiple other places in the lab in between each of the four task events.

end of each session, and the precise time each event occurred for each participant. Events were incidental; Participants were not asked to remember the events/locations/times at any point during this session. The average (and standard deviation) delay between starting the session and the occurrence of the first, second, third, and fourth events were 9.70 min (SD = 13.44), 97.44 min (SD = 18.37), 112.15 min (SD = 19.25), and 129.01 min (SD = 19.62), respectively. Thus, the four events of interest did not occur consecutively; there were intervening tasks/events for the participant which occurred in various places throughout the lab space (Figure 1), and a restroom break, which occurred outside the main lab space.

Retrieval phase

Participants' memory for each of the four events was tested in turn (in randomized order). For each event, we tested recall (e.g., "You helped me pick something up last time, what did you help me pick up?"), and recognition, if they did not recall it immediately (e.g., "You helped me pick up blocks. What colour were they?"). Then, they were asked to recall the spatial location of each of the four events; recognition was tested if they could not recall the spatial location (e.g., "In which of these 4 locations did the event occur?"). Then they were asked temporal memory questions. They were asked to order the four events, and then to mark the occurrence of each event on an arbitrary timeline. They were presented with a paper with a black solid line on it, and the experimenter stated that the beginning of the line represented the time they came into the lab to start the first session, and the end of the line represented the time they left the lab. They were asked to mark the line with the times each of the four events occurred. See Supplemental Figure 1 for a sample timeline. Participants marked this line for each of the four events.

To score this task, we measured in millimeters the distance between the beginning of the line and the place where each event was marked on the line by the participant. The line on the piece of paper given to participants (Supplemental Figure 1) was 233 mm in total length for all participants. Thus, for each event, we took the participant's event placement (in millimeters) and divided it by 233 mm. This can be thought of as the transformed participant placement. Next, to calculate correct placement for the line for each event, we used the participant's precise session start, session end and event start times. Specifically, we took each event's start time (in minutes) for that participant and divided it by the total session length for that participant (i.e., elapsed time between session start and session end) in minutes. This can be thought of as the transformed correct placement. Finally, for each event, we calculated the deviation – the absolute value of the difference between the transformed participant placement and transformed correct placement.[1] The scores analyzed are deviations averaged across the four events; thus, higher values for this task represent lower accuracy.

[1]This calculation is parallel to the Percent Absolute Error (PAE) calculations used in the numerical representation and arithmetic learning literature (e.g., Booth & Siegler, 2008). PAE equals the absolute value of the following: "child's answer"/ "scale of answers" minus "correct answer" / "scale of answers".

Conventional time knowledge task

The "months" portion of the Conventional Time Knowledge (CTK) task (Friedman, 1986; see Friedman et al., 2011; Pathman & Ghetti, 2014) was administered. Participants were given eight questions that involved them flexibly retrieving months of the year in a backwards direction. For example, they were asked "If you're going backward and you start in May, which would you come to first, September or January?" The proportion of accurate responses (out of eight possible) was calculated for each participant.

Corsi blocks task

The participant sat at a desk across from the experimenter. In between them was a board with nine blocks arranged on it. Task procedures (e.g., block arrangement, task instructions and administration, scoring) were the same as that reported in Kessels et al. (2008). The experimenter tapped a sequence of blocks and the participant was asked to repeat this tapping sequence. Two trials were given per block sequence of the same length (starting with 2 block lengths). If at least one of these was repeated correctly, the next two trials of sequence of an increased length was administered (i.e., 3 block length, 4 block length, and so on). The experimenter stopped when the participant could not reproduce two trials of equal length. We administered this task twice, once in the forward condition (imitate tapping in same order), and then once in the backward condition (imitate tapping in reverse order), just like in Kessels et al. (2008). Since the results for the regression analyses (see below) were the same whether we used the forward or backward scores, only the forward condition is used in this manuscript for brevity. The dependent measure was the block score obtained (the number of trials correct). Scores used in analyses were not age normed (for this task or any task in this paper). We report the additional scores obtained for this task in Supplemental Table A.

Happy-Sad task

Administration of this task followed procedures reported in Lagattuta, Sayfan, and Monsour (2011), which they developed as an alternative Stroop-like task that measures inhibitory control. Briefly, this task involved showing pictures of happy and sad faces. Participants were told they would be playing an opposite game, in which they should respond with "happy" when they see the sad face, and "sad" when they see the happy face. Just like the original task, practice was administered so it was clear participants understood the instructions, before administering the task which involved 20 trials. The only deviations from Lagattuta and colleagues' method were that a) stimuli were presented on a computer screen, instead of printed cards, b) stimuli were presented in a random order that was fixed across participants, instead of randomized for each participant, and c) participants were shown pictures of human faces that were matched to their own gender (i.e., male faces for male participants; female faces for female participants). Administering a computerized version of the task allowed the experimenter to record participant responses online via key presses, eliminating the need to determine reaction time from audio recordings of verbal responses post session (as was the case for Lagattuta and colleagues' study). The experimenter pressed a computer key corresponding to the participant's verbal response (1 = happy, 2 = sad) immediately upon hearing it. Key presses corresponded to the participant's initial response such that any subsequent verbal corrections made by the participant (e.g., "Oh, I meant to say sad, not happy") were not taken into account for scoring purposes (i.e., self-correction responses were not counted, consistent with Lagattuta et al., 2011). The recorded happy/sad key presses were then coded for accuracy after the experimental session. Performance was measured by computing mean accuracy across trials. We also measured mean reaction time (milliseconds) across trials.

WJIII picture vocabulary

This task was administered according to standard instructions for this subtest of the Woodcock-Johnson III Test of Cognitive Abilities (Woodcock, McGrew, & Mather, 2001). This task is a measure of oral language and vocabulary (broad ability: comprehension-knowledge) and involved participants viewing pictures and naming them. Trials were scored "0" if incorrect and "1" if correct, and then summed to measure overall performance.

Results

Naturalistic events timeline task

The means (and standard deviations in parentheses) for the 7-year-olds (n = 31), 9-year-olds (n = 34), 11-year-olds (n = 33) and young adults (n = 34) were 0.27 (0.13), 0.24 (0.11), 0.18 (0.09), and 0.21 (0.10), respectively. Analysis of Variance (ANOVA) on accuracy for the temporal memory timeline task revealed that there were age-related improvements such that younger participants were less accurate (greater deviations) than older participants, $F(3, 128) = 4.63$, $p = .004$, $\eta^2_p = .10$. Pairwise comparisons showed that 7-year-olds had greater deviations than both the 11-year-old ($p < .001$) and young adult ($p = .017$) groups. Also, 9-year-olds had greater deviations than 11-year-olds ($p = .03$). The two youngest age groups did not differ from each other ($p = .14$) and the two oldest age groups did not differ from each other ($p = .22$). Figure 2 shows individual participant data for each age group.

For comparison purposes, we conducted similar analyses for the other dependent measures from this naturalistic events task. We found no age-related differences in the recall, $F(3, 134) = 2.57$, $p = .06$, or recognition of events, $F(3, 134) = 1.31$, $p = .28$. We also found no age-related differences in spatial recall, $F(3, 135) = 0.39$, $p = .76$, spatial recognition, $F(3, 135) = 1.06$, $p = .37$, or accuracy in ordering the events, $F(3, 135) = 1.16$, $p = .33$.

Conventional time knowledge task

The score means (and standard deviations) for the 7-year-olds (n = 25), 9-year-olds (n = 25), 11-year-olds (n = 33) and young adults (n = 23) were 4.40 (2.12), 5.72 (1.49), 6.21 (1.96), and 7.17 (1.85), respectively. There was a main effect of Age, $F(3, 106) = 9.22$, $p < .0001$, $\eta^2_p = .21$. Seven-year-olds had lower scores than 9-year-olds ($p = .02$), 11-year-

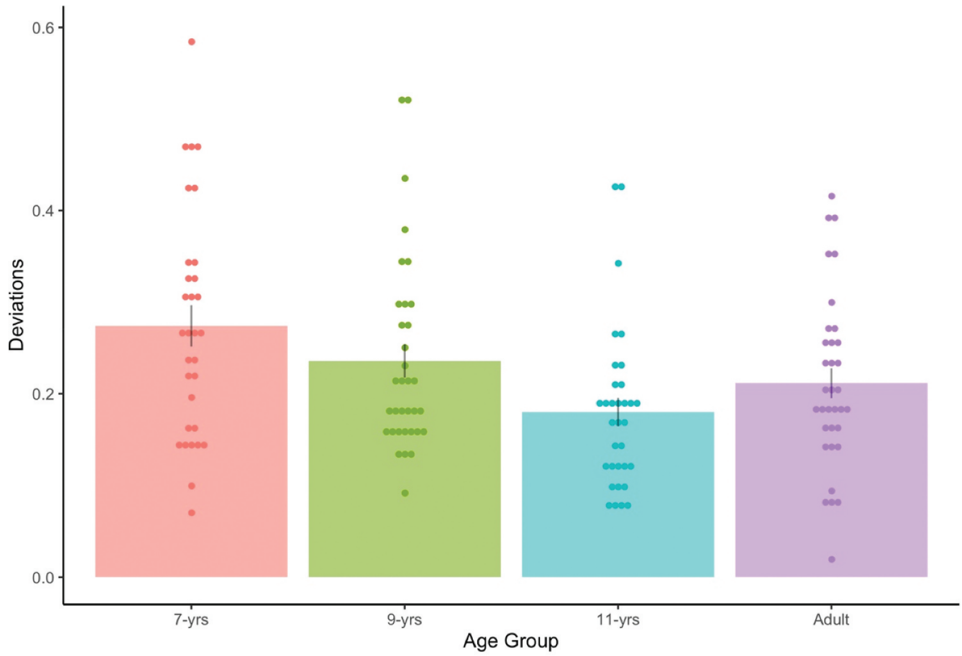

Figure 2. Deviation values for the naturalistic events timeline task.
Bar graph shows the mean value for each age group; Scatter shows individual participant deviation values. Error bars show standard errors.

olds ($p < .001$) and young adults ($p < .001$). In addition, 9-year-olds had lower scores than young adults ($p = .009$); 9-year-olds did not differ from 11-year-olds ($p = .33$). The two oldest age groups did not differ significantly ($p = .06$).

Other tasks

Table 1 shows descriptive statistics for the WJIII Picture Vocabulary, Corsi Blocks, and the Happy-Sad tasks by age group. ANOVAs were conducted to test for age-related differences with follow-up multiple comparisons, as noted in Table 1.

Does CTK predict temporal memory?

To test whether age and/or CTK scores predicted accuracy in the Naturalistic Events Timeline task, we conducted a linear regression. Age (precise age in years with two decimal places; continuous variable) was entered into the model first, and in the next step CTK task accuracy was added. For the first step (age only), the model did not reach significance, $F(1, 100) = 2.96$, $p = .09$, with $R^2 = .03$, Adjusted $R^2 = .02$. For the second step (age and CTK), the model was significant, $F(2, 99) = 4.89$, $p = .009$, with $R^2 = .09$, Adjusted $R^2 = .07$; Change statistics were as follows: F change = 6.65, $p = .01$, R^2 change = .06. The variance inflation

Table 1. Descriptive statistics and analyses for vocabulary, working memory, and inhibitory control measures

	7-year-olds			9-year-olds			11-year-olds			Young adults			ANOVA		
Task	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*F* ratio	*df*	η^2_p
Picture Vocabulary	36	15.03_a	1.30	34	15.56_a	1.28	35	16.46_b	1.17	34	17.50_c	2.35	16.08**	3, 135	.26
Corsi Blocks Forward	35	6.11_a	1.57	34	7.38_b	0.99	35	7.94_b	1.14	34	9.26_c	1.05	40.23**	3, 134	.47
Corsi Blocks Backward	35	6.31_a	1.92	34	8.24_b	1.48	35	8.40_b	1.61	34	9.62_c	1.35	24.98**	3, 134	.36
Happy Sad Accuracy	33	0.93	0.14	32	0.96	0.06	30	0.97	0.08	35	0.97	0.12	1.54	3, 126	.04
Happy Sad RT	28	1934.43_a	497.94	26	1619.63_b	369.87	30	1654.04_b	755.78	30	1433.72_b	271.56	4.69*	3, 110	.11

Picture Vocabulary (WJ III Picture Vocabulary task) served as a proxy for semantic knowledge/language. Corsi Blocks Forward and Backward scores served as proxies for working memory. Happy Sad Task accuracy and reaction time (RT) served as proxies for inhibitory control. For age group comparisons, when the ANOVA was significant, we followed up with multiple comparisons; means with different subscripts differ at the $p = .05$ level. For transparency, we conducted analyses again, correcting for multiple comparisons using the stringent Bonferroni adjustment; all age group effects remained unchanged, except the following: 1) Picture vocabulary: 7-yr-olds < 11-yr-olds < Adults and 9-yr-olds < Adults (9-yr-olds did not differ from 11-yr-olds with Bonferroni adjustment) 2) Happy Said Task Reaction Time: 7-year-olds > Adults (9- and 11-year-olds did not differ from 7-year-olds with Bonferroni adjustment).

$^*p = .004$. $^{**}p < .001$.

Table 2. Regression results for each task: how well does each task predict CTK performance after considering age?

Variable	B	95% CI for B LL	95% CI for B UL	SE B	β	R^2	Adjusted R^2	ΔR^2
Picture Vocabulary (Semantic Knowledge/Language)								
Step 1						.14	.14	.14***
Age	0.15	0.08	0.22	0.04	.38***			
Step 2						.28	.26	.13***
Age	0.09	0.02	0.16	0.04	.23*			
Task	0.47	0.25	0.68	0.11	.40***			
Corsi Blocks Forward Score (Working Memory)								
Step 1						.14	.14	.14***
Age	0.15	0.08	0.22	0.04	.38***			
Step 2						.23	.22	.09***
Age	0.06	−0.03	0.15	0.04	.15			
Task	0.48	0.21	0.75	0.14	.38***			
Happy-Sad Task Accuracy (Inhibitory Control)								
Step 1						.17	.17	.18***
Age	0.16	0.09	0.23	0.04	.42***			
Step 2						.18	.16	.003
Age	0.16	0.09	0.24	0.04	.43***			
Task	−1.29	−5.47	2.88	2.10	−.06			
Happy-Sad Task Reaction Time (Inhibitory Control)								
Step 1						.18	.17	.18***
Age	0.16	0.09	0.23	0.04	.42***			
Step 2						.18	.16	.003
Age	0.16	0.08	0.23	0.04	.41***			
Task	0.00	−0.001	0.001	0.00	−.05			

VIF values for all variables in regressions were < 1.62. We could not assume that Step 1 statistics would be the same in each regression because of sample size differences between tasks, thus Step 1 is not redundant. CI = confidence interval; LL = lower limit; UL = upper limit.
**p* < .05. ** *p* < .01. ****p* ≤ .001.

factor (VIF[2]) values for all predictors were less than 1.20. In summary, accuracy on the CTK task was predictive of performance on our temporal memory task, replicating the finding from past research which used different temporal memory tasks.

What predicts CTK?

To investigate factors predicting CTK accuracy, we conducted hierarchical regressions for each task with age entered as the first step and task performance entered as the second step in the model. See Table 2 for these results which show whether each task individually predicts CTK accuracy after accounting for age.

To test which factors *best* predict CTK task accuracy, we conducted a simultaneous regression (i.e., entry method; also known as enter or forced entry methods). Again, age was entered as a continuous variable (i.e., precise age in years with two decimal places). The model was significant, $F(4, 91) = 14.33$, $p < .001$, with R^2 =.39, Adjusted R^2 = .36, with two variables significantly predicting CTK accuracy, namely vocabulary

[2]VIF is a way to report multicollinearity, when predictors are correlated with each other, a concern in regression analyses. A VIF equal to 1 indicates no multicollinearity. There are different guidelines for cutoff levels of VIF; some guidelines suggest VIF > 5 or > 10 are problematic (e.g., Allison, 1999); the strictest guideline suggests that VIF >2.5 be considered an issue of concern and remedied (Johnston, Jones, & Manley, 2018). We report VIFs throughout; however, no VIF values reached values of concern.

Table 3. Regression model: does CTK still predict accuracy in the timeline task after accounting for age and other significant variables?

Variable	B	95% CI for B		SE B	β	R^2	Adjusted R^2	ΔR^2
		LL	UL					
Step 1						.03	.02	.03
Age	−0.003	−0.007	0.001	0.002	−0.17			
Step 2						.09	.07	.06**
Age	−0.002	−0.006	0.003	0.002	−0.07			
CTK	−0.01	−0.02	−0.003	0.005	−0.27**			
Step 3						.16	.13	.07*
Age	0.002	−0.003	0.007	0.003	0.11			
CTK	−0.006	−0.02	0.006	0.006	−0.11			
Picture Vocabulary	−0.01	−0.03	−0.001	0.006	−0.24*			
Corsi Blocks Forward	−0.02	−0.03	0.00	0.008	−0.24			

VIF values for all variables in regressions were < 1.78. CI = confidence interval; LL = lower limit; UL = upper limit.
**p* < .05. ** *p* ≤ .01.

(B = 0.43, SE = 0.10, β = 0.38, *p* < .0001) and working memory (B = 0.41, SE = 0.13, β = 0.34, *p* = .002). Age (B = 0.03, SE = 0.04, β =. 0.08, *p* = .50) and inhibitory control assessed via mean accuracy (B = −1.51, SE = 1.84, β = − 0.07, *p* = .41) were not significant predictors. (Inhibitory control assessed via mean reaction time shows the same pattern.) The variance inflation factor (VIF) values for all predictors were less than 1.83, thereby precluding the possibility that multi-collinearity prevented us from uncovering additional significant relations.

Does CTK predict temporal memory considering vocabulary and working memory?

To investigate whether CTK still predicted accuracy in the timeline task after accounting for the significant variables above, we conducted another linear regression. Age (in years) was entered into the model in the first step, CTK was entered in the model in the second step, and vocabulary and working memory scores were added into the model in the third step. The data are reported in Table 3. As shown in the table, age alone did not predict accuracy on the timeline task (step 1), but CTK score was predictive (step 2). However, once the vocabulary and working memory measures were added in the model (step 3), CTK score was no longer a significant predictor. As reported in Table 3, vocabulary (β = −0.235, SE B = .006, *p* = .033) was a significant predictor, and working memory failed to reach conventional levels of statistical significance (β = −0.243; SE B = .008, *p* = .053).

Discussion

The purpose of the present study was to assess temporal memory for past events in middle to late childhood using a naturalistic, yet controlled task. We tested whether there were age-related differences in temporal memory performance using this task, and explored the factors that influence temporal memory development. Based on the existing literature, our study focused on a measure of conventional time knowledge (CTK task), but we included additional measures to test whether we needed to qualify conclusions from past work. We aimed to test whether we would replicate the finding that CTK task performance predicted temporal memory accuracy, using a different temporal memory task than that used in previous studies. However, our primary goal was to test for the factors that best predict accuracy in the CTK task, and examine which factors best explain temporal memory performance. Together this would help us reveal the factors that relate to the development of temporal memory.

We found that in middle to late childhood, and into young adulthood, there were age-related improvements in temporal memory accuracy. Younger children were less accurate than older children and young adults when asked to place past events (that were engaging and naturalistic) on an arbitrary timeline. This is consistent with other types of temporal memory studies that have shown age-related improvements in early childhood (Friedman & Kemp, 1998) using an arbitrary timeline task. However, Friedman and Kemp's study involved placing *recurring* holiday events (e.g., Halloween) on a linear (spatially based) timeline, whereas our study involved placing *unique* events on the timeline. Our findings are also consistent with the few studies that have tested temporal memory in middle to late childhood. For example, age-related improvements in middle to late childhood were found in a study that tested memory for temporal order using lab-based stimuli (pictures of objects) presented on a computer screen (Pathman & Ghetti, 2014). Age-related improvements were also found in a study that tested children's ability to place past events on conventional time scales (Friedman & Lyon, 2005). Another study with similar age groups (8–12 years) showed no age-related differences when accuracy was assessed via parental report (e.g., Friedman et al., 2011). However, this could be due in part to the fact that the present study tested a wider age range and had an objective measure of accuracy. In fact, the present work showed that the largest improvements were between 7-year-olds and older children, outside the tested age range of Friedman et al. (2011), but consistent with other studies of episodic memory showing a steep increase in performance between 7-year-olds and older children (e.g., Picard, Cousin, Guillery-Girard, Eustache, & Piolino, 2012).

Another goal of this work was to determine whether CTK task performance would predict performance on our temporal memory task, and we found that it did. In fact, CTK was a better predictor than age, suggesting that performance on the CTK is indicative of developments in temporal memory, and consistent with previous studies that have found a positive relation between CTK task scores and other measures of temporal memory (Friedman et al., 2011; Pathman & Ghetti, 2014). However, our study allowed us to gain a deeper understanding of this effect. Given past and present evidence that the CTK task is related to temporal memory performance, we sought to examine the factors that predicted CTK task performance. We found that both vocabulary and working memory but not age or the measure of inhibitory control, predicted CTK scores. Further, vocabulary surpassed CTK task performance as a significant predictor of temporal memory. Together this work provides unique and novel insights into possible processes underlying the relation between the CTK task and measures of temporal memory. Specifically, it suggests that broader developments in semantic knowledge (not necessarily related to time concepts or words) and language concurrently develop with better grasps of conventional time knowledge itself. This finding is consistent with studies in which standardized language/semantic knowledge measures requiring children to select the pictures that best represents a word or object

(Peabody Picture Vocabulary Test; PPVT) were found to be positively correlated with accuracy in episodic memory tasks (e.g., Robertson & Köhler, 2007; Sipe & Pathman, 2021). In early childhood (4- and 6-year-olds) researchers found that both language (PPVT) and performance on an adapted version of the CTK (adapted to be used with younger children, and adapted to separate the knowledge from the flexible retrieval portion of the original CTK task) were unique predictors of temporal memory (e.g., Scales & Pathman, 2021). All of this signals that additional studies are needed to examine how developments in semantic organization and knowledge (e.g., Unger, Fisher, Nugent, Ventura, & MacLellan, 2016) may be related to episodic memory development, including temporal memory across childhood.

We did not find relations between our inhibitory control measure and performance on the CTK task. This could be because of high accuracy performance approaching ceiling by our participants, although this particular executive function measure was chosen because past work suggests it is less prone to ceiling effects than other executive function tasks (Lagattuta et al., 2011) like the day-night task, which is often used to test children's inhibitory control (Diamond, Kirkham, & Amso, 2002). However, even when we used mean reaction time on the Happy-Sad task as the measure of inhibitory control, for which we did see age-related differences, it was still not predictive of CTK task performance. Thus, it is possible that inhibitory control is not a driver of performance in the CTK task in middle to late childhood. Future work should further examine how the different aspects of executive function may relate to performance on different types of temporal memory tasks and vary across childhood. For example, Picard et al. (2012) found that certain aspects of executive function (like updating) were related to contextual features (temporal and spatial) in a lab-based memory task. Further, inhibitory control was a unique predictor of performance on children's recall of source memory (Rajan, Cuevas, & Bell, 2014). Thus, it is quite possible that changes in inhibitory control across childhood are not responsible for children's acquisition or flexible retrieval of conventional time knowledge, but inhibitory control may be important for the ability to remember past autobiographical events, especially when retrieval necessitates controlled memory processes (see Ghetti & Lee, 2010).

The relation between working memory and conventional time knowledge was hypothesized given that the CTK task requires maintenance and manipulation of the months of a calendar. Thus, although Friedman has discussed the importance of mental imagery on performance on the CTK task (based on participant reports; Friedman, 1986; see also, 1989), working memory also plays a significant role in performance. Further, we are not aware of studies that have examined the relation between working memory and the flexible retrieval of temporal knowledge. However, Picard et al. (2012) examined the relation between short-term feature binding and episodic details, including temporal memory, and found significant relations for a particular type of short-term memory task. Further, other studies have examined relations between working memory and episodic memory more broadly. For instance, working memory may predict future episodic memory decline in older adults (Memel, Woolverton, Bourassa, & Glisky, 2019), and both working memory and episodic memory show overlapping brain activation patterns in adults (Ranganath, Johnson, & D'Esposito, 2003). Given the present findings, studies showing that working memory improves across childhood and into adolescence (Gathercole, Pickering, Ambridge, & Wearing, 2004), the importance of working memory in cognitive development (see Cowan, 2014, for review), and that working memory is related to children's understanding of temporal words (i.e., before, after) in sentences (Blything, Davies, & Cain, 2015; see McCormack & Hoerl, 2017, for discussion), it is important that working memory be incorporated into future models of temporal memory development.

The present study involved testing children's episodic temporal memory – children and adults placed previously experienced naturalistic events in time using an arbitrary time scale, in addition to other recall and recognition judgments about the events. We note that our temporal memory task involved space, since participants were required to place events on a horizontally oriented line intended to represent time. Previous studies have successfully used spatial displays (e.g., board placed on table with one end representing recent time and the other end representing distance time) to examine the development of temporal memory, and have shown that young children use spatial timeline stimuli reliably (see Friedman & Kemp, 1998, Study 2). Still, we could consider whether developmental change in the ability to translate from time to space, rather than temporal memory could explain performance on the timeline task. It is true that in other domains (like magnitude representation) in which children are asked to mark abstract concepts like number, on a spatial scale, there are age-related differences from early to middle childhood. For example, when presented with number lines with endpoints of 0 and 100, and asked to mark-specific numbers on the line, most children in second grade (but not younger children) produce a linear function (such that numbers are evenly spaced throughout the line length; Siegler & Booth, 2004; see also for discussion Booth & Siegler, 2008; Newcombe, Levine, & Mix, 2015). However, with increasing number scales (e.g., 0 to 1000), even 7- and 9-year-olds have difficulty placing numbers accurately on a spatially based number line (Siegler & Opfer, 2003; younger children's estimates better fit a logarithmic function; 11-year-old and adult estimates better fit a linear function). It is impossible to directly compare the results of the present study to those emerging from research on number estimation, as our study involved placing past events on a spatial timeline, and these studies involve placing number magnitudes on a spatial number line. Nevertheless, it is important to note that common mechanisms for time, number, mass, and space have been theorized (e.g., Newcombe et al., 2015; Walsh, 2003).

One study involving memory could help us determine whether developmental change in the relations between time to space could explain performance on our spatially based timeline task. Based on the literature on the relation between space and time in the mind (e.g., Boroditsky, 2000; Bottini & Casasanto, 2013; Casasanto & Boroditsky, 2008; Merritt, Casasanto, & Brannon, 2010), Pathman and colleagues examined whether the mental timeline influences temporal and spatial memory for past events in children and adults. The mental timeline is the idea that time is represented in the mind linearly. For English speakers, the mental timeline is a horizontal display in which the left side represents earlier time, and the right side represents later time (e.g., Boroditsky, Fuhrman, & McCormick, 2011; see also Santiago, Lupiáñez, Pérez, & Funes, 2007). In their study, Pathman, Coughlin & Ghetti, (2018) presented object sequences on a computer screen that either were congruent or incongruent with the mental timeline. For example, presenting the 1st, 2nd, and 3rd object in the sequence, on the left, middle, and right side of the screen, respectively, is congruent with the mental timeline. After this study phase, participants were shown individual objects and asked to state whether each object was old or new (recognition memory) and then asked to judge the ordinal position of the object (was it 1st, 2nd or 3rd in the sequence?) and spatial position of the object (was it presented on the left, middle, or right side?). Their findings were consistent with research in the domains of language and thought, such that space influences time more than vice versa (e.g., Boroditsky, 2000). Researchers found that participants were more accurate at remembering time when sequences were presented in a way that matched the mental timeline (congruent trials) than when sequences were presented in a way that did not match the mental timeline (incongruent trials). Spatial memory accuracy was not influenced by this experimental manipulation. Importantly, for our purposes, these effects occurred across age groups (children as young as 7 to young adults): It was not the case that the spatiotemporal presentation of objects impacted some age groups more than others. This previous study suggests that children in the present study can represent time on a linear left-to-right display, and in fact have already formed a mental timeline in which time is represented from left to right. Thus, it seems unlikely that translation of time to space could have been responsible for developmental differences on our temporal memory task.

The present study tested participants' flexible retrieval of conventional time knowledge, using a task originally created by Friedman (1986). More recently, researchers have developed a broader questionnaire to test children's temporal knowledge. Labrell, Mikaeloff, Perdry, and Dellatolas (2016) asked children questions like, "In what season are we?," "Is a minute shorter or longer than a second?," and "Show me 2 o'clock" from a selection of six images of a clock. They found that children's accuracy on their time knowledge questionnaire (TKQ) was related to numerical skills. Further, Labrell, Camara Costa, Perdry, and Dellatolas (2020) discussed the need for future studies using their questionnaire to determine the additional cognitive processes playing a role: "Working memory could be the executive function children need to answer the different subtests in the TKQ correctly … Future investigations are also needed in order to examine the associations between time knowledge and other cognitive components, such as language skills and memory, during development" (p. 8). Indeed, future studies, along with the present work, can help to further specify the various cognitive processes and experiences that contribute to the development of children's temporal knowledge, and how this in turn impacts the development of episodic memory.

The present work has its limitations, namely that we used often-used tasks as a proxy for certain cognitive processes (e.g., working memory, inhibitory control), but tasks themselves are not process pure. Nevertheless, the findings provide novel evidence and a starting point to learn about factors that could underlie the development of the flexible retrieval of conventional time knowledge which in turn seems to support the development of temporal memory. Our findings showed that language/semantic knowledge and working memory may have driven the relations found in past research. Future studies, especially those employing longitudinal designs, are needed to more fully examine changes in temporal memory and semantic memory related to time, and the role of other individual differences.

Acknowledgement

We are grateful to the families and undergraduate students who took part in this research. We thank members of the MAD Lab (PI: S.G.) for help with data collection and members of the MDLaB (PI: T.P.) for help with data scoring and processing. A James S. McDonnell Foundation scholar award to S.G. supported data collection. C.C. is currently at the University of Texas at Austin. The MDLaB is supported by the Natural Sciences and Engineering Research Council of

Canada. The data that support the findings of this study are available from the corresponding author, upon request.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Thanujeni Pathman http://orcid.org/0000-0003-0017-7319

References

Allison, P. (1999). *Multiple regression: A primer*. Thousand Oakes, California, USA: Pine Forge Press.

Bauer, P. J., Doydum, A. O., Pathman, T., Larkina, M., Güler, O. E., & Burch, M. (2012). It's all about location, location, location: Children's memory for the "where" of personally experienced events. *Journal of Experimental Child Psychology*, *113*(4), 510–522. doi:10.1016/j.jecp.2012.06.007

Bauer, P. J. (2015). A complementary processes account of the development of childhood amnesia and a personal past. *Psychological Review*, *122*(2), 204–231. doi:10.1037/a0038939

Bauer, P. J., Stewart, R., White, E. A., & Larkina, M. (2015). A place for every event and every event in its place: Memory for locations and activities by 4-year-old children. *Journal of Cognition and Development*, *17*(2), 244–263. doi:10.1080/15248372.2014.959521

Blything, L. P., Davies, R., & Cain, K. (2015). Young children's comprehension of temporal relations in complex sentences: The influence of memory on performance. *Child Development*, *86*(6), 1922–1934. doi:10.1111/cdev.12412

Booth, J. L., & Siegler, R. S. (2008). Numerical magnitude representations influence arithmetic learning. *Child Development*, *79*(4), 1016–1031. doi:10.1111/j.1467-8624.2008.01173.x

Boroditsky, L. (2000). Metaphoric structuring: Understanding time through spatial metaphors. *Cognition*, *75*(1), 1–28. doi:10.1016/S0010-0277(99)00073-6

Boroditsky, L., Fuhrman, O., & McCormick, K. (2011). Do English and Mandarin speakers think about time differently? *Cognition*, *118*(1), 123–129. doi:10.1016/j.cognition.2010.09.010

Bottini, R., & Casasanto, D. (2013). Space and time in the child's mind: Metaphoric or ATOMic? *Frontiers in Psychology*, *4*, 803. doi:10.3389/fpsyg.2013.00803

Casasanto, D., & Boroditsky, L. (2008). Time in the mind: Using space to think about time. *Cognition*, *106*(2), 579–593. doi:10.1016/j.cognition.2007.03.004

Cowan, N. (2014). Working memory underpins cognitive development, learning, and education. *Educational Psychology Review*, *26*(2), 197–223. doi:10.1007/s10648-013-9246-y

Deker, L., & Pathman, T. (2021). Did I visit the polar bear before the giraffe? Examining memory for temporal order and the temporal distance effect in early to middle childhood. *Applied Cognitive Psychology*, *35*, 785–794. doi:10.1002/acp.3804

Diamond, A., Kirkham, N., & Amso, D. (2002). Conditions under which young children can hold two rules in mind and inhibit a prepotent response. *Developmental Psychology*, *38*(3), 352–362. doi:10.1037/0012-1649.38.3.352

Friedman, W. J. (1986). The development of children's knowledge of temporal structure. *Child Development*, *57*(6), 1386–1400. doi:10.2307/1130418

Friedman, W. J. (1989). The representation of temporal structure in children, adolescents and adults. In I. Levin & D. Zakay (Eds.), *Time and human cognition: A life-span perspective; time and human cognition: A life-span perspective* (259–304). North-Holland, Oxford: Elsevier Publishing B.V. doi:10.1016/S0166-4115(08)61044-4

Friedman, W. J. (1991). The development of children's memory for the time of past events. *Child Development*, *62*(1), 139–155. doi:10.2307/1130710

Friedman, W. J. (1992). Children's time memory: The development of a differentiated past. *Cognitive Development*, *7*(2), 171–187. doi:10.1016/0885-2014(92)90010-O

Friedman, W. J., & Kemp, S. (1998). The effects of elapsed time and retrieval on young children's judgments of the temporal distances of past events. *Cognitive Development*, *13*(3), 335–367. doi:10.1016/S0885-2014(98)90015-6

Friedman, W. J. (2000). The development of children's knowledge of the times of future events. *Child Development*, *71*(4), 913–932. doi:10.1111/1467-8624.00199

Friedman, W. J., & Lyon, T. D. (2005). Development of temporal-reconstructive abilities. *Child Development*, *76*(6), 1202–1216. doi:10.1111/j.1467-8624.2005.00844.x-i1

Friedman, W. J., Reese, E., & Dai, X. (2011). Children's memory for the times of events from the past years. *Applied Cognitive Psychology*, *25*(1), 156–165. doi:10.1002/acp.1656

Friedman, W. J. (2014). The development of memory for the time of past events. In P. J. Bauer & R. Fivush (Eds.), *Wiley-blackwell handbook on the development of children's memory* (pp. 394–407). West Sussex, UK: Wiley-Blackwell.

Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology*, *40*(2), 177–190. doi:10.1037/0012-1649.40.2.177

Ghetti, S., & Lee, J. (2010). Children's episodic memory. *WIREs Cognitive Science*, *2*(4), 365–373. doi:10.1002/wcs.114

Harris, R. J. (1985). *A primer of multivariate statistics* (2nd ed.). New York, NY: Academic Press.

Johnston, R., Jones, K., & Manley, D. (2018). Confounding and collinearity in regression analysis: A cautionary tale and an alternative procedure, illustrated by studies of British voting behaviour. *Quality & Quantity*, *52*(4), 1957–1976. doi:10.1007/s11135-017-0584-6

Kessels, R. P. C., van Zandvoort, M. J. E., Postma, A., Kappelle, L. J., & de Haan, E. H. F. (2000). The corsi block-tapping task: standardization and normative data. *Applied Neuropsychology*, *7*(4), 252–258. doi:10.1207/S15324826AN0704_8

Kessels, R. P. C., van den Berg, E., Ruis, C., & Brands, A. M. A. (2008). The backward span of the corsi block-tapping task and its association with the WAIS-III digit span. *Assessment*, *15*(4), 426–434. doi:10.1177/1073191108315611

Labrell, F., Mikaeloff, Y., Perdry, H., & Dellatolas, G. (2016). Time knowledge acquisition in children aged 6 to 11 years and its relationship with numerical skills. *Journal of Experimental Child Psychology*, *143*, 1–13. doi:10.1016/j.jecp.2015.10.005

Labrell, F., Camara Costa, H., Perdry, H., & Dellatolas, G. (2020). The time knowledge questionnaire for children. *Heliyon*, *6*(2), e03331. doi:10.1016/j.heliyon.2020.e03331

Lagattuta, K. H., Sayfan, L., & Monsour, M. (2011). A new measure for assessing executive function across a wide age range: Children and adults find happy-sad more difficult than day-night. *Developmental Science*, *14*(3), 481–489. doi:10.1111/j.1467-7687.2010.00994.x

McCormack, T., & Hoerl, C. (2017). The development of temporal concepts: Learning to locate events in time. *Timing & Time Perception*, *5*(3–4), 297–327. doi:10.1163/22134468-00002094

Memel, M., Woolverton, C. B., Bourassa, K., & Glisky, E. L. (2019). Working memory predicts subsequent episodic memory decline during healthy cognitive aging: Evidence from a cross-lagged panel design. *Aging, Neuropsychology, and Cognition*, *26*(5), 711–730. doi:10.1080/13825585.2018.1521507

Merritt, D. J., Casasanto, D., & Brannon, E. M. (2010). Do monkeys think in metaphors? Representations of space and time in monkeys and humans. *Cognition*, *117*(2), 191–202. doi:10.1016/j.cognition.2010.08.011

Milner, B. (1971). Interhemispheric differences in the localization of psychological processes in man. *British Medical Bulletin*, *27*(3), 272–277. doi:10.1093/oxfordjournals.bmb.a070866

Nelson, K., & Fivush, R. (2004). The emergence of autobiographical memory: A social cultural developmental theory. *Psychological Review*, *111*(2), 486–511. doi:10.1037/0033-295X.111.2.486

Nelson, K., & Fivush, R. (2020). The development of autobiographical memory, autobiographical narratives, and autobiographical consciousness. *Psychological Reports*, *123*(1), 71–96. doi:10.1177/0033294119852574

Newcombe, N. S., Levine, S. C., & Mix, K. S. (2015). Thinking about quantity: The intertwined development of spatial and numerical cognition. *Wiley Interdisciplinary Reviews: Cognitive Science*, *6*(6), 491–505. doi:10.1002/wcs.1369

Pathman, T., & Ghetti, S. (2014). The eyes know time: A novel paradigm to reveal the development of temporal memory. *Child Development*, *85*(2), 792–807. doi:10.1111/cdev.12152

Pathman, T., & St. Jacques, P. L. (2014). Locating events in personal time: Time in autobiography. In P. J. Bauer & R. Fivush (Eds.), *Wiley-blackwell handbook on the development of children's memory* (pp. 408–426). West Sussex, UK: Wiley-Blackwell.

Pathman, T., Coughlin, C., & Ghetti, S. (2018). Space and time in episodic memory: Effects of linearity and directionality on memory for spatial location and temporal order in children and adults. *Plos One*, *13*(11), e0206999. doi:10.1371/journal.pone.0206999

Picard, L., Cousin, S., Guillery-Girard, B., Eustache, F., & Piolino, P. (2012). How do the different components of episodic memory develop? Role of executive functions and short-term feature-binding abilities. *Child Development*, *83*(3), 1037–1050. doi:10.1111/j.1467-8624.2012.01736.x

Rajan, V., Cuevas, K., & Bell, M. A. (2014). The contribution of executive function to source memory development in early childhood. *Journal of Cognition and Development*, *15*(2), 304–324. doi:10.1080/15248372.2013.763809

Ranganath, C., Johnson, M. K., & D'Esposito, M. (2003). Prefrontal activity associated with working memory and episodic long-term memory. *Neuropsychologia*, *41*(3), 378–389. doi:10.1016/S0028-3932(02)00169-0

Robertson, E. K., & Köhler, S. (2007). Insights from child development on the relationship between episodic and semantic memory. *Neuropsychologia*, *45*(14), 3178–3189. doi:10.1016/j.neuropsychologia.2007.06.021

Santiago, J., Lupiáñez, J., Pérez, E., & Funes, M. J. (2007). Time (also) flies from left to right. *Psychonomic Bulletin & Review*, *14*(3), 512–516. doi:10.3758/bf03194099

Scales, M., & Pathman, T. (2021). Flexible retrieval of semantic knowledge predicts temporal memory, but not memory for other types of contexts, in 4-6-year-olds. *Cognitive Development*, *59*, 101080. doi:10.1016/j.cogdev.2021.101080

Siegler, R. S., & Opfer, J. E. (2003). The Development of Numerical Estimation: Evidence for Multiple Representations of Numerical Quantity. *Psychological Science*, *14*(3), 237–250. doi:10.1111/1467-9280.02438

Siegler, R. S., & Booth, J. L. (2004). Development of numerical estimation in young children. *Child Development*, *75*(2), 428–444. doi:10.1111/j.1467-8624.2004.00684.x

Sipe, S. J., & Pathman, T. (2021). Memory at Play: Examining Relations Between Episodic and Semantic Memory in a Children's Museum. *Child Development*, *92*(3), e270–e284. doi:10.1111/cdev.13484

Tillman, K. A., Marghetis, T., Barner, D., & Srinivasan, M. (2017). Today is tomorrow's yesterday: Children's acquisition of deictic time words. *Cognitive Psychology*, *92*, 87–100. doi:10.1016/j.cogpsych.2016.10.003

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory* (pp. 382–403). New York, NY: Academic Press.

Tulving, E. (1993). What is episodic memory? *Current Directions in Psychological Science*, *2*(3), 67–70. doi:10.1111/1467-8721.ep10770899

Unger, L., Fisher, A. V., Nugent, R., Ventura, S. L., & MacLellan, C. J. (2016). Developmental changes in semantic knowledge organization. *Journal of Experimental Child Psychology*, *146*, 202–222. doi:10.1016/j.jecp.2016.01.005

Walsh, V. (2003). A theory of magnitude: Common cortical metrics of time, space and quantity. *Trends in Cognitive Sciences*, *7*(11), 483–488. doi:10.1016/j.tics.2003.09.002

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). *Woodcock-Johnson III tests of cognitive abilities*. Itasca, IL: Riverside Publishing.