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The current dissertation was designed to examine relations between temporal memory abilities, time knowledge, executive function (EF) components, and language in early and middle childhood. Time is an essential feature of episodic memory—memory for events from a specific time and place (Tulving, 1972). Memory for temporal order and context (e.g., season, time) improves substantially from 4 to 8 years of age (Pathman, Larkina, et al., 2013). To recall the time of events, Friedman (1993) discussed a process called reconstruction, which includes combining recalled details with time knowledge. Reconstruction abilities emerge in early childhood, show marked development during the transition to middle childhood (Friedman, 2014), and might relate to EF skills given the need to monitor the retrieval process by coordinating event details with time knowledge. Study 1 investigated the relations between memory for temporal order and context of personal events, time knowledge, EF components, and language in early childhood. Ninety-five 4- and 5-year-old children were interviewed about two recent events, and responses were coded for temporal order and context information. Participants also completed an EF task battery, time knowledge task, and receptive language task. Working memory was related to preschoolers' memory for temporal context when controlling for age, cognitive flexibility, and time knowledge. Study 2 explored the relations between reconstruction abilities, time knowledge, and EF components in early and middle childhood. Eighty-one 4- to 7-year-olds heard two stories about child characters playing outside that took place in specific temporal contexts (e.g., Spring, Morning). The experimenter included temporal cues (e.g., flowers growing) but never stated the season or time. Participants then completed an EF task battery, which was followed by questions about the temporal contexts and cues of each story and

a time knowledge task. Both cognitive flexibility and time knowledge were related to temporal judgments when controlling for age and working memory. Overall, there is evidence from this dissertation that EF components and time knowledge are related to temporal memory abilities in early and middle childhood. These findings have implications for children's ability to construct narratives, create an autobiography and self-identity, and their ability to provide eyewitness testimony in early and middle childhood.

THE RELATIONS BETWEEN TEMPORAL MEMORY ABILITIES, TIME KNOWLEDGE, EXECUTIVE FUNCTION, AND LANGUAGE IN EARLY AND MIDDLE CHILDHOOD

by

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CHAPTER I: GENERAL INTRODUCTION

The first time I visited Washington, D.C. I was six, and it was a hot, humid summer afternoon. I was with my parents and two older brothers, and we took the Metro from northern Virginia into the city. The experience described is an *episodic memory*, memory for events from a specific time and place (Tulving, 1972). Episodic memory encompasses a continuum of phenomena ranging from laboratory-based memory for word or picture lists to detailed, personal accounts (Bauer, 2007; Wheeler et al., 1997). Based on Tulving's definition, time is an essential component of episodic memory. Friedman (1993) discussed how the events of our lives are organized by when they occurred, which allows us to create a life story via an autobiographical timeline. Furthermore, Conway and Pleydell-Pearce (2000) suggested that as adults our past is divided into specific lifetime periods (e.g., when I was in graduate school), which include various people and experiences. Although time is a critical feature of episodic memory, children's memory for the time of events, temporal memory, develops slower than memory for other types of contextual information (e.g., people, locations; Cuevas et al., 2015; Lee et al., 2016; Pathman et al., 2018; Reese et al., 2011).

The development of temporal memory is important for cognitive, socio-emotional, and clinical outcomes. We use our temporally organized experiences to build an autobiography and construct a self-identity (Friedman, 1993; Nelson & Fivush, 2004). Furthermore, through sharing past experiences we can connect with others, which promotes the establishment and strengthening of personal relationships (Friedman, 2004; Nelson & Fivush, 2004). Temporal memory development also has implications for legal settings where children are required to give testimony of events. Children’s understanding of, and memory for, time is crucial if legal practitioners expect children to make accurate temporal judgments (Friedman & Lyon, 2005).

Regarding clinical outcomes, the inability to retrieve specific, detailed episodic memories—*overgeneral memory*—is related to depressive symptoms and clinical depression in middle childhood (Drummond et al., 2006), late childhood (Kukyen et al., 2006; Raes et al., 2010; Vrielynck et al., 2007), and adulthood (see Williams et al., 2007, for review). Thus, it is important to determine and understand the cognitive processes and factors related to temporal memory development during early and middle childhood.

There are different types of temporal information we can recall, such as *temporal order* (relating events to each other in time, e.g., we visited Baltimore *before* we visited Portland) and *temporal context* (placing events on arbitrary or conventional time scales, e.g., we visited Baltimore in March). Memory for both the temporal order and temporal context of events improves from early (i.e., ages 3 to 5) to middle (i.e., ages 6 to 8) childhood, with substantial changes occurring from when children are 4 to 6 years of age (see Friedman, 2014; Pathman & St. Jacques, 2014, for review). Past work examining the development of memory for temporal order often includes tasks that require children to judge the order of two events (i.e., primacy/recency task), as well as the order of multiple events (i.e., ordering or sequencing tasks). When judging the order of two events, 5- to 8-year-olds make accurate judgments about staged events (Friedman, 1991), personal events (Pathman, Larkina, et al., 2013), holidays and birthdays (Friedman & Kemp, 1998), and laboratory-based events (Scales & Pathman, 2021), but 4-year-olds are less consistent. In one study, 4-year-olds performed below chance at judging the order of a recent (i.e., 4-5 weeks ago) and a distant (i.e., 11-12 weeks ago) personal event (Pathman, Larkina, et al., 2013), but in another study, 4-year-olds performed above chance at ordering staged events that occurred 5-6 weeks apart (Friedman, 1991). Given that younger children have more difficulty remembering events after longer delays (see Bauer, 2007, for review), it is possible that the longer retention interval affected 4-year-olds' ability to order events correctly in the study by Pathman, Larkina et al. Indeed, Scales and Pathman (2021) found that 4-year-olds performed above chance at judging the order of two events from stories after a two-minute delay. Additionally, findings from a longitudinal investigation of temporal order memory yielded age-related improvement from 4 to 8 years of age on judging the order of two items selected from 8- and 12-item lists after a one-minute delay (Canada et al., 2020).

Regarding memory for the temporal order of more than two events, Scales and Pathman (2021) examined 4- and 6-year-olds' memory for the temporal order of four drawings they made during the delays between other tasks and found that 6-year-olds performed better than 4-year-olds at putting their drawings in the correct temporal order. Similarly, 3- and 4-year-olds' memory for the temporal order of five staged events was less accurate than 5- and 6-year-olds', but only 3-year-olds performed below chance on ordering the events on an immediate test and after a 30-minute delay (Scarf et al., 2017). In a longitudinal sample, Canada et al. (2020) also observed improvements from age 4 to 8 in ordering 9-item picture lists. Researchers have also used a timeline method to measure children's memory for temporal order, which typically involves children placing pictures of specific events on a spatial timeline. Friedman and Kemp (1998) used a timeline that only represented the past, with the left side of the timeline representing "a longer time ago" and the right side representing "a shorter time ago," and asked 4- to 6-year-olds to place pictures depicting holidays on the timeline. Overall, children placed cards in relatively accurate positions given the delay between different holidays and testing. Another study used a timeline that included the past, present (i.e., a space labeled "today"), and future, and 5- to 7-year-olds placed personal and hypothetical events with specific distances from the present (e.g., yesterday, one week, two weeks, tomorrow) on the timeline (Hudson &

Mayhew, 2011). There were no differences in children's accuracy in placing personal events on the timeline, but 5- and 6-year-olds made more errors in placing hypothetical events on the timeline compared to 7-year-olds. Additionally, 7-year-olds' accuracy for hypothetical events did not differ across temporal distance (e.g., yesterday, two weeks, one month), but 5- to 6-year-olds' accuracy decreased as temporal distance increased. Tillman et al. (2017) also used timelines that included the past, future, and today, and asked 3- to 8-year-olds and young adults to place familiar events (e.g., breakfast, your next birthday) and general temporal terms (e.g., this morning, tomorrow, last year) on them. Across ages, there were no differences in accuracy between the individual placements of familiar events and temporal terms, but age-related improvements were observed for each age from 3 to 7, while 7- and 8-year-olds did not differ from each other or adults. Tillman et al. also examined the order of placements and found that 8-year-olds' scores were equal to adults' but 7-year-olds' scores were lower than adults'. Additionally, 3-year-olds performed at chance for individual placements and below chance on ordering, whereas 4-year-olds performed above chance on both measures. In sum, children's ability to remember the order of multiple events shows similar age-related changes from early to middle childhood across a range of study methods.

There is also work examining children's use of temporal organization in personal narratives of past events. Reese et al. (2011) coded children's and adults' personal event narratives for chronology and found that preschoolers were able to order some parts of an event correctly, but their overall chronology scores were low. From age 6 to 11, Reese et al. observed a substantial improvement in children's ability to provide event narratives that maintained accurate temporal order. Additionally, Fivush et al. (1995) examined 4-, 5-, and 6-year-olds' personal event narratives in a longitudinal study, and results indicated that with age, children included more temporal markers (e.g., then, next, before, after). Thus, children's temporal language use and narrative organization parallel the development of memory for the temporal order of two or more events.

To measure memory for the temporal context of events, a common method involves asking participants to place events on various time scales (e.g., time of day, day of week, month, season). By age 4, children make accurate judgments about the time of day of personal and staged events that occurred multiple weeks in the past (i.e., 4 to 11 weeks), but on other time scales, 4-year-olds are less accurate than 6- and 8-year-olds (Friedman, 1991; Pathman, Larkina, et al., 2013). Additionally, in personal event narratives, there is evidence that children's inclusion of information about temporal context increases from 3 to 5 years of age (Haden et al., 1997) and 6 to 11 years of age (Reese et al., 2011). Regarding laboratory-based tasks, Scales and Pathman (2021) investigated 4- and 6-year-olds' memory for temporal context of stories that included characters performing actions either in the morning or afternoon. Both age groups performed above chance on temporal context questions, and overall, 6-year-olds performed better than 4-year-olds. Across personal, staged, and laboratory-based events, children's ability to place past events in time improves from 4 to 8 years of age, which coincides with the age-related changes observed in temporal order memory from early to middle childhood.

Development of Children's Understanding of Time and Temporal Cognition

McCormack and Hoerl (2017) proposed a theoretical model of the development of children's understanding of temporal concepts and how the ability to think and reason about time (i.e., temporal cognition) changes across childhood. Importantly, the stages of the model correspond to the developmental trajectories of temporal order and context memory across early and middle childhood. The model is based on the acquisition of three components of adults' understanding of time: (1) adults represent time as linear in the form of a timeline that includes past events (left side/going back on the timeline) and future events (right side/going forward on the timeline), (2) adults represent all events on one, single timeline, and on that timeline, each event has a specific before/after position in relation to all other events on the timeline, and (3) adults understand that time is independent of events, in other words, adults can reason about how multiple events could occur at a particular point in time and can think about points in time separately from events. The model consists of four stages that are based on age, and the last two stages are most relevant for the current dissertation because they correspond to the age-related changes in temporal order and context memory that occur across early and middle childhood. Critically, McCormack and Hoerl discuss each stage as dynamic, in which development and change are occurring within a specific period. The model also provides insight into other cognitive factors that relate to temporal concepts and cognition.

The third stage of the model is particularly significant because it marks the point when children begin to understand all three components of adults' temporal understanding, which is estimated as 4 to 5 years of age. Regarding the first two components, representing time as linear, with events falling on a timeline and having before/after relations, McCormack and Hoerl (2017) discussed findings from studies that examined children's memory for temporal order and the ability to place past and future events on timelines (Friedman, 1991; Friedman & Kemp, 1998; Hudson & Mayhew, 2011; Tillman et al., 2017). Findings from most of these studies demonstrate that by 4 years of age, children can accurately judge the order of two unrelated events and place events on spatial timelines. McCormack and Hoerl interpreted these findings as evidence that by 4 to 5 years of age, children have a basic understanding of time as linear and how before/after relations exist between events. Additionally, studies that included measures of children's understanding of the terms before and after provide further evidence for the latter concept. McCormack and Hanley (2011) investigated 4- and 5-year-olds' understanding of the terms before and after with a task that consisted of children viewing videos of two actions (e.g., a person eating chocolate, a person reading a book) in both possible orders. After viewing both videos, the experimenter read a sentence (e.g., "The girl was eating chocolate *before* she read a book."), and participants pointed to the video which corresponded to the experimenter's sentence. The task included both matching and non-matching sentences to describe the video clips, with matching sentences mentioning events in the same order as they occurred in the video and non-matching sentences mentioning events in the opposite order. Four- and 5-year-olds both performed above chance on matching sentences, but only 5-year-olds performed above chance on non-matching sentences. In another study, Arterberry and Albright (2020) presented 3- to 6-year-old children with a "typical day" timeline that included three anchor events placed at the beginning (waking up), middle (eating lunch), and end (going to sleep). Children then answered questions about where other typical events went on the timeline (e.g., "Do you eat breakfast before or after you wake up?"). On this task, 5- and 6-year-olds performed better than 3- and 4-year-olds. Thus, by 4 to 5 years of age, children show some understanding of time as linear and before/after relations, but this understanding is not yet adult-like.

Concerning the third component, McCormack and Hoerl interpret findings from studies examining children's counterfactual thinking abilities as preliminary, indirect evidence that at age 4 and 5 children are beginning to think about and understand time as event-independent. Counterfactual thinking is defined as the ability to consider possible alternatives for a particular outcome and involves the understanding that events can have different outcomes depending on various factors (Beck & Riggs, 2014). In a classic example from Harris et al. (1996), children are told about a girl who wears her muddy shoes in the house and walks across a clean floor, which results in the floor getting dirty. Children answer questions about what would have happened *if* the girl took her shoes off (i.e., "Would the floor be dirty?"). McCormack and Hoerl suggest that the ability to consider alternatives for past events which would lead to different outcomes is connected to understanding time as event-independent because by speculating on possible alternatives (e.g., if the girl had taken her shoes off) children are taking on the perspective that the event has not yet occurred and can be changed. Thus, the event in question is not intrinsically tied to the time when it occurred. Researchers debate about the age when children can think and reason about counterfactuals, but there is evidence that children can provide accurate counterfactuals about past events by age 4 and future events by age 5 (see Beck & Riggs, 2014, for review).

McCormack and Hoerl (2017) also discuss children's planning abilities as indirect evidence of children's developing understanding of time as event-independent. Planning tasks require children to think flexibly about the consequences of potential actions, the order of actions, and how changes to the temporal order impact a goal or outcome. For example, McColgan and McCormack (2008) told children a story about a character going to a zoo who wanted to stop at a specific location to take a picture, and asked children which location they should leave the character's camera so she could then take the picture in the specified location. Five-year-olds chose the correct location for this task, whereas 4-year-olds did not. Overall, children's performance on various planning tasks shows marked improvement from 3 to 5 years of age (see McCormack & Atance, 2011, for review). McCormack and Hoerl posit that to be successful on planning tasks, children must be able to reflect on and reason about the temporal relations between actions. These abilities may be connected to both an early understanding of time as event-independent and before/after relations.

The fourth and final stage of the model marks the point when children have a comprehensive understanding that time is event-independent and can represent time in concrete and abstract ways, which is 5 years of age and older. It is important to note that McCormack and Hoerl (2017) do not claim that children have mature, adult-like temporal understanding and reasoning abilities by age 5, but rather age 5 and older represents the stage when children are developing an understanding of time as an abstract concept. Critically, during this period children gain a more sophisticated understanding of the clock and calendar systems. McCormack and Hoerl suggest that children's learning of clock and calendar systems during this stage provides children with the ability to think and reason about time without any reference to specific events (i.e., time as event-independent). From age 5 to 7 there is improvement in children's ability to place conventional time patterns (e.g., days of the week, months, seasons) in the correct order, but an understanding of the cyclical and recurring nature of time is not present until age 8 (Friedman, 1978). Although children understand time as cyclical by age 8, Friedman (1986, 1989) suggested that in adolescence, children's mental representations of time patterns change from verbal lists of items to spatial images, which allows them to be more flexible in how they think about time patterns.

In addition to the importance of children's understanding of time patterns (i.e., clock and calendar systems) for the development of temporal concepts, there is evidence that flexible thinking about time patterns (i.e., time knowledge) is related to memory for temporal order and context across childhood (Friedman et al., 2011; Pathman & Ghetti, 2014; Scales & Pathman, 2021). Friedman et al. assessed time knowledge with the Conventional Time Knowledge (CTK) task, which measures children's flexibility in thinking about the order of the months (e.g., "If you're going backward and you start in May, which would you come to first, September or January?"). Friedman et al. found that CTK performance was related to 8- to 12-year-olds' accuracy in placing personal events on various time scales (e.g., day of week, month, year, season) when controlling for age. There is also evidence that CTK performance is related to memory for temporal order. Pathman and Ghetti (2014) found that CTK performance was related to 7- to 10-year-olds' and adults' memory for the temporal order of object sequences when controlling for age. In another study, Pathman et al. (in press) asked 7-, 9-, and 11-year-olds and adults to place four staged events that occurred in a laboratory setting (e.g., drawing a picture, helping an experimenter pick up blocks) on a spatial timeline, with the beginning of the line marking when the participant came into the lab and the end of the line marking when the participant left the lab. Participants completed the timeline task one week after they encoded the staged events. Pathman et al. found that CTK performance was related to 7-, 9-, and 11-year-olds' and adults' accuracy scores on the timeline task over and above age.

Scales and Pathman (2021) created a version of the CTK task for use with younger children. The task consisted of a card ordering subtask and a flexible retrieval subtask, which included questions about various time scales (e.g., meals of the day, seasons, time of day). The card ordering subtask required participants to place pictures depicting items in a time scale (e.g., breakfast, lunch, and dinner cards) in the correct temporal order. The flexible retrieval questions required participants to manipulate forward and backward orders of the time scales (e.g., "If it's Fall, what season comes *next*?"; "If it's Fall, what season comes next going *backwards*?"). Scales and Pathman found that across time scales, 6-year-olds performed better than 4-year-olds on both subtasks, and that overall performance on the flexible retrieval questions was related to

4- and 6-year-olds' temporal memory (combined order and context) for story events over and above age. Thus, there is evidence that time knowledge and temporal memory are related in early and middle childhood.

In addition to proposing this model, McCormack and Hoerl (2017) also speculated about the role of language in the development of children's temporal concepts and cognition. Nelson (1996) suggested that developing an understanding of temporal concepts is entirely dependent on language and conversations with adults. Children begin to use temporal terms around age 2 or 3, but do not demonstrate comprehension and accurate use of them until age 4 or 5. However, even at ages 4 and 5, children's accuracy in using temporal terms is not always consistent (see Busby Grant & Suddendorf, 2010, for discussion). Nelson claimed that children's understanding of temporal terms comes from conversations with adults about past events because through this shared reminiscing adults provide scaffolding and organization, which in turn influences the development of children's understanding of time and temporal cognition abilities. Indeed, there is ample evidence that maternal reminiscing style is related to age-related changes in children's episodic memory abilities across early childhood, including how children organize and structure event narratives and use temporal terms (see Nelson & Fivush, 2004, for review).

In sum, McCormack and Hoerl's model (2017) of the development of temporal concepts provides a comprehensive review of how children's ability to think about and represent time changes with age. The age-related changes in temporal concepts parallel those found in children's memory for temporal order and context across early and middle childhood. The model provides insight into the complexity of how children understand time, which likely relates to the protracted development observed in temporal memory abilities. McCormack and Hoerl's discussion of various factors related to the development of temporal concepts and cognition (e.g., language, knowledge of time patterns, flexible thinking) offers several avenues for additional research on children's understanding of and memory for time. Furthermore, the model highlights early childhood and the transition to middle childhood as pivotal stages in the development of temporal concepts, which aligns with evidence of age-related changes in memory for time.

Language and Temporal Memory Development

In addition to the importance of temporal language in the development of temporal memory discussed by McCormack and Hoerl (2017), there is also evidence that general language abilities are related to episodic and temporal memory in early and middle childhood. Language is a component of semantic memory, defined as general knowledge of language, facts, and concepts, which is separate from the episodic memory system (Tulving, 1972). Tulving suggested that a person's semantic memory can influence the type of information that is encoded into episodic memory representations. Indeed, there is evidence that performance on receptive language tasks, which consist of an experimenter saying a set of words and for each word the participant points to the image (from a set of four) that matches it, is related to performance on episodic memory tasks from age 4 to 7 (Robertson & Köhler, 2007; Sipe & Pathman, 2020). Additionally, there is longitudinal evidence for an association between language skills and memory for personal events during the preschool period (see Reese, 2009, for review).

Regarding temporal memory, Scales and Pathman (2021) found that 4- and 6-year-olds' receptive language scores were related to temporal memory scores (i.e., combined order and context) over and above age and time knowledge. Pathman et al. (in press) extended this work by examining relations between 7-, 9-, and 11-year-olds', and adults' vocabulary and memory for temporal order of personal, staged events. Vocabulary was measured with a standardized task in which participants viewed a series of images and labeled them with the appropriate word

(Woodcock et al., 2001). Participants were asked to place the staged events in order and received an accuracy score, which was separate from the timeline task discussed above. Pathman et al. found that vocabulary scores were related to temporal order memory over and above age. Thus, children's receptive language (i.e., comprehension) is related to temporal memory in early childhood and children's vocabulary (i.e., comprehension and knowledge) is related to temporal order memory in middle and late childhood. Similar to Tulving (1972), Reese (2009) discussed how age-related changes in language abilities likely relate to how much information children encode from events and that the use of language in verbally recalling events strengthens children's ability to remember those events after long delays. Concerning temporal memory, it is possible that as children's language abilities develop, including temporal language, they are more likely to encode event information that is relevant to time (e.g., weather, sun), which could increase the likelihood that they are able to place events in time during retrieval. It is also possible that with better language abilities, children have a better understanding of questions and tasks that experimenters include while assessing memory for events.

Executive Function and Temporal Memory Development

Although not explicitly mentioned in McCormack and Hoerl's (2017) model, it is possible that executive function (EF)—higher-order, neurocognitive skills that bring about conscious control of thought and behavior during goal-relevant tasks (Jacques & Marcovitch, 2010; Zelazo et al., 2016)—is related to age-related changes in temporal cognition. Miyake et al. (2000) characterized EF in college students as both a unitary and partially diverse construct made up of the following components: updating, inhibition, and shifting. Updating involves adding information to representations held in working memory, keeping track of the information, and manipulating the information in response to task demands. Inhibition, or inhibitory control, is the ability to suppress a prepotent or habitual response. Shifting, or cognitive flexibility, is the ability to switch and reason between conflicting mental sets or perspectives. Across early and middle childhood, developmental gains have been observed for all three components across several tasks (see Garon et al., 2008, and Zelazo & Müller, 2002, for reviews). Theoretical accounts of EF development provide insight into why age-related changes in temporal concepts might be related to EF abilities in early and middle childhood.

Zelazo and colleagues suggest that EF development is driven by changes in children's representational and reflective abilities (Marcovitch & Zelazo, 2009; Zelazo, 2004, 2015; Zelazo et al., 2003). This group of theories describes how advances in reflection—deliberate reprocessing of information (i.e., a mental representation)—spur age-related changes in children's ability to control their thoughts and behavior. Engaging in reflection allows both children and adults to create more integrated, complex representations (Zelazo, 2015). Additionally, with increased reflection on a representation, children are better able to use cognitive control in situations that require it. Moreover**,** Marcovitch and Zelazo (2009) suggest that a potential source of errors on EF tasks is the lack of reflection. Without reflecting, children and adults are more likely to respond automatically, without full appreciation of the task or situational demands.

In addition to the role of reflection in EF development, Allen and Bickhard (2018) proposed that reflection is a domain-general ability that drives age-related changes in several areas of development during early childhood. For example, on planning tasks, McCormack and Hoerl (2017) suggested that children must *reflect* on temporal relations between events to complete the tasks correctly. Counterfactual thinking tasks also require children and adults to reflect on a specific event to generate various alternative outcomes. Furthermore, there is evidence that performance on planning tasks in early childhood is related to cognitive flexibility and inhibition (see McCormack & Atance, 2011, for review), and performance on counterfactual thinking tasks is related to all three EF components (Beck et al., 2009; Drayton et al., 2009; Guajardo et al., 2009). Thus, the development of EF components and temporal concepts may rely on age-related changes in children's reflection abilities across early and middle childhood. If this is the case, it is also possible that children's EF skills are related to their temporal memory abilities across early and middle childhood.

More specifically, Friedman and Lyon (2005) theorized that children need to use EF when recalling the time of events. Given age-related changes discussed previously in temporal memory and the understanding of temporal concepts, the ability to place events in time is arguably more complex compared to retrieval of other types of contextual information (e.g., people, places). Friedman (1993, 2014) reviewed studies examining the strategies and processes used by adults to place events in time. Friedman concluded that although all events occur at a specific location in time, representations of events are not automatically tagged with temporal information. Rather, across studies, there was evidence that adults engage in distance and reconstruction processes when recalling time. Distance processes rely on strength of memory representations by evaluating how vivid or clear a memory is to decide how recently (or distantly) an event occurred, with increased vividness signaling more recent events. Evidence from a few studies indicates that children do not typically use distance processes to make temporal judgments until middle and late childhood (Friedman, 2014; Pathman, Doydum, et al., 2013). According to Friedman, distance processes are automatic, rely on initial impressions of temporal distance, and can be used to judge both temporal order and temporal context. However, Friedman also suggests that distance processes are less useful when placing events on time scales (i.e., temporal context).

Compared to distance processes, adults use reconstruction processes more often to make temporal judgments. Reconstruction processes are effortful and entail the linking of temporally relevant event information (e.g., there was snow on the ground, it was cold outside) with knowledge of time patterns (e.g., months, seasons) to infer when an event occurred. There is evidence from a few studies that reconstruction abilities emerge in early childhood and show marked development during the transition to middle childhood, particularly from age 4 to 8 (see Friedman, 2014, for review). Successful reconstruction involves more than just recalling an experience. Rather, it requires that children and adults can form representations of events (i.e., memories) that include temporal information, accurately retrieve that information, and understand how relevant details connect to various time patterns. Concerning the ability to form and retrieve detailed representations, Bauer (2007) discussed the importance of age-related changes in encoding, consolidation/storage, and retrieval of event representations for episodic memory development. From early to middle childhood, these changes are evidenced by increases in the amount of overall information recalled about events, decreases in the number of cues needed during recall, and an improved ability to remember events after longer delays (Bauer, 2007; Reese et al., 2011). Younger children's heavier reliance on cues and reduced spontaneous recall likely indicate a difference in the quality of their memory representations. Thus, differences in children's ability to form representations during experiences and to retrieve them later improve with age. These changes in representational abilities likely have consequences for children's ability to engage in a process like reconstruction in early and middle childhood. Given that the reconstruction process is more complex than just retrieving event information, Friedman and Lyon (2005) proposed that children and adults rely on EF when using reconstruction to exert control over the retrieval process by monitoring the contents of event representations and evaluating those contents in the context of time knowledge.

Similarly, Rajan et al. (2014) discussed the importance of the specific EF components for memory of contextual information of events more broadly. Rajan et al. suggested that EF is especially important for contextual memory because to remember details about context, a child must combine various event features by switching their attention during the event (i.e., encoding) and keep track of those details during retrieval. Specifically, better working memory could allow children to keep more information in mind during encoding and retrieval. This would result in more details being encoded about the event, and then potentially more details being retrieved later. Indeed, Conway (1996) discussed how retrieval of memories is a cyclical process in which retrieved details serve as cues to additional information. Thus, with better working memory, children could hold more details in mind during retrieval, which could then result in more information being recalled. With better inhibitory control, children could inhibit familiar or habitual thoughts during retrieval of a specific event. With better cognitive flexibility, children could shift attention to relevant details more easily during encoding and retrieval. These proposed roles of EF components for memory of context information can be expanded and applied to temporal memory more specifically.

First, in the context of remembering temporal order, more advanced working memory skills might allow children to organize event information in mind more effectively, which would facilitate the process of reporting event actions in the correct chronological order. Working memory skills could also be important for the reconstruction of temporal context, given the need for recall of temporally relevant event information. By holding more event details in mind, which would act as a cue for more details, it is more likely that a piece of event information relevant to temporal context would be retrieved. Second, regarding inhibitory control, children might need to inhibit the urge to report event details as they come to mind, as opposed to reporting them in chronological order. For temporal context, it is possible that during early and middle childhood, children might be more familiar with responding to questions about the present temporal context and might have difficulty inhibiting that information when recalling the context of a past event. This could especially be the case in early childhood when children have a less sophisticated understanding of time and temporal patterns (McCormack & Hoerl, 2017) and as a result, do not often think about time periods other than the present. Third, cognitive flexibility might be related to how well children can shift between thinking about different events when they are trying to place them in temporal order. When recalling temporal context, cognitive flexibility might be especially important during reconstruction and could facilitate children's ability to shift between event details and time knowledge to infer when an event took place. To date, no studies have examined the relation between EF components and reconstruction abilities in childhood, but there is evidence from three studies that EF components are related to temporal memory in childhood (Arterberry & Albright, 2020; Pathman et al., in press; Picard et al., 2012).

Picard et al. (2012) investigated the roles of EF components in 4- to 16-year-olds' memory for temporal details of a character's actions in a story. Participants were shown a large photo of the inside of a house, and experimenters told a story about a typical day for the child who lived there. The story had three parts: morning, afternoon, and night, and during each part, the character participated in three different actions. After a ten-minute delay, participants answered free recall, cued recall, and forced-choice recognition questions about the story actions and their spatial and temporal details. The forced-choice response options for temporal questions concerned the temporal order of events (e.g., "Did she feed the fish before or after she had breakfast?"). Picard et al. conducted a hierarchical regression analysis to examine which factors predicted free recall temporal scores. The scores for each EF component were entered in the first step, followed by scores on a short-term binding task, and age was entered in the last step. Results indicated that together, EF components were significantly related to spontaneous memory for temporal information (i.e., free recall) in the first step and this relation held in all steps of the model. More specifically, cognitive flexibility and inhibitory control were each significantly related to memory for time in all steps of the model.

Looking at just early childhood, Arterberry and Albright (2020) investigated the associations of 3- to 6-year-olds' memory for the temporal order of actions from a storybook with cognitive flexibility and inhibitory control. After listening to the story, participants completed a timeline task, where they placed photos of five story events in temporal order. Next, participants answered a series of yes/no questions about the temporal order of story events, which included the events from the timeline task (rehearsed events) and other events from the story (non-rehearsed events). Results indicated that cognitive flexibility, but not inhibitory control, was related to performance on the timeline task and yes/no order responses for the rehearsed events. Additionally, cognitive flexibility predicted performance on both tasks over and above age. Pathman et al. (in press) investigated the association between 7-, 9-, and 11-year-olds', and adults' memory for the temporal order of staged, personal events, and working memory. In a regression analysis, Pathman et al. found no association between children and adults' accuracy on the timeline task and working memory performance. Given that Pathman et al.'s study focused on older children and adults, it is possible that there is a relation between working memory and temporal memory for younger children. Indeed, Bauer and Larkina (2017) found that working memory was related to the amount of contextual information that children included in personal narratives at the ages of 5, 7, and 9. In sum, the findings from Picard et al. (2021) and Arterberry and Albright (2020) provide initial evidence for a relation between temporal memory and EF components, particularly cognitive flexibility and inhibitory control, in early and middle childhood.

Given the slower developmental trajectory of memory for temporal information of events and the complexity involved in both ordering events and placing them in time, it is clear that remembering time is a complicated process. Based on the literature reviewed above, this process likely relates to knowledge of time and temporal concepts, the ability to think and reason about time, language skills, and EF components, all in addition to the ability to recall specific events. The current dissertation studies were designed to investigate how these various factors relate to age-related changes in temporal memory across early and middle childhood and which (if any) of these factors serve as unique predictors of age-related changes in temporal memory abilities. The goals of the current dissertation include: (1) examining relations between temporal memory of personal events, time knowledge, receptive language, and EF components in early childhood, and (2) examining relations between reconstruction abilities, time knowledge, and EF components across early and middle childhood.

CHAPTER II: STUDY 1 INTRODUCTION

The goal of Study 1 was to examine the relations between temporal memory (order and context) of personal events, EF components, time knowledge, and receptive language (i.e., comprehension) at the ages of 4 and 5. Early childhood (i.e., preschool period) is a particularly important period for episodic memory development because it marks the emergence of children's ability to recall personal events (Nelson & Fivush, 2004), and the period when children start to include information about time in their narrative reports. Moreover, according to McCormack and Hoerl's (2017) model of the development of temporal concepts, children begin to have a more complex understanding of time at ages 4 and 5, which coincides with changes in memory for temporal order and context observed across early childhood. The study was designed to examine relations between temporal memory, EF components, time knowledge, and language. Previous work demonstrates relations between 4- to 6-year-olds' memory for temporal order and context of events and EF components (Arterberry & Albright, 2020; Picard et al., 2012), time knowledge (Scales & Pathman, 2021), and language (Scales & Pathman, 2021). However, each of these studies investigated temporal memory of laboratory-based story tasks. The use of personal events in the current study allows for an examination of memory for time of richly detailed experiences, and previous work demonstrates that children have better and more detailed memory for personal events compared to laboratory-based ones (Mandler, 1983; Nelson, 1986; Pathman et al., 2011).

Although Picard et al. (2012) included all EF components in their study, the story task included many events that young children may have script-based knowledge of (e.g., character wakes up in the morning, then eats breakfast, then brushes their teeth), which they could rely on when answering questions about temporal details. They also did not calculate specific scores for temporal order and temporal context information. Additionally, the use of the same EF tasks across a large age range (4- to 16-year-olds) might not have provided accurate estimates of EF abilities for each age group given that different EF tasks are typically used in preschool, middle childhood, and adolescence (see Jacques & Marcovitch, 2010, for review). It is possible that younger children's performance on the tasks was underestimated or that older children's performance was overestimated depending on the difficulty level. Arterberry and Albright (2020) focused on the preschool period (3- to 6-year-olds), but only measured memory for temporal order and did not include a measure of working memory. Pathman et al. (in press) included measures of language (e.g., vocabulary), time knowledge, and working memory, but their study also only assessed temporal order memory and focused on older children (7-, 9-, and 11-year-olds). Additionally, Pathman et al. included an inhibitory control task, but did not include it in the regression analysis when examining relations between various factors and temporal order memory. The study by Scales and Pathman (2021) is the most like the current study given the inclusion of time knowledge and language measures but did not examine the associations between temporal memory and EF components in 4- and 6-year-old children.

In Study 1, 4- and 5-year-old children were interviewed about two events they experienced in the previous month (provided by their parents), which were coded for information about temporal order and context. Participants also answered time scale questions about the time of day, day of week, month, and season of each event. The interview provided a method to examine children's spontaneous memory for temporal information, but we did not want to underestimate children's memory for time, particularly temporal context. Indeed, Friedman and Lyon (2005) found that 4- to 13-year-old children did not provide spontaneous temporal information in reports of past events but were able to answer time scale questions. Therefore, we included the time scale questions as another method for measuring memory for temporal context of personal events. After the interview, participants completed tasks that assessed working memory, inhibitory control, cognitive flexibility, time knowledge (Scales & Pathman, 2021), and a standardized assessment of receptive language.

Study 1 Predictions

I examined temporal context and temporal order scores separately. Past studies that used a combined score included laboratory-based story tasks where the temporal context and temporal order information were incorporated more cohesively (Picard et al., 2012; Scales & Pathman, 2021). For example, Scales and Pathman included stories with details such as, "Mary was at school in the *morning*, and at school, the teacher took attendance *before* Mary ate her snack." The children in the current study were interviewed about naturally occurring personal events, and those events do not seamlessly combine temporal context and order information in the same way as laboratory story tasks. Thus, I chose to examine relations with EF components, time knowledge, and language separately for temporal context and temporal order of personal events.

First, I predicted that memory for temporal order and context would be related to EF components, time knowledge, and receptive language, replicating previous findings (Arterberry & Albright 2020; Picard et al., 2012; Scales & Pathman, 2021). Second, I predicted that in an ordinal logistic regression analysis that includes temporal memory as the dependent variable and age, working memory, inhibitory control, cognitive flexibility, time knowledge, and receptive language as independent variables, the only factors that would be significantly related to temporal memory would be the three EF components and time knowledge. I did not predict that receptive language would be related to temporal memory over and above the other variables. There is consistent evidence of a relation between EF and language skills during the preschool period (see Gooch et al., 2015, for review). Additionally, theories of EF development state that age-related changes in language abilities allow for more explicit reflection, resulting in the ability to exert control over thought and behavior (Marcovitch et al., 2008; Zelazo, 2004). Thus, I predicted that language abilities would be accounted for by age-related changes in the EF components. These predictions for the ordinal regression apply to both a model that includes memory for temporal order as the dependent variable and another model that includes memory for temporal context as the dependent variable.

CHAPTER III: STUDY 1 METHOD

Participants

We collected data from 4- (*n* = 47, M_{age} = 54.67 months, 21 females) and 5-year-olds (*n* = 48, M_{age} = 65.44 months, 24 females). Participants were recruited from Greensboro, NC and surrounding areas, using a database of families who previously volunteered to be contacted. Parents identified participants as: White (61%), African American (22%), Biracial (8%), Asian (4%), Other (2%), and 2% of the sample did not report race information. Most participants were identified as Not Hispanic (95%), Hispanic (3%), and a portion (2%) of the sample did not report ethnicity information. Regarding socioeconomic status, 49% reported a yearly income greater than $90,000, 25% reported a yearly income of $60,000 to $90,000, 14% reported a yearly income of $40,000 to $60,000, 3% reported a yearly income of $25,000 to $40,000, 4% reported a yearly income of $15,000 to $25,000, and 4% of the sample did not report income information. Informed consent was provided by parents or legal guardians, and verbal assent was provided by participants. All participants were tested at the university in a single session.

Based on the predictions regarding the regression model, a sensitivity analysis in G*Power was conducted to determine the effect size (R^2) which could be detected for 4 predictor variables (of 6 total predictor variables) in a regression analysis with a sample size of 93 (two participants were excluded from the main analysis) and power of .80. The analysis yielded an R^2 of .12. In previous work, R^2 values for EF components and the CCT flexible retrieval task as predictor variables for temporal memory dependent measures ranged from .085 to .19 (Picard et al., 2012; Scales & Pathman, 2021). Although the main analysis used in the study was an ordinal logistic regression, this sensitivity analysis serves as an appropriate estimate for the ordinal logistic regression analysis. This is because the coefficients in an ordinal logistic regression are log-odds ratios of cumulative probabilities (Kleinbaum & Klein, 2010).

Procedure

Participants received tasks in a fixed order: experimenter-child interview, three EF tasks, a time knowledge task, and a receptive language task. The experimenter-child interview took place first to avoid any interference from the time knowledge task.

Experimenter-Child Interview

At the beginning of the study session, parents were instructed to choose 2 events that their child had experienced during the last 4 weeks. We asked that parents nominate one-time, specific events that spanned less than 1 day (i.e., not a multi-day trip), and to avoid routine events or holidays if possible. After the events were selected, we conducted an experimenter-child interview (ECI; Bauer & Larkina, 2016, 2019; Cleveland & Reese, 2005; Farrant & Reese, 2000) with participants, where we discussed the events chosen by parents. The ECI is a semi-structured, open-ended interview that consists of general questions (e.g., “What can you tell me about your trip to the science center?”), followed by specific WH-questions (i.e., who, what, when, where, why, how) about the events of interest. Participants were asked about the events in the order that the parents provided them. As a result, for 45 participants, the first event in the interview was the more recent event, for 47 participants, the second event in the interview was the more recent event, and for 3 participants, both events occurred on the same day. While each participant was interviewed, parents observed and recorded notes about the accuracy of responses. Any information that was indicated to be inaccurate by a parent was not coded. The criteria for including data from the interview in analyses was that the participant remembered at least two unique details about each event (Bauer & Larkina, 2014, 2019).

Coding

Each interview was transcribed verbatim by a research assistant and was later double-checked by a different research assistant. To minimize any coder bias, each participant was randomly assigned a coding ID, which was different than their participant ID. The coding ID was not linked to any other data from the participant (e.g., EF task scores, CCT scores, language scores). First, participants' interview responses were parsed into propositional units (i.e., subject-verb phrase; Bauer & Larkina, 2014, 2019; Kian et al., 2021). I was the primary parser, and two research assistants who did not work on the study and were blind to study hypotheses each parsed a random 25% of transcripts for reliability. We used intraclass correlation coefficients to assess parsing reliability (Bauer & Larkina, 2019; Kian et al., 2021), which were .992 and .979. Transcripts parsed by the primary parser were used for subsequent coding.

Next, participants' responses were coded for temporal information using a temporal coding scheme (Kian et al., 2021; Pathman, personal communication), which was adapted from a more extensive narrative coding scheme used with autobiographical narratives (Bauer & Larkina, 2014, 2016; Bauer et al., 2017). The current temporal coding scheme expands on previous narrative coding schemes (Bauer & Larkina, 2016; Haden et al., 1997; Newcombe & Reese, 2004) by breaking up a broad 'when' or context (i.e., location and/or time of event) category into more specific codes for certain types of temporal information (Kian et al., 2021; Pathman, personal communication). Temporal codes and examples are included in Table 1. The codes of interest for the current study were *time*, which locates the event in historical or narrative time (e.g., we went to the zoo in the *afternoon*, my soccer game was in the *Fall*), and *temporal connection*, which refers to information about the within-event order or sequence (e.g., *first* we ate dinner, *then* we watched a movie). Both the time and temporal connection codes map onto how memory for temporal order and temporal context of personal and staged events have been measured in previous studies (Fivush et al., 1995; Friedman, 1991; Pathman, Larkina, et al., 2013). The time code represents information about the temporal context of events given that it includes words and phrases that place events on conventional or subjective time scales. The temporal connection code represents information about the temporal order in which an event unfolds. For the time and temporal connection codes, participants received a score for the number of total instances across events. For example, if a participant had 1 temporal connection when describing the first event and 3 temporal connections when describing the second event, they received a temporal connection score of 4.

Interviews were coded by me and a research assistant who did not work on the study and was blind to study hypotheses. To minimize any coder bias, each participant was randomly assigned a coding ID, which was different than their participant ID. The coding ID was not linked to any other data from the participant (e.g., EF task scores, CCT scores, language scores). After being trained on the coding system by me, the research assistant independently coded 50% of the transcripts for reliability. Cohen's Kappa was calculated for each category and yielded values of 1.00 for time and .99 for temporal connections. For all analyses, the codes from the primary coder were used.

Table 1. Temporal Codes and Examples

Codes	Examples
Time	Two days ago, Fall, when I was four
Temporal Connection	Before, after, then, when

Shortly after data collection began, I decided to include time scale questions about the time of day, day of week, month, and season of the events as part of the interview. After conducting the interview with seven participants, it was clear that children were not spontaneously including very much temporal information about the events. I added the time scale questions to ensure that I was not underestimating children's temporal memory for the events, especially given evidence from previous studies that children as young as 4 can provide accurate responses to forced-choice time scale questions about personal and staged events (Friedman, 1991; Friedman & Lyon, 2005; Pathman, Larkina, et al., 2013). By including these questions, we had a measure of participants' cued memory for temporal context information, as well as a measure of spontaneous memory for temporal information from the open-ended interview. The time scale questions are included in Table 2 and were added to the interview protocol after the first 7 testing sessions. For the time of day, day of week, and month questions, participants received a score of 1 for a correct response and score of 0 for an incorrect response. For the season questions, we used the same flexible scoring system as Pathman, Larkina, et al., given that participants in the study live in an area of the United States where seasons do not map perfectly onto specific calendar periods and sometimes overlap. In this scoring, each season corresponds to 4 months, and there are specific months that can be considered two different seasons. Thus, *Winter* included events from December, January, February, and March, *Spring* included events from March, April, May, and June, *Summer* included events from June, July, August, and September, and *Fall* included events from September, October, November, and December. Like with the other time scale questions, participants received a score of 0 if they provided an incorrect response and a score of 1 for a correct response. For the season scoring specifically, if an event had occurred in March, the participant would receive 1 point for either a

Winter or Spring response. Additionally, we summed scores across the two events for each separate scale so that all participants had a total time score, total day score, total month score, and total season score (each of these scores ranged from 0-2). We also calculated a total time scale score, which was the sum of all the separate scale scores (total time scale score ranged from 0-8).

Table 2. Time Scale Questions

Time Scale	Question
Time of day	"Do you remember what time of day it was on the clock, like morning, afternoon, or night?"
Day of week	"Do you remember what day of the week it was like, Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, or Saturday?"
Month	"Do you remember what month it was, like January, February, March, April, May, June, July, August, September, October, November, or December?"
Season	"Do you remember what season it was like, Spring, Summer, Fall, or Winter?"

Executive Function Tasks

We assessed participants' EF with three tasks, one per component. The order of the EF tasks was counterbalanced (i.e., there were 6 possible orders).

Working Memory

We assessed working memory with a visual counting span task (Case et al., 1982). Participants saw cards with green frogs and red ladybugs and were instructed to only count the green frogs. The number of green frogs on the cards ranged from 3 to 7. In a 2-card trial, after counting the frogs on one card, another card was placed on top. The experimenter then removed both cards from view and asked how many frogs were on each card. The task consisted of 2-card trials, 3-card trials, and 4-card trials (three per trial type). Each trial was worth one point: (a) for 2-card trials, each card was worth .50 point, (b) for 3-card trials, each card was worth .33 point, and (c) for 4-card trials each card was worth .25 point. Participants did not need to provide responses in sequential order to earn points (Marcovitch et al., 2010).

Inhibitory Control

We assessed inhibitory control with the Happy/Sad Stroop task (Lagattuta et al., 2011). Participants saw cards with 'happy' and 'sad' round, yellow faces, and were instructed to say "sad" when they saw a 'happy' face and "happy" when they saw a 'sad' face. The task included 20 trials (i.e., 10 happy faces, 10 sad faces), and participants received one point for each correct response.

Cognitive Flexibility

We assessed cognitive flexibility with the Dimensional Change Card Sort (DCCS) Borders Version (Zelazo, 2006), which required participants to sort a series of bi-dimensional cards (i.e., blue boats, red rabbits) according to either shape or color. The task had three levels: pre-switch, post-switch, and borders, and the sorting rule changed between each level. In the pre-switch level, participants sorted 6 cards by one dimension (e.g., color), and the experimenter repeated the sorting rule before each trial. To pass the pre-switch level, participants needed to sort 5 out of 6 cards correctly. In the post-switch level, participants sorted 6 cards by the other dimension (e.g., shape), but the rule was only given once and not repeated before each trial. If children 'passed' post-switch by sorting 5 of 6 cards correctly, they continued to the borders level. In the borders level, participants were instructed to sort cards with a black border by color and cards without a black border by shape. Participants sorted 12 cards in the borders level (6 with a black border, 6 without), and sorting 10 trials correctly was considered ‘passing’. Participants received a score for how many levels passed (0 = failed pre-switch, 1 = passed pre-switch, 2, = passed pre- and post-switch, or 3 = passed pre- and post-switch and borders).

Children’s Conventional Time Task

We assessed time knowledge with the flexible retrieval subtask of the Children’s Conventional Time (CCT) task developed by Scales and Pathman (2021). We included two of the time scales (e.g., meals of the day: breakfast, lunch, dinner; and seasons of the year: spring, summer, fall, winter) from this task. For the flexible retrieval subtask, participants answered both forward (e.g., “If you’ve had breakfast, what is the next meal going forward in time you’ll eat?”) and backward (e.g., “If you’ve had breakfast, what is the next meal going backwards in time?”) questions about the order of the time scales. Participants received forward (possible range: 0 to 3 for meals, 0 to 4 for seasons), backward (possible range: 0 to 3 for meals, 0 to 4 for seasons), and total (i.e., forward plus backward; possible range: 0 to 6 for meals, 0 to 8 for seasons) scores based on the total number of correct responses for each time scale. They also received an overall flexible retrieval score, which was the proportion of correct responses across time scales (possible range: 0 to 1.00). To complete the flexible retrieval subtask, participants had to first pass a practice trial which included ordering 3 cards (a whole apple, an apple with one bite out of it, and an apple core). The experimenter used the cards to explain that the left side of the table was the beginning, and the right side of the table was the end. Participants were asked to point to the beginning and end of the apple sequence to ensure they understood the ordering instructions.

Only participants who passed this practice trial (i.e., correctly pointing to the beginning and end of the apple sequence) completed the CCT task, including the flexible retrieval subtask.

Receptive Language

We used the Test of Language Development: Primary Fourth Edition (TOLD-P; Newcomer & Hammill, 2008) to measure receptive vocabulary. The experimenter read a list of 35 words, and for each word participants pointed to which of 4 pictures matched the word. If participants were incorrect on 5 consecutive trials, the task ended. Participants received one point for each correct response.

Temporal Language Task

We included a parent questionnaire on participants' temporal language use (Busby Grant & Suddendorf, 2010) as an exploratory measure. Parents indicated whether their child used a list of temporal words/phrases, and how frequently their child used the words/phrases correctly. See Appendix A for parent questionnaire.

CHAPTER IV: STUDY 1 RESULTS

Missing Data

There are some participants missing data from tasks due to various reasons. One 4-year-old participant is not included in any analyses because they refused to complete the following tasks: visual counting span, Happy/Sad Stroop, CCT, and TOLD-P and did not meet the criteria for the event interview (i.e., providing two pieces of information per event). One 5-year-old participant did not meet the criteria for the event interview and therefore is not included in analyses of temporal code data. The first seven participants (four 4-year-olds, three 5-year-olds) do not have data for the temporal scale questions because those were added after data collection began. Additionally, one 4-year-old and one 5-year-old do not have data for the day of week time scale question for Event 2 because the exact event date was not provided by the parent, and one 4-year-old participant refused to respond to the time scale questions for Event 2. One 4-year-old participant refused to complete the DCCS task. Four participants (two 4-year-olds, two 5-year-olds) do not have data for the Stroop task due to experimenter error. Two 4-year-old participants do not have data for the CCT flexible retrieval questions because they did not pass the practice trial. One 4-year-old participant refused to complete the TOLD-P task. Participants who were missing data from a specific task were either partially or completely removed from analyses. Table 3 includes the means, standard deviations, ranges, and sample sizes for all study measures.

Description of Events

Since each participant was interviewed about 2 events, there were a total of 190 events. Using similar event categories from Pathman, Larkina, et al., the events in Study 1 consisted of: family events (62%, e.g., trips to the mountains or beach, visits to parks, visits to museums or science centers, movies, festivals), events with friends (19%, e.g., birthday parties, sleepovers, sporting events), school events (5%, e.g., receiving an award, fun run), family member birthdays (8%), holidays with fixed dates (2%, e.g., Thanksgiving, Diwali), and medical events (4%, e.g., going to the doctor or dentist).

As described in the above Method section, events were asked about in the order that parents provided them to the experimenters. For Event 1, an exact date is not available for 3 participants, and for Event 2, an exact date is not available for 2 participants. This was due to issues with parents either not being able to remember the exact date or providing an estimation (e.g., two weekends ago, in early October). Across events, the retention interval did not differ between Event 1 (M = 14.34 days, SD = 13.07) and Event 2 (M = 16.77 days, SD = 17.07), $t(87) = -1.290$, $p = .200$. I ran correlation analyses to examine whether there were relations between retention interval and the time code and temporal connection scores, as well as scores on the time scale questions. For both Event 1 and 2, the retention interval was not related to time code scores, temporal connection scores, or total time scale scores with r's ranging from -.069 to .101 and p's ranging from 0.359 to 0.963.

Analytic Plan

For the primary analyses, the first step of data analysis for the current study included running correlation analyses between age in months, visual counting span scores, Stroop total scores, DCCS levels passed, CCT proportion scores, TOLD-P scores, time code scores, and temporal connection code scores. The second step included running ordinal logistic regression analyses, one analysis with time code scores as the dependent variable, and another analysis with temporal connection code scores as the dependent variable. However, the second step was dependent on the results from the first step. The independent variables for the regression analyses were chosen based on the results of the correlation analyses. Only variables that were significantly related to the dependent variables would be included in the regression analyses.

Primary Analyses

Correlation analyses were conducted to examine relations between time code and temporal connection scores, with age in months, visual counting span total scores, Stroop total scores, DCCS levels passed, CCT proportion scores, and TOLD-P scores (see Table 4). Time code scores were significantly related to age in months, $r(91) = .237$, $p = .022$, counting span scores, $r(91) = .341$, $p = .001$, DCCS levels passed, $r(90) = .326$, $p = .001$, and CCT proportion scores, $r(89) = .222$, $p = .034$. However, time code scores were not significantly related to Stroop scores, $r(87) = .197$, $p = .065$, or TOLD-P scores, $r(90) = .141$, $p = .179$.

Temporal connection scores were not related to age in months or any of the other measures (see Table 5). Given the large range of temporal connection scores, the range was reduced to include scores from 0 to 6 or more by assigning a value of 6 to all participants with a score greater than 6. Correlation analyses were conducted again with the revised temporal connection scores. There was only a significant relation between revised temporal connection scores and DCCS levels passed, $r(90) = .245$, $p = .019$. Due to a lack of associations between other measures of interest (age, counting span, Stroop, CCT performance, TOLD-P), I did not perform further regression analyses with temporal connection scores as a dependent variable.

Table 3. Descriptive Statistics for Study 1 Primary Measures

Measure	N	Mean	Standard Deviation	Observed Range
Experimenter-Child Interview				
Time (T)	93	0.63	0.86	0 to 3
Temporal Connection (TC)	93	1.94	3.75	0 to 23
Time Scale Questions				

Time of day	87	1.10	0.82	0 to 2
Day of week	87	0.36	0.59	0 to 2
Month of year	87	0.34	0.59	0 to 2
Season	87	1.06	0.88	0 to 2
Total: All Scales	87	2.83	1.72	0 to 8
EF Tasks				
Visual Counting Span	94	4.77	1.92	0 to 8.25
H/S Stroop	90	13.90	3.63	0 to 20
DCCS	93	1.94	0.46	1 to 3
CCT Task				
Meals Forward	92	2.06	.99	0 to 3
Meals Backward	92	1.17	1.13	0 to 3
Meals Total	92	3.23	1.56	0 to 6
Seasons Forward	92	1.76	1.29	0 to 4
Seasons Backward	92	1.20	1.13	0 to 4
Seasons Total	92	2.96	1.95	0 to 8
Total: Meals and Seasons	92	6.19	2.79	0 to 14
Receptive Language				
TOLD-P	93	18.69	4.61	7 to 30

Table 4. Correlations between Primary Measures and Time Code Scores

	1. Age (months)	2. Count total	3. Stroop total	4. DCCS levels	5. CCT proportion correct	6. TOLD-P	7. Time code score
1. Age (months)	1	--	--	--	--	--	--
p-value							
N							
2. Count total	.484	1	--	--	--	--	--
p-value	< .001						
N	94						
3. Stroop total	.319	.356	1	--	--	--	--
p-value	.002	.001					
N	90	90					
4. DCCS levels	.441	.338	.273	1	--	--	--
p-value	< .001	.001	.010				
N	93	93	89				
5. CCT proportion correct	.309	.368	.045	.182	1	--	--
p-value	.003	< .001	.676	.083			
N	92	92	88	92			
6. TOLD-P	.371	.397	.056	.286	.259	1	--
p-value	< .001	< .001	.600	.006	.013		
N	93	93	89	92	91		
7. Time code score	.237	.341	.197	.326	.222	.141	1
p-value	.022	.001	.065	.001	.034	.179	
N	93	93	89	92	91	92	

Table 5. Correlations between Primary Measures and Temporal Connection Scores

	1. Age (months)	2. Count total	3. Stroop total	4. DCCS levels	5. CCT proportion correct	6. TOLD-P	7. Temporal connection score
1. Age (months)	1	--	--	--	--	--	--
p-value							
N							
2. Count total	.484	1	--	--	--	--	--
p-value	< .001						
N	94						
3. Stroop total	.319	.356	1	--	--	--	--
p-value	.002	.001					
N	90	90					
4. DCCS levels	.441	.338	.273	1	--	--	--
p-value	< .001	.001	.010				
N	93	93	89				
5. CCT proportion correct	.309	.368	.045	.182	1	--	--
p-value	.003	< .001	.676	.083			
N	92	92	88	92			
6. TOLD-P	.371	.397	.056	.286	.259	1	--
p-value	< .001	< .001	.600	.006	.013		
N	93	93	89	92	91		
7. Temporal connection score	.176	.104	.026	.186	.070	-.006	1
p-value	.091	.323	.807	.076	.511	.958	
N	93	93	89	92	91	92	

Time code scores ranged from 0 to 3, and due to the ordinal nature of the variable and its limited range, I ran an ordinal logistic regression with age in months, visual counting span scores, DCCS levels passed, and CCT proportion scores as independent variables and time code scores as the dependent variable. To check for multicollinearity issues, I ran a multiple linear regression with the same independent and dependent variables. I used this approach because the ordinal logistic regression analysis does not provide diagnostics for multicollinearity. For the independent variables the VIF values ranged from 1.193 to 1.457, which fall below conventional threshold levels of 10, 5, and a more conservative 2.5 (James et al., 2017; Johnston et al., 2018; Menard, 2001). Thus, none of the VIF values for the independent variables indicated major issues with multicollinearity.

In the ordinal regression, the assumption of parallel lines for the proportional odds model was violated for this analysis. This assumption is that the coefficient or odds ratio that measures the relation between an independent variable and a dependent variable will be the same for all the comparisons in the model (i.e., the odds ratio comparing participants with a score of 0 to those with a score greater than 0 is the same as the odds ratio comparing participants with a score greater than or equal to 2 to those with a score less than 2). Because of this, I rescored the time code data to have fewer ordinal categories. We combined the 2 and 3 categories into a score of 2 or more category. Therefore, the rescored data reflected participants with time code scores of 0 (n = 49), 1 (n = 26), and 2 or more (n = 15). I then ran an ordinal logistic regression with the rescored time code scores as the dependent variable and age in months, counting span total, DCCS levels, and CCT proportion scores as the independent variables. For this analysis, the assumption of parallel lines was met. The results of this ordinal logistic regression are included in Table 6.

All values for confidence intervals correspond to the odds ratio for each independent variable. Results indicated a significant relation between counting span performance and time code scores when controlling for other variables in the model. Specifically, a single unit increase in visual counting span performance was associated with an increase in the odds of having a higher time code score with an odds ratio of 1.409, (95% CI, 1.043, 1.904), Wald $\chi^2(1) = 4.987$, $p = .026$. There was no relation between age in months and time code scores when controlling for other variables in the model, and the odds ratio was .995, (95% CI, .920, 1.077), Wald $\chi^2(1) = .013$, $p = .910$. There was no relation between DCCS levels passed and time code scores when controlling for other variables in the model, and the odds ratio was 2.651, (95% CI, .868, 8.101), Wald $\chi^2(1) = 2.924$, $p = .087$. There was no relation between CCT proportion scores and time code scores when controlling for other variables in the model, and the odds ratio was 3.804, (95% CI, .405, 35.695), Wald $\chi^2(1) = 1.367$, $p = .242$.

Table 6. Ordinal Logistic Regression Results

Covariate	Estimate	*SE*	Odds Ratio	Wald (χ^2)	*p*-value	95% Confidence Interval	
						Lower	Upper
Age (months)	-.005	.040	.995	.013	.910	.920	1.077
Count total	.343	.154	1.409	4.987	.026	1.043	1.904
DCCS levels	.975	.570	2.651	2.924	.087	.868	8.101
CCT proportion	1.336	1.142	3.804	1.367	.242	.405	35.695
Intercept T = 0	4.168	2.151					
Intercept T = 1	5.758	2.194					

Exploratory Analyses

Time Scale Questions

A 2 (Age: 4-years-old, 5-years-old) X 4 (Time Scale: time, day, month, season) mixed ANOVA with Time scale as the within-subject variable was conducted on time scale scores. There was no main effect of Age, $F(1, 85) = 3.276$, $\eta_p^2 = .037$, $p = .074$. There was a significant main effect of Time Scale, $F(3, 255) = 32.495$, $\eta_p^2 = .277$, $p < .001$. Bonferroni-corrected pairwise comparisons indicated that across age, participants performed better on time of day questions, $M = 1.100$, $SE = .088$, compared to day of week, $M = .355$, $SE = .063$, $p < .001$, and month questions, $M = .340$, $SE = .062$, $p < .001$. Performance on time of day questions did not differ from season questions, $M = 1.056$, $SE = .095$, $p = 1.000$. Additionally, participants performed better on season questions compared to day of week, $M = .355$, $SE = .063$, $p < .001$, and month questions, $M = .340$, $SE = .062$, $p < .001$. Performance on day of week questions did not differ from month questions, $p = 1.000$. There was no Age X Time Scale interaction, $F(3, 255) = .263$, $\eta_p^2 = .003$, $p = .852$.

Correlation analyses were conducted to investigate if there were relations between time scale scores and time code scores. Time code scores were significantly related to month scores, $r(84) = .288$, $p = .007$, and total time scale scores, $r(84) = .297$, $p = .005$, but not related to time of day scores, $r(84) = .191$, $p = .078$, day of week scores, $r(84) = -.004$, $p = .969$, or season scores, $r(84) = .203$, $p = .061$. We also ran correlation analyses to examine if there were relations between total time scale scores and counting span total scores, Stroop total scores, DCCS levels passed, and CCT proportion scores. Total time scales scores were only significantly related to counting span total scores, $r(86) = .332$, $p = .002$, and CCT proportion scores, $r(83) = .298$, $p = .006$.

Temporal Language

Parents reported whether their child used various temporal terms and phrases. The total number of 4- and 5-year-olds reported as using each term/phrase is included in Table 7. To examine participants' accuracy in using temporal words and phrases, we combined the number of participants who used each temporal term correctly either 'often' or 'always' (Busby Grant & Suddendorf, 2010), and those totals are presented in Table 8. We also ran correlation analyses to examine relations between participants' time code and temporal connection scores with their accuracy in using temporal terms (see Tables 9 and 10). Each participant received a score for incorrect use, sometimes correct use, and correct use. The incorrect use score is the total number of temporal terms that a participant was reported as 'never' using correctly. The sometimes correct use score is the total number of temporal terms that a participant was reported as 'occasionally' or 'sometimes' using correctly. The correct use score is the total number of temporal terms that a participant was reported as 'often' or 'always' using correctly. Time code scores were significantly related to correct use scores, $r(91) = .326$, $p = .001$, but not related to incorrect use scores, $r(91) = -.161$, $p = .123$, or sometimes correct use scores, $r(91) = -.113$, $p = .282$. Temporal connection scores were not significantly related to correct use scores, $r(91) = .052$, $p = .621$, incorrect use scores, $r(91) = .060$, $p = .566$, or sometimes correct use scores, $r(91) = -.094$, $p = .368$.

Table 7. Participants' Reported Use of Temporal Words and Phrases

Word/Phrase	Participants Use of Word/Phrase (N)	
	4-year-olds	5-year-olds
Today	46 (100%)	48 (100%)
Tomorrow	43 (93.5%)	46 (95.8%)

Yesterday	38 (82.6%)	45 (93.8%)
Later	45 (97.8%)	46 (95.8%)
Soon	34 (73.9%)	41 (85.4%)
Now	46 (100%)	48 (100%)
After	42 (91.3%)	46 (95.8%)
Before	41 (89.1%)	45 (93.8%)
Next Week	32 (69.6%)	37 (77.1%)
Last Week	28 (60.9%)	36 (75.0%)
Months	35 (76.1%)	39 (81.3%)
Days	43 (93.5%)	43 (89.6%)
Hours	28 (60.9%)	32 (66.7%)
Minutes	36 (78.3%)	42 (87.5%)
When little	43 (93.5%)	48 (100%)
When big	44 (95.7%)	47 (97.9%)
In the past	11 (23.9%)	13 (27.1%)
In the future	12 (26.1%)	15 (31.3%)

Table 8. Participants' Reported Correct Use of Temporal Words and Phrases

Word/Phrase	Correct Use (N)	
	4-year-olds	5-year-olds
Today	35 (76.1%)	38 (79.2%)
Tomorrow	26 (56.6%)	29 (60.5%)
Yesterday	16 (34.8%)	23 (47.9%)
Later	31 (67.4%)	34 (70.8%)
Soon	20 (43.4%)	22 (45.8%)

Now	41 (89.2%)	44 (91.6%)
After	34 (74.0%)	38 (79.2%)
Before	23 (50.0%)	33 (68.7%)
Next Week	8 (17.4%)	7 (14.6%)
Last Week	6 (13.0%)	8 (16.7%)
Months	6 (13.0%)	10 (20.8%)
Days	15 (32.6%)	12 (25.0%)
Hours	4 (8.7%)	6 (12.5%)
Minutes	10 (21.7%)	8 (16.7%)
When little	24 (52.2%)	30 (62.5%)
When big	34 (73.9%)	38 (79.2%)
In the past	5 (10.9%)	7 (14.6%)
In the future	5 (10.9%)	7 (14.6%)

Table 9. Correlations between Accuracy of Temporal Language Use and Time Code Scores

	1. Time code scores	2. Incorrect Use	3. Sometimes correct use	4. Correct use
1. Time code scores	1	--	--	--
p-value				
N				
2. Incorrect use	-.161	1	--	--
p-value	.123			
N	93			
3. Sometimes correct use	-.113	.205	1	--
p-value	.282	.048		
N	93	94		
4. Correct use	.326	-.348	-.646	1
p-value	.001	< .001	< .001	

N	93	94	94	

Table 10. Correlations between Accuracy of Temoral Language Use and Temporal Connection Code Scores

	1. Temporal connection scores	2. Incorrect Use	3. Sometimes correct use	4. Correct use
1. Temporal connection scores	1	--	--	--
p-value				
N				
2. Incorrect use	-.094	1	--	--
p-value	.368			
N	93			
3. Sometimes correct use	.060	.205	1	--
p-value	.566	.048		
N	93	94		
4. Correct use	.052	-.348	-.646	1
p-value	.621	< .001	< .001	
N	93	94	94	

CHAPTER V: STUDY 1 DISCUSSION

The goal of Study 1 was to investigate the relations of 4- and 5-year-olds' memory for temporal order and context of personal events with working memory, inhibitory control, cognitive flexibility, time knowledge, and language. The focus on early childhood in this study was particularly important because during this period children begin to include information about time in their recollections of personal events (Nelson & Fivush, 2004), have a more sophisticated understanding of temporal concepts (McCormack & Hoerl, 2017) and time scales (Scales & Pathman, 2021), and demonstrate substantial improvement in their EF abilities (Garon et al., 2008). Children's memory for the temporal order and context of personal events was assessed by coding responses from an open-ended interview. I found partial support for the prediction that temporal memory would be related to EF components, time knowledge, and receptive language in early childhood, as indicated by evidence that memory for temporal context of personal events was related to age, working memory, cognitive flexibility, and time knowledge during the preschool period. However, when these variables were entered into a regression analysis together, only working memory was related to temporal context memory when controlling for the other variables. The association is further supported by the exploratory finding that combined performance on time scale questions (i.e., another measure of temporal context memory) was related to working memory.

The relation between temporal context memory and working memory may stem from the influence of reflection and representational abilities. By using working memory skills to hold a representation in mind, children are then able to engage in reflection—the conscious process of thinking about a mental representation. Increased reflection allows one to build continually on a representation, making it more complex and integrating more features of experience (Zelazo, 2015). This process is likely important for both the encoding and retrieval of events, especially regarding the reconstruction process used to judge the time of events. Reconstruction depends on the recall of temporally relevant information (e.g., the leaves were different colors) to provide cues to the temporal context of an event. Thus, it is possible that during the preschool period, children's ability to recall temporal context information depends on their use of working memory while they encode and later retrieve events. This explanation is speculative though, given that the design of the current study was correlational and does not provide evidence of a causal relationship between working memory and temporal context memory.

It is also possible that children were not using reconstruction to recall temporal context information. A key part of reconstruction is the use of knowledge of time patterns in evaluating event details, but the temporal context code used in the current study captured a broader category of temporal context that included information about specific time scales (e.g., season), general time information (e.g., two days ago), and subjective time (e.g., when I was four). Additionally, evidence from previous studies indicates that children struggle to use reconstruction when recalling past events in early childhood (Friedman & Lyon, 2005; Pathman, Larkina, et al., 2013). Thus, a different type of strategy might have been employed by children in the current study when retrieving temporal context information during the interview. However, regardless of the strategy being used, evidence from the current study demonstrated that working memory was related to both broader memory for temporal context in the interview and specific memory for temporal context on the time scale questions. Therefore, working memory skills may be important more generally for recalling both specific and general information about temporal context.

The findings that cognitive flexibility (when controlling for age, working memory, and time knowledge) and inhibitory control were not related to temporal context memory were contrary to the study hypotheses. A possible explanation of why relations were observed with working memory but not the other components relates to the potential influence of working memory on children's ability to use inhibitory control and cognitive flexibility effectively. In their integrated developmental model of EF, Jacques and Marcovitch (2010) proposed that age-related changes in working memory are foundational for the development of cognitive flexibility and inhibitory control. They suggested that by using working memory to hold a representation in mind, children are then able to control their thoughts and behavior by engaging in cognitive flexibility or inhibitory control. If children are attempting to use a strategy like reconstruction, according to this theory they must have enough event details held in mind to both inhibit any non-relevant information or information from a similar event and to shift between event details and time knowledge. Thus, working memory skills in early childhood might impact the ability to engage in a process like reconstruction.

Memory for temporal context was also related to time knowledge, but not after controlling for age, working memory, and cognitive flexibility. Working memory was also related to time knowledge. Given that the time knowledge task in the study required flexible thinking and ordering of the meals and seasons, it is possible that working memory skills were required to manipulate the time scale information in mind while answering those questions. If this is the case, it could explain why time knowledge was not related to temporal context memory in the regression analysis, indicating that working memory abilities accounted for the performance on the time knowledge task. Similarly, Pathman et al. (in press) found that 7-, 9-, and 11-year-olds', and adults' working memory was related to time knowledge (assessed with the CTK task) over and above age. Friedman (1986, 1989) found that children's mental representations of time patterns change with age, and during early childhood, these patterns are represented as verbal lists in a particular order (e.g., breakfast, lunch, dinner), which makes it more difficult for children to think about the order more flexibly. However, with better working memory, children were likely more efficient at manipulating the forward and backward order of the time scales to meet task demands. Although the temporal language questionnaire was not considered a measure of time knowledge, it is interesting to note that accurate use of temporal terms was related to temporal context memory both for the interview and for the overall time scale score. These associations indicate that children who have a better understanding of temporal language also have better memory for temporal context information. Changes in children's understanding of temporal terms may impact their ability to recall temporal context because it provides them with the appropriate knowledge and vocabulary to express the information.

The association between temporal language and temporal context memory is especially interesting considering there was no association between receptive language and temporal context memory. Although Scales and Pathman (2021) found that receptive language related to temporal memory (order and context), it is possible that their story task required the use of language comprehension more so than the experimenter-child interview. The stories used in their study had a narrative-like style and it is possible that children's ability to encode the story information was dependent on their ability to understand the story as a whole. Perhaps the experimenter-child interview placed less demands on children's language comprehension skills. However, if the responses from the interview were coded for narrative cohesion (i.e., context, chronology, theme; Reese et al., 2011), it is possible that children's receptive language would be related to 4- and 5-year-olds' ability to produce cohesive narratives of personal events, especially given relations observed between receptive language and episodic memory from age 4 to 7 (Robertson & Köhler, 2007; Sipe & Pathman, 2020).

Temporal order memory was not related to age in this study, which does align with findings from Scales and Pathman's study (2021). Scales and Pathman found that 4- and 6-year-old children did not differ in their ability to recall the temporal order of within-event actions in a story task. While other studies find evidence for improvement in remembering the temporal order of two target events from age 4 to 6 (Canada et al., 2020; Friedman, 1991; Pathman, Larkina, et al., 2013), it is possible that recalling the order of multiple actions from one event is more difficult than ordering two separate events. Indeed, Canada et al. found that the magnitude of age-related changes in children's ability to order multiple item sequences (e.g., 8-item, 12-item) was greater than for the ability to judge the order of two items from a particular sequence. This increased difficulty in ordering multiple items could explain the lack of age difference in memory for order of within-event actions between 4- and 5-year-olds in the current study.

I did not find evidence that memory for the within-event temporal order of personal events was related to working memory, inhibitory control, receptive language, or time knowledge. There are several possible explanations for why there was no association between temporal order memory and the other variables in the study. Although Arterberry and Albright (2020) found a relation between 3- to 6-year-olds' cognitive flexibility and memory for the temporal order of story actions, their dependent measures consisted of yes/no forced-choice questions about the order of two specific story events (e.g., "Did they go to the rainforest room *before* the electricity room?") and a visual timeline task which required participants to place a selection of pictures from the story on a timeline. These measures did not require participants to recall the order of all events from the story spontaneously. Additionally, cognitive flexibility was only related to participants' performance on the forced-choice questions which referred to actions that were previously included in the timeline task. As discussed above, the ordering of multiple event actions is arguably more difficult than ordering fewer actions. Furthermore, the timeline task took place immediately after participants heard the story, which was then followed by the forced-choice order questions. Thus, the delay between encoding and retrieval was considerably shorter than the delay for the participants in the current study.

It is also possible that the measure of temporal order in the current study (i.e., temporal connection code) did not truly reflect children's temporal order memory abilities. The code that captured temporal order information was based on participant responses that included words that indicated the order or sequence of an event (e.g., then, next, first, before, after). There is evidence that children use a variety of temporal terms, like those captured in the temporal order code, during the preschool period, but they do not use those terms appropriately or correctly (Busby Grant & Suddendorf, 2010). I also found evidence of this in the data from the temporal language parent questionnaire. Parents indicated that 4- and 5-year-old participants' accuracy in using temporal terms ranged from never to always, meaning that the use of a term is not indicative of understanding. Additionally, participants' accurate use of temporal terms was not related to their temporal order memory. It is possible that during the interview, participants used temporal order terms without conveying true event order (e.g., using the word 'then' between statements about various actions).

This idea aligns with Nelson's (1996) theory about young children's use of temporal language in personal event narratives. Nelson suggested that as children start to recall past experiences, they have some knowledge of how events are structured (e.g., there is a beginning, middle, end), which results in their use (although incorrect) of temporal terms. By age 3 children have established schemas for certain types of events (e.g., baking cookies, going to a restaurant), which have a specific structure and unfold in a set order (Nelson & Gruendel, 1981, 1986). Thus, at ages 4 and 5 children have some understanding of event structure and organization. However, Nelson explained that children develop comprehension of these terms and how to use them appropriately as they experience shared conversations about unique, one-time events with adults. Complementary to this theory, evidence from multiple studies investigating the development of memory for personal events in early childhood demonstrates that scaffolding provided by mothers during shared reminiscing is related to age-related changes in children's episodic memory skills, including their ability to produce coherent and organized personal narratives (Nelson & Fivush, 2004). The interview used in the current study was open-ended with some scaffolding provided by the WH-questions, but this is different than the high elaborative style used by mothers during shared reminiscing which consists of asking open-ended questions, providing follow-up details, and asking questions based on children's specific responses (Reese et al., 1993). Additionally, Fivush et al. (1995) suggested that personal narratives do not need to be told in the exact order that the events unfolded, but rather the use of temporal language (e.g., then, before, after) provides coherence and organization. Therefore, the use of temporal terms related to order might be evidence of more sophisticated narrative skills as opposed to accurate memory for the order of event actions.

Limitations and Future Directions

One limitation of the current study was the method used to measure memory for the temporal order of within-event actions. It is possible that participants' temporal connection scores reflected their ability to use temporal terms but did not reflect *accurate* use of these terms.

Additionally, it is possible that children did not understand that they should report their memory of an event in the order it unfolded as they experienced it. The current study did not include any other measures of temporal order memory used previously (e.g., judgments of the order of two events), which might have provided a better indication of children's memory for temporal order at this age. Future studies examining children's memory for temporal order of within-event actions should provide more specific questions related to order. For example, in addition to the interview used in the current study, participants could then be asked to place the event actions they recalled in the correct order.

Another limitation of the current study is inconsistency in the amount of missing data across tasks. It is possible that this affected whether relations with temporal memory were observed for certain measures. For example, there was no association between inhibitory control and memory for temporal context or order, but the number of participants with useable data from the Happy/Sad Stroop task was lower (n = 90) compared to the Visual Counting Span (n = 94) and DCCS (n = 93) tasks. Additionally, some parents could not recall the exact dates of events, which resulted in missing data for the time scale questions for certain participants. In future studies, experimenters should make sure that parents only select events for which they can provide exact date information. One strategy that could address this issue is having parents record special or unique events on a calendar before coming into the lab (Pathman, Larkina, et al., 2013) to not be taxed with having to recall specific dates.

The current study provided evidence of a relation between working memory and memory for temporal context in early childhood, but more research is needed to understand why this relation exists. One potential direction for future studies is to examine the relation between working memory and children's use of reconstruction when recalling the temporal context of events. Previous work has examined reconstruction use in early and middle childhood by having participants provide justifications (e.g., "How did you know it was Fall?") for their responses to time scale questions (Friedman & Lyon, 2005; Pathman, Larkina, et al., 2013), and found that 4-year-olds are much less likely to provide justifications compared to children 6 years of age and older. However, it is not clear from these studies why younger children have more difficulty with reconstruction. It may stem from the fact that they recall less information about events, have a less developed understanding of time and time patterns, or have less sophisticated working memory skills which would facilitate the use of reconstruction. Including measures of reconstruction in future studies could help elucidate the extent to which each of these factors influences the development of children's reconstruction abilities.

Conclusions

The results from the current study demonstrate that age, working memory, cognitive flexibility, and time knowledge are related to children's memory for temporal context in the preschool period. In addition, working memory is potentially influential for young children's temporal memory abilities given it was the only variable related to temporal context memory when controlling for the other variables. The use of working memory skills in updating and manipulating mental representations could be especially useful in children's efforts to recall the temporal context of events. The current study adds to the broader literature on temporal memory development and provides insight into the nature of how multiple factors might work to support temporal memory abilities in early childhood. These findings have implications for how children begin to understand how time plays a role in the construction of a life story and self-identity, as well as the capabilities of preschool children in the context of providing eyewitness testimony about significant events.

CHAPTER VI: STUDY 2 INTRODUCTION

The findings from Study 1 demonstrated relations between 4- and 5-year-olds' memory for the temporal context of personal events, working memory, cognitive flexibility, and time knowledge. Additionally, working memory was the only factor related to temporal context memory when controlling for the other variables. The first goal of Study 2 was to extend Study 1 by examining how working memory, cognitive flexibility, and time knowledge related to children's reconstruction abilities in early and middle childhood. The second goal of Study 2 was to investigate the types of temporal information that children use during reconstruction. Evidence from previous work indicates that between ages 4 and 8 there are substantial changes in children's reconstruction abilities (Friedman, 1991; Friedman & Lyon, 2005; Pathman, Larkina, et al., 2013), EF components (Garon et al., 2008), and time knowledge (Friedman et al., 2011; Scales & Pathman, 2021). The current study examined children's ability to use reconstruction to make judgments and provide justifications about the temporal context of events from laboratory-based stories. By using laboratory-based stories in this study, we could control the types of temporal information surrounding the story events. Past studies that have investigated reconstruction included justification questions for judgments of temporal contexts (e.g., time of day, day of week, month, season). Therefore, the current study focused on the reconstruction of temporal context using similar time scales (i.e., time of day and season).

Friedman (1991) asked 4-, 6-, and 8-year-olds to place a staged event on the following time scales: time of day, day of week, month, and season, and had participants justify their responses (e.g., "How do you know X event happened in the Fall?"). The justification questions were considered an indirect measure of reconstruction, given that the content of responses would reveal if participants were using temporally relevant information from the event to make their judgments. Friedman found that 6- and 8-year-olds, but not 4-year-olds, were logical in their justifications, by referring to details such as their clothing at the time or the weather outside. In addition, Friedman and Lyon (2005) examined 4- to 13-year-olds' temporal memory and reconstruction abilities for staged classroom demonstrations. The demonstrations took place close to Halloween, and both included specific temporal cues (e.g., fake leaves, Halloween mask). Three months after the demonstrations, participants were tested for memory of the temporal cues and answered time scale and justification questions (Friedman, 1991). Overall, memory for the planted temporal cues was very low, and participants rarely included the cues in their reports of the demonstrations. Regarding time scale justifications, from age 4 to 6 and age 6 to 8 there was pronounced improvement in children's ability to explain their responses with relevant, logical information.

Friedman and Lyon (2005) also investigated how children used temporal cues of hypothetical events to make temporal judgments. First, in a cue interpretation task, participants were given a cue (e.g., it was hot outside), and asked the corresponding time scale question (e.g., "What time of year/season was it?"). Eight- to 13-year-olds, performed either close to or at ceiling for these questions. Four-year-olds performed best on the time of day cue (e.g., eating cereal), and there was substantial improvement across time scales (e.g., time of year/season, time of day, day of week) from age 4 to 6. Second, in a cue evaluation task, participants were given a cue (e.g., a character jumped in a pile of leaves), and asked if that information could help answer the appropriate time scale question (e.g., Can that help him/her know what time of year/season it was?). For the season cue, all 8- to 13-year-olds and the majority of 4- and 6-year-olds responded 'yes.' For the time of day cue (e.g., children cannot eat cookies because it will spoil their appetite), the majority of 6- to 13-year-olds responded ‘yes,’ but less than half of 4-year-olds responded ‘yes.’

The findings from both studies provide evidence for a pronounced shift in children’s ability to justify temporal judgments between the ages of 4 and 8. Interestingly, the cue interpretation and evaluation tasks do not rely on children’s ability to recall temporal details. Rather, they provide an assessment of children’s ability to connect temporally relevant information with time knowledge, a crucial element of reconstruction. The similar pattern of results from the justification and cueing tasks provides complementary evidence for the improvement of reconstruction abilities across early childhood. Pathman, Larkina, et al. (2013) extended this line of work by investigating 4-, 6-, and 8-year-olds’ temporal memory for recent (i.e., 4-5 weeks previously) and distant (i.e., 11-12 weeks previously) personal events, and included time scale and justification questions (Friedman, 1991; Friedman & Lyon, 2005). Furthermore, to understand the different types of information children use to make temporal judgments, Pathman, Larkina, et al. coded participants’ justification responses as references to environmental cues, routine events, calendar events, or other. Across recent and distant events, 4-year-olds provided far fewer justifications than 6- and 8-year-olds, and of the justifications provided most referenced environmental cues. Whereas 6- and 8-year-olds referenced routine events, calendar events, and environmental cues.

From age 4 to 8, there is evidence that age-related changes in temporal memory are paralleled by the development of reconstruction abilities. These changes were observed across staged and personal events after various delay intervals (e.g., 4-5 weeks to 3 months). Although the justification questions provide an indirect assessment of reconstruction, it is somewhat dichotomous. If the justification is appropriate or plausible, the conclusion is that a child used reconstruction. Whereas if the justification is not appropriate or plausible, then the conclusion is that a child did not use reconstruction. To have a more comprehensive understanding of children's reconstruction abilities during early childhood, it is important to examine cognitive factors that are related to temporal memory and reconstruction, especially given their complex nature.

Although Friedman and Lyon (2005) included temporal cues in the staged classroom demonstrations, the cues did not fit well with the content of the demonstrations. Additionally, memory for the demonstrations and temporal cues was not assessed until three months later, and overall retrieval of the cues was poor across ages 4 to 13. The current study included a novel story task to assess children's ability to recall temporal information and use it to infer the temporal context of events. This task was partially based on the cue interpretation task from Friedman and Lyon. The stories that children heard included both visual and non-visual information about various temporal contexts (e.g., time of day, season). The visual and non-visual details referred to environmental cues (e.g., leaves and flowers outside) and routine or seasonal events (e.g., eating breakfast, decorating a pumpkin). Participants heard two stories about the activities of child characters, and each story took place in particular temporal contexts (e.g., Fall, Morning). The experimenter included both visual and non-visual cues relevant to each type of context, but critically, did not mention them explicitly (e.g., did NOT say "This story takes place in the Fall."). For example, in a Fall story, the experimenter pointed out that there are different colored leaves on a tree (visual) and that the character will decorate a pumpkin later (non-visual) but did not state that it was Fall. After a delay, the participants were asked to make temporal judgments about the season and time of each story by answering forced-choice questions and providing justification for their responses, similar to the procedure used in previous studies (Friedman, 1991; Friedman & Lyon, 2005; Pathman, Larkina, et al., 2013). Children's responses to these questions could provide indirect evidence of the use of reconstruction processes given the need to recall the temporally relevant information from the stories and combine it with time knowledge to make accurate judgments. Participants also completed tasks that assessed working memory, cognitive flexibility, and time knowledge (Scales & Pathman, 2021).

Study 2 Predictions

First, I predicted that in an ordinal logistic regression analysis that included temporal judgments as the dependent variable and age, working memory, cognitive flexibility, and time knowledge as independent variables, only the EF components and time knowledge would be significant predictors of temporal judgments. More specifically, each EF component would be related to temporal judgments over and above the other factors, and time knowledge would be related to temporal judgments over and above the other factors. These predictions were based on previous findings that indicate relations between temporal memory with time knowledge (Scales & Pathman, 2021) and EF components (Arterberry & Albright, 2020; Picard et al., 2012). I also predicted that these relations would extend to children's reconstruction abilities, assessed by temporal judgments because time knowledge and EF components are likely associated with the various components of the reconstruction process. Second, I predicted that across time scales, 4- and 5-year-olds would use mostly visual cues in their justifications, whereas 6- and 7-year-olds would use both visual and non-visual cues in their justifications. These predictions were based on changes in the use of different types of temporally relevant information to make temporal judgments observed from age 4 to 8 (Friedman, 1991; Friedman & Lyon, 2005; Pathman, Larkina, et al., 2013).

CHAPTER VII: STUDY 2 METHOD

Participants

To estimate the effect size for the relation of working memory and cognitive flexibility to spontaneous temporal judgments for a power analysis, I conducted correlations and a hierarchical regression analysis using a portion of the data from Study 1. The correlational analysis showed that children's spontaneous memory for temporal context of personal events (i.e., time code) was related to working memory, $r = .341$, $p = .001$, and cognitive flexibility, $r = .326$, $p = .001$. Next, I ran a hierarchical regression with memory for temporal context as the dependent measure, age in months was entered in step 1 as an independent variable, and scores for the EF tasks (working memory and cognitive flexibility) were entered in step 2 as independent variables. The R^2-change for the second step was .11. The R^2 value for flexible retrieval from Scales and Pathman (2021) was .085. For Study 2, I estimated an R^2 effect size of .12 given the change in age range from 4- to 5-year-olds to 4- to 7-year-olds, which would likely increase the variability across tasks. With an R^2 effect size of .12 for 3 predictor variables (cognitive flexibility, working memory, and CCT flexible retrieval) out of 4 total predictors (age is the 4th predictor) and a power of .80, the power analysis yielded a sample size of 77. Thus, Study 2 included a sample of 80 participants (40 per age group: 4- to 5-year-olds and 6- to 7-year-olds). Although the main analysis used in the study was an ordinal logistic regression, this power analysis serves as an appropriate estimate for the ordinal logistic regression analysis. This is because the coefficients in an ordinal logistic regression are log-odds ratios of cumulative probabilities (Kleinbaum & Klein, 2010).

I collected data from 41 4- and 5-year-olds ($M_{age} = 59.24$ months, 25 females) and 41 6- and 7-year-olds ($M_{age} = 83.00$ months, 17 females). One 4-year-old participant's data was excluded from all analyses because they did not complete the DCCS-Borders task or finish the CCT task. Participants were recruited from Greensboro, NC and surrounding areas, using a database of families who previously volunteered to be contacted. Participants were also recruited from other regions in the United States using social media and the Children Helping Science website. Parents identified participants as: White (53%), African American (4%), Mixed Race (17%), Asian (9%), Middle Eastern or North African (1%), Other (1%), and a portion (11%) of the sample did not report race information. Participants were identified as Not Hispanic (82%), Hispanic (6%), and a portion (10%) of the sample did not report ethnicity information. Regarding socioeconomic status, 32% reported a yearly income greater than $120,000, $90,000, 21% reported a yearly income of $90,000 to $120,000, 13% reported a yearly income of $60,000 to $90,000, 10% reported a yearly income of $40,000 to $60,000, 2% reported a yearly income of $25,000 to $40,000, and 17% of the sample did not report income information. Informed consent was provided by parents or legal guardians, verbal assent was provided by participants. All participants were tested on Zoom in a single session, which took about 30 minutes.

Procedure

Participants received tasks in a fixed order: story task encoding, two EF tasks, a distractor task, story task retrieval, and a time knowledge task (CCT). I used a fixed order to ensure that there was no interference from the time knowledge task on temporal judgments or temporal cue recall for the stories. The order of the EF tasks was counterbalanced to prevent possible order effects.

Story Task Encoding

The story task consisted of an encoding phase and a retrieval phase. During the encoding phase, the experimenter told participants two stories, which each featured a child character participating in 3 actions outside their home, which could theoretically occur in any temporal context (e.g., reading a book). As the experimenter was telling the story, participants viewed images on the computer via the Zoom screensharing feature. Critically, each story took place within specific temporal contexts, including: (a) season (e.g., Fall or Spring) and (b) time of day (i.e., morning or evening). For each story, the experimenter included 2 temporal cues (1 visual, 1 non-visual) about each type of temporal context (i.e., season, time of day) in addition to information about the actions (see Table 11 for all temporal cues). The temporal cues were chosen based on piloting, which was done with 4- to 6-year-olds to ensure that children in this age range understood various characteristics of the seasons (e.g., leaves change colors in the Fall, flowers grow in the Spring) and time of day (e.g., the sun rises in the morning, the sun sets in the evening/night).

Table 11. Temporal Cues

Time Scale	Cue Type	Cue
Time of day	Visual	Sun coming up in the sky; Sun going down in the sky
Time of day	Non-visual	Eating breakfast; Eating dinner
Season	Visual	Leaves changing colors/falling; Flowers growing
Season	Non-visual	Decorate a pumpkin; Water plants in garden

Importantly, during encoding the specific season and time of day was never stated explicitly by the experimenter. Participants also answered questions about the stories during encoding (e.g., "What color is Gabby's shirt?") to ensure they were engaged in the task. The story narrations all followed the same format, the set of stories was constrained so that there was no repetition across any temporal contexts. For example, if one story took place during the

Spring and in the morning, the other story would take place during the Fall and in the evening. Additionally, the presentation of the temporal cues was counterbalanced (i.e., there were 8 possible orders for the Spring/Morning and Fall/Night story combination and 8 possible orders for the Fall/Morning and Spring/Night combination). There were 6 character actions across the two stories, which were randomized for each counterbalance. Figures 1 and 2 include an example story set that a participant would see on the screen, which includes: (1) a Morning/Spring story and (2) a Night/Fall story. Appendix B includes a different story combination (Morning/Fall, Night/Spring).

Figure 1. Morning/Spring Story Example

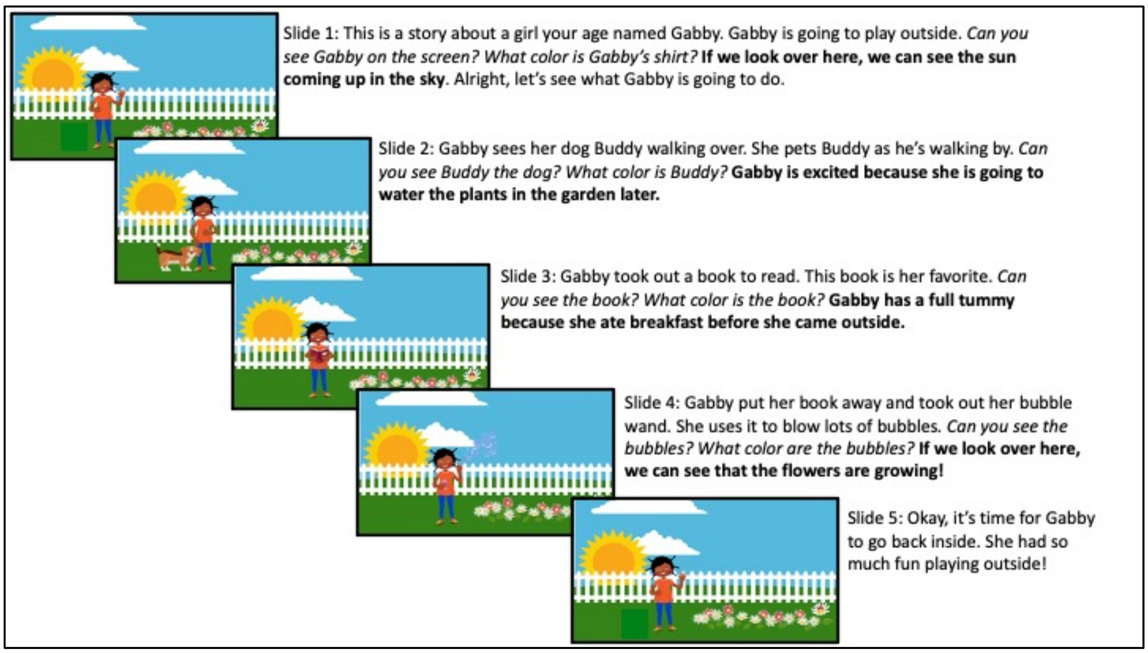
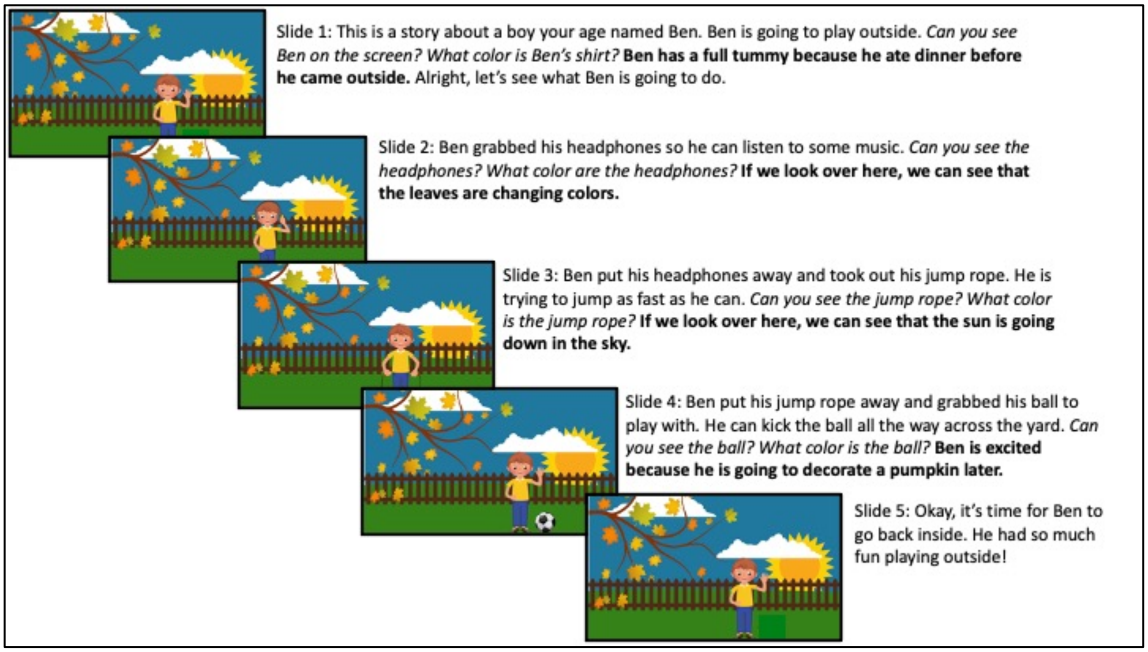


Figure 2. Fall/Night Story Example

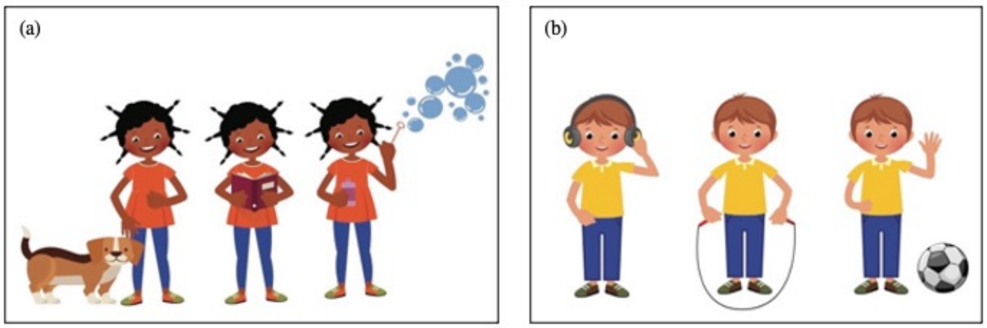


Story Task Retrieval

After hearing both stories, children completed the two EF tasks and a picture search task, which served as a distractor task. The delay between the end of the encoding phase and start of the retrieval phase was 18 minutes for all participants. I chose this delay time to ensure that participants were not performing at ceiling on the retrieval questions. By including the distractor task, I was able to equate the delay time between encoding and retrieval for all participants regardless of their performance and length of time spent on the EF tasks. Additionally, this delay is similar to the delay between encoding and retrieval in another study which examined the relation between 3- to 6-year-olds' source memory and EF components (Rajan et al., 2014).

During the retrieval phase, participants answered questions about the stories in the order that the stories were presented. For example, if the first story a participant heard was the Spring/Morning story, they answered questions about that story first followed by questions about the Fall/Night story. For each story, participants viewed images of the character and their actions while answering questions (see Figure 3).

Figure 3. Character and Story Action Images



For each story participants first answered forced choice temporal judgment questions about the season (e.g., “When Gabby pet her dog, read her book, and blew bubbles, was it Fall or Spring?”) and time of day (e.g., “When Gabby pet her dog, read her book, and blew bubbles, was it Night or Morning?”). After responding, participants were asked a justification question for each judgment (e.g., “How do you know it was Spring?”). Participants received 1 point for each correct temporal judgment question, and a temporal judgment score was calculated by summing their points across questions (possible score range: 0 to 4).

For all correct temporal judgment responses, we coded the corresponding justification responses for content to understand the types of temporal information (i.e., visual, non-visual, or both) children used when making their temporal judgments. I chose only to code justifications for correct temporal judgments because a goal of the current study was to examine children’s ability to reconstruct the time of events, which is best demonstrated through accurate responses about the temporal context of the stories that participants heard. Even if participants provided an accurate justification for an incorrect judgment, it would still indicate that the participant did not correctly recall the temporal context of the target story.

Responses that did not include relevant temporal information or phrases such as “I don’t know” were given a code of 0. Responses that included only visual information received a code of 1. Responses that included only non-visual information received a score of 2. Responses that included both visual and non-visual information received a score of 3. An independent research assistant who was naïve to study hypotheses coded all justifications for reliability. Kappa values ranged from .91 to 1.00. The codes from the primary researcher were used in all analyses. Table 12 includes a description of all codes and examples.

Table 12. Justification Code Descriptions and Examples

Code	Description	Examples
0	Response does not contain any information from cues	“I don’t know,” “because you know like Spring that means like Spring is when you wake up for a lot of time”
1	Response contains only *visual* cue information from the story	“because flowers were growing,” “cause the sun was going down”
2	Response contains only *non-visual* cue information from the story	“because she just ate breakfast,” “because it said he was going to water the garden later”
3	Response contains both *visual* and *non-visual* cue information from the story	“cause the sun was going down and he ate dinner,” “because I saw the leaves changing colors and she was going to paint a pumpkin”

We also scored justification responses (for correct temporal judgments only) for accuracy. Participants received 1 point if they provided an accurate justification that included fully detailed information from the story that was relevant to the time or season. Participants received .5 point if they provided an accurate justification that included some information from the story that was relevant to the time or season. Participants received 0 points if they provided an inaccurate justification that did not provide information relevant to the time or season. An independent researcher assistant who was naïve to study hypotheses scored all the justifications for reliability. Kappa values ranged from .95 to 1.00. The scores from the primary researcher were used in all analyses. We calculated a total justification score by summing each participant's points across the 4 justifications. Table 13 includes descriptions of and examples from this scoring system.

Table 13. Justification Accuracy Code Descriptions and Examples

Score	Description	Examples
1	Correct/accurate justification that includes fully detailed information from the story that is relevant to the time of day or season; justifications that contrast the stories and provide temporal information	**Morning:** "because she ate breakfast," "because the sun was rising/coming up," "because the sun was up"
		Night: "because she ate dinner," "because the sun was going down/setting"
		Fall: "because the leaves were changing colors," "because the leaves were falling down," "because she was gonna decorate a pumpkin"

		Spring: “because the flowers/plants were growing/blooming,” “because she was gonna water the plants,” “because the leaves weren’t changing colors”
0.5	Correct/accurate justification that includes *some* information from the story that is relevant to the time of day or season but is *not fully detailed*	**Morning:** “because the sun,” “because I saw the sun”
		Fall: “because the leaves”
		Spring: “because the flowers/plants”
0	Incorrect/inaccurate justification that either is not relevant to the correct time of day or season; justifications that contrast the two stories but do NOT mention specific temporal details	**Morning:** “because it was dark outside,” “because the other one was dinner”
		Night: “because the sun was up”
		Fall: “because I saw the tree”
		Spring: “because the leaves were changing colors,” “because that was the different weather because I already said Fall and now it’s Spring”

Participants next answered forced-choice questions about the 4 temporal cues in the story (e.g., “Before Gabby pet her dog, read her book, and blew bubbles, did she eat dinner or breakfast?”). Participants received 1 point for each correct temporal cue response (8 total), and a temporal judgment score was calculated by summing their points across questions (possible score range: 0 to 8).

Executive Function Tasks

Working Memory

We assessed working memory with the digit recall task (forward and backward; Gathercole et al., 2004; Wechsler, 2003). During the forward version of the task, the experimenter said strings of digits (e.g., "1-3"), and the participants were to repeat back the digit strings in the same order. There were 2 practice trials, which included a 1-digit and 2-digit string. Participants received 2 trials per string length, starting with 2 digits and ending with 9 digits. Participants continued the task until they produced incorrect responses to both trials of a digit string. Participants then completed the backward version of the task. The experimenter said strings of digits (e.g., "1-3"), but the participants were instructed to repeat the string in backward order (e.g., "3-1"). There were 2 practice trials, which both included 2-digit strings. The procedure was the same as the forward version, starting with 2-digit trials and ending with 8-digit trials. Participants continued the task until they produced incorrect responses to both trials of a digit string. Participants received .5 point for each correct trial, and a total score was calculated for each version (i.e., forward and backward) by summing the points for all correct trials (Caporaso, 2021). Performance on the backward span task was most relevant for the current study because it serves as a measure of working memory given the need to both maintain the digit strings and reverse them in mind. Performance on the forward span task is thought to reflect short-term memory abilities, given it only requires participants to maintain the digit strings in mind but does not require manipulation (Alloway et al., 2006).

Cognitive Flexibility

We assessed cognitive flexibility with a shortened, virtual adaptation of the Dimensional Change Card Sort (DCCS) Borders Version (Zelazo, 2006). Participants provided verbal responses for all trials. For example, if sorting by color in the pre-switch phase, participants saw cards that each had a number on them (e.g., blue boat card with a "1" on it; red bunny card with a "2" on it) and were told to respond "1" for blue and "2" for red. In the post-switch phase, participants also saw cards with numbers on them (e.g., blue bunny card with a "1" on it; red boat card with a "2" on it) and were told to respond "1" for bunny and "2" for boat. In the borders phase, participants were instructed that if a card had a black line around it, then they would play the color game (i.e., say "1" for blue and "2" for red), and if the card did not have a black line around it, then they would play the shape game (i.e., say "1" for bunny and "2" for boat). The borders level was shortened from 12 to 6 trials and sorting 5 trials correctly in the borders level was considered 'passing'. Participants received a score for how many levels they passed (e.g., 0 = failed pre-switch, 1 = passed pre-switch, 2, = passed pre- and post-switch, or 3 = passed pre- and post-switch and borders).

Distractor Task

Participants completed a distractor task after the EF tasks to ensure an 18-minute delay between encoding and retrieval. The distractor task was a visual hidden picture search, which included 14 objects hidden in an animated image of a walrus reading a newspaper (https://www.highlightskids.com/games/hidden-pictures/mr-walrus).

Children's Conventional Time Task

After the story task retrieval, participants completed a shortened version of the Children's Conventional Time task (CCT; Scales & Pathman, 2021), which included questions about the meals and seasons. For each time scale, the experimenter first asked the participant to name the 3 meals or the 4 seasons. If the participant could not name the 3 meals or 4 seasons, they were provided by the experimenter. The experimenter next asked the flexible retrieval questions for each time scale. Participants answered both forward (e.g., "If you've had breakfast, what is the next meal going forward in time you'll eat?") and backward (e.g., "If you've had breakfast, what is the next meal going backwards in time?") questions about the order of the time scales. Participants receive forward, backward, and total (i.e., forward plus backward) scores based on the number of correct responses for each time scale. They also received an overall time knowledge score, which was the average number of correct responses across time scales.

CHAPTER VIII: STUDY 2 RESULTS

Missing Data

One 4-year-old participant is not included in any analyses because they did not complete the DCCS task or the CCT task. One 5-year-old participant did not complete the seasons portion of the CCT task and is therefore not included in analyses that examine CCT performance. Tables 14 and 15 include the means, standard deviations, ranges, and sample sizes for all study measures for the 4- to 5-year-old and 6- to 7-year-old groups, respectively.

Table 14. Descriptive Statistics for 4- and 5-year-olds

Measure	N	Mean	Standard Deviation	Range
Story Retrieval				
Temporal Judgments	40	2.98	1.00	1 to 4
Temporal Cues	40	6.75	1.32	2 to 8
EF Tasks				
Forward Digit Span	40	2.88	0.81	1.5 to 5.5
Backward Digit Span	40	1.56	1.05	0 to 3
DCCS	40	2.00	0.55	1 to 3
CCT Task				
Meals Forward	40	2.03	.92	0 to 3
Meals Backward	40	1.43	1.13	0 to 3
Meals Total	40	3.45	1.47	1 to 6
Seasons Forward	39	2.10	1.39	0 to 4
Seasons Backward	39	1.28	1.19	0 to 4
Seasons Total	39	3.38	1.97	0 to 8
Total: Meals and Seasons	39	6.87	3.03	2 to 14

Table 15. Descriptive Statistics for 6- and 7-year-olds

Measure	N	Mean	Standard Deviation	Range
Story Retrieval				
Temporal Judgments	41	3.56	0.67	2 to 4

Temporal Cues	41	7.54	0.84	5 to 8
EF Tasks				
Forward Digit Span	41	3.71	0.80	1.5 to 5
Backward Digit Span	41	2.60	0.75	1 to 4.5
DCCS	41	2.46	0.55	1 to 3
CCT Task				
Meals Forward	41	2.80	0.46	1 to 3
Meals Backward	41	2.41	0.89	0 to 3
Meals Total	41	5.22	0.99	3 to 6
Seasons Forward	41	3.02	1.49	0 to 4
Seasons Backward	41	2.63	1.53	0 to 4
Seasons Total	41	5.66	2.84	0 to 8
Total: Meals and Seasons	41	10.88	3.45	4 to 14

Temporal Judgment and Cue Analyses

I ran a 2 (Age group: 4- to 5-year-olds, 6- to 7-year-olds), X 2 (Time scale: Season, Time of day) mixed ANOVA on temporal judgment scores, with Time scale as the within-subject variable. There was a significant main effect of Age group, $F(1, 79) = 9.305$, $p = .003$, $\eta_p^2 = .105$, which indicated that older children performed better across Time scale on temporal judgments ($M = 1.780$, $SE = .065$) compared to younger children ($M = 1.500$, $SE = .065$). There was not a main effect of Time scale or an Age group X Time scale interaction, *p*-values > .20.

I ran a 2 (Age group: 4- to 5-year-olds, 6- to 7-year-olds), X 2 (Season: Fall, Spring) X 2 (Cue type: Visual, Non-visual) mixed ANOVA on temporal cue scores, with Season and Cue type as within-subject variables. There was a significant main effect of Cue type, $F(1, 79) = 3.967$, $p = .050$, $\eta_p^2 = .048$, which indicated that across Age group and Season, all participants performed better on temporal cue season questions about non-visual cues ($M = 0.950$, $SE = .018$) compared to visual cues ($M = 0.888$, $SE = .024$). There was also a significant main effect of Age group, $F(1, 79) = 8.652$, $p = .004$, $\eta_p^2 = .099$, which indicated that older children performed better overall on temporal cue season questions (*M* = 0.963, *SE* = .021) compared to younger children (*M* = 0.875, *SE* = .021). There was no main effect of Season, $F(1, 79) = 3.009$, $p = .087$, $\eta_p^2 = .037$, and none of the interactions were significant, all *p*'s > .30.

I ran a 2 (Age group: 4- to 5-year-olds, 6- to 7-year-olds), X 2 (Time of day: Morning, Night) X 2 (Cue type: Visual, Non-visual) mixed ANOVA on temporal cue scores, with Time of day and Cue type as within-subject variables. There was a significant main effect of Age group, $F(1, 79) = 5.317$, $p = .024$, $\eta_p^2 = .063$, which was qualified by an Age group X Time of day X Cue type interaction, $F(1, 79) = 4.635$, $p = .034$, $\eta_p^2 = .055$. To follow up the interaction, I ran the 2 (Time of day: Morning, Night) X 2 (Cue type: Visual, Non-visual) repeated measures ANOVA for each Age group separately. For younger children, there was a Time X Cue type interaction, $F(1, 39) = 4.333$, $p = .044$, $\eta_p^2 = .100$. However, Bonferroni-corrected pairwise comparisons did not indicate any significant differences in memory performance for visual and non-visual cues for either Morning or Night contexts, all *p*'s > .10. For older children, there was only a main effect of Time of day, $F(1, 40) = 4.642$, $p = .037$, $\eta_p^2 = .104$, which indicated that performance on temporal cue questions about Morning (*M* = 0.976, *SE* = .017) was better compared to questions about Night (*M* = 0.866, *SE* = .049).

Plan for Regression Analyses

For the regression analyses, the first step of data analysis for the current study included running correlation analyses between age in months, DCCS levels passed, forward digit scores, backward digit scores, CCT proportion scores, temporal judgments scores, and temporal cue scores. The second step included running ordinal logistic regression analyses, a series with temporal judgment scores as the dependent variable and a series with temporal cue scores as the dependent variable. However, the second step was dependent on the results from the first step.

The independent variables for the regression analyses were chosen based on the results of the correlation analyses. Only variables that were significantly related to the dependent variables would be included in the regression analyses.

Additionally, for each dependent measure, I ran a regression analysis with age as an independent variable and another regression analysis without age included in the model. This approach is similar to the use of hierarchical regression in which variables of interest are entered in different steps, with the final step reflecting the full model. Given that all the independent variables of interest (DCCS levels passed, backward digit scores, and CCT proportion scores) were related to age, I wanted to investigate if any of these factors would emerge as independent predictors. In addition to these variables changing due to age, it is possible that there is overlap in the types of abilities or factors required to perform well on these tasks. For example, the CCT task likely requires working memory skills given the need to manipulate the order of familiar time scales. In Study 1, CCT scores were not related to temporal context memory when controlling for age, working memory, and cognitive flexibility, and working memory was the only variable related to temporal context memory. It is possible that working memory abilities accounted for performance on the CCT task. Thus, I wanted to examine the possibility that any of the variables of interest related to the dependent measures when controlling for the other variables in a model that did not include age.

Relations between Temporal Judgment Scores, Age, Cognitive Flexibility, Working Memory, and Time Knowledge

Correlation analyses were conducted to examine relations between temporal judgment scores, age in months, DCCS levels passed, forward digit scores, backward digit scores, and CCT proportion scores (see Table 16). Temporal judgment scores were significantly related to age in months, $r(79) = .373$, $p = .001$, DCCS levels passed, $r(79) = .347$, $p = .001$, forward digit scores, $r(79) = .270$, $p = .015$, backward digit scores, $r(79) = .417$, $p < .001$, and CCT proportion scores, $r(78) = .399$, $p < .001$.

Given that the temporal judgment variable was ordinal and had a limited range, I ran an ordinal logistic regression instead of a multiple linear regression. The ordinal logistic regression included age in months, DCCS levels passed, backward digit scores, and CCT proportion scores as independent variables and temporal judgment scores as the dependent variable. To check for multicollinearity issues, I ran a multiple linear regression with the same independent and dependent variables. For the independent variables the VIF values ranged from 1.459 to 2.032, which fall below conventional threshold levels of 10, 5, and a more conservative 2.5 (James et al., 2017; Johnston et al., 2018; Menard, 2001). Thus, none of the VIF values for the independent variables indicated major issues with multicollinearity.

In the ordinal regression, the assumption of parallel lines for the proportional odds model was violated for this analysis. This assumption is that the coefficient or odds ratio that measures the relation between an independent variable and a dependent variable will be the same for all the comparisons in the model (i.e., the odds ratio comparing participants with a score of 0 to those with a score greater than 0 is the same as the odds ratio comparing participants with a score greater than or equal to 2 to those with a score less than 2). Because of this, I combined the 1 and 2 categories into a score of 2 or less category. Therefore, the rescored data reflected participants with temporal judgment scores of 2 or less ($n = 15$), 3 ($n = 23$), and 4 ($n = 42$). I then ran an ordinal logistic regression with the rescored temporal judgment scores as the dependent variable and age in months, DCCS levels, backward digit scores, and CCT proportion scores as the independent variables. For this analysis, the assumption of parallel lines was met. The results of this ordinal logistic regression are included in Table 17.

All values for confidence intervals correspond to the odds ratio for each independent variable. Results indicated a significant relation between DCCS levels passed and temporal judgment scores when controlling for other variables in the model. Specifically, a single unit increase in DCCS performance was associated with an increase in the odds of having a higher temporal judgment score with an odds ratio of 2.604, (95% CI, 1.014, 6.686), Wald $\chi^2(1)$ = 3.956, p = .047. There was also a significant relation between CCT proportion scores and temporal judgment scores when controlling for other variables in the model. Specifically, a single unit increase in CCT performance was associated with an increase in the odds of having a higher temporal judgment score with an odds ratio of 9.885, (95% CI, 1.133, 86.228), Wald $\chi^2(1)$ = 4.298, p = .038. There was no relation between age in months and temporal judgment scores when controlling for other variables in the model, with an odds ratio of 0.997, (95% CI, .666, 1.040), Wald $\chi^2(1)$ = .023, p = .881. There was also no relation between backward digit scores and temporal judgment scores when controlling for other variables in the model, with an of odds ratio of 1.330, (95% CI, .717, 2.467), Wald $\chi^2(1)$ = 0.817, p = .366.

I also ran an ordinal logistic regression that did not include age as a variable, with DCCS levels passed, backward digit scores, and CCT proportion scores as independent variables and temporal judgment scores as the dependent variable. Results indicated a significant relation between DCCS levels passed and temporal judgment scores when controlling for other variables in the model. Specifically, a single unit increase in DCCS performance was associated with an increase in the odds of having a higher temporal judgment score with an odds ratio of 2.568, (95% CI, 1.006, 6.547), Wald $\chi^2(1)$ = 3.894, p = .048. There was also a significant relation between CCT proportion scores and temporal judgment scores when controlling for other variables in the model. Specifically, a single unit increase in CCT performance was associated with an increase in the odds of having a higher temporal judgment score with an odds ratio of 9.393, (95% CI, 1.177, 75.038), Wald $\chi^2(1) = 4.467$, $p = .035$. There was no relation between backward digit scores and temporal judgment scores when controlling for other variables in the model, with an of odds ratio of 1.310, (95% CI, .740, 2.316), Wald $\chi^2(1) = 0.858$, $p = .354$. The results of this ordinal logistic regression are included in Table 18. Comparing across the two regression models, the results were the same with and without age group as an independent variable. This pattern of results could indicate that age-related changes were captured by scores on the DCCS and CCT tasks.

Table 16. Correlations between Temporal Judgments and Other Measures

	1. Age (months)	2. DCCS levels	3. Forward digit	4. Backward digit	5. CCT proportion correct	6. Temporal judgment scores
1. Age (months)	1	--	--	--	--	--
p-value						
N						
2. DCCS levels	.421	1	--	--	--	--
p-value	< .001					
N	81					
3. Forward digit	.444	.298	1	--	--	--
p-value	< .001	.007				
N	81	81				
4. Backward digit	.608	.529	.430	1	--	--
p-value	< .001	< .001	< .001			
N	81	81	81			
5. CCT proportion correct	.540	.429	.473	.560	1	--
p-value	< .001	< .001	< .001	< .001		
N	80	80	80	80		
6. Temporal judgment scores	.373	.347	.270	.417	.399	1

p-value	.001	.001	.015	< .001	< .001
N	81	81	81	81	80

Table 17. Ordinal Logistic Regression Results with Age

Covariate	Estimate	*SE*	Odds Ratio	Wald (χ^2)	*p*-value	95% Confidence Interval	
						Lower	Upper
Age (months)	-.003	.022	0.997	.023	.881	.666	1.040
DCCS levels	.957	.481	2.604	3.956	.047	1.014	6.686
Backward span	.285	.315	1.330	0.817	.366	.717	2.467
CCT proportion	2.291	1.105	9.885	4.298	.038	1.133	86.228
Intercept							
Temporal judgment scores = 2 or less	2.115	1.365					
Intercept Temporal judgment scores = 3	3.819	1.411					

Table 18. Ordinal Logistic Regression Results without Age

Covariate	Estimate	*SE*	Odds Ratio	Wald (χ^2)	*p*-value	95% Confidence Interval	
						Lower	Upper
DCCS levels	.943	.478	2.568	3.894	.048	1.006	6.547
Backward span	.270	.291	1.310	0.858	.354	.740	2.316
CCT proportion	2.240	1.060	9.393	4.467	.035	1.177	75.038
Intercept	2.250	0.964					

Temporal judgment scores = 2 or less		
Intercept Temporal judgment scores = 3	3.9555	1.033

Relations between Temporal Cue Scores, Age, Cognitive Flexibility, Working Memory, and Time Knowledge

Correlation analyses were conducted to examine relations between temporal cue scores, age in months, DCCS levels passed, forward digit scores, backward digit scores, and CCT proportion scores (see Table 19). Temporal cue scores were significantly related to age in months, $r(79) = .322$, $p = .003$, DCCS levels passed, $r(79) = .381$, $p < .001$, forward digit scores, $r(79) = .356$, $p = .001$, backward digit scores, $r(79) = .469$, $p < .001$, and CCT proportion scores, $r(78) = .360$, $p = .001$.

Temporal cue scores ranged from 2 to 8. Given the ordinal nature of the variable, I ran an ordinal logistic regression that included age group (0 = 4- to 5-year-olds, 1 = 6- to 7-year-olds), DCCS levels passed, backward digit scores, and CCT proportion scores as the independent variables and temporal cue scores as the dependent variable. However, the parallel lines assumption was violated for this analysis. I rescored the temporal cue data by combining the 2, 3, and 5 scores into a score of 5 or less category. The rescored data reflected participants with temporal cue scores of 5 or less (n = 6), 6 (n = 23), 7 (n = 14), and 8 (n = 44). With the rescored temporal cue scores as the dependent variable, the parallel lines assumption was still violated. Thus, I ran a multiple linear regression with age in months, DCCS levels passed, backward span scores, and CCT proportion scores as the independent variables and non-rescored temporal cue scores (range: 2 to 8) as the dependent variable. The overall model was significant, $F(4, 79) =$

6.521, $R^2 = .258$, $p < .001$. The only variable that was significantly related to temporal cue scores when controlling for the other variables was backward span scores, β = .340, $p = .019$. Temporal cue scores were not related to age in months, β = -.012, $p = .928$, DCCS levels passed, β =. 158, $p = .193$, or CCT proportion scores, β = .109, $p = .396$, when controlling for the other variables. Table 20 includes the results of the multiple linear regression.

I also ran a multiple linear regression that did not include age in the model, with DCCS levels passed, backward span scores, and CCT proportion scores as the independent variables and non-rescored temporal cue scores (range: 2 to 8) as the dependent variable. The overall model was significant, $F(3, 79) = 8.807$, $R^2 = .258$, $p < .001$. The only variable that was significantly related to temporal cue scores when controlling for the other variables was backward span scores, β = .335, $p = .012$. Temporal cue scores were not related to DCCS levels passed, β =. 157, $p = .191$, or CCT proportion scores, β = .105, $p = .388$, when controlling for the other variables. Table 21 includes the results of the multiple linear regression. Comparing across the two regression models, the results were the same with and without age as an independent variable. This pattern of results could indicate that age-related changes were captured by scores on the backward digit span task.

Table 19. Correlations between Temporal Cue Scores and Other Measures

	1. Age (months)	2. DCCS levels	3. Forward digit	4. Backward digit	5. CCT proportion correct	6. Temporal cue scores
1. Age (months)	1	--	--	--	--	--
p-value						
N						
2. DCCS levels	.421	1	--	--	--	--
p-value	< .001					

N	81					
3. Forward digit	.444	.298	1	--	--	--
p-value	< .001	.007				
N	81	81				
4. Backward digit	.608	.529	.430	1	--	--
p-value	< .001	< .001	< .001			
N	81	81	81			
5. CCT proportion correct	.540	.429	.473	.560	1	--
p-value	< .001	< .001	< .001	< .001		
N	80	80	80	80		
6. Temporal cue scores	.322	.381	.356	.469	.360	1
p-value	.003	< .001	.001	< .001	.001	
N	81	81	81	81	80	

Table 20. Multiple Linear Regression Results with Age

Variables	*B*	*SE*	*β*	*t*	*p*-value
Age (months)	-.001	.011	-.012	-.091	.928
DCCS levels	.308	.234	.158	1.315	.193
Backward digit	.390	.162	.340	2.399	.019
CCT proportion	.468	.548	.109	.854	.396

Table 21. Multiple Linear Regression Results without Age

Variables	*B*	*SE*	*β*	*t*	*p*-value
DCCS levels	.306	.232	.157	1.320	.191
Backward digit	.384	.148	.335	2.584	.012

CCT proportion	.454	.522	.105	.869	.388

Justification Response Analyses

I conducted separate Fisher's exact test analyses for each temporal context (i.e., Morning, Night, Fall, Spring) to examine if there were differences in the types of information that younger and older children used to justify their temporal judgments. For the Morning context, there were differences based on age group, $p < .001$ (Fisher's exact test), and the results are included in Table 22. Among 4- and 5-year-olds, 62.5% referred to only visual information (i.e., the sun), and among 6- and 7-year-olds, 63.4% referred to only visual information. References to only non-visual information (i.e., breakfast) made up 5% of 4- and 5-year-olds responses, whereas 26.8% of 6- and 7-year-olds referenced non-visual information. None of the 4- and 5-year-olds made justifications that referred to both visual and non-visual information but 7.3% of 6- and 7-year-olds did. Additionally, 30% of 4- and 5-year-olds had responses coded as "other," whereas none of the 6- to 7-year-olds did.

For the Night context, there were differences based on age group, $p = .045$ (Fisher's exact test), and the results are included in Table 23. In their justifications, 25% of 4- and 5-year-olds only referenced visual information (i.e., the sun) compared to 51.2% of 6- and 7-year-olds. For non-visual information only (i.e., dinner), 15% of 4- and 5-year-olds included it, compared to 7.3% of 6- and 7-year-olds. Looking at references to both visual and non-visual information, 2.5% of 4- and 5-year-olds mentioned both, compared to 12.2% of 6- and 7-year-olds. Additionally, 17.5% of 4- and 5-year-olds had responses coded as "other" compared to 7.3% of 6- and 7-year-olds.

For the Fall context, there were differences based on age group, $p = .005$ (Fisher's exact test), and results are included in Table 24. For visual information only (i.e., colored, falling leaves), 42.5% of 4- and 5-year-olds included it, compared to 78% of 6- and 7-year-olds. Looking at non-visual information (i.e., decorating a pumpkin), none of the 4- and 5-year-olds made references to it and only 2.4% of 6- and 7-year-olds did. None of the 4- and 5-year-olds included both types of information in their responses compared to 4.9% of 6- and 7-year-olds. Additionally, 22.5% of the 4- and 5-year-olds' responses were coded as "other" compared to 4.9% of 6- and 7-year-olds.

For the Spring context, there were differences based on age group, $p = .001$ (Fisher's exact test), and results are included in Table 25. For visual information only (i.e., flowers), 27.5% of 4- and 5-year-olds included it, compared to 53.7% of 6- and 7-year-olds. For non-visual information only (i.e., watering plants in the garden), none of the 4- and 5-year-olds referenced it compared to 12.2% of 6- and 7-year-olds. Only 2.4% of the 6- and 7-year-olds mentioned both visual and non-visual information, whereas none of the 4- and 5-year-olds did. Additionally, 50% of the 4- and 5-year-olds had responses coded as "other," compared to 22% of the 6- and 7-year-olds.

Table 22. Frequencies of Justification Codes for Morning

Code	Other	Visual	Non-visual	Both	Total
Age Group					
4- and 5-year-olds	12	25	2	0	39
6- and 7-year-olds	0	26	11	3	40

Table 23. Frequencies of Justification Codes for Night

Code	Other	Visual	Non-visual	Both	Total
Age Group					
4- and 5-year-olds	7	10	6	1	24
6- and 7-year-olds	3	21	3	5	32

Table 24. Frequencies of Justification Codes for Fall

Code	Other	Visual	Non-visual	Both	Total
Age Group					
4- and 5-year-olds	9	17	0	0	26
6- and 7-year-olds	2	32	1	2	37

Table 25. Frequencies of Justification Codes for Spring

Code	Other	Visual	Non-visual	Both	Total
Age Group					
4- and 5-year-olds	20	11	0	0	31
6- and 7-year-olds	9	22	5	1	37

Correlation analyses were conducted to examine relations between temporal justification accuracy scores, age in months, DCCS levels passed, forward digit scores, backward digit scores, and CCT average scores (see Table 26). Temporal justification accuracy scores were significantly related to age in months, $r(79) = .534$, $p < .001$, DCCS levels passed, $r(79) = .412$, $p < .001$, forward digit scores, $r(79) = .423$, $p < .001$, backward digit scores, $r(79) = .561$, $p < .001$, and CCT average scores, $r(78) = .575$, $p < .001$.

I ran a multiple linear regression with age in months, DCCS levels passed, backward span scores, and CCT proportion scores as independent variables and temporal justification accuracy scores as the dependent variable. The overall model was significant, $F(4, 79) = 14.343$, $R^2 = .433$, $p < .001$. The only variable that was significantly related to temporal justification accuracy scores when controlling for the other variables was CCT scores, β = .320, $p = .005$. Temporal justification scores were not related to age in months, β = .214, $p = .069$, DCCS levels passed, β =. 088, $p = .407$, or backward span scores, β = .183, $p = .144$, when controlling for the other variables. The results from this regression analysis are included in Table 27.

I also ran a multiple linear regression without age in the model, with DCCS levels passed, backward span scores, and CCT proportion scores as independent variables and temporal justification accuracy scores as the dependent variable. The overall model was significant, $F(3, 79) = 17.435$, $R^2 = .408$, $p < .001$. Temporal justification accuracy scores were significantly related to CCT scores when controlling for the other variables, β = .378, $p = .001$. Temporal justification accuracy scores were also significantly related to backward span scores when controlling for the other variables, β = .272, $p = .021$. There was no relation between temporal justification accuracy scores and DCCS levels passed when controlling for other variables, β = .053, $p = .327$. The results from this regression analysis are included in Table 28. Comparing across the two regression models, the results did change when age was not included as an independent variable, with backward digit span being significantly related to temporal justification accuracy scores over and above the DCCS and CCT measures. However, there was no association between age and temporal justification scores when controlling for other variables. This pattern of results could indicate that working memory abilities were accounted for when age was included in the model. Without age in the model, it is possible that scores on the backward digit span and CCT captured age-related changes.

Table 26. Correlations between Justification Accuracy Scores and Other Measures

	1. Age (months)	2. DCCS levels	3. Forward digit	4. Backward digit	5. CCT average correct	6. Justification scores
1. Age (months)	1	--	--	--	--	--
p-value						
N						
2. DCCS levels	.421	1	--	--	--	--
p-value	< .001					
N	81					
3. Forward digit	.444	.298	1	--	--	--
p-value	< .001	.007				
N	81	81				
4. Backward digit	.608	.529	.430	1	--	--
p-value	< .001	< .001	< .001			
N	81	81	81			
5. CCT average correct	.540	.429	.473	.560	1	--
p-value	< .001	< .001	< .001	< .001		
N	80	80	80	80		
6. Justification scores	.534	.412	.423	.561	.575	1
p-value	< .001	< .001	< .001	< .001	< .001	
N	81	81	81	81	80	

Table 27. Multiple Linear Regression Results with Age

Variables	*B*	*SE*	*β*	*t*	*p*-value
Age (months)	.019	.010	.214	1.846	.069
DCCS levels	.181	.217	.088	.834	.407

Backward digit	.222	.150	.183	1.475	.144
CCT proportion	1.460	.508	.320	2.876	.005

Table 28. Multiple Linear Regression Results without Age

Variables	*B*	*SE*	*β*	*t*	*p*-value
DCCS levels	.217	.219	.105	.987	.327
Backward digit	.330	.141	.272	2.349	.021
CCT proportion	1.725	.495	.378	3.486	< .001

Order Effects Analyses

To check for order effects, I ran a series of mixed ANOVAs. In reporting these analyses, I will only focus on significant effects with order variables. For temporal judgments of seasons, I ran a 2 (Season: Fall, Spring) X 2 (Story Order: Fall first, Spring first) X 2 (Age group: 4- to 5-year-olds, 6- to 7-year-olds) mixed ANOVA with Season as the within-subject variable. There was a significant main effect of Story order, $F(1, 77) = 5.021$, $p = .028$, $\eta_p^2 = .061$, which indicated that across age, participants performed better on temporal judgments of seasons when they heard the Spring story first ($M = 0.883$, $SE = .048$) compared to when they heard the Fall story first ($M = 0.724$, $SE = .051$). None of the interactions with Story order were significant, all *p*-values > .190.

For temporal judgments of time, I ran a 2 (Time of day: Morning, Night) X 2 (Story Order: Morning first, Night first) X 2 (Age group: 4- to 5-year-olds, 6- to 7-year-olds) mixed ANOVA with Time of day as the within-subject variable. There were no significant main effects or interactions with Story Order, all *p*’s > .10

I ran a 2 (Season: Fall, Spring) X 2 (Cue type: Visual, Non-visual) X 2 (Story order: Fall first, Spring first) X 2 (Age group: 4- to 5-year-olds, 6- to 7-year-olds) mixed ANOVA with Season and Cue type as within-subject variables on temporal cue season scores. The 4-way interaction was significant, $F(1, 77) = 5.325$, $p = .024$, $\eta_p^2 = .065$. I followed up the interaction by running the 2 (Season: Fall, Spring) X 2 (Cue type: Visual, Non-visual) X 2 (Story order: Fall, first, Spring first) ANOVA separately for each Age group. For younger children only, there was a 3-way interaction, $F(1, 38) = 4.900$, $p = .033$, $\eta_p^2 = .114$. However, Bonferroni-corrected pairwise comparisons did not indicate any significant differences in temporal cue season scores, all *p*'s > .05. For older children, there were no significant effects of order, all *p*'s > .05.

I ran a 2 (Time of day: Morning, Night) X 2 (Cue type: Visual, Non-visual) X 2 (Story order: Morning first, Night first) X 2 (Age group: 4- to 5-year-olds, 6- to 7-year-olds) mixed ANOVA with Time of day and Cue type as within-subject variables on temporal cue time scores. There was a significant Cue type X Story order X Age group interaction, $F(1, 77) = 4.303$, $p = .041$, $\eta_p^2 = .053$. Bonferroni-corrected pairwise comparisons indicated that for younger children only, if they heard the Morning story first, performance on the visual cue question (i.e., sun) was better ($M = 0.826$, $SE = .054$) compared to on the non-visual cue question (i.e., breakfast; $M = 0.674$, $SE = .052$), $p = .017$. Additionally, for younger children only, if they heard the Night story first, performance on the non-visual cue question (i.e., dinner) was better ($M = .971$, $SE = .061$) compared to on the visual cue question (i.e., sun; $M = .824$, $SE = .063$), $p = .045$.

CHAPTER IX: STUDY 2 DISCUSSION

Previous work demonstrates that age-related changes in children's memory for temporal context from early to middle childhood are paralleled by changes in their ability to use reconstruction (Friedman, 1991; Friedman & Lyon, 2005; Pathman, Larkina, et al., 2013). However, it is not clear if changes in reconstruction abilities arise from age-related changes in episodic memory abilities, understanding of time patterns, EF components, or some combination of those factors. The first goal of Study 2 was to examine relations between 4- to 7-year-olds' reconstruction abilities, working memory, cognitive flexibility, and time knowledge by using a story task paradigm that promoted the use of reconstruction to recall the season and time of day of different stories. Participants heard stories about child characters playing outside in different temporal contexts (e.g., Spring, Morning; Fall, Night) and the stories included visual and non-visual cues about those contexts, without explicitly labeling them. After a delay, participants made temporal judgments about the contexts of each story, justified those judgments, and answered questions about the temporal cues. The second goal of Study 2 was to investigate possible age differences in the types of temporal cues that 4- to 7-year-olds use to justify their temporal context judgments.

Overall, 6- and 7-year-olds performed better on temporal judgments compared to 4- and 5-year-olds, which is consistent with previous work examining the development of memory for temporal context and reconstruction abilities (Friedman, 1991; Pathman, Larkina, et al., 2013), as well as age-related changes in children's understanding of the types of cues that are relevant to different time scales (Friedman & Lyon, 2005). The story task used in the current study required children to draw on temporal information from the stories to make accurate judgments about the time of day and season. Thus, it provided a way to examine both memory for event information and children's ability to connect that with their knowledge of time patterns. Indeed, the information that participants included in their justifications provided evidence that across age and time scales, most children used visual temporal cues from the stories to inform their temporal judgments. This finding was contrary to my hypothesis that 4- and 5-year-olds would mostly use visual cues and 6- and 7-year-olds would use both visual and non-visual cues. However, there were a few 6- and 7-year-olds who did make justifications that included both visual and non-visual cues compared to only one younger child. Additionally, 4- and 5-year-olds had more responses coded as "other," which consisted of information that either was not relevant to the story or did not reference specific story details. Thus, although both age used visual information in their justifications more frequently, the pattern indicates that 6- and 7-year-olds were more likely to draw on relevant story information when making their judgments.

Similarly, Pathman, Larkina et al. (2013) found that the majority of 4-, 6-, and 8-year-olds justified their judgments of seasons of personal events by referencing environmental cue information (e.g., there was snow on the ground). Additionally, most 6- and 8-year-olds justified their judgments of time of day by referencing a routine event (e.g., going to church in the mornings), but 4-year-olds more often referenced environmental cue information. The similar use of visual and environmental cues across these two studies is particularly interesting given the large difference in retention intervals, with the current study being 18 minutes and the Pathman, Larkina, et al. study being 4-5 weeks for recent events and 11-12 weeks for distant events. Perhaps visual information about time scales is particularly salient to children in this age range and more likely to be encoded as a result.

It is also possible that most children in the current study referenced visual cue information because of a difference in the encoding time for visual and non-visual cues. While the non-visual cues were verbally included in the story, the visual cues were verbally included and remained in the story background for the whole story. This difference in exposure time for visual and non-visual cues might have made it easier for children to encode the visual cues since they were readily available throughout the encoding period. Based on the overall high-performance levels of temporal cue memory, it is also possible that children remembered both visual and non-visual cue information when making their temporal judgments but did not include both types of information in their justifications. Furthermore, in the current study, the experimenter only asked the justification once for each judgment and did not ask participants to elaborate (e.g., "Why else do you think it was Spring?") on their justifications. If participants received additional prompts, it is possible that more children would have included both visual and non-visual cue information in their justifications.

Although the design of the story task encouraged the use of reconstruction when making temporal judgments, it is possible that participants did not need to use reconstruction to make accurate judgments. For example, if children understood the temporal contexts of the stories during encoding based on the temporal cues (e.g., it's Fall), they might have encoded that temporal context information as part of their event representation. Later during retrieval, perhaps that information came to mind more automatically as they saw pictures of the character from the story. Thus, it is possible that some children used a familiarity-based process to make their temporal judgments about the stories. Familiarity processes are a key strategy used in recognition memory (i.e., participants seeing items during retrieval and judging whether they saw them during encoding), which occur very quickly upon seeing a stimulus, and are described as relying on a feeling of knowing, as opposed to retrieval of information about the event context (see Yonelinas, 2002, for review). In the current study, if children saw the character from the Fall story on the screen during retrieval, they might have used familiarity process when making their temporal judgments as opposed to using reconstruction to recall the temporal context.

Temporal judgments were related to age, working memory, cognitive flexibility, and time knowledge. Additionally, both cognitive flexibility and time knowledge were related to temporal judgments when controlling for other variables. Zelazo et al. (2003) suggested that with better cognitive flexibility, children can shift between conflicting mental sets more efficiently because they can create more complex representations of the current task or goal. More specifically, in the DCCS task, children sort successfully in the post-switch phase because they create an integrated representation of the task rules, which includes an “if, then” conditional structure (i.e., if playing the color game, then the blue bunny goes here, if playing the shape game, then the blue bunny goes there). The borders phase of the task requires an even more complex representation because children must maintain both “if, then” rules and shift between them depending on the card being sorted. Thus, the demand on shifting abilities increases as the task becomes more difficult and multiple rules need to be coordinated. Based on this theory, it is possible that having age-related changes in cognitive flexibility would assist children in using reconstruction since it requires them to shift between event information (e.g., flowers growing) and knowledge of time patterns (e.g., flowers grow in the Spring) during retrieval. It is also possible that age-related changes in cognitive flexibility were related to children’s encoding of the story information, particularly if they shifted their attention between time of day and season cues as the experimenter told the story. However, I am cautious in this interpretation given that the focus of the study was on retrieval, and the encoding of the stories was not directly assessed.

Scales and Pathman (2021) found that time knowledge was related to 4- and 6-year-olds’ temporal memory (order and context combined score) when controlling for age, receptive language, and time ordering (i.e., placing the meals and seasons in the correct order). The relation between temporal judgments and time knowledge in the current study extends that finding by also examining relations with working memory and cognitive flexibility. Children's ability to manipulate the order of time scales likely depends on their mental representations of those time patterns. Indeed, Friedman (1989) found that adolescents and adults represent time patterns visually, whereas children tend to represent them as verbal lists, which lack a visual component. These verbal lists are more difficult to manipulate in the context of ordering questions, especially those that require children to reverse the order (i.e., backward CCT questions). Even though children in this age range might represent time patterns in a similar way, it is possible that more flexibility in thinking about the order of the meals and seasons could indicate more advanced knowledge of and familiarity with these time patterns. Indeed, 6- and 7-year-old children performed better on the time knowledge task compared to 4- and 5-year-old children. As children enter school, they likely have more regular exposure to various types of time patterns (e.g., calendars with days of the week, months of the year) and organizing events around them (e.g., going to school on weekdays, special holidays, or calendar events), which likely influences their knowledge of time patterns and ability to think about them more flexibly. Thus, increased knowledge and flexibility that occurs with age could influence children's reconstruction abilities by facilitating their ability to connect temporal cue information with the appropriate temporal contexts.

Time knowledge was also related to justification accuracy when controlling for age, cognitive flexibility, and working memory, which complements the relation between time knowledge and temporal judgments. Justification accuracy provides another way to examine children's ability to make temporal judgments by using appropriate temporal cues. It is possible that age-related changes in knowledge and flexibility in thinking about time patterns also influence the extent to which children recognize and connect event information with temporal contexts during retrieval. Additionally, Friedman (1991) posited that even if preschool children can sometimes make an accurate temporal judgment without full knowledge of a particular time scale, accuracy and consistency in placing events on time scales improves with age as children's understanding of time patterns develops. When age was removed from the regression model, working memory was also related to temporal justification accuracy when controlling for time knowledge and cognitive flexibility. Therefore, it is possible that age-related changes in working memory abilities relate to children's ability to select time-relevant event information when making temporal judgments. Perhaps with better working memory skills, older children are able to organize and revise relevant information in mind during retrieval more efficiently, allowing for more accurate responses.

It is also interesting to note that in the current study, justification accuracy of 4- and 5-year-olds was higher compared to 4-year-olds' temporal judgment justifications in previous studies (Friedman, 1991; Friedman & Lyon, 2005). This difference could stem from the longer retention intervals (e.g., 6-7 weeks, 3 months) used previously because there are age-related changes in the number of details children recall about events from early to middle childhood (Bauer, 2007). Thus, although younger children might have more difficulty using reconstruction after longer delays due to constraints on episodic memory abilities, the current study shows that they can still use temporal cues to recall the temporal context of events after shorter delays.

Age differences in temporal judgments were consistent across time scales, but for temporal cue memory, age differences varied depending on the time scale. For time of day cues, there were no differences between age groups. Conversely, for season cues, 6- and 7-year-old children performed better than 4- and 5-year-old children. These findings are similar to those from previous studies, which demonstrate that 4-year-old children are as accurate as 6- and 8-year-old children in recalling the time of day of personal and staged events, but are less accurate in recalling seasons (Friedman, 1991, Experiment 1; Pathman, Larkina, et al., 2013). Additionally, temporal cue memory was related to age, working memory, cognitive flexibility, and time knowledge. However, working memory was the only variable related to temporal cue memory when controlling for the other variables.

It is possible that with age-related changes in working memory skills, children can hold more information about the stories in mind during retrieval, which would result in better recall of temporal cues. As participants first responded to questions about the time of day and season of the stories, they might have kept that information in mind, which would appropriately cue the corresponding temporal cue information. For example, if a participant correctly recalled that a story took place in the Morning and the participant kept that detail in mind, the Morning context would act as a cue for the sun coming up and the character eating breakfast. It is also possible that better working memory skills influenced how much information participants encoded while hearing the stories. Bauer (2007) suggested that working memory abilities contribute to how much information is encoded during the preschool years, and this could be the case for older children as well. This interpretation is speculative given that encoding was not assessed in the current study.

The order effect of season, which showed that across age if the Spring story was first, then performance on temporal season judgments was better compared to if the Fall story was first, might have occurred if children in this age range think of Spring as coming before Fall in the season order. If children represent the order of the seasons to correspond with the calendar year, then Spring would indeed come before Fall. If this is the case, hearing the Fall story first might have created confusion when trying to make judgments about the different stories if children experienced interference from their typical representation of Season order compared to the order of the stories.

Additionally, 4- and 5-year-olds performed better on the sun question compared to the breakfast question if they heard the Morning story first and performed better on the dinner question compared to the sun question if they heard the Night story first. It is possible that younger children had more difficulty retrieving the breakfast cue in this case if that cue was less salient than the sun cue, especially given that the Morning story occurred earlier in encoding than the Night story. Similarly, the dinner cue might be a more salient indicator of Night for younger children compared to the sun cue.

Limitations and Future Directions

Although the story task used in the current study was designed to encourage the use of reconstruction to recall temporal context, one limitation of the study is that we cannot be certain that children used reconstruction to figure out the time of day and season of each story. As discussed above, it is possible that children were able to use different retrieval processes, such as familiarity, to recall temporal context. Future studies could examine retrieval strategy use by asking participants additional questions such as, “How did you remember that it was Fall?” or “What did you do to remember that it was Fall?” It is possible that including more questions that probe strategy use could provide more direct evidence for the use of reconstruction or other processes. A related point is that the story task retrieval was likely easier than recalling the temporal context of personal events that occurred several days or weeks before retrieval. Although this study does provide evidence that 4- and 5-year-olds were less accurate than 6- and

7-year-olds in their temporal judgments, 4- and 5-year-old still performed reasonably well on the task. Future studies could compare performance on the story task to retrieval of temporal context of personal events with varying delay intervals to investigate the extent to which the story task generalizes to naturally occurring events.

Another limitation of the current study was the use of temporal cue information (e.g., decorating a pumpkin, watering plants) that might not generalize to children's seasonal experiences across cultures, which could impact their ability to encode and retrieve that information. Even within the sample, it is possible that not all children typically carve or decorate pumpkins in the Fall or water plants in the Spring. However, it is possible that even if children do not engage in those types of seasonal activities, they still understand the different seasons and activities associated with them. Indeed, in the current study children's memory performance on the season cues was high overall. Additionally, the temporal cues in the current study were selected to represent general features of Fall and Spring that are distinct from each other to ensure that there was no interference between information about the two seasons. More specifically, if Spring and Summer had been used in the stories, there would have been more overlap in the visual cues, which could increase the difficulty of the task. Future studies with this story task that include a story for each season could help establish a more comprehensive understanding of age-related changes in children's ability to use reconstruction across all seasons.

A final limitation of the current study was the lack of measures of inhibitory control, receptive language, and temporal language. These measures were removed due to revisions made as a result of the COVID-19 pandemic and the corresponding shift to a virtual study format. Although inhibitory control was not related to temporal memory in Study 1, it is possible that it would have been related in Study 2 given the larger age range. The inclusion of inhibitory control could have also provided a fuller picture of the relation between EF and temporal memory in early and middle childhood. Given that the current study relied on children's understanding of the story narration, a receptive language measure could have indicated potential differences in receptive language abilities that might have impacted children's encoding of the stories. A measure of temporal language could have provided particularly interesting information about how temporal language use changes between early and middle childhood. Evidence from Study 1 indicated that children's use of temporal terms and accuracy in that use improves across preschool but does not reach ceiling levels by the end of preschool. Thus, it would have provided evidence of any changes in the use and accuracy of temporal terms from early to middle childhood. Future studies examining age-related changes in temporal memory and reconstruction abilities would benefit from including a range of cognitive measures to further our understanding of the specific factors related to temporal memory development.

Conclusions

The results from the current study demonstrate that children's memory for temporal context and cue information improves from early to middle childhood. In addition, EF components and time knowledge are related to 4- to 7-year-olds' ability to judge the temporal context of events using appropriate temporal cues and to recall temporal cue information. Age-related changes in cognitive flexibility skills might influence how well children can shift between event information and time knowledge when making judgments of temporal context while age-related changes in working memory skills might influence how much event information children can keep in mind while retrieving various event details. Additionally, children's developing ability to manipulate representations of time patterns might play a role in how well they connect cues about time with specific temporal contexts. Other findings from the study indicate that 4- to 7-year-old children tend to rely on visual cues when recalling the time of events as opposed to non-visual cues. The current study adds to the existing literature on children’s temporal memory and reconstruction abilities by highlighting relations with EF components and time knowledge. These findings have implications for how age-related changes in the understanding of and memory for time could impact children's organization of their experiences into an autobiography, which might contribute to how children view themselves and their developing identity.

CHAPTER X: GENERAL DISCUSSION

The findings from the current dissertation are relevant to McCormack and Hoerl's (2017) theoretical model of the development of temporal concepts and cognition (i.e., thinking and reasoning about time). Stage three of the model marks the point when children begin to understand that time is linear, the existence of before/after relations between events, and time as event-independent, which takes place at ages 4 and 5. The relation found in Study 1 between correct temporal language use and time code scores (i.e., temporal context) provides evidence that as children's understanding of temporal terms develops during the preschool period, their memory for temporal context also improves. Findings from previous studies that demonstrate an initial understanding of before/after relations in early childhood focus on children's knowledge of temporal terms, particularly "before" and "after" (see McCormack & Hoerl, 2017, for review). Due to the correlational design of Study 1, it is not clear if children's correct use of some temporal terms at ages 4 and 5 underlies the ability to recall temporal context of events or vice versa. However, age-related changes in understanding and use of temporal terms and memory for temporal context during the preschool period may be supported by a growing understanding of the temporal concepts proposed by McCormack and Hoerl. Additionally, in Study 1, children's time knowledge was not related to temporal context memory when controlling for other factors. Children's more limited ability to manipulate time scales during this period may also be a result of having a less sophisticated knowledge of temporal concepts and temporal reasoning abilities.

Stage four of the model represents the point when children gain a more mature understanding of time, which includes understanding time as event-independent and thinking about time in both concrete and abstract ways. This developmental stage occurs when children are 5 and older, and during that period children's knowledge of time patterns and cycles becomes more refined, with an established understanding of time as cyclical by age 8 (Friedman, 1978). In Study 2, time knowledge was related to 4- to 7-year-olds' temporal judgments when controlling for other factors. It is possible that age-related changes in knowledge and familiarity with time patterns, particularly during the transition to middle childhood, drive changes in children's ability to use processes like reconstruction to place events in time. This flexibility in thinking about time could pave the way for children's understanding of time as abstract and the ability to reason about time as event-independent. However, it is also possible that age-related changes in children's temporal reasoning abilities, including understanding time as event-independent, drive changes in children's time knowledge, allowing for more flexible manipulation of time patterns.

Both studies found evidence for relations between temporal memory abilities and EF components. In Study 1, preschoolers' memory for temporal context of personal events was related to working memory when controlling for other factors. In Study 2, 4- to 7-year-olds' temporal judgments of context were related to cognitive flexibility when controlling for other factors. McCormack and Hoerl (2017) emphasized the role of reflection in the development of temporal concepts and cognition and suggested that children's counterfactual thinking and planning abilities stem from reflecting on the before/after relations that exist between events. By reflecting on how events are related in time, children (and adults) are then able to reason about alternative possibilities or plan for future scenarios. As discussed previously, researchers posit that age-related changes in EF occur due to changes in children's ability to reflect on and construct mental representations of a current task or goal, which then allow for the control of thought and behavior (Marcovitch & Zelazo, 2009; Zelazo, 2004, 2015; Zelazo et al., 2003). Age-related changes in episodic and temporal memory are also supported by the development of children's encoding and retrieval of event representations (Bauer, 2007). Thus, age-related changes in reflective and representational abilities may be the driving force behind the development of several areas of cognition. Indeed, reflection has been proposed as a domain-general process that drives age-related changes in cognitive, social, and emotional development (Allen & Bickhard, 2018).

Future studies examining relations between temporal memory and other factors in childhood should include a measure of reflection to assess if temporal memory abilities and EF components, for example, both share a relation with reflection. Allen and Bickhard (2018) found that 4-year-olds' performance on a reflection task was related to their performance on several theory of mind tasks. The reflection task, called the leaning blocks task, consisted of an experimenter holding a wooden block at a specific angle in the air and asking children what would happen to the block if they dropped it (i.e., "fall" or "stay up"). After two one-block trials, the experimenter held two blocks that were leaning on each other (and therefore would not fall) and asked what would happen if they dropped the blocks. Allen and Bickhard suggested that to pass the two-block trial, children must reflect on the relation between the two blocks. Another reflection task, called the candy monster task (Allen et al., 2021), required children to reverse the order of three colored "candies" that a monster was going to eat (e.g., "If the monster eats the candy from this end, which candy will the monster eat first, second, and third after I turn the tube?"). Three- to 5-year-olds' performance on the leaning blocks and candy monster tasks were related to performance on the DCCS and an inhibitory control task. Although it is difficult to be certain that these tasks serve as valid measures of reflection, the relations found with EF tasks might indicate a common ability that is required for both types of tasks.

The notion of different tasks having some overlap in the types of abilities required is relevant to the structure of EF in children and adults. Miyake et al. (2000) used a latent variable analysis to determine the structure of EF in college students, and found evidence for a three-factor structure, consisting of updating (of representations in working memory), shifting, and inhibition, in which the three latent variables were moderately correlated but also separable and distinct from each other. Miyake and Friedman (2012) concluded that the relation between the EF components likely stems from a common ability shared by all three and that the separability represents distinct, non-shared features of each component. Miyake and Friedman proposed that the commonality of EF components stems from actively maintaining task goals in mind (e.g., sorting cards by color in the DCCS task) and the ability to use those goals to guide other cognitive processes. There is evidence from work with adults that active goal maintenance facilitates performance on a Stroop inhibition task (Kane & Engle, 2003). Additionally, preschoolers' active goal maintenance has also been shown to facilitate performance on the DCCS (Marcovitch et al., 2007; Marcovitch et al., 2010).

The evidence concerning the structure of EF in 4- to 7-year-olds is mixed. Lee et al. (2013) reviewed developmental studies that used a latent variable approach to determine the factor structure of EF in childhood. From age 4 to 7, there is evidence for both a single factor and two-factor structure of EF, however, there is inconsistency across studies in the number of EF components included, with some studies only examining working memory and inhibition tasks, for example. Additionally, studies vary in their classification of which tasks represent which EF component, with some studies considering the DCCS task a measure of shifting and others considering it a measure of working memory. Nonetheless, there is a general pattern of EF components becoming more specialized with age, demonstrated by more studies with preschool children indicating a unitary structure (i.e., single factor) and more studies in middle childhood indicating a two-factor structure. The current dissertation examined EF components separately and only used one task per component in both studies, which makes it more difficult to ascertain which specific features of different EF components are driving the relations temporal memory abilities. Future studies could avoid this issue by including multiple tasks per EF component, extracting latent variables, and exploring relations with the latent variables and temporal memory abilities. This type of approach could also help to illuminate what types of abilities (e.g., reflection, goal maintenance) are common across EF components and temporal memory in early and middle childhood.

Limitations and Future Directions

The studies in the current dissertation were limited in the types of conclusions that could be drawn about the role of EF components and time knowledge in temporal memory development. Given that both studies only examined relations between EF components and time knowledge with temporal memory, I am not able to assert that EF components or time knowledge cause age-related changes in children's temporal memory abilities. Additionally, it is also possible that EF skills, particularly working memory, allow children to manipulate the order of time scales, but the current studies could not substantiate this claim. Future studies could examine if there is a causal relation between EF components and temporal memory in childhood by manipulating EF and determining the effect on temporal memory and time knowledge tasks. Evidence from previous studies shows that having preschool children complete an EF-depletion task negatively impacts performance on theory of mind (Powell & Carey, 2017) and social problem-solving tasks (Caporaso & Marcovitch, 2021). Thus, it is possible that a study that included an EF-depletion task could provide evidence for a causal role of EF in temporal memory abilities and manipulation of time scales.

Another limitation of the current dissertation concerns children's time knowledge and understanding of time scales. Although the CCT task provides a measure of children's ability to manipulate the order of time scales, it does not assess all aspects of children's knowledge of time. To have a more comprehensive understanding of the scope of children's knowledge of time at different ages, it would be beneficial to examine preschool and elementary school curriculums for teaching clock and calendar systems and design measures that evaluate how well children meet the learning objectives. For example, the North Carolina Standard Course of Study Guide for Kindergarten (2021) lists the following objectives in the science section: "Summarize daily weather conditions noting changes that occur from day to day and throughout the year," and "Compare weather patterns that occur from season to season." Both these objectives concern children's learning about specific features of different temporal patterns, which is important for a developing understanding of time. By including measures of different aspects of time knowledge in future studies, researchers can examine how different types of time knowledge relate to temporal memory abilities and how that might differ based on age.

Future studies should also examine other types of factors that might be related to temporal memory development, such as mothers' use of temporal language and inclusion of information about temporal order and context during shared reminiscing. Given that mothers' conversation style during early childhood is predictive of children's autobiographical memory skills during the preschool period and in adolescence (Reese et al., 2010; Reese & Robertson, 2019), mothers' talk about the time of events may be related to temporal memory development. Indeed, Nelson (1996) suggested that children learn how to construct narratives of past events from conversations with adults. Additionally, two key elements of narrative cohesion are context, which includes temporal and spatial details, and chronology, which concerns the ordering of an event narrative (Reese et al., 2011). Examining the relations between maternal use of temporal language and information and children's narrative skills across early and middle childhood could broaden our understanding of temporal memory development and the various factors related to it.

Conclusions

The current dissertation provided evidence of relations between working memory and cognitive flexibility with temporal memory abilities in early and middle childhood. Time knowledge was also related to temporal context memory across both studies. These studies extend the literature on temporal memory development by providing additional support for relations between EF, time knowledge, and temporal memory abilities in early and middle childhood. Additionally, the findings from the current dissertation offer insight into the complexity of temporal memory development and the various factors that are related to it and provide several directions for future research in this area of cognitive development. Finally, these findings have implications for theories of the development of temporal memory, concepts, and cognition, as well as practical implications for children's developing abilities to organize their experiences around time. These abilities are important for the sharing of experiences with others, which facilitates the formation of social relationships (Nelson & Fivush, 2004) and contribute to the development of an understanding and sense of self based on a life history.

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APPENDIX A: PARENT QUESTIONNAIRE: CHILDREN'S TEMPORAL LANGAUGE

Today's Date (mm/dd/yy): ___________________________
Child's Birth Date (mm/dd/yy): ________________________
Child's Daycare/School: _______________________

Please answer the following questions about the child participating in the current study.

1a. Is your child in Kindergarten?

YES NO

1b. If yes, what date did they begin attending Kindergarten?

For each of the following words/phrases referring to time, please indicate whether your child uses the word/phrase and how appropriately (correctly) they use it.

2. Word/Phrase: **Today**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):

Never **Occasionally** **Sometimes** **Often** **Always**

3. Word/Phrase: **Tomorrow**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

4. Word/Phrase: **Yesterday**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

5. Word/Phrase: **Later**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):

Never **Occasionally** **Sometimes** **Often** **Always**

6. Word/Phrase: **Soon**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

7. Word/Phrase: **Now**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

8. Word/Phrase: **After**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

9. Word/Phrase: **Before**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

10. Word/Phrase: **Next week**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

11. Word/Phrase: **Last week**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

12. Word/Phrase: **Months of the year (e.g., January, February)**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

13. Word/Phrase: **Days of the week (e.g., Monday, Tuesday)**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

14. Word/Phrase: **Hours (e.g., in two hours)**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

15. Word/Phrase: **Minutes (e.g., in two minutes)**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

16. Word/Phrase: "**When I was little/a baby…**"

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

17. Word/Phrase: "**When I'm bigger/grow up…**"

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

18. Word/Phrase: **"In the past…"**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

19. Word/Phrase: **"In the future…"**

Child use (circle): **YES** **NO**

If YES, Appropriate/correct use (circle):
Never **Occasionally** **Sometimes** **Often** **Always**

20. If your child uses other words or phrases to describe time, please enter and detail them here:

.

APPENDIX B: FALL/MORNING AND SPRING/NIGHT STORY EXAMPLES

Fall/Morning Encoding Script:

Slide 1: This is a story about a girl your age named Danielle. Danielle is going to play outside. *Can you see Danielle? What color is Danielle's dress?* She has a full tummy because she ate breakfast before she came outside. Alright, let's see what Danielle is going to do.

Slide 2: Danielle grabbed her headphones so she can listen to some music. *Can you see Danielle's headphones? What color are the headphones?* Oh, look! The leaves are changing colors!

Slide 3: Danielle put away her headphones, and grabbed her jump rope. She is trying to jump as fast as she can. *Can you see the jump rope? What color is the jump rope?* Oh, look! The sun is coming up in the sky!

Slide 4: Danielle put away her jump rope, and sees her dog, Buddy, walking over. She pets Buddy as he's walking by. *Can you see Buddy, the dog? What color is Buddy?* Danielle is excited because she is going to decorate a pumpkin later!

Slide 5: Oh! It's time for Danielle to go back inside. She had so much fun playing outside!

Spring/Night Encoding Script:

Slide 1: This is a story about a boy your age named Alex. Alex is going to play outside. *Can you see Alex? What color is Alex's shirt?* Oh, look! The sun is going down in the sky! Alright, let's see what Alex is going to do.

Slide 2: Alex took out his bubble wand. He uses the wand to blow lots of bubbles. *Can you see the bubbles? What color are they?* Alex is excited because he is going to water the plants in the garden later.

Slide 3: Alex put away his bubble wand, and took out a book to read. This book is his favorite. *Can you see the book? What color is the book?* Alex has a full tummy because he ate dinner before he came outside.

Slide 4: Alex put away his book, and grabbed his ball to play with. He can kick the ball all the way across the yard. *Can you see the ball? What color is the ball?* Oh, look! The flowers are growing!

Slide 5: Oh! It's time for Alex to go back inside. He had so much fun playing outside!