The Role of Language in the Development of Temporal Cognition in 6- to 10-Year-Old Children

Danielle DeNigris

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THE ROLE OF LANGUAGE IN THE DEVELOPMENT OF TEMPORAL
COGNITION IN 6- TO 10-YEAR-OLD CHILDREN

By
Danielle DeNigris, M.A.

A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of
the requirements for the degree of Doctor of Philosophy, The City University of New
York
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This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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THE CITY UNIVERSITY OF NEW YORK
THE ROLE OF LANGUAGE IN THE DEVELOPMENT OF TEMPORAL COGNITION IN 6- TO 10-YEAR-OLD CHILDREN

By

Danielle DeNigris

Advisor: Dr. Patricia J. Brooks

The ability to represent and make sense of time requires the mental representations of the ordering of events and temporal relations, abstract time concepts, natural biological rhythms, the self and other through time, and causal relationships. This representational ability undergoes significant refinement in middle childhood concurrent with advances in children’s language and nonverbal skills. This study explored the representational development of temporal cognition, diachronic thinking, and behavioral prediction in relation to a battery of language and nonverbal abilities with the aims of confirming age-related improvements, exploring whether disparate measures are indices of an underlying ability, and examining the role of language and nonverbal abilities.

Sixty-two children (32 girls, 30 boys, M=8 years; 2 months, range 6;0-10;8) completed standardized assessments of receptive vocabulary, receptive grammar, reading, nonverbal intelligence, and working memory, in addition to the four representational thought tasks. The temporal cognition tasks consisted of the Months Relative Order task, assessing event ordering ability (e.g., knowledge of the sequence of months), and the Time Labeling task, assessing knowledge of conventional time patterns (e.g., day or month associated with specific events). The diachronic thinking task, Draw Lifecycle of a Tree, assessed awareness of biological change over time and the behavioral
prediction task, *Character Intentions* task (a measure of theory of mind adapted here to assess the ability to predict future behaviors) assessed children’s understanding of causality in time to infer a character’s future actions.

The first aim was supported providing confirmation of the age-related improvements in representational thought documented in previous research. Results revealed that accuracy on the Months Relative Order, Time Labeling, Draw Lifecycle of a Tree, and Character Intentions tasks improved with age; however, the Draw Lifecycle of a Tree task was only marginally significant. The second and third aims of the study was to explore whether the four disparate measures of representational were significantly related and if they provided evidence of an underlying ability. All tasks were significantly correlated with one another after controlling for the effects of age. Principal components analysis revealed one underlying factor explaining 57.84% of the variance across tasks. To address the final aim, stepwise regressions explored relationships between this latent variable and developmental changes in nonverbal intelligence, working memory, and language ability. Results revealed that language ability predicted gains in representational thought over and above effects of age, nonverbal intelligence, and working memory. Additionally, mediation analyses showed that the effects of age, nonverbal intelligence, and working memory were mediated by language abilities. These results extend prior work by demonstrating the representational changes occurring in middle childhood across complex cognitive domains while highlighting the role of language as a mechanism promoting representational development.

*Keywords:* representational thought; temporal cognition; diachronic thinking; behavioral prediction; language; middle childhood
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CHAPTER ONE: INTRODUCTION

The ability to understand and represent time plays a critical role in supporting daily living (Suddendorf, 2006). Mental representations of complex cognitive knowledge undergo dramatic representational change during middle childhood, changing from implicit (i.e., not consciously accessible) procedural knowledge to explicit (i.e., consciously accessible) knowledge that is able to be verbalized. One domain in which representational change occurs is in the understanding of time. The ability to make sense of time involves the representation of various forms of functional knowledge, including temporal cognition (event ordering—i.e., awareness of one event following or preceding another—and time labeling—i.e., knowing the days of the week or the months of the year), diachronic thinking (grasping biological transformations across the lifespan), and behavioral prediction (understanding causality in time in order to make inferences based on past/current events and intentions). These disparate forms of representational knowledge are rarely studied within the same group of participants; hence it remains unclear whether they follow similar developmental trajectories and whether they are indices of similar underlying cognitive abilities.

Theoretical Perspectives of Representational Development

Theories of cognitive development have been primarily motivated by research from two camps, domain-generality and domain-specificity, in which cognitive development progresses through the refinement of mental representations over time. Much of the early literature on cognitive development stemmed from a Piagetian (1926) model of cognitive construction. This model takes a domain-general approach suggesting that development occurs sequentially (in stages) across all aspects of cognition. As we
progress through stages, procedural (sensorimotor) knowledge makes way for more advanced mental representations of the world through the processes of assimilation (i.e., using existing schemas to interpret incoming information), accommodation (i.e., altering existing and creating new schemas to accommodate incoming information), and equilibration (i.e., the process in which we balance new and old information).

In contrast, domain-specific accounts, such as the modular system proposed by Fodor (1983), maintain that the mind is made up of innate specified input systems (modules) that are responsible for acting on certain types of input. To create mental representations and make sense of the world, the mind’s central processor must combine the output from specified modules with information stored in long-term memory. However, there are some critical limitations to a modular theory of domain-specificity. The following sections will discuss more recent approaches that argue for a similar developmental framework to explore how mental representations change over time.

**Karmiloff-Smith’s Representational Redescription View**

Karmiloff-Smith (1992) provides an argument against both a fully Piagetian constructivist approach and a fully nativist approach to the understanding of cognitive development. She argues that Piaget’s domain-general approach cannot account for specifically linguistic changes. She supports this view citing research on chimpanzees (e.g., Premack, 1986) which have rich sensorimotor and representational abilities, but are unable to have complex, human-like language. As such, the Piagetian notion that development occurs across the board cannot hold true for language, and as an extension, other specific aspects of cognition.
On the other hand, Karmiloff-Smith critiques a completely modularized view of the domain-specificity of development (i.e., Fodor’s 1983 theory of modularity). She argues against modularity on three main accounts: modules are not so pre-specified in detail as Fodor suggests; the dichotomy between the specified modules and the central processor is not as strongly divided; and the modules do not automatically encode data into a single language of thought. Although she argues for domain-specificity, she draws a clear distinction between her theory and Fodor’s (1983) modularity. Karmiloff-Smith’s theory goes “beyond modularity” to propose a domain-specific view that synthesizes neonativism and constructivism. Domains are defined as a set of representations sustaining a specific knowledge area (e.g., language, physics, etc.); whereas a module is a processor that encapsulates knowledge and conducts computations on it. Each domain encompasses many microdomains, or subdomains (e.g., gravity is a microdomain of physics). Karmiloff-Smith (1994) argues that development goes beyond “the triggered unfolding of a genetic program” (p. 706); it is a gradual process by which information that is in a cognitive system becomes progressively explicit knowledge to that system.

Karmiloff-Smith proposes a phase (not stage) theory of development in which recurrent phase changes occur across microdomains and within each domain. Crucial to this phase theory is that development within domains does not occur at the same time across domains. In the first phase, the child focuses on external, procedural information resulting in behavioral mastery (successful performance) within that microdomain. Eventually (phase two) the child no longer focuses predominantly on external information and instead focuses on the internal representations of knowledge in that
Finally, in phase three, the internal representations and external information are integrated and a balance is found.

The critical aspect in this process is representational redescription. Karmiloff-Smith (1992) describes this as a mental process whereby the child redescribes, or alters, existing internal mental representations to clear the way for more explicit and sophisticated representations and use of knowledge. This process increases the flexibility of the knowledge that is stored in the mind and the child’s representations become progressively more manipulable leading to explicit (i.e., conscious) access to knowledge. The process of representational redescription is a uniquely human way of gaining access to and making use of information stored in the mind, first within a domain and then sometimes across domains.

Karmiloff-Smith posits four levels, each with different representational formats, in which knowledge is represented and redescribed moving from implicit to explicit. In the first level, Level Implicit, information from the external environment is represented in procedural form. There is no representational links within or between domains. At the second level, Level Explicit-1, implicit representations are redescribed into a new explicit format. These explicit representations are now manipulable and allow children to introduce violations to their knowledge of the world. This allows for developments like false-belief; however, these representations are not available to conscious access nor able to be verbalized. Level Explicit-2 enables representations to be consciously accessible, but still not verbalized. Finally, at Level Explicit-3, representations are redescribed into a format similar to natural language that allows for both conscious access and verbal report.
As a result of this process, there exists multiple representations in the mind of similar knowledge at different levels of explicitness across domains.

**Nelson’s Experiential (Social-Cultural) View**

For Nelson (1993; 1996) children develop representational thought through lived experience. These representations emerge through interaction with a social and cultural world, but are constructed according to “built in” cognitive principles. Like Karmiloff-Smith, Nelson believes that there are levels of representation that undergo representational change. And while both theorists recognize the representational function of language that allows for representational change from implicit mental representations to explicit and linguistic representations, they differ in the specific role that language plays. Where Karmiloff-Smith suggests that representational changes occur within the child who interacts with the physical world, Nelson believes that representational change occurs through socially-mediated processes. More specifically, language plays a critical role in the change from implicit to explicit mental representations. Nelson (1996) argues that it is the “mental representation function of language that…is the basis for the evident cognitive advances in the latter part of the preschool years” (p.15).

Nelson (1996) outlines her experiential view of representational change as constituted by chunks of socially- and culturally-situated events that the child experiences that provide critical information about the events from which they are embedded. This information becomes stored as *mental event representations (MERs)*, representations of familiar significant repeated events. Eventually, as the child continually adds to their stock of MERs, they can be generalized across events, people, places, etc. and stored in an increasingly elaborate “world model.” Central to this idea, is that the child must make
use of previously stored information to explore and interpret current events. The child
must combine their previously internalized representations with the specific features of
the present context. This highlights the critical role of the memory system, and
particularly episodic memory, in the development of advanced cognitive representations.
Indeed, the child’s general knowledge base is informed by the episodic memory system,
in which is stored event information about the location and sequence of activities that
constitute specific events.

The main function of a representational system is to provide information about
present conditions, informed by the past, and to anticipate future conditions. To do so,
the child must accumulate information about general events. Within an event, actions are
sequentially organized which allows for the creation of script-like representations
(Nelson & Gruendel, 1981). Using these representations of repeated events, the child can
understand “what happens in a general case.” This script knowledge is evident in
children as young as 3-years of age, who are able to produce verbal scripts for familiar
events (such as having lunch). Indeed, Nelson (1986) suggests that young children are
more likely to produce general scripts than specific memory accounts. The scripts
produced by young preschoolers are found to be similar in structure to those produced by
adults, suggesting that general script knowledge precedes more explicit forms of specific
event representations (Nelson, 1996). It is in this movement from implicit procedural
scripts to explicit and verbal scripts, and then to explicit MERs that forms the backbone
for Nelson’s experiential, and socio-cultural, theory of cognitive development.

Nelson proposes that individual MERs support and are changed by linguistic
representations, all of which occurs as the child is mastering language. Throughout the
preschool years, language systems become organized and they begin to reorganize the child’s conceptual systems. Language is based on categorical structures (e.g., phonemes, morphemes, word meanings, and grammatical structures); as such, children apply categorization strategies to the learning of language, as well as MERs. For example, object concepts are first embedded in event representations. Children experience the ways in which words are used by adults during social interactions and results in the drawing out of “event embedded object categories” and eventual representational change (Nelson & Lucariello, 1985), or redescription (Karmiloff-Smith, 1992). For example, the child learns not only the link between the word “lunch” and the event “lunch,” but a “representation of an entire event sequence that incorporates the word as well as the props and the sequence of actions that constitute that event” (Nelson, 1996, p. 97). These event categories are then combined and organized into a type of representational hierarchy of event knowledge. Temporal representation, and particularly temporal cognition, is central to the development of event knowledge. Time is organized according to domain-specific principles and varies as a function of socio-cultural and linguistic constructs (Nelson, 1991; 1996).

**Representational Development of Temporal Knowledge**

As adults, we make sense of time in terms of the ordering of events and temporal relations, abstract manipulations of time concepts, natural biological rhythms, and an understanding of the self and other through time. We refer to time in terms of two basic dimensions, duration and sequence, that are extracted and constructed from our experiences and memories for events. We also make sense of time based on our understanding of temporal relations or sequences (i.e., that one component occurs before...
and after others). These relations become a part of the child’s developing representational system and may aid in the learning of the temporal language used to express them. However, implicit aspects of experience (e.g., that certain events take place during specific times during the day/week/year and not others) are more difficult for young children to transform into linguistic concepts. The regularity of events may aid in the understanding of conventional time concepts, such as clock-times, days, months, etc., and thus provide meaning for these concepts. Particularly, as many concepts that are used for marking time may be based on arbitrary divisions (e.g., minutes, hours, months, etc.), in comparison to those based on natural cycles (e.g., morning, afternoon, day, night, etc.) or social events (lunchtime, naptime, etc.).

Both Karmiloff-Smith (1992; 1994) and Nelson (1991; 1996) propose an approach to cognitive development based on a continual process of representational change from implicit (i.e., not consciously accessible) to explicit (i.e., consciously accessible) knowledge. Applied to temporal knowledge, the two theories (Karmiloff-Smith’s representational redescription and Nelson’s experiential view of event representations) highlight the importance of language, though they differ in its specific role. Karmiloff-Smith’s theory, though not specifically making claims about the development of temporal knowledge, would suggest that children learn temporal concepts from verbal interactions with others, but that early knowledge forms are stored in a code not yet accessible or linked to similar knowledge stored in other forms. Nelson, on the other hand, has described the emergence of the temporal mind in several theoretical pieces (e.g., 1991; 1993; 1996). Time is organized according to domain-specific principles and varies as a function of socio-cultural and linguistic constructs. She
suggested that an understanding of time concepts results from involvement in and representation of events and that this event knowledge may “implicitly embed” them allowing for the “explication” through language to occur.

According to Nelson, knowledge of temporal concepts develops gradually through experience with language forms relevant to ongoing events as they are used by adults and others. Early on, children are exposed to, and oftentimes explicitly taught, the temporal language about the seasons and holidays; yet, the language used to convey conventional time units (days, months, years, etc.) are not explicitly taught until the child enters formal schooling. Because these linguistic forms are used informally in discourse, the child may become familiar with their forms, but when used, are often done in an inaccurate way without expressing true meaning. Indeed, as the child observes its use across multiple contexts, the temporal word or phrase, may become more generalized. This constant adjustment of representation is essential as the child moves from preschool into early childhood.

Building on the theoretical work by Nelson (1991; 1996) in which temporal cognition is understood as developing through the involvement in and representation of events, McCormack (2015) proposes a model of developmental stages in children’s representation of time in which children develop increasingly event-independent representations. In the earliest stage, children orient themselves in time through creating representations of repeated event sequences. Here, children’s concepts of the past, present, and future are of events as having been completed, ongoing, or yet to come. It is not until the second stage in which children can understand the ontological difference between the past (i.e., unalterable) and the future (i.e., potentially alterable). At this
stage, children can still not represent time independent of events nor linearly. Linear representations of time occur in the third stage in which children begin to grasp how causality operates in time. However, it is not until the fourth and final stage that children’s representations of time become completely event-independent (i.e., a representation of time that makes no references to events, as in the clock and calendar systems).

As with the cognitive development models of Karmiloff-Smith and Nelson, McCormack’s (2015) model of temporal cognition proposes a shift in the way time is represented in the mind. This provides a foundation for the understanding of how children represent the locations of events in time before fully mastering an explicit and verbal event-independent representational system. McCormack’s (2015) theory suggests that for children to have a full mastery of event-independent temporal cognition, they must have a more general understanding of temporal sequence and causality.

**Summary**

Together, the three theoretical views of the role of representational change in the development of temporal knowledge suggests that early on children rely on procedural (sensorimotor) event knowledge from routinized prior experience to acquire and interpret basic temporal concepts and patterns that can then be altered in order to be represented verbally in event-independent ways. Those concepts that are directly related to representations of time (e.g., sequence, duration, frequency, etc.) would be learned and generalized to novel contexts more easily than those concepts that are not implicit in the child’s mental representations (e.g., abstract concepts of temporal location and measuring
units). As such, socially-mediated language provides the fundamental component for children to represent the passage of time.

The current study sought to evaluate this hypothesis while assessing the extent to which tasks measuring disparate forms of temporal knowledge (temporal cognition, diachronic thinking, and behavioral prediction) relate to an underlying construct of temporal representation during middle childhood. This age-range is particularly important for exploring the representational development of temporal knowledge, and cognitive development in general, because this is when children are at a level of representation in which knowledge is explicitly defined but may not be fully accessible to verbal reports. Middle childhood represents a time where children have the basic skills needed for temporal representation, but may still not be fully successful in their attempts to pass temporal representation tasks.
CHAPTER TWO: REPRESENTATIONS OF TIME

Time has often been treated as a dimension of events with a focus on duration processing, but time can also be treated as a framework (e.g., a flexible mental representation) within which events can be located. Temporal frameworks can be distinguished along the lines of perspectival (location of events is relative to where one is currently located in time) vs. nonperspectival (location of events is specified without reference to where one is currently located in time) and repeating cycles (e.g., the repeating cycle of the times of day, days of week, seasons of the year, etc.) vs. particular times (unique temporal location that does not repeat, e.g., Monday, January 2, 2017; McCormack, 2015).

Unlike in many areas of developmental psychology, there is no single established set of tasks put forth to explore children’s representations of time. This is likely due the varied ways in which temporal knowledge has been conceptualized in the literature. In the following sections, the representational development of two event-independent components of temporal cognition (event ordering and time labeling), biological temporal sequence (diachronic thinking), and temporal causality (behavioral prediction) are reviewed along with the role of verbal and nonverbal abilities in their development.

Temporal Cognition

Event Ordering

As adults, we have the ability to represent the position of events in time in terms of location (to mark an event’s occurrence in terms of conventional time patterns), distance (to estimate how far an event is from the present) and relative order (to determine whether an event occurred/will occur before or after some other event). How
does this ability to order events in time develop? Early on, infants appear to form representations of routine events that occur in their daily lives, such as taking a bath, mealtime, or playing peek-a-boo (Bruner, 1983; Nelson, 1996; McCormack, 2015). These script-like representations allow young children to anticipate events in their daily lives and make predictions about what will happen next (Schank & Abelson, 1977; Forman, 2015). Scripts also allow children to locate themselves in time by locating themselves at a particular point within a scripted event (McCormack, 2015).

With regards to verbalizing the order in which events unfold, children as young as 3 years can correctly report sequences of events, such as how to get ready for bed, and by the age of 4 years, they can arrange everyday events, such as waking up, eating breakfast, going to school, eating dinner, and going to bed, in correct temporal order (Friedman, 1990). Young children’s success on this type of task suggests that they have ready access to temporally structured representations that provide the foundation for children to represent the temporal locations of events relative to each other. Research indicates that event ordering abilities, although emerging during the preschool years, undergo developmental advances during middle childhood (Friedman, 1993; 2000; 2005; Friedman, Gardner, & Zubin, 1995; Friedman & Kemp, 1998; Friedman, Reese & Dai, 2011). Four- and 5-year-olds can make accurate judgments about the past when comparing two events experienced several weeks apart (Friedman et al., 1995); however, children at this age, as well as some older children (8- and 9-year-olds), made errors when asked to place future annual events (e.g., common holidays) in temporal order (Friedman, 2000).
By the time children are 8 to 10 years, they can reliably order the months of the year and can successfully integrate the order of conventional time labels with the fact that they are cyclical and reoccur (Friedman, 1978). At this point, children can then start to order temporal sequences using different starting points. However, children find it more difficult to conduct relative order tasks using different starting points for months of the year than for days of the week (Friedman, 1978). More recent work (Moore et al., 2014), asking children to sequence events in forward or backward order, confirmed that older children (8- to 10-year-olds) were more accurate in ordering events than younger children (5- to 7-year-olds).

Together, these results suggest that early on children can verbally represent the temporal locations of actions within repeated script-like events relative to each other. These scripts enable children to locate events relative to other events within thematic contexts (e.g., holidays, daily routine, going to the supermarket, etc.). However, scripts do not provide children with a way to locate events from one thematic context relative to events from another unrelated context (McCormack, 2015). Compare this to the clock and calendar systems which allow children to consider the relative temporal locations of any two events, whether they are related or not. Yet, these systems are not mastered until middle-late childhood (Friedman, 2000).

**Time Labeling**

Children’s understanding of life events depends upon their understanding of time concepts and an implicit understanding of temporal relations (Nelson, 1996). As such, children must have a functional representation system for time in terms of sequence, duration, and frequency. These implicit aspects of experience may be difficult for young
children to translate into linguistic concepts and they may instead make use of event
labels (e.g., lunch) that are based in daily routines prior to using other conventional time
labels (e.g., 12 o’clock). For example, preschool children typically respond to time-
related questions about an event by referencing other events or by thinking about time in
terms of their distance from the present, rather than locating the event on a calendar or
referring the associated time of the day (McCormack, 2015; Nelson, 1996).
Eventually, children learn to link regularly experienced events with times of the day or
the year which serves to ground the meaning of specific time labels, such as 12 o’clock or
noon, in relation to events, such as lunch. It is not until middle childhood that children
reliably use conventional calendar terms, such as days and months of the year, in place of
event-based or distance-based judgements to mark time.

Under Nelson’s view, initial learning of temporal concepts occurs informally in
the context of social interaction. Children’s first temporal references are usually
“interpretatively framed by adults (e.g., the child says ‘berries’ and the adult responds
‘Yes, we ate berries for breakfast this morning, didn’t we?’)” (Nelson & Fivush, 2004, p.
492). Temporal concepts are elaborated through conversational language, especially in
contexts where caregivers and children reminisce about past events and plan for the
future. Many lexical and grammatical terms integral to the discussion of events, such as
relative and specific time labels (e.g., tomorrow, November) and locators (e.g., before,
after, during) are learned through conversation and begin to be used more consistently at
around the age of 5 years (Nelson, 1996; Weist, 1986).

Upon school entry, children are formally taught specific concepts of temporality,
such as the days, months, seasons, and holidays of the year. By around 6 to 7 years,
children can recite sequences of time labels, such as the days of the week, in order, and at around 9 years of age, they show understanding of the cyclical nature of time (Friedman, 1978). In one study, Friedman, Reese, and Dai (2011) examined memory for the times of events that had occurred in the past 6 months to 4 years, and observed that 8- to 12-year-old children were able to localize many of the events in time in terms of the season, month, and time of day. Using similar tasks, Moore and colleagues (2014) found that 8- to 10-year-olds were more accurate in their labeling of time concepts than 5- to 7-year-olds. However, research indicates that even in this age range children make errors. Friedman and Laycock (1989) suggested that children possess knowledge of individual time markers (e.g., knowing the month of one’s birthday or the clock times of an activity) before understanding the conventional system (e.g., order of the months or times of day) as a whole. These findings suggest that by middle childhood, children are beginning to master conventional temporal systems and use them along with their knowledge of repeated events within the annual cycle to aid in the ability to locate events in time (McCormack, 2015). The mastery of the clock and calendar systems enables children to flexibly represent time in a linear, unified, event-independent way.

**Diachronic Thinking**

Diachronic thinking, defined as the capacity to represent and understand changes that occur over time, has been extensively explored by Montangero, Pons, and colleagues from a Piagetian framework in which a child’s actions and observations of the world lead the child to construct more abstract conceptualizations of object transformations over time (e.g., Boucher et al., 2007; Montangero, 1985; Montangero, Pons, & Cattin, 2000; Pons & Montangero, 1999; Tryphon & Montangero, 1992). This can be compared to
Nelson’s (1996) discussion of natural time, or time thought of in terms of basic biological rhythms and cycles of the natural world. One widely studied aspect of diachronic thinking concerns children’s understanding of qualitative biological changes, for example, the understanding that a seed becomes a plant and an infant becomes an adult, all the while never changing in identity.

Children’s understanding of biological transformation has been investigated in relation to the life cycle of plants and animals (e.g., Inagaki & Hatano, 1996; Labrell & Stefaniak, 2011; Leddon, Waxman, & Medin, 2008; Maurice-Naville & Montangero, 1992; Tryphon & Montangero, 1992) where children come to understand time relating to birth, death, and aging. Research suggests that children do not initially include plants in the “living” domain (Nguyen & Gelman, 2002), which Labrell and Stefaniak (2011) suggested was due to the fact that the surface properties of plants do not promote this classification. Hickling and Gelman (1995) reported that although children as young as 4 years of age understood the origins of seeds, they did not understand the diachronic conception of biology (i.e., that growth is a cycle of changes over time). As such, the understanding of time is integral to the development of diachronic thinking; yet, apart from Montangero (1996), few have explored the connection of time and diachronic change.

According to Montangero, the temporal concepts of span, sequentiaity, and chronology are fundamental to an advanced understanding of biological change. Children appear to progress through three levels of diachronic thinking (Maurice-Naville & Montangero, 1992; Montangero, Pons & Scheidegger, 1996; Pons & Montangero, 1999; Tryphon & Montangero, 1992). At the first level, they fail to construct links
between past, present, and future stages of life (i.e., change is not thought of as a continuous process). At the second level, emerging at around 9 years of age, children conceive of continuous change, but only in quantitative terms (i.e., growth). At the third stage, thought to emerge at 11 or 12 years of age, children grasp that objects change both quantitatively and qualitatively over time.

Other researchers (e.g., Cox & Hodsoll, 2000; Labrell & Stefaniak, 2011; Nguyen & Gelman, 2002) have argued that children grasp aspects of diachronic change at earlier ages than those proposed by Montangero and colleagues (e.g., Maurice-Naville & Montangero, 1992; Tryphon & Montangero, 1992). For example, Labrell and Stefaniak (2011) examined the development of the diachronic conceptions of growth and death of plants and animals among 163 children aged 6 to 11 years. Results showed a main effect of age with 6- and 7-year-olds performing more poorly than older children; however, the researchers failed to observe differences among children between 8 and 11 years of age on either the animal or plant tasks. Nevertheless, despite some disagreements about the precise ages at which children pass specific tasks, these studies and others (e.g., Moore et al., 2014) indicate significant changes in diachronic thinking in middle childhood.

Causality and the Prediction of Future Behaviors

In order to understand and interact with others, a child must be successful at the prediction of others’ and one’s own future actions and reactions (Nelson, 1996). The ability to predict future events likely draws upon the temporal skills previously reviewed, as well as the understanding of the causal structure that connects events in time (McCormack, 2015). The ability to distinguish between past and future events involves the ability to take a temporal perspective other than the present. For example, “it
involves realizing that from the perspective of the past, some events were in the future that are now in the past, and from the perspective of the future, events will be in the past that are now in the future” (McCormack, 2015, p. 654). This ability to shift temporal perspective relies upon the understanding of how causality operates in time.

However, a majority of the literature on children’s projective minds focuses on their ability to plan for a specific future task or their understanding of others’ mental states (i.e., theory of mind). Of the research focused on future planning, many have been concerned with the emergence of future-oriented thinking in preschool-aged children, with a typical task requiring children to select items for use in a future event. For example, Atance and O’Neill (2005) asked 3-year-olds to imagine going on a trip with their parents; children were shown a group of eight items of which they had to choose three to take on the trip and to provide a reason for their choice. Justifications were coded for reference to present or future states. Results showed that the 3-year-olds referred to the future 37% of the time when choosing items for their trip, compared with 46% referral to the present.

Similarly, Atance and Meltzoff (2005) gave 3-, 4-, and 5-year-olds a book with different landscapes and asked them to choose an item that they would take with them if they were walking across the landscape in the photograph and to explain their choices. Choices were tailored to each photograph, e.g., given a photograph of a sunny desert, children chose between sunglasses, soap, and a mirror (with the sunglasses being the correct choice because in the future scenario one could anticipate wanting to shield the eyes from the sun). Not only did older children choose the correct choice more often than younger children, they also provided more future-oriented reasons for their choice.
Russell, Alexis, and Clayton (2010) replicated these findings with children selecting items needed to play a future game. Together these findings support the claims (e.g., Atance & Meltzoff, 2005; Atance & O’Neill, 2005; Russell et al., 2010) that the ability to think about the future emerges during the preschool years. However, little is known about the development of this ability beyond the preschool years.

To fully grasp that events in the future are altered by events occurring between now and then (and that events from the past influence present actions and events), children must be able to think about points in time as representing a temporal sequence with open slots at the end that can be filled in various ways (McCormack, 2015). The ability to predict future behaviors relies on an understanding of temporal order and an ability to situate events in time. Additionally, to move beyond general script memory to episodic “autonoetic” memory (i.e., the awareness of our existence and identity extending from the personal past through the present to the future; Mahr & Csibra, 2017; Tulving, 1972; 1985), the child must have an understanding of the self in time. This includes awareness of how a person’s current and future actions are influenced by past experiences and other people. Theory of mind provides children with the tools needed to understand the subjective nature of memories and to appreciate that others may hold different beliefs, values, and thoughts that cause them to act in various ways. As such, theory of mind is necessary for making behavioral predictions. As the child comes to understand and interpret what other people believe, they become able to predict their actions based on these interpretations.

The ability to track the mental lives and experiences of individuals typically does not emerge until the ages of 3 to 5 years as demonstrated in the theory of mind literature.
(see Liu, Wellman, Tardif, & Sabbagh, 2008, for a review). However, few have explored developments in theory of mind in middle childhood (see Aldrich & Brooks, 2017; Cantin, Gnaedinger, Gallaway, Hesson-McInnis & Hund, 2016; Miller, 2009; 2012 for exceptions). More so, majority of research has focused on false-belief tasks, wherein a child must predict the behavior of a character who holds a mistaken belief about an object (e.g., Wimmer & Perner, 1983), which requires an understanding of intentional mental states. This line of research tends to have a ceiling effect after the age of 5 years, limiting its utility in exploring developments beyond emergence (Devine & Hughes, 2013). The literature focusing on tasks suitable for studying advanced theory of mind has explored tasks requiring perspective taking (e.g., Apperly, Warren, Andrews, Grant & Todd, 2011), understanding others’ beliefs (e.g., Devine & Hughes, 2013; Happé, 1994), and identifying others’ emotions (e.g., Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001), and suggest that theory of mind continues to develop into adolescence. These types of advanced theory of mind tasks may tap into similar cognitive abilities needed in behavioral prediction, as one would likely draw on others’ perspectives, beliefs, and emotional states in order to make predictions about their future behaviors.

**Influence of Language and Nonverbal Abilities**

Concurrent with the development of temporal cognition, diachronic thinking and behavioral prediction skills, children are advancing their language and nonverbal skills. The literature highlights the links between temporal knowledge and nonverbal intelligence (e.g., Moore et al., 2014) and general memory systems (see Nelson, 1996 for a review); however, a much larger body of literature has discussed the importance of various language skills on the development of disparate forms of temporal representation.
Links between temporal representation and children’s ability to understand and use temporal terms and verb tenses have been proposed (Harner, 1975; 1980; Weist, 1986), suggesting that children can reason about the past and future only once they can flexibly use verbal constructions that convey temporal meanings. As discussed previously, Nelson (1991; 1996) provides a theoretical perspective highlighting the ways in which language and experience inform and change mental representations. Children are thought to develop representations of temporal concepts and patterns through informal experiences with the language forms (i.e., grammar and the lexicon) related to temporal knowledge during ongoing activities.

Grammar is integral in the understanding of temporal relations; it encompasses tense, aspect, and syntactic constructions that indicate temporal perspective. Although, toddlers begin to refer to the past in terms of just-completed tasks or familiar routines (e.g., “All gone”; Fivush & Nelson, 2004), it is not until the age of 2 to 3 years of age that the child’s vocabulary increases, producing short sentences and engaging in conversations with others. At this age, children begin to use past and future tense and other temporal grammatical structures, but often inaccurately. Gerhardt (1989) argues that young children’s early use of tense and aspect are not true distinctions between past and present, but rather present and not-present. As such, children must continually adjust their grammatical representations of time before accurately distinguishing between temporal perspectives. Indeed, between the ages of 3 and 7 years, children’s accurate use and understanding of the past and future tense increases dramatically (Harner, 1975; 1980). Regarding temporal language, grammar is proposed to precede semantic conceptualizations (Nelson, 1996). These semantic conceptualizations can take the form
of nouns, adverbs, prepositions, and conjunctions and can refer to a location in time, a sequence of events, or a duration of time.

There is debate in the field as to whether all or only particular aspects of language are involved in representational development, with a significant body of research in the domain of theory of mind. Here it is argued that certain theory of mind skills, e.g., inferring intentions and making predictions, are an integral component in the development of temporal knowledge and reflect an understanding of the causal and linear characteristics of time (McCormack, 2015). Research from this literature has predominantly debated the role of semantic ability (facts) versus syntactic ability (rules). For example, some (e.g., Astington & Jenkins, 1999; deVilliers, 2005) argue that measures of syntax and memory for sentential complements allow the child to represent the beliefs of others and would therefore be important in the development of theory of mind. Alternatively, semantics allow a child to participate in social conversations that become the basis for the development of the mental representations needed to represent the beliefs of others (Nelson, 2005; note that Nelson also highlights the importance of grammar). A recent meta-analysis of 104 studies of theory of mind in children under the age of 7 indicates that general language abilities were more strongly related to theory of mind than any specific aspect of language (Milligan, Astington, & Dack, 2007). A study of theory of mind in middle childhood (Grazzani & Ornaghi, 2012) demonstrated a link between theory of mind and metacognitive language comprehension, use of psychological lexicon, and general verbal ability, again suggesting that the specific type of language measure is not integral to the relationship between representational thought and language.
This is the perspective held by Bates (1994; Bates & Goodman, 1997) who argues for the inseparability of grammar and the lexicon in the development of representational thought. She argues that since grammar and the lexicon develop similarly in infancy and break down similarly in brain-injured patients, the two are therefore represented together in the mind and processed by the same mechanisms for other cognitive abilities. Like Nelson (1996), Bates (1994) proposes that language is a system embedded in time and that language learning is fundamental to the development of temporal cognition and other temporal representations and vice versa. As such, the current study aims to explore the links between various components of language (receptive vocabulary, receptive grammar, and reading) and nonverbal (nonverbal intelligence and working memory) abilities in the representational development of temporal cognition, diachronic thinking, and behavioral prediction during middle childhood.
CHAPTER THREE: CURRENT RESEARCH

Rationale

Despite the verbal and nonverbal gains that are apparent in middle-childhood, a time when children are entering formal schooling and becoming increasingly independent in managing their own schedules, much of the literature on the development of temporal cognition has focused on its emergence. This study seeks to explore temporal cognition in relation to other aspects of temporal representation (diachronic thinking and behavioral prediction) to confirm the age-related representational changes that have been documented in the literature (e.g., Boucher et al., 2013; Friedman, 2000; McCormack, 2015; Moore et al., 2014) in a community sample of 6- to 10-year-old children. We utilized two tasks of temporal cognition, *Months Relative Order* and *Time Labeling*, to assess event ordering and time labeling abilities, respectively. Additionally, we utilized two additional tasks of complex temporal representation, *Draw Lifecycle of a Tree* and *Character Intentions*, to assess diachronic thinking and behavioral prediction, respectively. The Character Intentions task is a novel means of exploring behavioral prediction as this task was originally designed to assess advanced theory of mind by requiring individuals to predict the future behavior of characters by inferring their intentions. This type of theory of mind task requires similar skills needed in many future planning and behavioral prediction tasks and requires an understanding of the causal nature of time, making it a unique way to explore an aspect of representational thought necessary for a full mastery of temporal cognition.

This research also examines individual differences in task performance on the four measures as evidence that underlying changes apply across disparate aspects of
cognition. Building on work by Moore and colleagues (2014) who explored individual differences in event ordering, time labeling and diachronic thinking over middle childhood, we used principal components analysis to determine whether disparate measures of temporal representation would load onto one or more underlying factors. Moore et al. (2014) observed performance on battery of event ordering, time labeling, and diachronic thinking tasks to load onto two factors, with Factor 1 associated with performance across all tasks, as well as measures of verbal and nonverbal intelligence, and Factor 2 distinguishing one of the measures of diachronic thinking from the spatial event ordering task and the time labeling task. Their study provided a starting point for the exploration of representational change in the domain of temporal knowledge; however, there are several notable limitations to address. The first is that the researchers used standardized scores in regression analyses. Considering that the regressions also included age as a predictor, this is problematic as standardized scores already have parsed out age effects. Yet, that the results of vocabulary remained significant suggests the strength of the contribution of language to temporal abilities above and beyond age-related changes.

Additionally, the study conducted by Moore and colleagues (2014) included only one assessment of verbal ability (receptive vocabulary) and one assessment of nonverbal ability (nonverbal intelligence). Considering what is theorized about the contribution of language to temporal abilities, studies employing a battery of language assessments are needed. This is particularly helpful in teasing apart the debate on the separability of grammar and the lexicon (e.g., Bates & Goodman, 1997; de Villiers, 2005). Additionally, research should include additional measures of nonverbal abilities, particularly those
measuring executive function skills as these have been found to contribute to temporal abilities such as planning (e.g., Cohen, 1996; Owen, 1997; Gilhooly, 2005).

Therefore, the current study examines performance on two traditional tasks of temporal cognition in relation to temporal tasks of diachronic thinking and behavioral prediction. This study explores the relationship of these four disparate tasks and various indices of verbal and nonverbal abilities. Including measures of receptive vocabulary, receptive grammar, and reading is integral for a study exploring the role of language in the development of temporal cognition and related temporal representation abilities to determine if gains are driven by general or specific language abilities above and beyond the influence of nonverbal abilities.

**Research Aims**

This study explores the role of language in the development of temporal representation in middle childhood. Specifically, the current study examines the relations among tasks of temporal cognition (event ordering and time labeling), diachronic thinking, and behavioral prediction across age, as well as the role of verbal and nonverbal abilities among a community sample of 6- to 10-year-old children. The aims of the current study are guided by the following research questions:

1. Does performance on temporal cognition, diachronic thinking, and behavioral prediction tasks provide support for the age-related improvements in representational thought reported in prior research?
2. Is performance on two traditional tasks of temporal cognition (event ordering and time labeling) related to performance on tasks of diachronic thinking and behavioral prediction?
3. Does the shared variance in performance across these four tasks provide evidence that underlying changes in representational thought apply across disparate aspects of cognition?

4. What is the role of language and nonverbal abilities in the development of temporal representation in middle childhood?
   
a. More specifically, does language predict gains in representational change above and beyond the influence of age and nonverbal abilities?
   
b. Are representational changes better predicted by specific language abilities or general language?

Research has documented increased temporal abilities throughout middle childhood in temporal cognition (e.g., Friedman, 2000; Moore et al., 2014), as well as in diachronic thinking (e.g., Boucher et al., 2013; Montangero, 1996; Moore et al., 2014). To my knowledge, there has not been formal research on behavioral predictions related to temporal knowledge in middle childhood; however, research suggests that middle childhood is a time of increasing theory of mind and perspective taking abilities (e.g., Baron-Cohen et al., 2001; Dumontheil et al., 2010; Happé, 1994). Therefore, it is predicted that age will be correlated with all four tasks in the current study. Additionally, based on the work by Moore and colleagues (2014) who reported links between tasks of event ordering, time labeling, and diachronic thinking, it is hypothesized that the four tasks in the current study will load onto one factor, providing support for an underlying representational ability across disparate forms of temporal knowledge.

The final aim of the paper is to explore the roles of language and nonverbal abilities in the development of temporal representation. Both Karmiloff-Smith (1992;
1994) and Nelson (1991; 1996) propose a driving role of language in cognitive development in that language provides the representational format for making procedural (sensorimotor) knowledge more explicit (consciously accessible). Although the current study will be the first to explore various components of representational change in relation to a battery of language and nonverbal assessments, prior work suggests that language will predict gains beyond the contributions of age, nonverbal intelligence, and working memory. Here it is proposed that language is an interconnected system and not a mere labeling of time concepts; as such, verbal mediation of representational development across domains of temporal knowledge (temporal cognition, diachronic thinking, and behavioral prediction) will be explored. Lastly, it is predicted that regardless of the language assessment entered in to the model, language will predict gains above and beyond age and nonverbal abilities. Support for this hypothesis comes from the research of Bates (1998; Bates et al., 1979; Bates & Goodman, 1997) on the general role that language plays in the development of symbolic or representational thought and the inseparability of grammar and the lexicon.
CHAPTER FOUR: METHOD

Participants

Participants were 62 school-aged children, 30 boys and 32 girls ($M = 8$ years; 2 months, $SD = 1;3$, range 6;0−10;8) from the New York City metropolitan area, primarily Staten Island and New Jersey. Participants were recruited through a child subject pool or using flyers posted at the college and neighboring institutions. Parents were asked to fill out an online background questionnaire about themselves and their children (see Appendix A). Ethnicity was distributed as follows: 64.5% Caucasian ($n = 40$), 11.3% Black/African American ($n = 7$), 6.5% Middle Eastern ($n = 4$), 4.8% Hispanic/Latino ($n = 3$), 1.6% Asian ($n = 1$), and 11.3% Mixed Race ($n = 7$). Formal socio-economic status information was not obtained, however, see Appendix B for parent education level. All children were native speakers of English; ten children spoke another language in addition to English at home. None of the children met clinical cut-offs for language disorders (Core Language Score: $M = 105.87$; $SD = 13.15$; range = 75 − 126) as evidenced by scores on the Clinical Evaluation of Language Fundamentals–Fourth Edition (CELF–4; Semel, Wiig, & Secord, 2003; see also Appendix C for parental report of children’s language abilities). Institutional Review Board approval was obtained. Informed consent was obtained from parents and children provided written assent. Families were given $20 gift cards at the end of each session as compensation for their time.

Materials and Measures

Temporal Representation Tasks

Four tasks were selected from the published literature to evaluate relationships among disparate assessments of temporal representation.
**Months Relative Order task** (Friedman, 2000). This *temporal cognition* task is a measure of event ordering ability that assessed children’s abilities to position specific months in relation to other months. Children were shown stimulus cards, each with the name of a month written on it. Eight stimulus cards were used in total, displaying the name of a month (two months randomly selected from each quarter of the calendar year). On each of eight trials, children were given two response choices (four and eight months in the future) and asked to indicate the month that would come next in the calendar (Figure 1). For example, individual questions would take the form: “Does February or June come next after October?” (Friedman, 2000, p. 928). Each response was scored as correct (score of 1) or incorrect (score of 0). Scores were tallied across the trials and averaged to create an overall accuracy score.

*Figure 1. Months Relative Order stimulus and response choice cards.*
Time Labeling task (adapted from months of the holidays task; Friedman, 2000). This *temporal cognition* task is an assessment of children’s knowledge of conventional time patterns that involved associating events with a specific day of the week or month of the year. Children were presented with stimulus cards (summer, Christmas, start of the school year, Thanksgiving, Halloween, Valentine’s Day, start of the school week, and weekend; Figure 2) one at a time in random orders. Children were asked, “What month(s) is(are) ____?” for each of the four holidays, summer, and start of school year cards, and “What day(s) of the week is(are) ____?” for the start of the school week and weekend cards. Each response was scored as correct (score of 1) or incorrect (score of 0). For the summer and weekend cards, responses were scored as correct if the child responded with any combination of the correct responses. Scores were tallied across the 8 trials and averaged to create an overall accuracy score.

![Time Labeling Task stimulus cards](image)

*Figure 2. Time Labeling Task stimulus cards (note that the calendar card was used for “start of the school week” and “weekend” trials).*
**Draw Lifecycle of a Tree task (adapted from Transformation task; Boucher, Pons, Lind, & Williams, 2007).** This *diachronic thinking* task is an assessment of children’s understanding of biological change and transformation. Children were given a blank sheet of paper and a set of colored pencils/markers and asked to draw a picture of a tree. After completing the drawing, children were given two additional sheets of paper, one to the left and one to the right of the paper with their drawing of the tree, and told: “I want you to draw some more pictures to show me the *whole life of the tree*, how it looked *before* this and how it will look *after* this. I’ll write “Before” over here (paper on the left), and “After” over here (paper on the right). You can draw as many pictures as you like. Remember to draw the *whole life* of the tree” (Boucher et al., 2007, p. 1416-1417). Non-specific prompts (e.g., “Now show me how it looked after this” or “Remember, I want you to draw the *whole life* of the tree”) were provided as necessary. Any comments made by children while drawing were written down. Testing was terminated when a child drew at least one before and one after picture. Modified by Moore and colleagues (2014) from the original transformation task, if a child failed to draw a picture, the researcher asked if the child knew how to draw what they were thinking about. If this was the case, the child was asked to explain what he or she would like to draw and the response was written verbatim on the paper. The sets of trees were scored from 0 to 2 (Figure 3), with a score of 0 reflecting drawings that differed only in size with no indication of a qualitative change (e.g., three drawings of similar-looking trees increasing in height), a score of 1 reflecting drawings that differed in size and depicted a qualitative change in either the before or after drawings (e.g., a smaller, but qualitatively similar tree to the original drawing and a tree without leaves, a tree lying on the ground, or just a
stump), and a score of 2 for drawings that included trees showing qualitative changes in both the before and after drawings (e.g., drawings of a seedling or young shoot, a tree, and a fallen tree or stump). In instances where verbal responses or comments were recorded, the child received a score that reflected what he or she said the drawing was.

Figure 3. Draw Lifecycle of a Tree scoring examples.
**Character Intentions task (modified from Brunet et al., 2003).** This *behavioral prediction* task was originally developed as a nonverbal assessment of theory of mind for adults with schizophrenia, but was adapted here for use with children to explore behavioral prediction and the understanding of causality in time. The task required children to infer a character’s future action from a series of depicted events. The task consisted of 16 short, 3-picture comic strips, each featuring a character with a specific intention (Figure 4). Children were provided a choice of 3 possible conclusions to each scenario in the form of answer cards. One answer card was a logical conclusion that matched the character’s intention and causal sequence (far right) and 2 answer cards were distractors: one unrelated to the context of the scenario (far left) and one not unrelated, but with no causal link to the *intentional* context of the scenario (middle). Scored across trials were tallied and averaged to create an overall accuracy score.

*Figure 4. Character Intentions task (printed with permission from Brunet et al., 2003)*

cartoon trial (top) and response choices (bottom).
Assessments of Language Abilities

**Global language.** The Clinical Evaluation of Language Fundamentals–Fourth Edition (CELF–4; Semel, Wiig, & Secord, 2003) is a norm-referenced assessment of receptive and expressive language abilities related to content, memory, and structure suitable for individuals between the ages of 5 and 21 years; 11 months. To characterize the sample and test for the presence of a language disorder, all children completed the following sections: Concepts and Following Directions, Recalling Sentences, Formulated Sentences, Word Classes-Receptive, Word Classes-Total. Additionally, children ages 6 to 8 years completed the Word Structure and Sentence Structure sections; while children ages 9 to 11 years completed the Word Classes-Expressive section.

**Receptive vocabulary.** The Peabody Picture Vocabulary Test–Fourth Edition (PPVT–4; Dunn & Dunn, 2007) is a norm-referenced, untimed test of receptive vocabulary (i.e., understanding of spoken language) for Standard American English suitable for individuals between the ages of 2 years; 6 months and 90+ years. Children were presented with sets of four pictures, one set at a time. The examiner spoke a word referring to one of the four pictures and the child was asked to point to the picture that best fit the word. For example, if the child was presented a page with pictures of a dog, chair, boy, and bicycle, the examiner asked, “Can you point to the picture of the boy?” After the child pointed to a picture on the page, the examiner proceeded to the next set of pictures. Items were organized in ascending order based on difficulty level.

**Receptive grammar.** The Test for the Reception of Grammar–Second Edition (TROG–2; Bishop, 2003) is a measure of the understanding of grammatical contrasts suitable for individuals from the age of 4 through adulthood. The test targets sentence
comprehension and contains 80 stimulus items arranged in blocks of 4, where children were required to point to one of the four items that they consider is correct. Children were tested on 20 grammatical concepts. Items were organized in ascending order based on difficulty level.

**Reading ability.** The Woodcock Reading Mastery Tests–Third Edition (WRMT–3; Woodcock, 2011) is a norm-referenced assessment of reading readiness and achievement. Children completed the following sections: Word Identification, Word Attack, Word Comprehension (Antonyms, Synonyms, Analogies), Passage Comprehension, and Oral Reading Fluency. These subtests yielded scores of children’s basic reading skills (first two subtests), reading comprehension (third and fourth subtests), and oral reading fluency (fifth subtest). Test items were organized in ascending order based on difficulty level.

**Assessments of Nonverbal Abilities**

**Nonverbal intelligence.** The Test of Nonverbal Intelligence–Third Edition (TONI–3; Brown, Sherbenou, & Johnsen, 1997) is a language-free assessment of intelligence, aptitude, abstract reasoning, and problem solving suitable for individuals between the ages of 6 years and 89 years; 11 months. The test consisted of 60 items arranged in order of increasing difficulty. Children were presented with a series of shapes/patterns, with one empty space in the series. Children then chose, among possible shapes/patterns, the one that best completed the series.

**Working memory.** The 1-shape array memory task (Cowan, AuBuchon, Gilchrist, Ricker & Saults, 2011; Cowan, Morey, AuBuchon, Zwilling, & Gilchrist, 2010) is an assessment of working memory ability suitable for school-aged children.
(Figure 5). Children were instructed to attend to a set of colored circles that appeared in a grid of 12 boxes for 500 ms duration. After the grid disappeared, it appeared again with a single, colored circle (the probe item) and children were asked to decide where the stimulus belonged (no change, location change, or new color). To make the task more engaging for children, the grid was presented as a classroom with the colored circles representing students with different colored shirts. Children were instructed to click the seat (box) in which the student (probe item) belonged and if that student (probe item) did not belong anywhere in the classroom, the door icon was to be clicked to send the student (probe item) to the principal’s office. Children completed 6 practice trials followed by 32 test trials.

Figure 5. 1-Shape Array Memory task (Cowan et al., 2010; 2011) with no change, location change, and new color probe trials.
Procedure

Children were tested individually in a laboratory at an urban, public college over two sessions of approximately 2 hours in duration. The majority of the sessions were conducted by the author of this dissertation. Other sessions were conducted by a second doctoral candidate and three undergraduate research assistants. Research assistants were trained to administer all assessments and were supervised to ensure the accuracy of procedures. The order of tasks was counterbalanced across participants.
CHAPTER FIVE: OVERVIEW OF ANALYSES

Scoring of Tasks and Assessments

Trained research assistants scored data from the 62 participants. Standardized assessments received a second pass to double-check scoring. The working memory task was scored by the computer. Inter-rater reliability was calculated for the scoring of all experimental tasks. The author of this dissertation served as the second rater and scored data from 13 participants for all tasks. All disagreements were resolved through discussion. Inter-rater reliability was above 90% on all tasks. Arcsine transformations were performed on all proportional data.

Analytic Plan

As preliminary analyses, we computed partial correlations (controlling for age) between each temporal representation task (event ordering, time labeling, diachronic thinking, and behavioral prediction) and individual measures of language and nonverbal abilities. Due to issues of multicollinearity between the language assessments, we subjected them to a principal components analysis. We then computed Pearson correlation coefficients between each temporal representation task and age to confirm the age-related advances documented in the literature. Next, we explored whether the disparate measures of representational change were significantly related using correlations and principal components analysis. We computed additional partial correlations (controlling for age) between the temporal representation component and individual language and nonverbal assessments. In order to address the fourth aim of our study and explore relationships between temporal representation and developmental changes in language ability, nonverbal intelligence, and working memory, we ran
stepwise regression models. We next conducted mediation analyses to further examine the role of language in the representational development of temporal abilities. Finally, we ran five stepwise regression analyses entering individual language measures in the final step to determine if representational abilities are driven by specific language abilities as opposed to general language skills.
CHAPTER SIX: RESULTS

Preliminary Analyses

The mean accuracy for the temporal cognition, diachronic thinking, and behavioral prediction tasks are presented in Table 1. As can be seen in the table, children had a range of representational abilities.

Table 1

*Mean accuracy for temporal representation tasks.*

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Mean (SD)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temporal Cognition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Months Relative Order</td>
<td>75.4% (23.7)</td>
<td>25 – 100%</td>
</tr>
<tr>
<td>Time Labeling</td>
<td>71.3% (28.5)</td>
<td>0 – 100%</td>
</tr>
<tr>
<td><strong>Diachronic Thinking</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Draw Lifecycle of a Tree</td>
<td>60.5% (34.0)</td>
<td>0 – 100%</td>
</tr>
<tr>
<td><strong>Behavioral Prediction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Character Intentions</td>
<td>73.9% (19.2)</td>
<td>13 – 100%</td>
</tr>
</tbody>
</table>

The mean standardized and raw scores for assessments of receptive vocabulary, receptive grammar, reading ability, and nonverbal intelligence, as well as mean accuracy (percent correct) for performance on the working memory task, are presented in Table 2. The sample displayed diverse verbal and nonverbal abilities.
Table 2

*Mean standardized and raw scores for language and nonverbal tasks.*

<table>
<thead>
<tr>
<th>Assessments</th>
<th>Standardized Scores</th>
<th>Raw Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
</tr>
<tr>
<td><strong>Standardized Scores</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Verbal Abilities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receptive Vocabulary (PPVT–4)</td>
<td>113.4 (14.5)</td>
<td>78 – 146</td>
</tr>
<tr>
<td></td>
<td>147.3 (21.1)</td>
<td>93 – 183</td>
</tr>
<tr>
<td>Receptive Grammar (TROG–2)</td>
<td>103.0 (15.2)</td>
<td>67 – 130</td>
</tr>
<tr>
<td></td>
<td>15.0 (3.4)</td>
<td>5 – 20</td>
</tr>
<tr>
<td>Reading Ability (WRMT–3)</td>
<td>109.8 (17.2)</td>
<td>78 – 145</td>
</tr>
<tr>
<td>Basic Reading</td>
<td>40.0 (15.2)</td>
<td>0 – 67</td>
</tr>
<tr>
<td>Reading Comprehension</td>
<td>112.4 (17.1)</td>
<td>77 – 144</td>
</tr>
<tr>
<td></td>
<td>46.2 (20.0)</td>
<td>0 – 80</td>
</tr>
<tr>
<td>Oral Reading Fluency</td>
<td>107.7 (15.6)</td>
<td>78 – 139</td>
</tr>
<tr>
<td></td>
<td>34.0 (18.3)</td>
<td>0 – 62</td>
</tr>
<tr>
<td><strong>Nonverbal Abilities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonverbal Intelligence (TONI–3)</td>
<td>114.3 (13.8)</td>
<td>81 – 144</td>
</tr>
<tr>
<td></td>
<td>21.1 (6.4)</td>
<td>4 – 34</td>
</tr>
<tr>
<td>Working Memory (percent correct)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>64.5% (14.2)</td>
<td>28 – 87%</td>
</tr>
</tbody>
</table>

**Data Reduction**

Next, we conducted partial correlations, controlling for age (in months), between temporal cognition, diachronic thinking and behavioral prediction tasks and individual measures of language and nonverbal abilities (Table 3).
Table 3

Partial correlations (controlling for age) between temporal representation tasks and measures of language and nonverbal abilities (raw scores).

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temporal Cognition</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Months Relative Order</td>
<td>.45****</td>
<td>.31*</td>
<td>.33**</td>
<td>.40***</td>
<td>.42***</td>
<td>.25†</td>
<td>.11</td>
</tr>
<tr>
<td>Time Labeling</td>
<td>.39***</td>
<td>.34**</td>
<td>.54****</td>
<td>.51****</td>
<td>.59****</td>
<td>.26*</td>
<td>.21</td>
</tr>
<tr>
<td><strong>Diachronic Thinking</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Draw Lifecycle of a Tree</td>
<td>.33*</td>
<td>.30*</td>
<td>.19</td>
<td>.28*</td>
<td>.26*</td>
<td>.12</td>
<td>.31*</td>
</tr>
<tr>
<td><strong>Behavioral Intention</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Character Intentions</td>
<td>.37***</td>
<td>.34**</td>
<td>.21</td>
<td>.40***</td>
<td>.36***</td>
<td>.33**</td>
<td>.31*</td>
</tr>
</tbody>
</table>

*p < .06, *p < .05, **p < .01, ***p < .005, ****p < .001
Due to issues of multicollinearity among the standardized assessments of verbal abilities (Table 4), we subjected the raw scores of receptive vocabulary (PPVT–4), receptive grammar (TROG–2), and reading (three subscales of WRMT–3) assessments to principal components analysis.

Table 4

*Pearson correlation coefficients between language assessments (raw scores).*

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Zero-Order Correlations</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPVT–4</td>
<td>.67****</td>
<td>.64****</td>
<td>.76****</td>
<td>.66****</td>
</tr>
<tr>
<td>TROG–2</td>
<td>–</td>
<td>–</td>
<td>.76****</td>
<td>.59****</td>
</tr>
<tr>
<td>WRMT–3: Basic Reading</td>
<td>–</td>
<td>–</td>
<td>.89****</td>
<td>.85****</td>
</tr>
<tr>
<td>WRMT–3: Reading Comprehension</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>.85****</td>
</tr>
<tr>
<td><strong>Partial Correlations (controlling for age)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPVT–4</td>
<td>.63****</td>
<td>.51****</td>
<td>.65****</td>
<td>.53****</td>
</tr>
<tr>
<td>TROG–2</td>
<td>–</td>
<td>.63****</td>
<td>.77****</td>
<td>.53****</td>
</tr>
<tr>
<td>WRMT–3: Basic Reading</td>
<td>–</td>
<td>–</td>
<td>.86****</td>
<td>.79****</td>
</tr>
<tr>
<td>WRMT–3: Reading Comprehension</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>.78****</td>
</tr>
</tbody>
</table>

* **** p < .001
The principal components analysis met the assumptions of linearity (all variables had at least one correlation coefficient greater than 0.30), sampling adequacy (overall Kaiser-Meyer-Olkin measure was 0.85), and sphericity (Bartlett's test of sphericity was statistically significant, \( p < .001 \)). This analysis yielded one component (hereinafter referred to as “language ability”) with an eigenvalue greater than 1 and explained 78.98% of the variance, see Table 5 for item loadings.

Table 5

*Loadings of the principal components analysis for language abilities (raw scores).*

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Component 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPVT–4</td>
<td>.84</td>
</tr>
<tr>
<td>TROG–2</td>
<td>.83</td>
</tr>
<tr>
<td>WRMT–3: Basic Reading</td>
<td>.92</td>
</tr>
<tr>
<td>WRMT–3: Reading Comprehension</td>
<td>.96</td>
</tr>
<tr>
<td>WRMT–3: Oral Reading Fluency</td>
<td>.89</td>
</tr>
</tbody>
</table>

**Age-Related Changes in Representational Thought**

The first aim of the current study was to replicate age-related developments in temporal representation among tasks of temporal cognition (Months Relative Order and Time Labeling), diachronic thinking (Draw Lifecycle of a Tree) and behavioral prediction (Character Intentions). Pearson correlation coefficients revealed that accuracy on the Months Relative Order, \( r(60) = .48, p < .001 \), Time Labeling, \( r(60) = .44, p < .001 \),
Draw Lifecycle of a Tree, $r(60) = .23, p = .07$, and Character Intentions, $r(60) = .32, p = .01$, tasks increased with age (in months). This provides confirmation of age-related improvements in representational thought documented in previous research; however, the diachronic thinking task (Draw Lifecycle of a Tree) did not reach significance.

**Correlations Among Representational Tasks**

The second aim of the study was to examine whether performance on two traditional measures of temporal cognition (event ordering and time labeling abilities) are related to performance on tasks of diachronic thinking and behavioral prediction. Each of the four tasks were significantly correlated with one another (Table 6), suggesting a relationship between four disparate forms of temporal representation.

Table 6

*Pearson correlation coefficients between temporal representation tasks.*

<table>
<thead>
<tr>
<th></th>
<th>Time Labeling</th>
<th>Draw Lifecycle of a Tree</th>
<th>Character Intentions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Zero-Order Correlations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Months-Relative-Order</td>
<td>.64****</td>
<td>.39***</td>
<td>.39***</td>
</tr>
<tr>
<td>Time Labeling</td>
<td>–</td>
<td>.46****</td>
<td>.37***</td>
</tr>
<tr>
<td>Draw Lifecycle of a Tree</td>
<td>–</td>
<td>–</td>
<td>.33**</td>
</tr>
<tr>
<td><strong>Partial Correlations</strong> (controlling for age)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Months-Relative-Order</td>
<td>.55****</td>
<td>.33**</td>
<td>.28*</td>
</tr>
<tr>
<td>Time Labeling</td>
<td>–</td>
<td>.41****</td>
<td>.27*</td>
</tr>
<tr>
<td>Draw Lifecycle of a Tree</td>
<td>–</td>
<td>–</td>
<td>.28*</td>
</tr>
</tbody>
</table>

*p < .05, **p < .01, ***p < .005, ****p < .001*
Principal Components Analysis

The third aim of the study was to evaluate whether the shared variance in performance across the four tasks provide evidence that underlying changes in representational thought apply across disparate aspects of cognition related to the understanding of time. The principal components analysis met the assumptions of linearity (all variables had at least one correlation coefficient greater than 0.30; see Table 6 for zero-order correlations), sampling adequacy (overall Kaiser-Meyer-Olkin measure was 0.73) and sphericity (Bartlett's test of sphericity was statistically significant, $p < .001$). The principal components analysis revealed one underlying factor (hereinafter referred to as “temporal representation”) with an eigenvalue greater than 1. This factor accounted for 57.84% of the variance in scores across the four tasks, see Table 7 for item loadings.

Table 7

*Loadings of the principal components analysis for temporal representation tasks.*

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Component 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Months Relative Order</td>
<td>.82</td>
</tr>
<tr>
<td>Time Labeling</td>
<td>.84</td>
</tr>
<tr>
<td>Draw Lifecycle of a Tree</td>
<td>.77</td>
</tr>
<tr>
<td>Character Intentions</td>
<td>.66</td>
</tr>
</tbody>
</table>
The Role of Language and Nonverbal Abilities

Next, we ran partial correlations, controlling for age (in months), between temporal representation (latent variable) and raw scores of measures of verbal and nonverbal abilities (Table 8). Finally, we examined the relationship between temporal representation and assessments of nonverbal intelligence, working memory, and language. We conducted stepwise regression analysis with temporal representation (latent variable) as the outcome measure and entered age (months) in Step 1, nonverbal intelligence (raw scores) and working memory in Step 2, and language abilities (latent variable) in Step 3.

Table 8

Partial correlations controlling for age between temporal representation and verbal and nonverbal tasks (raw scores).

<table>
<thead>
<tr>
<th>Assessments</th>
<th>Temporal Representation (latent variable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonverbal Intelligence</td>
<td>.33**</td>
</tr>
<tr>
<td>Working Memory</td>
<td>.32*</td>
</tr>
<tr>
<td>Language Abilities (latent variable)</td>
<td>.59****</td>
</tr>
</tbody>
</table>

*p < .05, **p < .01, ****p < .001

Results of the regression analysis are presented in Table 9. At Step 1, age contributed significantly to temporal representation, \( F(1, 60) = 19.44, p < .001 \), accounting for 24.5% of the variation. At Step 2 nonverbal intelligence and working memory accounted for an additional 12.8% of the variance, \( F(3, 58) = 11.47, p < .001 \),
and at Step 3, language abilities explained an additional 15.6% of the variation, $F(4, 57) = 15.97, p < .001$. Results revealed that language abilities predicted gains in temporal representation over and above effects of age, nonverbal intelligence, and working memory. Indeed, these three variables were no longer significant predictors at Step 3.

Table 9

*Stepwise multiple regression coefficients with temporal representation as the outcome variable.*

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Beta (β)</th>
<th>$t$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (months)</td>
<td>.49</td>
<td>4.41**</td>
</tr>
<tr>
<td><strong>Step 2:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (months)</td>
<td>.27</td>
<td>2.15*</td>
</tr>
<tr>
<td>TONI–3</td>
<td>.27</td>
<td>2.16*</td>
</tr>
<tr>
<td>Working Memory</td>
<td>.24</td>
<td>2.04*</td>
</tr>
<tr>
<td><strong>Step 3:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (months)</td>
<td>.10</td>
<td>0.86</td>
</tr>
<tr>
<td>TONI–3</td>
<td>.08</td>
<td>0.69</td>
</tr>
<tr>
<td>Working Memory</td>
<td>.12</td>
<td>1.15</td>
</tr>
<tr>
<td>Language Abilities (latent variable)</td>
<td>.54</td>
<td>4.34****</td>
</tr>
</tbody>
</table>

*p < .05, ****p < .001
Language as a Mediating Variable

Taken together, the regression results suggest that language abilities mediate the effects of age, nonverbal intelligence and working memory on temporal representation. To explicitly test mediation, we employed bootstrapping to estimate the 95% confidence intervals of the indirect effect, using the procedure suggested by Hayes and Preacher (2012) for multiple independent variables and the associated SPSS macro (PROCESS, downloaded from http://www.afhayes.com/spss-sas-and-mplus-macros-and-code.html). Mediation is assumed to be present when the confidence interval for the indirect effect does not include 0. The confidence intervals for the indirect effect of all predictors on temporal representation, based on 5,000 bootstrap samples, was 0.0045 – .0224. Inspection of the independent indirect effects of each individual independent variable showed that the effects of age, nonverbal intelligence, and working memory on temporal representation were mediated by language abilities (Figure 6).
Individual Language Measures as Predictors

To further explore the role of language in the development of temporal representation, five additional stepwise regression models were run with each individual language task (raw scores) as predictors in Step 3. For all language variables, Step 3 was significant accounting for additional variance (Table 10).
Table 10

Stepwise multiple regression coefficients for language measures separately entered at step 3 with temporal representation as the outcome variable.

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Beta (β)</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPVT–4</td>
<td>.46</td>
<td>3.85****</td>
</tr>
<tr>
<td>TROG–2</td>
<td>.30</td>
<td>2.43*</td>
</tr>
<tr>
<td>WRMT–3: Basic Reading</td>
<td>.34</td>
<td>2.77**</td>
</tr>
<tr>
<td>WRMT–3: Reading Comprehension</td>
<td>.51</td>
<td>3.86****</td>
</tr>
<tr>
<td>WRMT–3: Oral Reading Fluency</td>
<td>.50</td>
<td>4.67****</td>
</tr>
</tbody>
</table>

*p < .05, **p < .01, ****p < .001

The model with receptive vocabulary (PPVT) entered at Step 3 was significant, $F(4, 57) = 14.37, p < .001, \Delta R^2 = .13$, with PPVT being the only significant predictor at this step ($\beta_{\text{age}} = .11; \ \beta_{\text{TONI}} = .17; \ \beta_{\text{WM}} = .15; \ \beta_{\text{PPVT}} = .46$). The model with receptive grammar (TROG) entered at Step 3 was significant, $F(4, 57) = 10.80, p < .001, \Delta R^2 = .06$, with TROG and age being significant predictors at this step ($\beta_{\text{age}} = .27; \ \beta_{\text{TONI}} = .12; \ \beta_{\text{WM}} = .18; \ \beta_{\text{TROG}} = .30$). The model with basic reading entered at Step 3 was significant, $F(4, 57) = 11.51, p < .001, \Delta R^2 = .07$, with basic reading being the only significant predictor at this step ($\beta_{\text{age}} = .18; \ \beta_{\text{TONI}} = .15; \ \beta_{\text{WM}} = .18; \ \beta_{\text{BasicR}} = .34$). The model with reading comprehension entered at Step 3 was significant, $F(4, 57) = 14.39, p < .001, \Delta R^2 = .13$, with reading comprehension being the only significant predictor at this step ($\beta_{\text{age}} = .07; \ \beta_{\text{TONI}} = .11; \ \beta_{\text{WM}} = .14; \ \beta_{\text{RComp}} = .51$). Lastly, the model with oral reading fluency entered at Step 3 was significant, $F(4, 57) = 16.40, p < .001, \Delta R^2 = .16$, with oral reading
fluency being the only significant predictor at this step (βage = .08; βTONI = .17; βWM = .15; βORFluency = .50). For all language variables except receptive grammar, the effects of age, nonverbal intelligence, and working memory were subsumed by language ability. For the model with receptive grammar (TROG), age remained a significant predictor of temporal representation at step 3, t = 2.28, p = .03.
CHAPTER SEVEN: SUMMARY AND DISCUSSION

Summary

This study explored the contributions of age, language and nonverbal abilities on the representational development of temporal cognition, diachronic thinking, and behavioral prediction. In the literature, these disparate forms of temporal representation have been separately explored (e.g., Atance & O’Neill, 2005; Boucher et al., 2007; Friedman, 2005; Montangero et al., 1996; 2000; Nelson, 1996). The current study provides an attempt to explore tasks measuring these disparate forms of temporal knowledge within the same sample. Here, a community sample of 62 6- to 10-year-old children completed two assessments of temporal cognition (event ordering and time labeling), one assessment of diachronic thinking, and one assessment of behavioral prediction, as well as a battery of language and nonverbal assessments. The results generally confirmed age-related changes in temporal representation that have been documented in the literature. Results also highlighted the contribution of language (receptive vocabulary, receptive grammar, and literacy) over the contributions of age and nonverbal abilities to performance on the four tasks. Indeed, language mediated the effects of age, nonverbal intelligence, and working memory. In the sections that follow, results are discussed in light of the four research questions posed in the introduction.

Discussion and Implications

Age-Related Improvements in Representational Thought

Research from the disparate literature points to similar representational development across aspects of temporal cognition, diachronic thinking, and behavioral prediction, i.e., an emergence during the preschool years (Atance & O’Neill, 2005;
Friedman, 2005; Nelson, 1996) and dramatic refinement through middle childhood (e.g., Boucher et al., 2007; Friedman, 2000; Montangero et al., 1996; 2000; Moore et al., 2014). The results of the current study provide partial support for these developmental trends. The relationship between age and each of the tasks replicated previous research about developmental improvements throughout middle childhood except for the diachronic thinking (Draw Lifecycle of a Tree) task, which was not significantly correlated with age. One possible explanation is the use of a stricter coding scheme in terms of defining qualitative change from that used by Boucher and colleagues (2007) which could have resulted in lower scores. Another possible explanation is that the three other tasks (Months Relative Order, Time Labeling, Character Intentions) relied more on socio-cultural knowledge and experience than the diachronic thinking task which requires formal teaching of biological knowledge. Thus, perhaps the three socio-cultural tasks were more closely tied to age-related changes in representational thought.

However, a more likely explanation for the diachronic thinking results may be the difficulty of the task for the age range in this study. Montangero and colleagues (e.g., Maurice-Naville & Montangero, 1992; Montangero et al., 1996; Pons & Montangero, 1999; Tryphon & Montangero, 1992) suggest that diachronic thinking involving the understanding of qualitative biological change does not reach maturity until the age of 11 to 12 years. Indeed, the average accuracy for this task was 60.5% compared to the other three tasks which had accuracy scores above 70%. As such, future research should include older children to fully capture the trajectory of diachronic thinking. However, despite the nonsignificant relationship between diachronic thinking and age in the current
sample, the temporal representation latent variable was significantly predicted by age in the first step of the regression model.

**Relationships Among Temporal Representation Tasks**

The results suggest that the forms of representational knowledge explored in this study (temporal cognition, diachronic thinking, and behavioral prediction) require similar cognitive abilities that are verbally mediated. Each of the four assessments (Months Relative Order, Time Labeling, Draw Lifecycle of a Tree, and Character Intentions) displayed significant positive correlations with one another. The Months Relative Order task required children to determine the next month in a sequence when presented with a choice between a month, 2-months and 8-months in the future. This temporal cognition ability requires children to not only understand the months of the year, but to have a firm grasp of their order within the calendar. The Time Labeling task required children to provide the month(s) or day(s) of the week for significant holidays and events. This temporal cognition task served as a measure of children’s ability to label conventional time concepts. The Draw Lifecycle of a Tree task required children to draw pictures of a tree depicting the entire lifecycle from seedling to death. This diachronic thinking task assessed children’s understanding of biological change over time. Lastly, the Character Intentions task required children to make predictions about a character’s behavior based on the order of previous events. This behavioral prediction task measured children’s understanding of the causal aspect of temporal sequences. Together, these tasks comprise a variety of forms of temporal representation.

The ability to understand the sequence of events (temporal, biological and behavioral) may require similar cognitive representations of familiar and routine
events. Nelson (1996) has shown that children possess generalized event representations (e.g., general knowledge about familiar events) that are used to define the expected sequence of events. Children also rely on these generalized event representations to aid in general cognitive abilities such as memory, story production, and planning (Hudson et al., 1995; Nelson & Gruendel, 1981). As such, it is likely that children rely on these generalized event representations to order the months of a holiday, provide time labels for familiar holidays/events, depict the sequence in a tree’s life, and predict the behavior of a character during an event.

Not surprisingly, the most strongly correlated were the two temporal cognition tasks (Months Relative Order and Time Labeling) both adapted from Friedman (2000). These two tasks were measures of vocabulary/fact-based temporal concepts and patterns. Indeed, the ability to pass the Months Relative Order task requires the ability to label the months of the year and to place them in temporal order. However, it is interesting to note that although diachronic thinking and behavioral prediction have been explored as separate cognitive abilities in the literature, these tasks were correlated with the two temporal cognition tasks, as well as with each other.

**Shared Variance Across Temporal Tasks: Evidence of an Underlying Construct?**

All four tasks loaded similarly onto one factor that explained almost 58% of the variance. According to Nelson (1996), we make sense of time in terms of the ordering of events and temporal relations, abstract manipulations of time concepts, natural biological rhythms, and an understanding of the self and other through time. McCormack (2015) suggests that in addition to this list, we must understand the causal relation between events/actions in the past, present, and future. Taken together, these theories suggest that
the shared variance across tasks measuring temporal cognition, diachronic thinking, and behavioral prediction may provide evidence for an underlying construct of temporal representation. Yet, the one principal component explained just slightly more than half of the variance across tasks, leaving approximately 42% of the variance unexplained.

Another explanation is that the shared variance may only be reflecting broader cognitive changes in middle childhood. This shared variance likely includes some feature of temporal representation, but there may be more general cognitive processes that are playing a greater role, particularly those processes that are verbally mediated. For example, the behavioral prediction task (Character Intentions) was taken from the literature on theory of mind and the diachronic thinking task (Draw Lifecycle of a Tree) from the literature on children’s understanding of biological and qualitative change across time. Although these two tasks required temporal abilities, i.e., an understanding of the causal relations between events in time (McCormack, 2015) and an understanding of the natural biological rhythms that cycle through time (Nelson, 1996; Montangero, 1996), respectively, they are also indices of additional complex cognitive abilities. As such, it may be that the shared variance reflects a more general shift in representational thought, rather than strictly temporal abilities.

This explanation reflects the findings of Moore and colleagues (2014) who used a larger battery of event ordering, time labeling and diachronic thinking tasks and found two factors: one component that was associated with performance across all tasks and measures of vocabulary and nonverbal intelligence and a second component that distinguished the diachronic thinking synthesis task (conceiving a temporal succession of events as a unitary whole) from the spatial (marking events spatially in time using a
picture of a road) and labeling (providing conventional time concepts for the months of holidays) tasks. This suggests that the ability to “envision and name an event given a set of distinct sub-events (i.e., moments in time) was unrelated to knowledge of conventional time patterns” (Moore et al., 2014; p. 289). It may be that the first component in their study reflected greater cognitive development, rather than specific advances in temporal abilities; whereas the second factor was able to distinguish between temporal cognition and diachronic thinking tasks suggesting that these abilities may not be as closely tied beyond broader cognitive changes.

Indeed, both Karmiloff-Smith (1992) and Nelson (1996) propose theories of representational development within and across cognitive domains as a function of representational change from implicit procedural knowledge to explicit and flexible mental representations throughout infancy and childhood. The results of the current study do not have the power to arbitrate between the two theories (e.g., Karmiloff-Smith’s representational resdescription and Nelson’s experiential view of representational development), but rather suggests that both may explain the general developmental gains in temporal representation during middle childhood.

**Influence of Nonverbal Abilities**

Temporal representation was related to nonverbal intelligence and working memory abilities. A representation of time requires the flexibility of thought and draws on the ability to hold on to multiple representations at once and the ability to detect and represent patterns. These executive function skills are also required to complete the assessments of nonverbal intelligence and working memory used in the current study. Working memory is important in planning, particularly in the development,
maintenance, and execution of plans (Gilhooly, 2005; Owen, 1997). Hudson and colleagues have proposed that knowledge about the world, particularly event knowledge, plays an integral role in the development of plans (Hudson & Fivush, 1991; Hudson et al., 1995). A variety of tasks and standardized measures have been designed to assess planning skills as they relate to executive function (Carlson, Moses, & Claxton, 2004; Delis, Kaplan, & Kramer, 2001; Gardner & Rogoff, 1990; Hudson et al., 1995). However, this study is, to our knowledge, the first to explore the effects of working memory on a battery of temporal representation tasks measuring temporal cognition, diachronic thinking, and behavioral prediction. Our findings expand upon the work of Moore and colleagues (2014), which reported links between temporal representation and nonverbal intelligence, to highlight the role of working memory in the development of temporal skills. Together, this suggests that there may be a link between general (nonverbal) cognitive abilities and the ability to recognize and represent temporal concepts, patterns, change, and causality.

**Language as the Mechanism for Representational Change**

Although age, nonverbal intelligence, and working memory were significant predictors of temporal representation, the results suggest that these effects are mediated by language skills. When entered into the regression model at the final step, language abilities alone accounted for the added variance. This supports the theoretical views of Karmiloff-Smith (1992) and Nelson (1996), who emphasize the role of language, albeit differently, in representational development. According to Karmiloff-Smith (1992), at the final level of representational redescription, links across common microdomains can be made, and then eventually links across domains, using the “cross-system code…close
enough to natural language for easy translation into stable, communicable form” (p. 23). In the current study, language would allow manipulations of knowledge to occur across the microdomains of temporal cognition, diachronic thinking, and behavioral prediction. For Nelson (1996) language plays a role in representational development through its use during and about events. As children participate in everyday activities, they internalize information about events to form mental event representations that become more flexible and accessible to verbal reporting. As these representations are refined, children become able to make sense of and verbally represent time. Both theoretical positions make the case for the critical role of language in representational development; yet, only Nelson (1996) proposed a theory for how language would contribute to a representation of time, making it difficult for the current study to arbitrate between these theories. However, the current results provide initial evidence of representational changes in temporal knowledge throughout middle childhood as mediated by language.

It is important to note that all tasks required verbal instructions, and an understanding of said instructions, in addition to the linguistic demands of the tasks themselves. Although two of the tasks (Draw Lifecycle of a Tree and Character Intention) did not require verbal responses, participants tended to use language to guide them in completing the task or to help explain their responses. Participants also used this type of private speech to aid in their completion of the Months Relative Order task. This observation matches Friedman’s (1990) findings that children have a difficult time starting at an arbitrary point when asked to order the days of the week and months of the year; children tend to start at the beginning (e.g., Sunday and January) and proceed in order until they reach this arbitrary starting point.
This can be directly connected to Karmiloff-Smith’s (1992) theory where proceduralized knowledge occurs prior to explicit (i.e., consciously accessible) representations that can eventually be manipulated and verbalized. This would suggest that younger children may rely more on procedural knowledge to solve temporal tasks than older children who have temporal representations in a format similar to natural language that allows for both conscious access and verbalization. Here, the temporal representation tasks were neither audio- nor video-recorded and as such, conclusions cannot be drawn regarding the verbal strategies used during task completion, something that future tasks should explore in relation to representational development during middle childhood.

In the current study, language was restricted to receptive vocabulary, grammar, and literacy. However, this is only part of the range of language skills refined during middle childhood. In addition to incorporating semantic and syntactic assessments, future studies should explore expressive language abilities and the role of conversation. Nelson and Fivush (2004) have documented the role of conversation in the development of episodic memory and personal narrative ability: language provides the organizational structure for personal experience, it provides the representational format for positioning the self in time through narrative discourse, and enables children to enter into dialogues with others and engage in perspective taking. Therefore, early conversations with parents may be integral to the development of the language skills required of temporal representation.

Evidence suggests that children’s speech reflects the language patterns of adults and that mother-child interactions during events influence children’s later recall; for
example, children whose mothers provided more details during an event reported more
details of that event after a delay than children of less elaborative mothers (Haden,
Ornstein, Eckerman, & Didow, 2001). In this study, mothers interacted with their 30- to
40-month-old children around three novel play events (birdwatching, camping, and ice-
cream shop). In the birdwatching event, mother and child went on a birdwatching
adventure in the lab. They were first asked to select from an array of birdwatching gear
(e.g., binoculars, bird-callers, clothing) to use in their adventure. Then the dyads used
these tools to explore the lab, finding clues (e.g., feathers, eggs) that lead them to various
locations of birds. Lastly, the dyad retrieved the birds and brought them to a new garden
location with trees, flowers, birdhouses, and birdfeeders. The camping and ice-cream
shop events were set up in a similar fashion. Children were asked to recall these events 1
day or 1 week later. The few details that children recalled were the aspects of the events
that mothers talked about and children responded to either verbally or nonverbally (e.g.,
pointing). Therefore, future research should explore the influence of parental input,
particularly in terms of temporal concepts and event representations, on children’s
temporal representation abilities.

It is important to note that the relationship between language and temporal
representation held regardless of the language measure used in the current study; the
independent regression models with each individual language measures remained
significant (in the model with receptive grammar, the effect of age remained significant
in the final step). This suggests that it is not one specific language ability, but rather
verbal abilities in general that contributes the development of representational thought.
This is consistent with Bates’ (1998; Bates & Goodman, 1997) discussion of the
inseparability of grammar and the lexicon (i.e., that the same mechanisms used to acquire vocabulary are used to acquire grammar), a challenge to traditional linguistic nativism and grammatical autonomy (e.g., Chomsky, 1965). Bates suggests that “the heterogeneous set of linguistic forms that occur in any natural language (i.e., words, morphemes, phrase structure types) may be acquired and processed by a unified processing system, one that obeys a common set of activation and learning principles” (1997, p. 135).

The current findings also confirm those from the literature on language and theory of mind abilities. For example, a meta-analysis on young children’s understanding of false-belief explored the role of language in 104 studies (N = 8,891; Milligan et al., 2007). The meta-analysis explored language in terms of general language, receptive vocabulary, semantics, syntax, and memory for complements. Results indicated significant moderate effect sizes for each language aspect independent of age, suggesting that theory of mind skills are not reliant upon any particular aspect(s) of language, but rather language in general. This is contradictory to de Villier’s (2005) theory that false-belief understanding is contingent upon the child’s ability to master the grammar of complements. As such, future studies of temporal representation, particularly studies involving the prediction of behaviors or projection of the self into the future (abilities that draw on theory of mind skills), should incorporate additional measures of semantics and syntax in order to further disentangle the relationship between representation and language.
Limitations and Future Directions

This study adds to the literature demonstrating the developmental trends in temporal cognition (event ordering and time labeling), diachronic thinking, and behavioral prediction throughout middle childhood. These abilities, particularly those that require forward-ordering abilities, may be especially important in the study of the development of episodic foresight (i.e., the ability to imagine personal future events; Suddendorf & Corballis, 2007). When planning for future events, it is important, and necessary, to consider when the event will take place (Hudson & Mayhew, 2011). It is also likely that imagining possible future events may employ similar mechanisms to imagining (i.e., “re-living”) events from the past (Atance & O’Neill, 2001; Busby & Suddendorf, 2005; Suddendorf & Corballis, 1997; Tulving, 1985) and rely on general cognitive skills such as executive function and working memory (Ford, Driscoll, Shum, & Macaulay, 2012). Indeed, support for this theory comes from studies with individuals with episodic memory deficits. Research shows that these individuals present with difficulties imagining events that might happen in their personal future as well as recalling their personal past (Addis, Sacchetti, Ally, Budson, & Schacter, 2009; Addis, Wong, & Schacter, 2008; D’Argembeau, Raffard, & Van der Linden, 2008; Klein, Loftus, & Kihlstrom, 2002; Tulving, 1985).

This study did not incorporate measures of episodic memory or foresight, and therefore is limited in its ability to generalize the developmental improvements found in the current study to more “autonoetic” (i.e., the awareness of our existence and identity extending from the personal past through the present to the future) domains of temporal representation. Tulving (1972; 1985) suggests that the ability to travel through time and
represent events temporally is a function of the declarative memory system (e.g., it requires semantic knowledge of general temporal concepts and episodic knowledge on one’s personal experiences). For example, it is our semantic memory that allows us to recall the location and appearance of our childhood home, but it is our episodic memory that allows us to recall, and re-experience, the emotions and events during our first family Christmas in that home. Researchers (Mahr & Csibra, in press; Nelson, 1996) have proposed similar representational mechanisms of episodic memory development as those proposed for temporal understanding in general. Nelson’s experiential theory has been discussed at length in this dissertation and as such will not be revisited here; however, Mahr and Csibra (in press) offer a metarepresentational approach suggesting that episodic memory plays a generative role in communicative interaction. They draw a distinction between event memories and episodic memories. Both share the qualities of being quasi-experiential, event specific, and past-directed. However, event memories include more limited source information, are not located in subjective time, are not self-referential, are not always conscious, and do not have a narrative structure; whereas episodic memory is autonoetic and epistemically generative.

Future research should therefore explore differences in semantic temporal representation and episodic temporal representation during this time period (i.e., middle childhood). Research on other forms of temporal representation (i.e., event ordering, time labeling, diachronic thinking, predicting future behaviors, and episodic memory) has shown developmental trends throughout middle childhood regarding the ability to think about the past and future. Therefore, it would follow that similar trends would exist in episodic foresight abilities. Future event ordering may be especially important in the
study of the development of episodic foresight in that when planning for future events, it is important, and necessary, to consider when the event will take place (Hudson & Mayhew, 2011). Thinking about an event that will take place tomorrow may be different from thinking about an event that will take place next year.

An additional limitation to the present study is the somewhat small size of the sample for the number of analyses that were run. Future studies that use the same methods should collect data from a larger group of children in order to increase the chances of detecting small to moderate effects. Additionally, due to the vast variability in temporal representation abilities, researchers may want to include children encompassing a wider age range, from 5- to 12-years. This may be especially important in findings that use additional measures of diachronic thinking abilities, as Montangero and colleagues (Maurice-Naville & Montangero, 1992; Montangero et al., 1996; Pons & Montangero, 1999; Tryphon & Montangero, 1992) suggest that these skills continue to develop through the age of 12 years. Future studies may also wish to consider including a more diverse sample in terms of socioeconomic status. Flores (as cited in Nelson, 1996) found that Headstart children from homeless and poverty homes performed more poorly on sequencing tasks and temporal knowledge, indicating that poverty may influence MERs and temporal representation in general and should be explored further, particularly in regard to the effect of language on temporal skills.

Lastly, the present study focused on the relationship between language and temporal representation in typically developing, English-speaking children and thus is limited in its generalizability. Future research should explore the development of temporal representation in languages other than English and include a range of clinical
populations, particularly children with autism spectrum disorders. Autism spectrum disorder is characterized by impairments in social-communication and restricted interests and inflexible or repetitive behaviors (American Psychiatric Association, 2013); research with this population has also documented difficulties in theory of mind (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997), executive function (Hill, 2004), and language abilities (Tager-Flusberg, 1996). Difficulties in these domains may make it difficult for individuals with autism to project themselves forward and backward in time. Indeed, research has highlighted marked impairments in diachronic thinking (Boucher et al., 2007), episodic memory (Goldman, 2008; Goldman & DeNigris, 2015; Terret et al., 2013), and future thinking (Terret et al., 2013) among school-aged children with autism spectrum disorder. As the results of the current study suggest, language plays a critical role the development of temporal representation and therefore should be explored further among this clinical population.

**Conclusions**

This study examined the relationship between disparate measures of temporal representation that have emerged in the literature. Research has independently explored developments in temporal cognition (event ordering and time labeling), diachronic thinking, and behavioral prediction, but none to date have examined the relationship among these four abilities in connection to advances in language, nonverbal intelligence, and working memory. This study builds on prior work to explore the developmental trajectory of these representational skills through middle childhood, a time when children are attending school and experiencing dramatic gains in cognitive function. Results suggest that age-related developments in temporal representation are mediated by general
language abilities, a view that is consistent with Nelson’s (1996) view of language acquisition and children’s conceptualization of time. Given the importance of an advanced representation of time on one’s ability to effectively manage the demands of daily life, future work should explore the role that differences in temporal skills in middle childhood may play in self-regulation, academic development, and independent functioning.
APPENDIX A: PARENT/GUARDIAN QUESTIONNAIRE

A.
Child's Name: ____________________________________________ Age: ____________
Date of Birth: _______________ Home Phone Number: __________________________
School: ___________________________ Grade: ____________

Mother's Name: __________________________
Occupation: __________________________
Highest Level of Education: Less than High School/GED ______ High School/GED ______
Some College but No Degree ______ Associate’s Degree ______ Bachelor’s Degree ______
Master’s Degree ______ PhD ______ JD/MD ______ Prefer not to say ______

Father's Name: __________________________________________
Occupation: __________________________
Highest Level of Education: Less than High School/GED ______ High School/GED ______
Some College but No Degree ______ Associate’s Degree ______ Bachelor’s Degree ______
Master’s Degree ______ PhD ______ JD/MD ______ Prefer not to say ______

Race/Ethnicity (check as many as applicable)

☐ White/Caucasian
☐ Black/African American/Caribbean
☐ Hispanic/Latino/a
☐ Asian
☐ Middle Eastern
☐ Other: __________________________
B.

List as many different languages that are spoken at home (for example, English, French, Spanish, Patois, Arabic, etc.): ____________________  ____________________  ____________________  ____________________  ____________________  ____________________  ____________________  ____________________

What is your child’s primary language? ________________________________

What other languages does your child speak? ________________________________

Mother’s Primary Language: ________________________________

Other languages the mother speaks fluently: ________________________________

Father’s Primary Language: ________________________________

Other languages the father speaks fluently: ________________________________

Who are the people the child frequently interacts with (parents, siblings, grandparents, nanny, etc.)?

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<tr>
<th>Name</th>
<th>Age</th>
<th>Relationship</th>
<th>Language spoken</th>
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C.

Is your child's speech difficult to understand? No _____ Yes _____

(If YES, please explain) _________________________________________________

Do you think your child exhibits a language delay? No _____ Yes _____

(If YES, please explain)

_______________________________________________________________

(If YES, when did you first notice the language delay? ____________________________

Is there any history of the following in the family (check all that apply):

Speech/Language disorders _____ Hearing impairments _____ Learning disorders _____

(If YES, please explain)

_______________________________________________________________

Has your child been evaluated by or worked with any of the following? (check all that apply):

Ear Nose and Throat (ENT) Doctor ______ Neurologist ______ Psychologist ______

Speech Language Pathologist ______ Audiologist ______ Reading Specialist ______

Occupational Therapist ______ Physical Therapist ______ Other________________________

(If YES, please explain)

_______________________________________________________________

Do you think your child hears well? No _____ Yes _____

(If NO, please explain)

_______________________________________________________________
D.

Does your child exhibit any antisocial or socially inappropriate behaviors (for example, avoiding interactions, consistently playing alone, etc.)? No _____ Yes _____

(If YES, please explain)

Does your child exhibit any repetitive behaviors or self-stimulating behaviors (for example, rocking or arm flapping, etc.) for no apparent reason? No _____ Yes _____

(If YES, please explain)

Does your child maintain eye contact? No _____ Yes _____

(If NO, please explain)

E.

Can your child tell time? No _____ Yes _____

Does your child wear a watch? No _____ Yes, frequently _____ Yes, occasionally _____

Does your child use a calendar? No _____ Yes, frequently _____ Yes, occasionally _____

Does your child keep track of his/her own schedules and deadlines?

No _____ Yes, frequently _____ Yes, occasionally _____

Is there any information you would like to share with us to help us understand your child better?

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

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APPENDIX B: PARENT DEMOGRAPHIC INFORMATION

Parents’ demographic information. Frequencies reported (percentages in parentheses).

<table>
<thead>
<tr>
<th>Highest Level of Education</th>
<th>Mothers</th>
<th>Fathers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than a High School Degree</td>
<td>3 (5.1%)</td>
<td>4 (6.8%)</td>
</tr>
<tr>
<td>High School or GED</td>
<td>6 (10.2%)</td>
<td>12 (20.3%)</td>
</tr>
<tr>
<td>Associate’s Degree</td>
<td>5 (8.5%)</td>
<td>3 (5.1%)</td>
</tr>
<tr>
<td>Some College but no Degree</td>
<td>8 (13.6%)</td>
<td>3 (5.1%)</td>
</tr>
<tr>
<td>Bachelor's Degree</td>
<td>16 (27.1%)</td>
<td>18 (30.5%)</td>
</tr>
<tr>
<td>Master's Degree</td>
<td>15 (25.4%)</td>
<td>12 (20.3%)</td>
</tr>
<tr>
<td>PhD</td>
<td>5 (8.5%)</td>
<td>3 (5.1%)</td>
</tr>
<tr>
<td>MD/JD</td>
<td>0</td>
<td>1 (1.7%)</td>
</tr>
<tr>
<td>Prefer not to say</td>
<td>1 (1.7%)</td>
<td>4 (6.8%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Primary Language</th>
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<tbody>
<tr>
<td>English</td>
<td>44 (74.6%)</td>
</tr>
<tr>
<td>Other</td>
<td>15 (25.4%)</td>
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<tr>
<td>NA</td>
<td>—</td>
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</tbody>
</table>

Note: Out of the 62 children in the study, 59 parents responded to the parent/guardian questionnaire.
APPENDIX C: PARENTAL REPORT OF CHILD LANGUAGE ABILITIES

Frequencies reported (percentages in parentheses).

<table>
<thead>
<tr>
<th></th>
<th>Speech Difficult to Understand</th>
<th>Speech Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>56 (94.9%)</td>
<td>55 (93.2%)</td>
</tr>
<tr>
<td>Yes</td>
<td>3 (5.1%)</td>
<td>4 (6.8%)</td>
</tr>
</tbody>
</table>

Note: All children reported here (n = 59) met clinical cut-offs for language disorders on all standardized language assessments and were therefore included in all analyses.
REFERENCES


Brown, L., Sherbenou, R. J., & Johnsen, S. K. (1997). *Test of Nonverbal Intelligence (3rd Ed.)*. Austin, TX: PRO-ED.


