WESTOVER, AMBER E. M.S. Cognition in Kindergarten: The Role of Children's Metamemory and Teachers' Instructional Language. (2022)
Directed by Dr. Jennifer L. Coffman. 83 pp.

Over the course of the early elementary school years, children evidence significant improvements in their emerging memory and mathematical skills (Geary, 2006; Ornstein et al., 2008). However, researchers have primarily documented age-related changes rather than explore the developmental forces responsible for growth in these domains (Ornstein & Haden, 2001). Results from studies on metacognition indicate that metamemory may contribute to these developing cognitive abilities (Bellon et al., 2019; Fabricius & Hagen, 1984). In addition, research on adult-child conversations in the home (Fivush et al., 2006) and classroom settings (Chapin et al., 2009) links adult language to children's cognitive outcomes. Using data from the first cohort of children enrolled in an ongoing investigation, this study was designed to examine simultaneously the role of children's metamemory and teachers' instructional language on early cognitive skills. Children were assessed using a deliberate memory task and a standardized mathematics assessment at both the beginning and end of the Kindergarten year. Multiple regression models were used to assess whether children's metamemory or teachers' use of metacognitively rich language predicted strategic sorting behaviors or mathematical fluency at either time point. The analyses revealed that metamemory at school entry is predictive of mathematical fluency at the beginning of Kindergarten. However, metamemory was not a significant predictor of strategic sorting at either time point (beginning or end of the school year). Contrary to the hypothesized results, teachers' language was not predictive of either strategic sorting or mathematical fluency in Kindergarten. The findings from this study offer support for the importance of examining child- and classroom-level factors that may be associated with growing memory and mathematical skills. Additionally, they provide a groundwork for future

research. Specifically, the results suggest the need for understanding when exposure to metacognitively rich language is most beneficial for children, the role of child-level factors, and what other contextual influences may contribute to the development of these cognitive skills.

COGNITION IN KINDERGARTEN: THE ROLE OF CHILDREN'S METAMEMORY AND TEACHERS' INSTRUCTIONAL LANGUAGE

by

Amber E. Westover

A Thesis

Submitted to

the Faculty of The Graduate School at

The University of North Carolina at Greensboro

in Partial Fulfillment

of the Requirements for the Degree

Master of Science

Greensboro

2022

Approved by

Dr. Jennifer L. Coffman
Committee Chair

APPROVAL PAGE

This thesis written by Amber E. Westover has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

Committee Chair ____________________________
Dr. Jennifer L. Coffman

Committee Members ____________________________
Dr. Linda L. Hestenes

____
Dr. Karen M. La Paro

April 3, 2022

Date of Acceptance by Committee

April 14, 2022

Date of Final Oral Examination

ACKNOWLEDGEMENTS

Firstly, I would like to thank my advisor, Dr. Jennifer Coffman, for her invaluable feedback and support during this process. Your guidance and encouragement were instrumental to my successful completion of this thesis. I would also like to thank my committee members, Dr. Linda Hestenes and Dr. Karen La Paro, for their advice, insightful questions, and assistance.

A special thanks to all the members of the Cognition in Context Laboratory at UNCG and research assistants involved in the Classroom Memory Study. Specifically, I would like to acknowledge KellyAnn Bonanno for all her prompt responses, assistance gathering information, and guidance organizing data. I would also like to thank Olivia Cook for her diligent work helping code endless hours of teacher observations. This study would have not been possible without the teachers, parents, and children who agreed to participate in this study. This research was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A170637 to the University of North Carolina at Greensboro.

Finally, I would like to thank my wonderful cohort and family for their endless emotional support. I could not have finished this without all of you!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: INTRODUCTION

A vast body of literature documents children's growing cognitive abilities. Two fields of research have received particular attention in the last few decades – memory and mathematics (Cross et al., 2009; Ornstein et al., 2008; Schneider & Bjorklund, 1998). Children's developing skills in these domains evidence significant growth across the elementary school years (Geary, 2006; Ornstein et al., 2008; Ornstein & Haden, 2001). This is particularly apparent in improvements to children's use of active strategies for remembering information and solving mathematics problems (Ornstein et al., 1988; Ornstein et al., 2006; Siegler, 1987; Siegler & Robinson, 1982). As students progress throughout school, they learn to use deliberate memory strategies more effectively and improve their recall performance (Folds et al., 1990). Similarly, their arithmetic accuracy and fluency increase (Siegler 1987; Siegler & Robinson, 1982). The current literature predominately focuses on characterizing different levels of competency and documenting age-related changes in these early cognitive skills. Less research has focused on the factors underlying these developmental improvements (Ornstein & Haden, 2001; Haden, 2021). In this investigation, children's metamemory and teachers' instructional language during mathematics lessons are examined as potential predictors of students' performance on memory and mathematics assessments.

Students bring a wide range of individual knowledge and cognitive skills to the classroom. Past studies link metacognitive understanding to both memory and mathematics outcomes (e.g., Bellon et al., 2019; Fabricius & Hagen, 1984). However, little is known about the role of students' knowledge of memory processes (metamemory) in predicting memory and mathematics performance. Child and classroom factors simultaneously influence development.

Therefore, it is critical to examine what children bring to the classroom in conjunction with influential forces in the early elementary school environment.

The socialization of cognition perspective (Rogoff, 1990; Fivush, 2011) incorporates aspects of both information processing and sociocultural theories (Ornstein & Haden, 2001). This framework provides a lens to examine the role of social forces in the acquisition of strategic cognitive skills. Research on autobiographical memory development directs attention to adult-child interactions as one possible mechanism for memory changes (Ornstein et al., 2006). Children's growth in autobiographical memory skills is linked to shared parent-child conversations about past experiences (see Fivush et al., 2006 for a review). These findings underscore the importance of language exchanges in cognitive development.

Educational research on mathematics instruction further emphasizes the role of adult language in student outcomes (Chapin et al., 2009; Engel et al., 2013; Klibanoff et al., 2006; Rudd et al., 2008). Numerous studies document the importance of the amount, focus, and level of complexity of mathematical discourse in elementary school classrooms. Although these findings suggest the significance of examining teacher-led instruction, this body of literature fails to explain precisely which aspects of instructional language during mathematics lessons are related to children's growing skills. Similar questions arise in the memory literature. Despite evidence of children's improving memory abilities while attending formal schooling, classroom observations failed to capture teachers directly teaching students about memory (Moely et al., 1992). As a result, there is a need to understand what teachers are doing that supports students' cognitive processing in the domains of memory and mathematics.

Recent research indicates that metacognitively rich aspects of teachers' language during instruction correlate with improvements in students' deliberate memory strategy use and mathematical competencies (for a review, see Coffman & Cook, 2021; Hudson et al., 2021). Both longitudinal and experimental studies have supported these findings (see Coffman et al., 2008; Grammer et al., 2013; Hudson et al., 2018). Despite evidence to suggest positive associations between teachers' use of metacognitively rich language and children's memory performance, many questions remain about these relations (Ornstein & Coffman, 2020). Specifically, there is a need to understand (1) the role of child-level factors in performance, (2) what about these early learning environments is beneficial, and (3) the significance of timing in both child-level and contextual factors.

Furthermore, the majority of this work has focused on the early elementary school experience. Past studies have examined predominately the first-grade school year based on cut-off studies comparing deliberate memory skills in similar-aged children in Kindergarten and first grade (see, for example, Morrison & Dow-Ehrensberger, 1995). Evidence from Morrison et al. (1995) suggested the particular importance of first grade in cognitive outcomes. However, additional information is needed about the timing and nature of these educational experiences. This study is designed to examine the role of both children's metamemory knowledge and teachers' instructional language in children's developing cognitive skills across the Kindergarten year.

Theoretical Framework

This study is grounded in two theoretical frameworks – information processing (Baker-Ward & Ornstein, 2014; Brown & Craik, 2000; Goldhaber, 2000) and sociocultural (Gauvain, 2001; Rogoff, 1990; Vygotsky, 1978). These theories work together to create a foundation for exploring the growth in children's cognitive processes (learning, remembering, and using strategies) while also heeding the importance of social forces in shaping development (see

Ornstein & Haden, 2001). Researchers have used information processing and sociocultural theories separately in the memory and mathematics literatures (see Baker-Ward & Ornstein, 2014; Ornstein & Haden, 2001; Pellegrino & Goldman, 1987; Steffe et al., 2013; Van Oers, 1990). However, only recently have the two been combined in order to better understand how interactions between children and adults can influence cognition (Ornstein & Haden, 2001).

Information Processing Theories

Information processing theories of cognition (Baker-Ward & Ornstein, 2014) have predominately influenced the existing body of research on memory development. As this framework gained popularity in the 1960s, there was a corresponding surge in publications concerning children's memory. According to information processing theorists, the human mind acts as a processing system similar to a computer (Brown & Craik, 2000). Atkinson and Shiffrin (1968) proposed a model of memory comprising three structural components. The sensory register receives incoming data and stores it briefly before near-immediate decay. Long-term memory is a relatively permanent store for information. Meanwhile, short-term memory (i.e., working memory) receives input from the other two components. Information passes from the sensory register to the short-term memory, where it subsists for approximately 30 seconds before being lost. However, small amounts of information may be retained in this store through a process of rehearsal, repeating the data verbally to prolong decay (Atkinson & Shiffrin, 1968; Craik & Lockhart, 1972).

Data may also transfer from the short-term store to the long-term store for indefinite storage (Atkinson & Shiffrin, 1968). Likewise, information can flow from long-term to short-term memory for conscious access. However, the short-term memory store has a limited capacity (Craik & Lockhart, 1972; Miller, 1956). The flow of information between these stores, specifically transfer into long-term memory, is largely under the deliberate control of the individual (Atkinson & Shiffrin, 1968). Control processes, such as mnemonic or memory strategies, can aid in both storage (encoding) of information and its subsequent retrieval from long-term memory. Memory performance is primarily a function of effective processing, encoding, and strategy use (Brown & Craik, 2000; Craik & Lockhart, 1972; Pressley et al., 1989).

For example, Miller (1956) reports that the short-term memory store has a finite span allowing for the immediate processing of approximately seven units of information at one time. To increase the amount of data that is remembered and processed, individuals may organize information into groups. Building larger chunks of information allows for greater data storage within the constraints of finite stores (Atkinson & Shiffrin, 1968; Miller, 1956). Using grouping strategies while learning and trying to recall study materials may increase memory functioning. Similarly, according to information processing theories, retention of information is also a function of the depth of initial analysis (Craik & Lockhart, 1972). Once the sensory register identifies a stimulus, that information may experience increased processing through elaboration (e.g., making connections with other past knowledge or experiences). The type of encoding process can affect how long items last in memory stores and how accessible they are for retrieval.

Educational scholars have also used this theoretical framework to explore and explain children's growing mathematical understanding and abilities (Geary, 2006; Pellegrino & Goldman, 1987; Van Oers, 1990). Fundamental to successful performance on mathematics tasks is knowledge of rules or facts and procedures for solving problems (Pellegrino & Goldman, 1987). Information processing theories direct attention to not only children's breadth of mathematical knowledge, but how this information is organized, stored, and retrieved. Using this framework, differences in adults' mathematical fluency performance are attributed to how effectively individuals can activate and retrieve information from long-term memory stores. Moreover, deeper encoding (stronger associations during storage) leads to more rapid recollection of facts. However, young children often rely on strategies to calculate basic addition and subtraction problems. Through a similar process of activating knowledge stores, they can call upon previously learned counting procedures and addition strategies to solve arithmetic problems. According to Pressley (1986), children need to be able to process the information presented in a new mathematics problem and coordinate it with previous knowledge and their repertoire of strategies. Effective strategy users manage various stores of knowledge.

This theoretical framework provides a groundwork for understanding how memory processes function, why deliberate memory strategies are effective, and how these skills may improve children's memory performance. Additionally, it offers a structure for understanding and explaining differences in children's mathematical competencies. The successful retrieval of basic mathematics facts and problem-solving procedures is necessary for accurately solving equations. Despite the strengths of this framework, it offers little insight into the external factors that influence the development of these memory and mathematical skills.

Mechanistic and Contextualist Worldviews

Information processing theories primarily use a *mechanistic* worldview (Baker-Ward & Ornstein, 2014; Goldhaber, 2000). This perspective focuses on quantifiable variables and reducing behaviors to basic elements (Goldhaber, 2000). It relies on the belief that behavior is universal and classifiable. This is evident in a large portion of laboratory-based memory research (Baker-Ward & Ornstein, 2014). In contrast, the *contextualist* worldview posits that behavior is dependent on circumstances and context (Goldhaber, 2000). This perspective supports a holistic approach to analyzing human behaviors. Human development is situated in social and historical contexts and cannot be analyzed outside these situations. Many field-based studies are grounded in this worldview (Baker-Ward & Ornstein, 2014). Ornstein and Haden (2001) urge researchers to study the development of memory in its naturally occurring social contexts, congruent with a contextualist worldview.

Sociocultural Theory

Sociocultural theory provides a framework to examine development in context, specifically exploring social and cultural exchanges. According to this theory, social contexts have the power to shape cognitive processes (Vygotsky, 1978). Interactions with other members of society serve as a mechanism for cognitive growth and the development of higher-order thinking patterns (Gauvain, 2001; Rogoff, 1990; Vygotsky, 1978). Children engage in various cultural activities and through these exchanges learn about and practice thinking (Gauvain, 1998). They develop skills such as focusing attention, planning, and remembering (Gauvain, 2001). Social contexts both influence what children think about and how they think about these subjects, leading to the socialization of cognition (Gauvain & Perez, 2015). Moreover, culture determines which cognitive skills are valued, what is passed on to younger members of society, and which types of interactions or social structures are used (Fivush, 2011).

Through working with older individuals or more knowledgeable peers, children actively solve problems in the service of culturally relevant goals (Rogoff, 1990). This guided participation increases what a child is capable of learning independently (*zone of proximal development*; Rogoff, 1990; Vygotsky, 1978). A child's developmental potential increases through scaffolded social interactions. As children develop, they receive more cognitive responsibility and internalize mental processes. These interactions may occur through family settings, contact with peers, and formal schooling experiences (Gauvain & Perez, 2015).

One critical element in these social exchanges is language. Children initially experience this cultural tool through interpersonal interactions (Vygotsky, 1978). Thought and language skills develop along parallel lines during infancy until around age two. At this time, the two intermingle, leading to language shaping thought and thought shaping language. The type and way in which societies use language is fundamental to the outcomes of guided participation (Rogoff, 1990).

For example, autobiographical memory is a culturally specific activity and provides the structure for individuals to talk about their lives (Fivush, 2011; Fivush, 2019). Through discussions about the past children develop a sense of time, link events, and acquire a concept of self (Nelson & Fivush, 2004). Development of narrative language emerges through social interactions and reminiscing conversations with adults (Fivush, 2011; Fivush, 2019; Nelson & Fivush, 2004). Classroom instruction is another social process that provides opportunities for language encounters (Gauvain & Perez, 2015). School, like parent-child conversations, creates a structure for transferring knowledge from more experienced to less experienced members of society.

The proposed study uses a combination of information processing and sociocultural theories to examine children in social contexts, following the recommendations of Ornstein and Haden (2001). Information processing theories offer a foundation for understanding memory processes and the function of deliberate memory strategies. In addition, they provide a basis for understanding how mental processing contributes to mathematics performance. However, a contextualist perspective supplements this to include the examining of individuals within their environments, specifically the cultural interactions responsible for development. Sociocultural theory provides theoretical foundations for exploring the social forces that may shape development, specifically children's exposure to teachers' language. Together, these theories create a framework for exploring how early elementary school classrooms contribute to children's developing cognitive skills.

Literature Review

The following sections outline foundational research from the memory and mathematics literatures. First, age-related changes in strategy use and performance on deliberate memory and mathematics tasks are described. This review provides a groundwork for understanding developmental patterns during the early elementary school years. It is followed by a description of metamemory, a child-level factor, and an explanation of its relevance to both memory and mathematics performance. Next, there is a discussion of contextual factors that shape the development of these cognitive skills, specifically language exchanges between children and adults. This includes a review of the current body of literature on the role of teachers' instructional language in memory and mathematics growth. Finally, the research questions and aims of the current study are outlined.

Deliberate Memory Skills

A vast body of research explores changes in children's memory over time (for a review, see Ornstein et al., 2008). Researchers have paid particular attention to children's deliberate memory skills (Schneider & Bjorklund, 1998). These skills include a range of conscious strategies employed by individuals in the service of remembering (Pressley & Van Meter, 1993). The extant research has primarily focused on encoding strategies (used while working to remember) such as rehearsal, organization, and elaboration (Schneider & Bjorklund, 1998).

However, studies have also investigated strategies used while retrieving previously stored information (e.g., during recall). Rehearsal involves verbally repeating to-be-remembered items, facilitating the transfer of material from the short-term to the long-term memory (Ornstein & Naus, 1978). The second major strategy – organization – can happen during encoding (typically studied as categorical sorting) or recall (examined as clustering; Lange, 1978). Information is studied and stored in groups (e.g., categories) rather than as single units. Finally, elaborations involve pairing two objects through a relationship (e.g., relating new information to prior knowledge; Rohwer, 1973). Effective use of these mnemonic strategies has been linked to improved recall as children age (Lange, 1978; Ornstein & Naus, 1978; Rohwer, 1973). Researchers also report associations between strategic behaviors during the early elementary school years and more advanced study skills in later grades (Coffman et al., 2018).

Young children can intentionally use strategies in the presence of conscious memory goals (Ornstein & Haden, 2001). DeLoache et al. (1985) found that when presented with a memory demand (e.g., asked to find a hidden toy during a hide-and-seek game) children under the age of 2 engaged in more strategic behaviors (e.g., verbalizing, pointing, attempting to retrieve) than in the absence of a memory demand. Similarly, Baker-Ward et al. (1984) reported behavioral differences in how children ages 4 to 6 interacted with a group of 15 objects based on memory instructions. Children who were told to remember a subset of 5 items spent less time playing with the objects than those instructed to play with the items. Despite evidence of strategic behaviors in preschool-aged children, these actions are not often linked to improved memory performance in this age group (Schneider & Bjorklund, 1998).

Age-Related Changes in Deliberate Memory Strategy Use

The effectiveness of these strategic efforts, manifested as increased recall, improves with age (Folds et al., 1990). This is evident in both changes to the type of strategic behaviors used and in more effective deployment of identical processes. Sodian and Schneider (1999) conducted a longitudinal study of children ages 4 to 12. Notably, children rarely followed a linear trajectory in their deliberate memory skills growth, rather findings suggest rises and falls in strategy use over time. By age 8, recall and strategy use were moderately to highly correlated. Moreover, in children over 8, the best predictor for improved recall was strategic behaviors. During the early elementary school years, increased organizational efforts did not necessarily correlate with improved recall. At school entry, strategy use is often contingent on the demands of the task itself (e.g., sorting high- versus low-associated items; Ornstein et al., 1988; Sodian & Schneider, 1999). However, the time between ages 6 and 8 appears to be an important transitional period in strategy development (Sodian & Schneider, 1999). As children progress in their mnemonic competence, they learn to generalize strategies across settings, rely less on the demands of specific tasks, and consistently achieve improved recall (Ornstein et al., 1988). Eventually, these processes become automatic and routinely effective.

These age-related improvements are evident across the three main deliberate memory strategies – rehearsal, elaboration, and organization (Bjorklund et al., 1977; Ornstein et al., 1975; Ornstein et al., 1977; Ornstein & Naus 1978; Rohwer, 1973). For example, Bjorklund and colleagues (1977) examined age-related changes in children's performance on a sort-recall task. Children were given a list of words that could be grouped into related categories. Recall improved both with age and with more advanced sorting styles among third-, fifth-, and seventh-grade students. Older students created more taxonomically related categorical groups. Younger children are more likely to use clustering (grouping during recall) with strongly associated items, easily grouped into distinct categories (Lange, 1978). Yet with increased age, older children recognize more adult-defined categories and spontaneously search for conceptual groups while studying materials.

This body of research documents age-related changes in children's use of deliberate memory strategies across childhood. The early elementary school years are an important time for growth in cognitive skills. While domain-general skills, such as using memory strategies, are improving domain-specific skills, such as mathematical proficiency, also emerge and develop.

Early Mathematical Skills

Over the last hundred years, researchers have explored actively children's knowledge of mathematical concepts and ability to solve arithmetic problems (Geary, 2006). Several key areas have received particular attention: speed and accuracy in problem solving, strategy use, factors influencing learning, and the role of teaching in the growth of specific mathematical skills. In recent years, mathematical fluency has been identified as a key component of mathematical proficiency that is necessary for students to compete in the global marketplace (Clarke et al., 2016).

Mathematical fluency extends beyond the rapid recall of simple mathematics facts (Baroody, 2011). It also involves remembering procedures and being able to implement them effectively in the service of solving problems. Therefore, mathematical fluency is the ability to both accurately remember previously stored mathematics facts and to use strategies to solve equations that are not memorized. Development of this competency lays the foundation for more complex mathematical problem-solving skills and comprehension of higher-order concepts (Clarke et al., 2016).

Age-Related Changes in Mathematical Fluency and Strategy Use

During early childhood and elementary school, children use a variety of strategies to solve basic addition and subtraction problems. Two common procedural strategies in addition involve counting (Siegler, 1987). Children may start from 1 and count up both addends to achieve the sum (counting all; e.g., in the problem 3+6, start at 1 and count up to 9) or start from the larger addend (min strategy; e.g., in the problem 3+6, start at 6 and count up 3 to 9). A more complex strategy known as decomposition consists of using a known or simpler problem to derive an answer (e.g., using the double fact 4+4=8 to solve 4+5=9). Guessing and recalling memorized mathematics facts (retrieval) are also used frequently. Early research indicates that children initially rely on procedural strategies (e.g., counting all or decomposition) and progress to relying more heavily on retrieval as they age (Ashcraft, 1982; Groen & Parkman, 1972). An experiment by Siegler (1987), found that the use of retrieval increased across the early elementary school years. Kindergarteners only used retrieval to solve 16% of a set of addition problems, while first graders and second graders relied on previously stores facts much more frequently (44% and 45% respectively). Speed also increased as children transitioned to using faster strategies (e.g., decomposition compared to counting all).

Additional research reveals there is not a distinct linear progression from lower-order to higher-order strategies (Siegler, 1987; Siegler, 1996; Siegler & Robinson, 1982). When Kindergarten through second-grade children were asked how they solved addition problems, their answers indicated variety and flexibility (Siegler, 1987). Children use different strategies across problems (Kerman & Siegler, 1997; Siegler & Robinson, 1982). Siegler (1996) proposed an overlapping waves model of strategy use. Children rely on both old and new strategies simultaneously. The frequency of certain strategies decreases over time as new strategies are learned and added to a child's repertoire.

Similar to age-related improvements in recall performance, as children progress throughout the early elementary school years their ability to solve mathematics problems accurately increases. When Siegler and Robinson (1982) presented 3-, 4-, and 5-year-old children with a series of addition problems the percentage of correct answers increased with age. The 3-year-old children solved 20% of the addition problems correctly, compared to 66% by 4-year-olds, and 79% by 5-year-olds. Comparable results were found among school-age children. When Kindergarten through second-grade students were asked to solve 45 addition problems over several days, Kindergarten students produced errors on approximately half of the problems (51%; Siegler, 1987). Meanwhile, the error rate for first graders drastically dropped (13%) and continued to decrease among second-grade students (5%). Thus, with age and experience, children advance in their effective use of strategies and ability to solve mathematics problems accurately and fluently.

Additional Influences on Memory and Mathematical Skills

As outlined above, significant growth occurs in the domains of memory and mathematics during the early elementary school years. However, children's developing skills are related to additional factors beyond maturation and school experiences. Schneider and Bjorklund (1998) identify six elements related to strategic memory performance (1) metamemory (2) developmental differences in storage capacity (3) knowledge base (4) environmental or contextual factors (5) motivation (6) general intelligence. Similarly, Pressley and colleagues (1989) acknowledge that effective strategy use (across domains) requires more than just efficient implementation of procedural information but also includes metacognitive knowledge.

Verschaffel (1999) specifically emphasizes the importance of metacognition in mathematics problem-solving.

Children have a range of experiences at school that shape growth. However, they also enter the classroom with vastly different levels of metacognitive knowledge. Therefore, it is imperative to consider both child-level and environmental factors that may influence development during childhood. This study will specifically focus on the role of metamemory and contextual influences on memory and mathematical skills during Kindergarten.

Metamemory

Metacognition refers broadly to an array of knowledge, skills, or experiences related to cognitive activities (for a review, see Schneider, 2008). This includes regulatory or monitoring processes, understanding of cognitive tasks, and knowledge about strategies used in the service of meeting mental demands. Flavell (1971) used the term *metamemory* to describe a component of metacognition related to a person's knowledge of their own memory. This is composed of two specific types of understanding (Schneider, 1985). The *sensitivity* component (i.e., procedural metamemory) refers to an individual's ability to self-monitor, control, and regulate memory performance (Flavell & Wellman, 1977; Schneider, 1985; Schneider, 2008). The *variable* component (declarative metamemory) consists of a person's understanding of their own memory capacity, awareness that task demands can alter performance, and knowledge about memory strategies.

Similar to emerging deliberate memory and mathematical skills, metacognitive understanding increases over the elementary school years (Roebers, 2014). Aspects of declarative metamemory are evident in preschool-aged children and continue to grow across childhood and throughout adolescence (Schneider, 2008). Children in Kindergarten and first grade understand basic concepts related to memory abilities (e.g., remembering or forgetting), the importance of study time, have some knowledge of differences between memory tasks, and can describe potential strategic behaviors (Kreutzer et al., 1975). Across the latter elementary school years, this knowledge is refined and enhanced. Children begin to understand more nuanced aspects of memory strategies, differential task demands, and connections between to-be-remembered items. Metamemory for more complex tasks, such as reading comprehension strategies, continues to develop during the adolescent years (Roebers, 2014).

Grammer and colleagues (2011) explored the timing of metamemory development and children's use of strategic behaviors across the first-grade school year. They created models to explore whether metamemory and deliberate memory strategy use develop simultaneously or if one factor precedes the other. Metamemory predicted later strategy use on deliberate memory tasks across first and into second grade. Notably, findings from their data suggest a time-lagged association between metamemory and strategic behaviors, with metamemory preceding strategy use. These findings are corroborated by a microgenetic study conducted by Schlagmüller and Schneider (2002). In an examination of 8- to 12-year-old children, declarative metamemory preceded strategy use. Some children displayed knowledge of the importance of organizational strategies as early as 6 months prior to adopting sorting behaviors. Metamemory and deliberate memory strategy skills develop during the early elementary school years, however these studies indicate metamemory knowledge progresses in advance of behavior.

Roebers (2014) further emphasizes the importance of metamemory on strategic memory behaviors. Fabricius and Hagen (1984) conducted a study of first and second graders. Children engaged in two sort-recall tasks and were asked about their strategy use. Children who attributed recall performance to sorting behaviors displayed increased use of sorting over rehearsal strategies. Similarly, sorting related to increased clustering during recall and better memory performance. Understanding the connection between memory strategies and greater recall may positively contribute to children's use of organizational strategies. Researchers have also found connections between children's awareness of their own strategic behaviors and strategy use. Bjorklund and Zeman (1982) found that across first, third, and fifth graders, children who correctly identified their utilized strategy, while remembering classmate names, had higher clustering scores than those who inaccurately described their strategy use.

Metamemory may also be important for strategy uptake, transfer, and generalization. Cornoldi and colleagues (1991) examined strategy use and performance between first graders with either low or high levels of metamemory. Notably, when given strategy promptings both groups improved performance. However, only the children with high levels of metamemory were able to transfer the strategic behavior to a similar task. Cavanaugh and Borkowski (1979) found positive correlations between third-grade students' initial metamemory and maintenance of a learned rehearsal strategy two weeks after training. Weed et al. (1990) also found that metamemory was important for generalization and maintenance of strategic training in fourth graders' performance on a free recall task.

Metamemory has also been linked to memory recall. Schneider and Sodian (1988) reported correlations between metamemory, strategic behaviors, and recall among four- and six-year-old children. Children received instruction on how to use retrieval cues to find hidden objects. The majority of four-year-old subjects were able to articulate the usefulness of retrieval cues in finding hidden objects, with approximately half providing rationales for the effectiveness of using this strategy. The six-year-olds gave a greater number of justifications. Additionally, recall was associated with strategic behaviors prior to recall and the quantity of metamemory justifications provided for both groups. Schneider et al. (1998) reported contributions of declarative metamemory to recall even in situations including tasks dependent on content knowledge. In a content-specific task (focused on soccer terms), metamemory affected recall through strategic behaviors. In a general memory task, metamemory had direct effects on strategic behaviors and recall (though modest). However, the indirect effect of metamemory on recall, through strategy use, was considerable. Therefore, one pathway that metamemory may improve recall performance is through increasing strategic behaviors.

Less is known about direct links between metamemory and mathematics performance. However, researchers have examined associations between numerous components of procedural and declarative metacognitive knowledge and achievement on mathematics assessments (Schneider & Artelt, 2010). For example, Bellon and colleagues (2019) found that second graders' general metacognitive knowledge (including metamemory components) was associated with response times in addition problems, in so much that higher levels of knowledge correlated with faster performance. A limited number of studies also document associations between metacognitive knowledge and strategy use during mathematics tasks. Carr and colleagues (1994) examined second-grade children's strategy use while solving addition, subtraction, counting, and basic calculation problems. Additionally, the researchers asked the students mathematics-specific metacognitive questions. Their analyses revealed that metacognitive knowledge was correlated with the accurate use of internal strategies (e.g., counting in head). However, the association was not significant for well-known strategies (e.g., counting on fingers). This study, along with subsequent research (see Carr & Jessup, 1995) indicates that metacognition may be especially significant for new and developing strategies.

During the early elementary school years, children show variability in metacognitive understanding at school entry. Both child-level factors and aspects of the home environment predict metamemory at the beginning of first grade (Grammer et al., 2011). Specifically, the home literacy environment (maternal education and reading experiences in the home context), working memory, and child age predict initial metamemory levels. A study of German and American second graders also found that children's metacognitive understanding was related to strategy instruction received at home by parents through teaching and other activities (Carr et al., 1989). Therefore, when children enter the formal school setting, they bring differential levels of metamemory knowledge potentially contributing to their acquisition and use of strategic behaviors.

Past research on metacognition, specifically metamemory, indicates its vital role in growing memory and mathematical skills. However, there is little research examining metamemory simultaneously with aspects of the classroom environment – more specifically – whether metamemory at school entry can predict initial performance levels or continues to contribute to development across the school year. To better understand children's growing cognitive skills it is crucial to examine this child-level factor in conjunction with environmental influences.

Social Influences on Memory and Mathematics Development

Despite a vast amount of research that examines age-related changes in children's memory and mathematical abilities, large gaps remain in our existing knowledge. Little is known about the developmental mechanisms responsible for these changes. In the memory literature, Ornstein and Haden (2001) distinguish between "memory development" and the "development of memory" and call for researchers to investigate processes contributing to age-related improvements. Only a few studies have explored the role of metamemory and other child-level factors in the acquisition of these cognitive skills. Even less is known about the contextual factors influencing the development of memory and mathematical skills. Ornstein and Haden (2001) further emphasize the importance of longitudinal work in understanding the influence of contextual forces over time.

Studies conducted in the home and school settings provide insight into social forces that may influence the growth of these skills. Sociocultural theories direct attention specifically to language exchanges between adults and children (Vygotsky, 1978). Parallel lines of research in the fields of memory and mathematics indicate that language used in the home and elementary school classrooms may be associated with both children's developing mathematical and basic memory skills (Coffman et al., 2008; Klibanoff et al., 2006).

Research on autobiographical memory provides a groundwork for understanding the role of social forces on cognitive development (Ornstein et al., 2006). Both event and strategic memory rely on underlying processes of encoding, storage, and retrieval of information. Children must transfer information into long-term memory stores and successfully retrieve it when requested. This process is used to recall both basic memory and academic information. Contextual factors that contribute to the development of autobiographical memory may similarly benefit children's skills while working to remember in deliberate memory and mathematics-specific tasks.

Parent-Child Reminiscing

Using a sociocultural framework, researchers examined individual differences in maternal reminiscing style while mothers discussed shared past experiences with their children (for a review, see Fivush et al., 2006). Reese et al. (1993) asked mothers to select three unique past events to discuss with their 40-month-old children. These conversations were coded for mothers' use of elaborations (introducing a new event or aspect of the event, or adding information), repetitions, evaluations, associative talk (making connections), and metamemory comments (discussing the process of remembering). Children of high-elaborative mothers (those providing more elaborations relative to repetitions) provided more memory responses 1.5 and 2.5 years later. Similarly, Langely et al. (2017) found that maternal reminiscing style (composed of average elaborations, associative talk, confirmations, and metamemory talk scores) was correlated with children's autobiographical recall at ages 3, 5, and 6. Moreover, maternal style was associated with children's recall performance and use of deliberate memory strategies at age 3. Specifically, children with high-elaborative mothers remembered more objects on an object memory task than those with low-elaborative mothers.

Parent-child conversations during shared events were also associated with autobiographical recall and deliberate memory task performance (Haden et al., 2001). Mothers and children engaged in an imaginary play activity (e.g., taking a camping trip). Joint talk during these events was associated with children's recall of the experience 3 weeks later. Moreover, recall in these events was positively correlated with the number of objects children recalled on a deliberate object memory task. Parental conversations that support autobiographic memory development may similarly benefit deliberate memory performance.

Furthermore, children's participation in reminiscing conversations is also linked to early academic abilities. Cristofaro and Tamis-LeMonda (2012) examined the relationship between mothers' narrative prompts during reminiscing conversations and children's school readiness. These prompts (in contrast to statements) include incidences where the mother encouraged the child to remember and discuss critical aspects of the shared past experience (e.g., event, description, setting, evaluation, participant, and appendage). Maternal narrative prompts were linked to pre-Kindergarten children's independent contributions to the reminiscing discussion. These independent contributions in turn predicted school readiness, including students' ability to analyze and solve mathematics problems. Therefore, the conversational processes that support children's development of memory skills may also be linked to mathematics performance.

This literature demonstrates the significance of adult-child language interactions in the growth of children's autobiographical memory skills and links between event and strategic memory (Ornstein et al., 2006). Parent-child reminiscing conversations illustrate the importance of examining memory development in social contexts and long-term associations between adult language and children's deliberate memory performance. Moreover, parallel skills, such as academic readiness, may also be related to these interactions. However, the home environment is not the only salient context for development. The school has also been shown to be an important setting for cognitive growth.

The School as a Context for Development

A large body of literature documents associations between schooling experiences and changes in children's cognitive development (for a review, see Christian et al., 2001). Research on both memory and mathematics indicates the important role of the classroom environment in the development of strategic understanding and cognitive skills.

Evidence From the Memory Literature. Cross-cultural memory research reports links between formal, Western-style schools and children's deliberate strategy use (Rogoff, 1981; Scribner & Cole, 1978; Wagner, 1978). Studies in Morocco (Wagner, 1978), Liberia (Scribner & Cole, 1978), and Mexico (Rogoff, 1981) report differences between schooled and nonschooled individuals on deliberate memory tasks. Wagner (1978) found that as children aged those enrolled in Western-style schools performed better than nonschooled subjects on a short-term memory task. Furthermore, students from Koranic schools, which include a heavy emphasis on memorizing large passages of text, performed similarly to unschooled subjects. This body of research suggests that something about the Western-style school context is related to children's use of deliberate memory strategies.

Extending this work, cross-cultural comparisons between German and American students found differences in memory strategy use across Western-style schools (Carr et al., 1989; Kurtz et al., 1990; Schneider et al., 1986). Carr and colleagues (1989) examined strategic behaviors on a sort-recall task between second graders from both countries. Students were given two minutes to study a collection of 20 pictures and subsequently asked to remember as many as possible. German students engaged in more strategic behaviors than American students. However, additional trials with training sessions indicated that American students highly benefited from strategy instruction (Carr et al., 1989; Schneider et al., 1986). Follow-up studies examining teacher practices reported that German teachers engaged in more task-specific strategy instruction than American teachers (Kurtz et al., 1990).

Later studies explored changes in strategic memory behaviors in the context of American classrooms. Using a "cutoff experiment", Morrison and Dow-Ehrensberger (1995) investigated the significance of the first-grade school year in students' developing use of deliberate memory strategies. The arbitrary nature of cutoffs for Kindergarten entry was leveraged to compare school-rated effects for students of a similar age (those who just made and just missed the March 1st cutoff date). Young first graders (students with a January or February birthdate) were compared to older Kindergartners (students with a March or April birthdate). These students displayed no significant differences in memory performance at Kindergarten entry (for the older Kindergartners) and the beginning of first grade (for the young first graders). However, at the end of the school year, despite similar ages across both groups, students enrolled in first grade recalled significantly more during the posttest with a higher degree of improvement. The following school year, when the older Kindergarteners were in first grade, they displayed significant improvement in recall, while the other group (now second graders) did not increase in recall performance. This study indicates that there is something unique about the first-grade formal schooling experience that contributes to memory performance.

Evidence From the Mathematics Education Literature. Researchers report numerous links between classroom instruction and improvements in students' mathematics performance (Baroody & Ginsburg, 1983; Boonen et al., 2011; Klibanoff et al., 2006). Starkey and colleagues (2004) found that pre-Kindergarten students exposed to mathematics curriculum across the school year performed significantly better than a control group on numerous mathematics measures (e.g., knowledge of shapes, pattern extension, two-set addition, etc.). Additional research by Klibanoff et al. (2006) demonstrated that teacher language is also related to mathematical growth during preschool. The observed teachers used varying amounts of math-talk and this, rather than classroom atmosphere, was related to students' increases in mathematical knowledge.

However, additional classroom studies suggest that not only the quantity, but the type of instructional language is significant (see Chapin et al., 2009). Murata and colleagues (2017) observed two first-grade teachers during classroom mathematics discussions. These teachers had similar backgrounds, preparation, espoused values, and identical curriculum, yet the researchers saw differences in language and student outcomes. For example, one teacher used more process-focused questions (questions asking students about strategies for solving mathematics problems). Students in her class used higher-level strategies and a larger percentage had positive strategy trajectories (the evolution from low- to high-level strategies). Additional studies report differences in the complexity of mathematical concepts and type of math-focused language used (Engel et al., 2013; Rudd et al., 2008). The quality and type of instructional language for mathematic achievement may be just as important as the content.

The Role of Language in Cognitive Processing

Memory and educational research documents numerous links between the classroom context and the development of cognitive skills. Something about formal schooling is associated with children's improved use of deliberate memory strategies. Studies on mathematics teaching draw attention to the importance of teacher language and demonstrate that instruction is related to student performance. However, little is known about what particular aspects of instructional language are promoting positive student outcomes. What is leading to increased memory and mathematical skills? Moreover, through what mechanism does instruction lead to improved cognitive processing?

Moely and colleagues (1992) conducted a series of classroom observations across the early, middle, and later elementary school grades. These revealed that on average teachers spent relatively little time discussing cognitive processes (an average of 9.5% of the observed instructional intervals). Teachers spent even less time suggesting specific strategies of how students should study (2.28%). In less than 1% of the observed intervals, teachers offered rationales for suggested strategies. Moreover, very few instances were observed in which teachers suggested students generalize a presented strategy. Nearly one-tenth of the teachers who participated in this study gave no strategy suggestions during the observed lessons. The majority of classroom instruction focused on asking students to provide answers to presented questions (32.3%), confirmation of correct responses (27.8%), discussing procedures (27.1%), giving specific content information (26.1%).

Given the relative infrequency of instructional time focused on cognitive processes (Moely et al., 1992) questions emerged about what aspects of the classroom context contribute to student growth (Coffman & Cook, 2021). Building on the work of Moely et al. (1992), Coffman and colleagues (2008) sought to identify links between the classroom context and children's improvement in memory strategy use and recall across the first-grade school year. Guided by the reminiscing literature and data from a pilot study, they created an observational coding scheme to classify teacher behaviors related to mnemonic development, termed the *Taxonomy of Teacher Behaviors*. The taxonomy captures questions and statements used during whole class instruction that may promote deeper levels of cognitive processing (e.g., activities that support encoding of material; see Craik & Lockhart, 1972). A composite index was formed to measure teachers' *mnemonic orientation*, later termed *Cognitive Processing Language* (CPL; see Grammer et al., 2016). The composite score captures the occurrence of (1) *metacognitive questions* (2) *strategy suggestions* (3) deliberate *memory demands* paired with (i) *instructional activities* (ii) *cognitive structuring activities* (iii) and the presentation of *metacognitive information*.

A sample of 107 children (58 female and 49 male) and their teachers (15 teachers across 14 classrooms) was followed across the first-grade school year (Coffman et al., 2008). Observers rated classroom teaching across multiple lessons for a total of 60 minutes of language arts and 60 minutes of mathematics instruction. This was later analyzed to create a single index of CPL. Students were assessed on a battery of memory tasks to measure recall and strategic behaviors at the beginning, middle, and end of first grade. Children showed modest increases in recall on an object memory (OBJ) and sort-recall task (SRT) across the year. However, differences emerged after the first time point between students in classrooms where teachers used higher, compared to lower, levels of CPL. Students in high CPL classrooms demonstrated greater levels of recall and strategy use on OBJ, in addition to higher linear rates of growth. Additionally, these students had higher levels of sorting and clustering on SRT.

Students from the initial sample were followed across the second grade and into the fourth-grade school year (Ornstein et al., 2009; Ornstein et al., 2010a; Ornstein et al., 2010b). Differences based on the first-grade teachers' use of Cognitive Processing Language persisted through the fourth grade. During second grade, students from high-CPL first-grade classrooms continued to use more strategic sorting and clustering behaviors during a sort-recall task. They also recalled more items than their peers who were exposed to less CPL in first grade (Ornstein et al., 2010b). During the fourth grade, students completed a more complex, low-associated items, sort-recall task (Ornstein et al., 2010a). At this age, differences in strategic sorting also corresponded with the amount of CPL used in the first-grade classroom, with students from high-CPL classrooms outperforming those from low-CPL classrooms. These results indicate long-term associations between exposure to more memory-relevant language in early elementary school and students' later strategic behaviors.

Coffman et al. (2018) expanded these findings to explore linkages between first grade CPL exposure and more complex strategic study skills in fourth grade. Of the initial sample of 107 students, 58 (34 female, 24 male) completed all the assessments between first and fourth grade. Students performed a study skills task where they received a brief text passage and were given four minutes to "work to remember" the passage. Each student was given study materials (e.g., highlighter, note paper) but no explicit instructions in study techniques. After the four-minute study period, students verbally recalled as much information from the passage as possible and answered questions about study behaviors. Coffman and colleagues found that children who experienced more CPL in first grade used more strategic behaviors to study the passage. These findings suggest long-term benefits of early exposure to CPL.

Additional studies indicate that Cognitive Processing Language is particularly beneficial for specific subgroups of students. Ornstein et al. (2009) explored the moderating effect of students' level of academic achievement. First graders were tested using standard academic achievement tests and identified as higher or lower achieving. Their strategic performance was examined as a function of their first-grade teachers' use of Cognitive Processing Language (high-CPL or low-CPL). Higher achieving students used elevated levels of strategic sorting regardless of the classroom context. However, lower-achieving students' performance was linked to their teachers' use of CPL. Children exposed to lower levels of teachers' CPL used less strategic sorting behaviors. However, in classrooms with high levels of CPL, lower achieving students used greater levels of sorting, such that their behavior mirrored higher achieving students. These patterns continued across first and second grade. Lower achieving students who were placed into high-CPL first-grade classrooms continued to use more strategic behavior across the second grade as compared to peers who were placed into low-CPL first-grade classrooms.

Similar patterns emerge among students with low levels of self-regulated learning. Ornstein and Coffman (2020) investigated the interaction between students' self-regulation skills and teachers' level of CPL. First-grade teachers rated students' ability to self-regulate learning (e.g., self-monitored learning, planful behaviors, etc.). Students who were rated low in these skills had clear differences in sorting patterns as a function of teacher CPL. Low-regulated students in high-CPL classrooms made greater gains in strategic sorting behavior during first grade, as compared to peers in low-CPL classrooms. Moreover, these students continued to sort at more elevated levels across first and second grade. Similar to findings with academic achievement (see Ornstein et al., 2009), high-regulated students performed well when placed in either high-CPL or low-CPL classrooms. These studies indicate the importance of interactions between child-characteristics and the classroom context in developing deliberate memory strategies.

Initial studies showed support for beneficial links between Cognitive Processing Language and student outcomes. However, the correlational nature of early studies prevented researchers from establishing causality. In order to test causal links between CPL and student outcomes, Grammer et al. (2013) performed an experimental investigation. A total of 54 first- and second-grade students participated in a two-week after school program focused on engineering and physics principles used in Lego construction. Students were randomly assigned to either a control (low CPL) or intervention (high CPL) group. Teachers were provided scripted lessons and randomly assigned to either teach the high CPL or low CPL style lesson first. High-CPL lessons included more frequent *strategy suggestions* and use of *metacognitive questions*. Teachers also regularly paired *memory requests* with other *instructional* or *cognitive structuring activities* and during the provision of *metacognitive information*. Students in both groups received similar information and covered the same material, with the only difference being the type of instructional language used by teachers. After the two-week unit, students in the high-CPL group developed more strategic knowledge and demonstrated more meaning-based sorting on a content-specific sort-recall task (using items related to Lego construction).

CPL and Mathematics Outcomes

Additional studies link Cognitive Processing Language to domain-specific cognitive outcomes (e.g., mathematics). Grammer et al. (2016) explored associations between teacher CPL and mathematics performance across the second-grade year. A sample of 83 students in 17 classrooms was assessed on mathematical fluency and calculation at the end of first grade. Whole-class instruction was observed in second grade classrooms and an index of CPL was created for each teacher. At the end of first grade, there were no significant group differences on mathematical fluency or calculation. However, at the end of second grade, teachers' use of CPL was related to students' fluency and calculation scores. Students in high-CPL (compared to low) classrooms performed better on both mathematics achievement tests. Moreover, children in higher CPL classrooms had faster gains in mathematical fluency skills across the school year. A study of Kindergarten students' mathematics accuracy and strategy use by Hudson et al. (2018) found similar benefits of CPL. Children in high-CPL Kindergarten classrooms had higher levels of accuracy in solving addition problems than similar peers in low-CPL classrooms. Moreover, teachers' use of CPL predicted student's effective use of strategies to solve addition problems at the end of Kindergarten.

This body of work demonstrates significant associations between teachers' language related to cognitive processing and students' developing deliberate memory and mathematical skills. Correlational and experimental studies suggest that elevated levels of teachers' Cognitive Processing Language are related to more strategic sorting in first and second grade and more strategic study skills behaviors in upper elementary school (Coffman et al., 2008; Coffman et al., 2018; Grammer et al., 2013; Ornstein et al., 2010a). Although this research provides evidence for benefits of exposure to higher levels of CPL in the early elementary school years, more research is necessary to understand the concurrent influence of child-level characteristics and exposure to CPL (Ornstein & Coffman, 2020). Specifically, little is understood about how individual metacognitive knowledge and the classroom context may uniquely predict cognitive outcomes.

Kindergarten as the New First Grade

Research by Morrison and Dow-Ehrensberger in 1995 indicated the significance of first grade in deliberate memory strategy growth. Guided by these findings, the majority of Cognitive Processing Language literature has examined teacher language and student strategy use across the first-grade school year and beyond. A study by Hudson et al. (2018) examined links between CPL and mathematics performance in Kindergarten, however, no studies to date have explored relations between CPL and strategic memory behaviors prior to first grade. Over the last twenty years drastic changes have occurred in Kindergarten curriculum and expectations (Bassok et al., 2016). Specifically, between 1998 and 2010, the academic content and organizational structure of public Kindergarten classrooms have shifted to include a greater focus on literacy and mathematics instruction. Additionally, this time period also saw an increase in teacher-led direct instruction and more frequent use of standardized tests. These changes indicate that by 2010 Kindergarten classrooms grew to look more similar to first-grade classrooms from the late 1990s. In light of these changes, further work is needed in order to investigate the role of CPL across the Kindergarten school year. Timing may be a fundamental element in the effectiveness of metacognitively rich teacher language. Therefore, examining CPL during Kindergarten may expand our understanding of when and what factors best support growth in students' cognition.

The Current Study

Numerous studies document changes in children's deliberate memory and mathematical skills during the elementary school years. However, the extant research has predominately focused on how these abilities advance in conjunction with age-related changes, rather than their development over time (Ornstein & Haden, 2001). Moreover, very limited studies include contextual factors that contribute to these improvements. Using a socialization of cognition paradigm, promising work in early elementary school classrooms indicates that social exchanges between students and teachers may be associated with growth in children's use of deliberate memory strategies and mathematics performance (for a review, see Coffman & Cook, 2021; Hudson et al., 2021). Importantly, researchers have linked a measure of teachers' metacognitively rich language, or Cognitive Processing Language (CPL), to students' strategic sorting behaviors, recall, and mathematics achievement (Coffman et al., 2008; Coffman et al., 2018; Grammer et al., 2016; Hudson et al., 2018). The associations between CPL and cognitive skills during the elementary school years are confirmed in both longitudinal (e.g., Coffman et al., 2018; Hudson et al., 2018) and experimental studies (e.g., Grammer et al., 2013).

However, many important questions remain about these associations. Early elementary school experiences appear to be important in strategic memory and mathematical fluency development. Links between students' deliberate memory performance and teachers' use of Cognitive Processing Language (CPL) suggest the significance of the first-grade context (see Coffman et al., 2008). Changes over the last two decades in the structure and instructional content of Kindergarten (see Bassok et al., 2016) necessitate expanding research on CPL beyond the first grade. Limited studies have explored the relations between teachers' instructional language and children's strategic mathematics behaviors in Kindergarten (e.g., Hudson et al., 2018). More research is needed to understand the significance of the timing of children's exposure to a metacognitively rich classroom context. Specifically, researchers need to explore whether teacher instructional language also has a meaningful association with students' memory strategy use. Additionally, past studies have primarily focused on mathematics strategy use in Kindergarten, rather than other important indicates of growing mathematical proficiency, such as fluency.

Additionally, children enter the formal school setting with a variety of individual characteristics and knowledge that may also be important for developing memory and mathematical skills. Past research suggests that CPL is not the only factor that influences student performance. Factors such as academic achievement and self-regulation abilities have been found to moderate the link between CPL and student performance (see Ornstein et al., 2009; Ornstein & Coffman, 2020). Specifically, lower-performing children benefited most from classrooms where teachers used high levels of CPL. Similarly, experiences prior to school entry, specifically maternal language, are linked to children's performance on mathematics tasks at the beginning of Kindergarten (Hudson et al., 2018). Therefore, other relevant child-level factors may predict children's performance in conjunction with CPL. Importantly, exploring individual-level predictors may illuminate differences prior to school entry that are associated with performance at the start of Kindergarten and across the early elementary school years.

Metacognitive knowledge, specifically metamemory, may be a possible predictor of early memory and mathematical skills. Previous researchers have found significant correlations between metamemory knowledge and deliberate strategy use (Bjorklund & Zeman, 1982; Fabricius & Hagen, 1984; Grammer et al., 2011; Schneider et al., 1998). Similar relations have been found between metacognitive knowledge and mathematics performance (Bellon et al., 2019).

Metamemory is related to students' use of strategic behaviors and some studies report its influence either directly or indirectly on recall. Researchers have also documented the timing of metamemory and strategy use, findings suggest that metamemory knowledge may develop congruently but slightly in advance of strategic behaviors (Grammer et al., 2011; Schlagmüller & Schneider, 2002). Given the important relations between metamemory and deliberate memory strategies, this factor may predict strategic sorting behaviors in young children alongside classroom CPL exposure. Particularly since children have varying levels of metamemory understanding as they begin elementary school (Grammer et al., 2011). Less is known about the association between metamemory and mathematical skills. However, metacognition appears to be important in mathematical problem solving (see Scheinder & Artelt, 2010).

No studies to date have specifically examined associations between students' metamemory knowledge and teachers' memory-relevant language in the early elementary school years. Work investigating the training of children in strategies provides evidence that young children are capable of improved strategy use with explicit instruction (e.g., Ornstein et al., 1977; Paris et al.,1982). Metamemory may play an important role in the use, acquisition, and the transfer of these skills to other tasks. Children, regardless of their level of metamemory, can improve performance when given strategic prompts during deliberate memory tasks (Cordonli et al., 1999). Therefore, as children start Kindergarten metamemory may play an important role in initial strategic behaviors and memory performance in basic memory and content-specific tasks. However, across the year, children with higher levels of metamemory may more easily acquire and generalize metacognitive and content-specific strategy instruction provided by teachers. As a result, initial levels of metamemory may continue to predict strategic behaviors across the school year. This study was designed to address these questions.

Using data from a larger longitudinal investigation, this study examines relations between teachers' Cognitive Processing Language, students' metamemory knowledge, and their use of strategic behaviors and mathematical fluency performance across the Kindergarten year.

This study focuses on four primary research questions. The accompanying proposed hypotheses, displayed in Figure 1, were tested:

1. Does children's initial metamemory knowledge or teachers' Cognitive Processing Language predict students' use of deliberate memory strategies at Kindergarten entry?

Hypothesis 1: Students' metamemory will predict strategic sorting on a deliberate memory task at the beginning of the Kindergarten year. However, sorting behaviors will not vary as a function of teachers' use of CPL at school entry.

2. Does children's initial metamemory knowledge or teachers' Cognitive Processing Language predict students' use of deliberate memory strategies at the end of Kindergarten?

Hypothesis 2: Students' metamemory at school entry will continue to predict strategic sorting on a deliberate memory task at the end of the Kindergarten year. Additionally, sorting behaviors will vary as a function of teachers' use of CPL. Students in classrooms with high-CPL teachers will use higher levels of strategic sorting on a deliberate memory task compared to students in classrooms with low-CPL teachers at the end of the year.

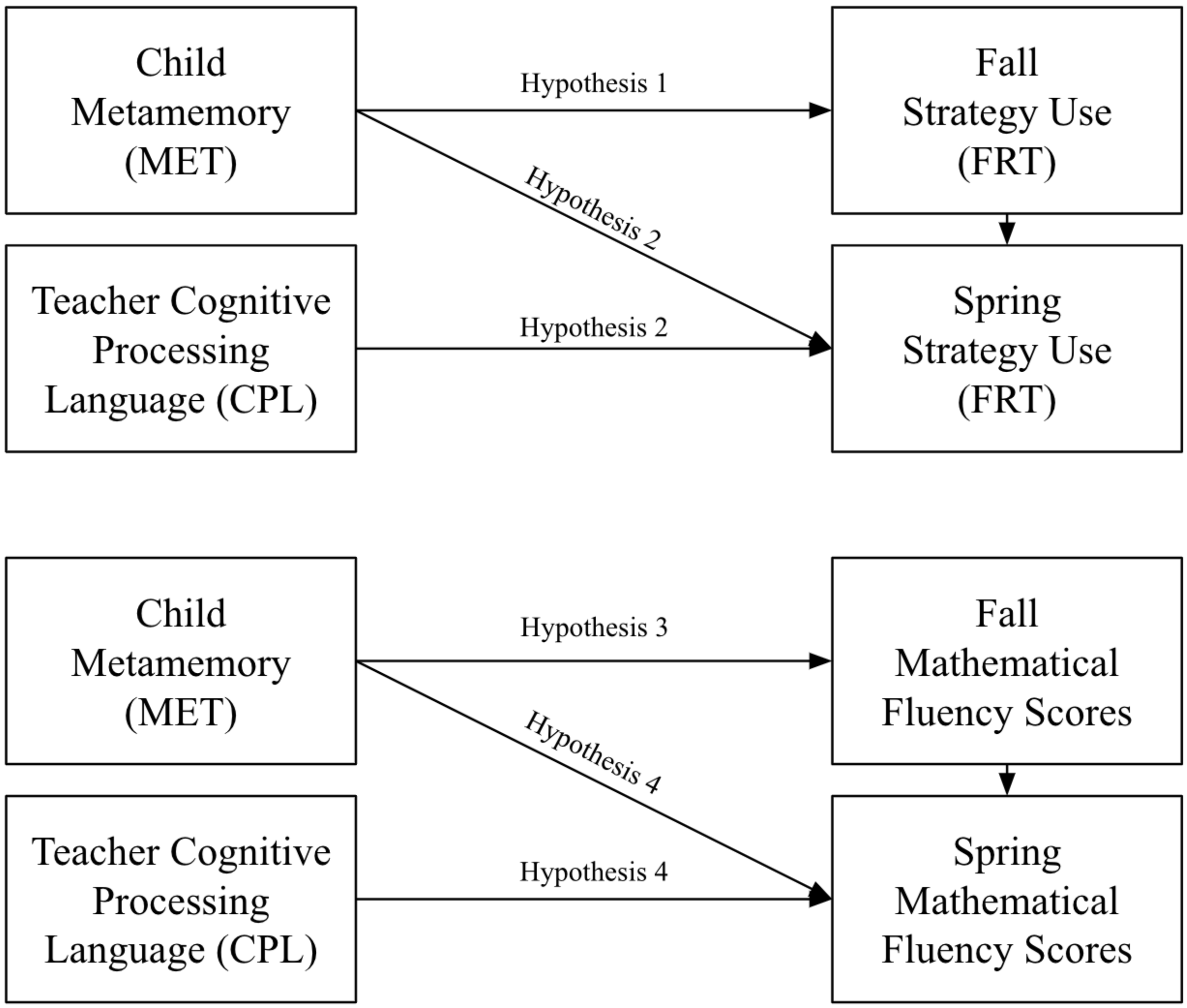
3. Does children's initial metamemory knowledge or teachers' Cognitive Processing Language predict students' mathematical fluency performance at Kindergarten entry?

Hypothesis 3: Students' metamemory will predict mathematical fluency performance at the beginning of the Kindergarten year. However, mathematical fluency will not vary as a function of teachers' use of CPL at school entry.

4. Does children's initial metamemory knowledge or teachers' Cognitive Processing Language predict students' mathematical fluency performance at the end of Kindergarten?

Hypothesis 4: Students' metamemory at school entry will continue to predict mathematical fluency performance at the end of the Kindergarten year. Additionally, mathematical fluency will vary as a function of teachers' use of CPL. Students in classrooms with high-CPL teachers will have higher mathematical fluency scores compared to students in classrooms with low-CPL teachers at the end of the year.

Figure 1. Models of Hypothesized Relationships Between Variables



CHAPTER II: METHODS

Participants

A sample of 76 Kindergarteners (41 female and 35 male) was recruited as part of a longitudinal research project entitled the Classroom Memory Study. This project examines aspects of the home and school environments, specifically language interactions, that shape students' deliberate memory strategy use, academic achievement, and higher-order strategic behaviors across the early elementary school years. Students and teachers were recruited at the beginning of the Kindergarten year and students were followed across the Kindergarten, first- and second- grade years. This analysis focuses on teachers and children during the first year of the investigation. All Kindergarten teachers at 3 participating schools in a southeastern state were invited to join the study. A sample of 10 female teachers – 8 Caucasian, 1 African American, and 1 Asian American – participated in the study. The teachers had a mean of 12.7 years teaching experience (range = 2-30 years) with 5 holding bachelor's degrees and 5 holding master's degrees.

All students in the selected classrooms were invited to join the study, with no criteria for exclusion. Every child who returned a signed consent form was enrolled in the study. Of the initial 76 participants, a subgroup of 72 students (38 female and 34 male) completed all relevant assessments and were the focus of the analyses presented in this study. Approximately 7 students from each classroom participated (range = 6-10). At Time Point 1, children were a mean age of 5.73 years (range = 4.93-6.43 years). The racial-ethnic composition of the student population reflects the demographics of the region with 54% of families describing their ethnicity as Caucasian, 11% as African American, 11% as Asian, 18% as Mixed, and 6% did not identify their ethnicity.

Procedures

Child Assessments

Child assessments were conducted at the beginning (Time Point 1) and end (Time Point 2) of the Kindergarten school year (see Table 1). Trained research assistants administered a battery of tests to assess students' memory and academic performance. Each assessment lasted approximately 45 to 60 minutes and was conducted at the child's school. This study focuses on deliberate memory strategy use, recall performance, mathematical fluency, and metamemory knowledge using a Free Recall with Organizational Training Task (Moely et al., 1992), Woodcock-Johnson Mathematical Fluency assessment (Woodcock et al., 2001), and a Metamemory Scale (Schlagmueller et al., 2001). Working memory (McCarthy, 1972) was also included as a potential control variable to assess basic memory capacity. All assessments were video recorded and subsequently scored by experienced research assistants.

Table 1. Timeline of Assessments

Fall (Time Point 1)	Mid-Year	Spring (Time Point 2)
Free Recall Task (FRT)	Working Memory	Free Recall Task (FRT)
Baseline Trial	Classroom Observations	Generalization Trial
Training Trail		Mathematical Fluency
Generalization Trial		Metamemory Scale (MET)
Mathematical Fluency		
Metamemory Scale (MET)		

Free Recall with Organizational Training Task (Moely et al., 1992)

At the beginning and end of the school year, children were administered the Free Recall with Organizational Training Task (FRT). This task assesses children's use of organizational strategies (e.g., categorical grouping) while working to remember and during subsequent recall. Children were shown 16 line-drawing pictures from four conceptual categories (e.g., fruits). Each item was individually presented in a quasi-random order while the child named the object.

The examiner corrected or provided names for any unknown items. The order of presentation ensured that categorically related picture cards were not viewed sequentially. At the beginning of the year (Time Point 1), children performed three trials of the task. During a baseline trial, children were told to do whatever they could to remember the cards, assessing spontaneous strategy use. After a study period, the cards were removed and children were asked to recall as many items as possible. The second trial served as a training trial. Children were instructed to use categorical groups during study (sorting) and later recall (clustering) to better remember the items. After a fifteen-minute delay, the final generalization trial was administered. Using the same procedure from the baseline trial, children were presented with a new set of cards to work to remember. At the end of the year (Time Point 2), children were only administered another generalization trial, with new cards and no additional training.

Trained research assistants recorded children's sorting patterns during the study period, the number of items recalled, and the order in which items were reported. Strategy use was calculated based on sorting during the study period and categorical grouping during recall. An Adjusted Ratio of Clustering (ARC) Score (Roenker et al., 1971) was calculated to standardize strategy scores. The ARC scores range from -1 to +1 (below chance organization to complete organization) allowing for comparison over time and between students. Recall scores reflect the total number of items remembered. Two trained research assistants scored each trial independently. Any discrepancies were resolved by examining the assessment video. For each trial, students received a recall score ranging from 0 to 16 and two ARC scores ranging from -1 to +1 (one for sorting and one for clustering).

Mathematical Fluency (Woodcock et al., 2001)

Children's mathematical fluency was assessed using a subscale of the Woodcock–

Johnson III Tests of Achievement. This Mathematical Fluency Subscale measures children's ability to recall mathematics facts quickly and accurately. Children were presented with a sheet of addition and subtraction problems (it also includes multiplication problems, however, no students advanced far enough on the task to complete them) and given three minutes to solve as many problems as possible. Scores reflect the total number of problems that children solved accurately in the given time frame.

Metamemory Scale (Schlagmueller et al., 2001)

This metamemory battery (MET) is adapted from the Würzburg Metamemory Test (Schlagmueller et al., 2001) to assess both general declarative metamemory and understanding of semantic categorization in young children. The task contains two sections – each includes general declarative metamemory and organizational strategy questions. During scoring, the general metamemory answers are combined across both sections to create a general declarative metamemory subscale. The organization strategy questions follow a similar procedure to create a second subscale.

Children are given an initial practice problem prior to beginning each section of the assessment to ensure they understand the task. During the first section, children are asked to rank specific scenarios, memory strategies, or people on a scale from 1 to 3. A ranking of 1 indicates the designated scenario will be easiest to remember, the strategy is the most effective, or the selected individual will most easily remember the required information. A ranking of 3 indicates the hardest scenario to remember, worst strategy, or the person who will have the most difficult time remembering. For example, children are asked the best way to remember a phone number – rehearsing the number one digit at a time, rehearsing the number in two-digit groups, remembering it is the date of Thanksgiving last year.

The second section follows a similar protocol. Children are again presented with scenarios, strategies, and people and asked to rank difficulty/effectiveness using medals (1st place, 2nd place, 3rd place). Both sections contain general declarative metamemory and semantic categorization questions. Semantic categorization questions specifically address scenarios where students can categorically sort information to promote better recall. For example, children are presented with a situation where they are asked to remember a list of animals and may do so by writing down the items in any order, using groups, or in alphabetical order.

Scoring for each item ranges from 0 to 3. Students received a score of 3 for correctly ranking each of the three items. A score of 1 or 2 was given for successfully ranking one or two of the pairs in the set. A score of 0 was given for incorrectly ranking all items. The general metamemory and categorization subscales both contain three questions for a possible total of 9 points per subscale. Summed scores across the assessment can range from 0 to 18.

Working Memory (McCarthy, 1972)

Children's working memory capacity was assessed in the middle of the school year using a backward version of the Digit Span Task (Jacobs, 1887). Children were read a string of numbers and asked to recall the numbers in reverse order. The initial trial used two numbers. Upon correct recollection of the numbers, each subsequent trial increased by one digit. After two incorrect answers on a given span, the assessment concluded. This process was repeated by an identical second assessment. Two research assistants recorded the longest string of numbers, up to 6, the children could remember. Any discrepancies were resolved by referring to the original video. The final digit span score reflects the largest string of numbers the child could recall across both assessments with scores ranging from 0 to 6.

Classroom Observations

Observations were conducted in each of the 10 classrooms. Teachers were directed to videotape a cumulative total of 60 minutes of whole-group mathematics lessons. Teachers also recorded language arts lessons; however, the focus of this study is on memory and mathematical fluency outcomes so only mathematics instruction was included in the analyses. The recorded lessons were of teachers' regular classroom instruction following the standard mathematics curriculum for Kindergarten. Observations ranged from 3 minutes to 17.5 minutes ($M = 9.85$ minutes) and were recorded over multiple months. To achieve the total 60 minutes, between six and nine lessons were recorded ($M = 6.7$ lessons).

The classroom observations were subsequently coded using the *Taxonomy of Teacher Behaviors* coding system (Coffman et al., 2008). Each lesson was broken down into 30-second intervals and teachers' language was characterized using 26 unique codes (see Table 2). The four main categories of teacher language include (1) *instructional activities* (2) *cognitive structuring activities* (3) *memory requests* (4) *metacognitive information*. *Instructional activities* are instances where the teacher provides information to the class (e.g., providing information about different shapes). *Cognitive structuring activities* include teacher language that promotes deeper levels of encoding and preparation for future retrieval. This may involve focusing attention or making connections to prior information (e.g., asking students to remember the previous day's lesson on counting on). *Memory requests* consist of the teacher asking students to remember previously stored information or to prepare for the future (e.g., asking students the sum of a given addition problem or asking students to remember a specific set of numbers). *Metacognitive information* are examples of teacher-talk that either request or give metacognitive information. This may include asking students about cognitive processes for solving problems or providing suggestion to help with remembering or curriculum specific strategies (e.g., telling students to write down facts about squares so they may remember them later or asking a child to explain how they solved an addition problem).

Table 2. Taxonomy of Teacher Behaviors Codes

Category	Abbrev.	Definitions
Non-Instruction/Non-Memory	NON	The teacher is not engaged in a memory or instructional activity
Instructional Activities		
Book Reading	BR	The teacher reads a book aloud to the group
General Information Giving	GIG	Presentation of factual information
Prospective Summary	PS	Description of upcoming events
Specific Task Information	STI	Instructions for performing a particular activity
Cognitive Structuring		
Attention Regulation: Behavioral Goal	ATB	Reprimand or guide behavior
Attention Regulation: Instructional Goal	ATI	Redirect or focus attention
Massed Repetition	MREP	Performance of an activity in unison
Identifying Features	IDF	Generate features of a category
Categorization	CAT	Verbally or physically putting material into categories
Identifying Relationships	REL	Comparison/elaboration on at least two items (similarities/differences)
Personal Experience Connections: Home	PEH	Associate a prior outside of school experience to a current activity
Personal Experience Connections: School	PES	Associate a prior in-school experience to a current classroom activity
Drawing Inferences	INF	Predict an outcome or assume the intentions or desires of another
Visual Imagery	IMG	Create visual mental images that relate to the material
Memory Requests		
Episodic	EPI	Retrieval of a specific past event in or out of the classroom
Semantic	SEM	Retrieval of an already learned fact, idea, or object
Procedural	PRC	Recollection of how to perform a series of activities to achieve a goal
Prospective	PRS	Non-instructional task to be completed in the future (behavioral goal)
Anticipated	ANT	Expectation for child to remember information (learning goal)
Metacognitive Instruction		
Metacognitive Rationale	MR	Provides rationale for strategy use or for planning, organizing, etc.
Metacognitive Questioning	MQ	Asks child to provide potential strategy or rationale for strategy choice
Suggestion	SUG	A recommended method for remembering information
Suppression	SUP	Refraining from using an unhelpful or inappropriate strategy
Replacement	REP	Recommendation of a more effective or alternative strategy

Two coders were trained in the *Taxonomy of Teacher Behaviors* coding scheme. Videotaped lessons from a previous study were used as practice files. After learning the coding scheme, both coders verified reliability on the taxonomy coding scheme using eight master files for a total of 60 minutes of instruction. The first two videos coded were used as practice files and each coder was required to reach 100% accuracy. On the remaining six files each coder was required to achieve 80% accuracy with the master files. Upon successful completion of the training process, each coder independently scored 25% of the intervals (a total of 150 minutes or 300 30-second intervals) to ensure interrater reliability. Coders achieved over 80% interrater reliability scores on all files, ranging from 80% to 100%, with an average of 86.55%.

Table 3. Cognitive Processing Language Component Codes

Code	Definition	Example
Strategy Suggestion	Recommending that a child adopts a method or procedure for remembering or processing information	"If you organize the dots in a line, it will make it easier to count them."
Metacognitive Question	Requesting that a child provides a potential strategy, a utilized strategy, or rationale for a strategy they have indicated using	"What are some strategies you could use to solve three plus seven?"
Co-occurrence of Memory Requests and Instructional Activities	Requesting information from children's memory while also presenting instructional information	"Today we are going to learn a brand-new shape. What shapes have we learned about so far?"
Co-occurrence of Memory Requests and Cognitive Structuring Activities	Requesting information from children's memory while simultaneously facilitating encoding and processing by focusing attention or organizing material	"Yesterday, we learned how to tell time to the half hour. Which hand is the hour hand?"
Co-occurrence of Memory Requests and Metacognitive Information	Requesting information from children's memory while providing or soliciting metacognitive information	"How many dots are there in all? How did you solve that problem? How did you know that you should add?"

Note. This table contains component codes from the Taxonomy of Teacher Behaviors used to index cognitive-processing language (adapted from Coffman et al., 2018)

Cognitive Processing Language (Coffman et al., 2008)

A composite index of *Cognitive Processing Language* (CPL) is based on a subset of codes. This measure uses five components related to deeper levels of processing and metacognitive understanding (see Table 3): (1) *strategy suggestions* (2) *metacognitive questions* (3) *co-occurrence of deliberate memory demands and instructional activities* (4) *co-occurrence* *of deliberate memory demands and cognitive structuring activities* (5) *co-occurrence of deliberate memory demands and metacognitive information* (Coffman et al., 2008).

Analytic Strategy

Analyses for this study were conducted in three phases using StataSE 17. First, descriptive statistics were run for classroom- and child-level data. To explore variability in teachers' instructional style across classrooms, the number of 30-second whole-class mathematics instruction intervals (out of 120) containing each code from *The Taxonomy of Teacher Behaviors* was summed. Each code was only used once per interval to allow the calculation of the percentage of total intervals that contained each target behavior. Descriptive statistics were used to make a preliminary assessment of variability across classrooms.

Following this initial examination, a composite measure of CPL was created for each teacher for comparison across classrooms. This score includes (1) *strategy suggestions* (2) *metacognitive questions*, and the *co-occurrence of deliberate memory demands* with (3) *instructional activities* (4) *cognitive structuring activities* (5) *metacognitive information*. Previous studies have documented significant variability in the frequency of these codes (see Coffman et al., 2008). To account for these differences, standard scores were computed for each code using its mean and standard deviation prior to the creation of a composite CPL score (following protocol used in Coffman et al., 2008). These five *T* scores (one for each component of CPL) were averaged to create a single index of Cognitive Processing Language. Although this variable is continuous, due to the small sample size (10 classrooms), a median split was used to segment classrooms into high and low CPL for comparison.

Descriptive statistics were calculated for each child level assessment at both time points (the beginning and end of Kindergarten). Specifically, working memory, metamemory, mathematical fluency, and both recall and ARC sorting strategy scores from the Free Recall with Organizational Training Task were assessed. Variability across children was evaluated. During the second phase, a series of bivariate correlations were run using the child-level data to explore relations between variables. Correlations were run both within each time point and within and across tasks specifically looking at metamemory, FRT strategy, FRT recall, mathematical fluency, and associations with working memory.

Third, multiple linear regressions were used to test hypotheses one, two, three, and four. To account for the nesting of children in Kindergarten classrooms, Huber-White sandwich estimators were used (Huber, 1967; White, 1980). To address the first research question, a regression analysis was run to assess whether children's initial metamemory or teachers' use of CPL predicted ARC sorting scores at the beginning of Kindergarten. Working memory was initially considered as a covariate to control for basic memory capacity but was excluded due to its significant correlation with metamemory and lack of association with FRT sorting scores. A second model was run to determine if either (CPL or metamemory) variable predicts ARC sorting scores at the end of Kindergarten. Sorting scores from the beginning of Kindergarten were used as covariates.

A third regression analysis was conducted to determine if metamemory at school entry or CPL predict mathematical fluency scores at the beginning of Kindergarten. The final model included fall mathematical fluency scores as a covariate and assessed whether metamemory or CPL predicted mathematical fluency scores at the end of the Kindergarten year.

CHAPTER III: RESULTS

The following section includes descriptions of children's memory and mathematics performance at the beginning and end of Kindergarten. First, descriptive statistics are presented to document variability in child-level task scores within and across time points. This is followed by bivariate correlations examining associations between working memory, metamemory, sorting, recall, and mathematical fluency across the fall and spring. The classroom context is then characterized by teachers' use of cognitive processing language during mathematics instruction. Finally, a series of multiple linear regressions are presented exploring linkages between children's metamemory, teachers' use of cognitive processing language, and child outcomes, specifically, strategic sorting and mathematical fluency.

Child-Level Descriptive Statistics

The overall sample means are presented in Table 4 to summarize child-level performance at the beginning and end of the Kindergarten school year. Children's working memory was assessed using a Digit Span task during the middle of the school year. This variable was included in preliminary analyses as a potential covariate to control for basic memory capacity. The maximum score on this task is 6, student scores ranged from 0 to 6 with a mean of 2.89 (*SD* = 1.04).

A Free Recall with Organizational Training Task (FRT) was used to assess deliberate memory skills and recall performance across the Kindergarten year. In the fall, children completed a baseline trial to assess initial strategy use. Sorting ARC scores were used to determine the level of categorical grouping used while studying 16 line drawings. Possible ARC scores range from -1 (below chance organization) to 1 (complete organization) with 0 representing chance performance. On average, students performed below chance with a mean score of -0.21 (*SD* = 0.12). After the baseline trial, children were given organizational training. Following a fifteen-minute delay, a generalization trial was conducted to assess the uptake of the instruction. In the fall, average sorting ARC scores increased to slightly above chance (*M* = 0.02, *SD* = 0.47). At the end of the year, students only performed a generalization trial. Sorting performance again increased with students obtaining a mean score of 0.11 (*SD* = 0.53). However, recall during the FRT showed a different pattern. Student scores slightly decreased from the baseline (*M* = 7.58, *SD* = 2.67) to generalization trial in the fall (*M* = 7.28, *SD* = 3.29). In the spring, students remembered one more item on average than in the fall (*M* = 8.21, *SD = 2.45*).

Children's metamemory knowledge was assessed using a Metamemory Scale. Total scores (including both general metamemory and categorization knowledge subscales) were used to examine metamemory across Kindergarten, with a possible score of 18 at each time point. As can be seen in Table 4, Students achieved a mean score of 8.86 (*SD* = 3.93) in the fall, with approximately a one point increase in the spring (*M* = 9.92, *SD* = 2.88).

Table 4. Summary of Child-Level Performance

	Fall			Spring		
	N	Mean *(SD)*	Range	N	Mean *(SD)*	Range
Digit Span						
Working Memory		--	--	72	2.89 *(1.04)*	0 - 6
Free Recall Task						
Baseline ARC Sorting Score	72	-0.21 *(0.12)*	-0.23 - 0.78		--	--
Baseline Recall	72	7.58 *(2.67)*	0 - 13		--	--
Generalization ARC Sorting Score	69	0.02 *(0.47)*	-0.23 - 1	72	0.11 *(0.53)*	-0.23 - 1
Generalization Recall	68	7.28 *(3.29)*	0 - 14	72	8.21 *(2.45)*	2 - 14
Metamemory Scale						
Metamemory Total	72	8.86 *(3.93)*	0 - 16	72	9.92 *(2.88)*	3 - 15
WJ Mathematical Fluency Task						
Raw Mathematical Fluency Score	71	4.86 *(4.99)*	0 - 24	71	12.08 *(8.06)*	0 - 32

In addition to memory measures, mathematics performance was assessed using a mathematical fluency task. Scores reflect the raw number of problems children were able to solve correctly in three minutes. During preliminary analyses, an outlier was identified (one student scored over three standard deviations above the mean at the spring time point) and was removed from the analysis. Children scored a mean of 4.86 (*SD* = 4.99) in the fall. At the end of the year, mean scores increased to 12.08 (*SD* = 8.06) demonstrating an increase in mathematical fluency across the school year. Overall, students exhibited growth in sorting use, recall, metamemory, and mathematical fluency during the Kindergarten year.

Bivariate Correlations Between Child-Level Variables

Following the preliminary investigation of descriptive statistics, a series of bivariate correlations were run to assess within and between task associations. First, correlations were used to examine Free Recall with Organizational Training Task performance within-task and across time points (see Table 5). In the fall, children's baseline sorting was not significantly correlated with recall ($r = .216$, p <.05). However, during the generalization trial, sorting and recall had a significant association ($r = .283$, $p < .05$). The strength of this correlation was greater at the end of the year ($r = .485$, $p < .01$).

Across time point correlations reveal baseline sorting scores were not associated with generalization sorting scores at either time point (fall: $r = -.014$, $p > .05$; spring: $r = .177$, $p > .05$). Meanwhile, generalization sorting scores were correlated in the fall and spring ($r = .421$, $p < .01$). Recall scores followed an opposite pattern. Baseline recall was moderately associated with fall generalization recall ($r = .391$, $p < .01$) and spring recall ($r = .366$, $p < .01$); however, the two generalization scores were not significantly associated ($r = .214$, $p > .05$). Finally, across-task correlations were investigated to determine the strength of the association between FRT performance, working memory, and fall metamemory. Working memory was only associated with fall baseline recall ($r = .251$, $p < .05$) and fall metamemory ($r = .241$, $p < .05$). Metamemory at school entry was also correlated with spring recall ($r = .409$, $p < .01$).

Table 5. Summary of Free Recall Task Correlations

	1	2	3	4	5	6	7	8
1. Working Memory	--							
2. Fall Baseline Sorting	-.009	--						
3. Fall Baseline Recall	.251*	.216	--					
4. Fall Generalization Sorting	.174	-.014	-.085	--				
5. Fall Generalization Recall	.177	.029	.391**	.283*	--			
6. Spring Sorting	-.064	.177	.053	.421**	.145	--		
7. Spring Recall	.191	.241*	.366**	-.002	.214	.485**	--	
8. Fall Metamemory	.241*	.194	.167	-.008	-.082	.189	.409**	--

$^{**}p < .01$ $^{*}p < .05$

As can be seen in Table 6, similar bivariate correlations were run for mathematical fluency scores. Mathematical fluency performance in the spring was significantly and moderately associated with fall performance (r = .586, p <.05). Working memory had a stronger association with fall (r = .474, p <.01) compared to spring (r = .320, p <.01) mathematical fluency scores. Meanwhile, initial metamemory had a stronger association with spring (r = .311, p <.01) than fall (r = .288, p <.05) mathematical fluency.

Finally, working memory and fall metamemory were associated (r = .241, p <.05; see Table 5). As a result, working memory was removed as a control variable to avoid collinearity in the primary analyses. Overall, these analyses demonstrate some within-task and across-time point correlations for FRT, specifically regarding sorting during the generalization trials. There were few FRT across-task correlations. Meanwhile, there were moderately strong in- and across-task correlations for mathematical fluency.

Table 6. Summary of Mathematical Fluency Task Correlations

	1	2	3	4
1. Working Memory	--			
2. Fall Mathematical Fluency	.474**	--		
3. Spring Mathematical Fluency	.320**	.586**	--	
4. Fall Metamemory	.241*	.288*	.311**	--

$^{**}p < .01$ $^{*}p < .05$

Classroom-Level Descriptive Statistics

To characterize the classroom context, teacher-led whole-class mathematics lessons were observed and analyzed. A total of 60 minutes of naturalistic classroom instruction was captured for each teacher (600 minutes across the sample). The *Taxonomy of Teacher Behaviors* was used to assess the frequency of different types of teacher instructional language. Individual codes were only assigned once per 30-second interval. Thus, the data presented in Table 7 represents the percentage of 30-second intervals (out of 120 per teacher) containing a given code.

As seen in Table 7, there was significant variability in the types and frequency of language used by Kindergarten teachers. The majority of 30-second intervals during teacher-led mathematics lessons contained some form of *instructional activity* (94.00%). The most prevalent forms of instructional language were providing *general information* (81.00%) or *specific task information* (54.08%). In addition, teachers used *cognitive structuring activities* in 51.17% of the observed intervals. Teachers devoted time to redirecting student *behavior* (21.83%) and focusing *attention* in the service of an instructional goal (19.00%). On average, 17.75% of intervals included teachers *identifying a relationship* between two concepts while 9.92% involved connecting the current mathematics lesson to a *previous school experience* or all students participating in *mass repetitions*.

Memory requests were also frequently used by teachers (64.00%). Approximately half of all intervals (51.17%) contained incidences of teachers asking students to recall semantic information, whereas other types of memory requests were much less common (e.g., asking students to *anticipate* future memory demands only occurred in 3.92% of intervals). Finally, *metacognitive instruction* was the least common of the four main categories of teacher language (24.83%).

Table 7. Teacher Behaviors Taxonomy Codes

Category	Overall Percent Occurrence	Range Across Teachers
Non-Instruction/Non-Memory	3.67%	0.00% - 9.17%
Instructional Activities	*94.00%*	*90.83% - 99.17%*
General Information Giving	81.00%	70.00% - 93.33%
Book Reading	0.00%	0.00% - 0.00%
Prospective Summary	6.42%	3.33% - 10.83%
Specific Task Information	54.08%	35.83% - 74.17%
Cognitive Structuring	*51.17%*	*29.14% - 75.83%*
Attention Regulation: Behavioral Goal	21.83%	11.67% - 40.00%
Attention Regulation: Instructional Goal	19.00%	6.67% - 31.67%
Massed Repetition	9.92%	2.50% - 22.50%
Identifying Features	7.83%	0.00% - 33.33%
Categorization	3.08%	0.00% - 10.83%
Identifying Relationships	17.75%	2.50% - 40.00%
Personal Experience Connections: Home	1.08%	0.00% - 5.83%
Personal Experience Connections: School	9.92%	3.33% -16.67%
Drawing Inferences	1.92%	0.00% - 8.33%
Visual Imagery	0.17%	0.00% - 1.67%
Memory Requests	*64.00%*	*46.67% - 72.50%*
Episodic	0.50%	0.00% - 1.67%
Semantic	51.17%	29.17% - 75.83%
Procedural	0.00%	0.00% - 0.00%
Prospective	1.58%	0.00% - 3.33%
Anticipated	3.92%	0.83% - 12.50%
Metacognitive Instruction	*24.83%*	*10.00% - 45.83%*
Metacognitive Rationale	4.25%	1.67% - 10.00%
Metacognitive Questioning	13.83%	3.33% - 38.33%
Suggestion	11.50%	2.50% - 22.50%
Suppression	1.33%	0.00% - 3.33%
Replacement	0.58%	0.00% - 2.50%

Note: Overall percent occurrences of teacher behaviors during mathematics instruction.

Cognitive Processing Language

Five component codes were used to create an index of cognitive processing language (CPL). The left-hand column of Table 8 depicts average scores across each factor of CPL (1) *strategy suggestions* – 11.50% (2) *metacognitive questioning* – 13.83% and the *co-occurrence of memory requests* with (3) *instructional activities* – 60.00% (4) *cognitive structuring* – 35.42% and (5) *metacognitive information* – 16.08%. Importantly, there was substantial variability across classrooms for each code. For example, *strategy suggestions* were used in 2.50% of intervals by some teachers. Meanwhile, others had significantly higher rates of occurrence (22.50%). Metacognitive questioning also displayed a large range, spanning 3.33% to 38.33% of intervals.

Table 8. CPL Percent Occurrences

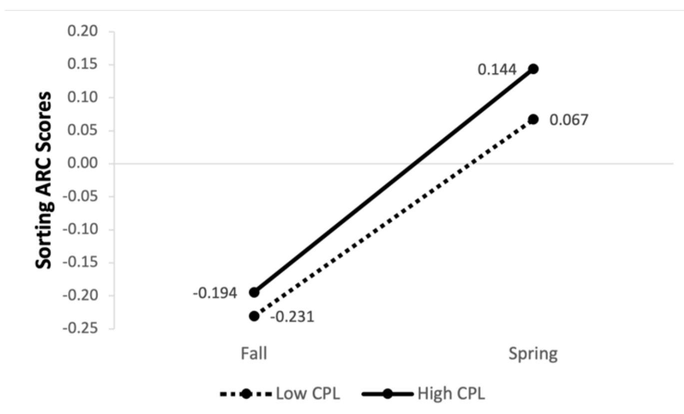
	Overall	Low CPL	High CPL
Taxonomy Codes			
Strategy Suggestion	11.50% (2.50%-22.50%)	8.83% (2.50%-20.83%)	14.17% (6.67%-22.50%)
Metacognitive Questioning	13.83% (3.33%-38.33%)	9.00% (3.33%-19.17%	18.67% (7.50%-38.33%)
Co-occurrence of Memory Requests with:			
Instructional Activities	60.00% (44.17%-65.83%)	58.17% (44.17%-65.00%)	61.83% (56.67%-65.83%)
Cognitive Structuring	35.42% (20.83%-55.00%)	32.22% (22.50%-55.00%)	38.50% (20.83%-55.00%)
Metacognitive Information	16.08% (7.50%-28.33%)	12.33% (7.50%-14.17%)	19.83% (11.67%-28.33%)

Note: Percent occurrence of teacher behaviors during mathematics lessons.

Due to the high level of variability, standardized scores were generated for each code using the means and standard deviations. Each of the resulting *T* scores was averaged to create a composite index of CPL. The mean *T* score was 50 (*SD* = 5.22) with a range of 41.19 to 58.60. Though CPL is a continuous measure, due to the small number of classrooms (*n* = 10) teachers were divided into high and low groups based on a median split. Despite differences in teachers' use of cognitive processing language, the two groups were similar in other key areas. Teachers in each group were similar in age (average 35.60 for the low and 36.40 for the high) and educational degrees (2 with masters in the low compared to 3 with masters in the high). The low group had slightly more years of overall teaching experience (*M* = 14, range = 3-30) compared to the high group (M = 11, range = 2-25). However, the high group was slightly more experienced at teaching Kindergarten (M = 9.4, range 1-25 compared to M = 7.8, range = 2-21). Differences across these demographic statistics were not statistically significant ts(8) ≤ .435, ps ≥.675.

There were observable mean differences in the sorting scores of students placed in low- compared to high-CPL classrooms. At the beginning of the year, students in both classroom contexts sorted below chance on the FRT task (see Figure 2). Children in low-CPL classrooms had lower mean sorting scores (M = -0.231) compared to students in high-CPL classrooms (M = -.194). At the end of the year, children in low-CPL classrooms (M = 0.067) continued to sort less than peers in higher CPL classrooms (M = 0.144), however this gap increased (see Figure 2).

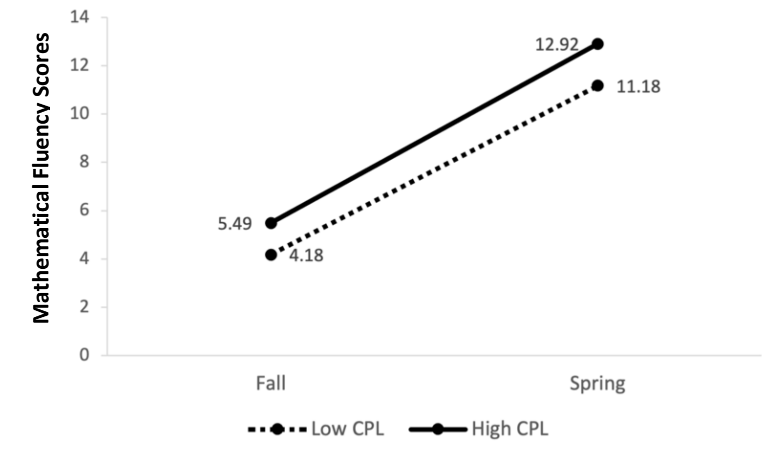
Figure 2. Mean Sorting ARC Scores



Note: Differences in mean sorting ARC scores according to teachers' use of CPL.

Similar results are evident in mathematical fluency scores (see Figure 3). At the beginning of the year, students in low-CPL classrooms (M = 4.18) scored lower in mathematical fluency than students in high-CPL classrooms (M = 5.49). The same pattern is observed at the end of the year (low-CPL: M = 11.18; high-CPL: M = 12.92). However, the difference between the mean scores remained relatively constant across time points.

Figure 3. Mean Mathematical Fluency Scores



Note: Differences in mean mathematical fluency scores according to teachers' use of CPL.

Multiple Regression Analyses Predicting Child Outcomes

Four multiple regressions were conducted to determine the extent to which children's metamemory at school entry and teachers' use of CPL were associated with sorting behaviors and mathematical fluency. Huber-White sandwich estimators were used to account for nesting within classrooms and unequal residual variances. Working memory was correlated with metamemory (see Table 5) and therefore not included as a covariate in the regression models to avoid issues of collinearity. First, analyses are presented for sorting behaviors at the beginning and end of Kindergarten. These are followed by similar analyses for mathematical fluency. For both outcomes, Time 1 performance is included as a covariate to control for initial level of performance when predicting the end of Kindergarten scores.

Children's Sorting Scores

First, a multiple regression was run to determine whether children's initial metamemory or teachers' use of CPL predicted sorting behavior at the beginning of Kindergarten. The overall model was not statistically significant**,** *F*(2, 69) = 1.11, *p* = .335. As expected, CPL did not predict sorting at school entry. However, metamemory was also not a significant predictor of performance at the beginning of the year. Results are displayed in Table 9.

Table 9. Multiple Regression 1

Measure	ß	Robust *SE*	*t*	*p*
Metamemory at Time 1	.19	.01	0.94	.349
Teacher Cognitive-Processing Language	.15	.03	1.35	.180

$^{**}p < .01$ $^{*}p < .05$

Note: Summary of multiple regression for sorting at the beginning of Kindergarten.

Next, a regression was conducted to examine if initial metamemory or teachers' CPL predicted sorting behaviors at the end of Kindergarten (see Table 10). Time 1 sorting was included as a covariate to control for initial performance. The overall model was statistically significant, *F*(3, 68) = 8.51, *p* = .0001. However, sorting at Time 1 was the only significant predictor with a small effect size (standardized regression coefficient = .14, *p* = .004). As expected, metamemory did not predict end-of-year performance. However, contrary to expectations, CPL was also not a significant predictor of end-of-year sorting behaviors (standardized regression coefficient = .05, *p* = .677).

Table 10. Multiple Regression 2

Measure	ß	Robust *SE*	*t*	*p*
Sorting at Time 1	.14	.20	2.97	.004**
Metamemory at Time 1	.16	.01	1.46	.149
Teacher Cognitive-Processing Language	.05	.12	0.42	.677

$^{**}p < .01$ $^{*}p < .05$

Note: Summary of multiple regression for sorting at the end of Kindergarten.

Children's Mathematical Fluency Scores

Two similar regressions were run to determine if metamemory or teachers' CPL predicted mathematical fluency scores at the beginning or end of Kindergarten. The overall model for the beginning of Kindergarten was statistically significant, *F*(2, 68) = 4.08, *p* = .021.

Children's metamemory at school entry was a moderate predictor of mathematical fluency in the fall (standardized regression coefficient = .29, p = .008). As expected, teachers' CPL did not predict performance at Kindergarten entry. Results are displayed in Table 11.

Table 11. Multiple Regression 3

Measure	*ß*	Robust *SE*	*t*	*p*
Metamemory at Time 1	.29	.13	2.72	.008**
Teacher Cognitive-Processing Language	.13	1.13	1.12	.266

$^{**}p < .01$ $^{*}p < .05$

Note: Summary of multiple regression for mathematical fluency at the beginning of Kindergarten.

Finally, similar to sorting scores, the overall model for end of the year mathematical fluency was statistically significant, $F(3, 67) = 16.19$, $p = .000$. Mathematical fluency at Time 1 was included as a covariate and was the only statistically significant predictor (standardized regression coefficient = .54, p = .000). At the end of the year, initial metamemory was no longer a significant predictor, and contrary to expectations neither was teachers' use of CPL. Table 10 includes the results for this model.

Table 12. Multiple Regression 4

Measure	*ß*	Robust *SE*	*t*	*p*
Mathematical Fluency at Time 1	.54	.14	6.10	.000**
Metamemory at Time 1	.16	.22	1.46	.150
Teacher Cognitive-Processing Language	.04	1.59	.36	.723

$^{**}p < .01$ $^{*}p < .05$

Note: Summary of multiple regression for mathematical fluency at the end of Kindergarten.

CHAPTER IV: DISCUSSION

This investigation was designed to examine the predictive utility of children's metamemory and teachers' instructional language on cognitive skills during Kindergarten. Specifically, it focused on students' sorting behaviors during a deliberate memory task and their mathematical fluency on a standardized assessment of academic achievement. It uses a socialization of cognition perspective (combining information processing and sociocultural theories) to explore the role of social forces in cognitive development (see Fivush, 2011; Rogoff, 1990; Ornstein & Haden, 2001).

This study contributes to the extant body of research in three meaningful ways: (1) expanding the research on metamemory and cognitive skills during elementary school (2) focusing on the role of teacher language in the development of basic and domain-specific cognitive skills concurrently, and (3) highlighting cognitive performance in the Kindergarten year, whereas most previous work examined children's skills in the first grade. Although the majority of the proposed hypotheses were unsupported, the findings provide insight into the role of classroom and individual factors in developing cognitive skills. Moreover, the results support several notable future directions for this work.

Metamemory and Strategic Sorting

Over the course of the Kindergarten year, students increased in their use of strategic sorting behaviors during a free-recall task. Given past reports of metamemory predicting children's strategy use on deliberate memory tasks (see Grammer et al., 2011; Schlagmüller & Schneider, 2002), it was hypothesized that this study would yield similar results across Kindergarten. However, metamemory was not a significant predictor of sorting scores at the beginning or end of the school year. Several factors may account for these findings. First, only one specific memory strategy was assessed – sorting. Metamemory may be more strongly related to other behaviors such as rehearsal or elaboration. Bebko et al. (2014) reported that metamemory was a significant predictor of rehearsal use in a serial recall task. Additionally, the measure of metamemory used is a shortened version of the Würzburg Metamemory Test (see Schlagmueller et al., 2001) containing only six items. Perhaps the scale was unable to accurately assess variability in metamemory at this age.

This study used the combined total of both metamemory subscales (general declarative and organizational strategies). It is possible that task-specific metamemory knowledge is more important than a general understanding of memory processes. For example, Weed and colleagues (1990) discovered independent contributions of general and task-specific metamemory on recall performance during a free-recall task. However, task-specific metamemory appears to be more strongly related to memory performance than general metamemory (Short et al., 1993). Additionally, the results of numerous investigations suggest that metamemory may be more important for strategy training, maintenance, and generalization than performance (see Cavanaugh & Borkowski, 1979; Weed et al., 1990). Therefore, metamemory may be more correlated with growth trajectories than measures of strategy use or recall scores at a given time point.

Moreover, declarative metamemory is only one aspect of metacognition. Metamemory also contains procedural components including skills such as monitoring and regulating performance (Flavell & Wellman, 1977; Schneider, 1985; Schneider, 2008). Information processing theorists propose that effective strategy users both plan their thinking and monitor their behaviors (Pressley et al., 1989). Perhaps these process-focused abilities are more directly related to effective implementation of strategic behaviors than is conceptual knowledge.

Metamemory and Mathematical Fluency

This is one of the first studies to examine specifically the role of declarative metamemory in mathematical achievement. Unlike the findings for strategic sorting, metamemory did predict mathematical fluency at the beginning of Kindergarten. This finding underscores the notion that children enter formal schooling with an array of academic and metacognitive skills. Differences in metamemory knowledge in elementary school students are linked to home and individual factors such as the home literacy environment, age, and working memory (Grammer et al. 2011). Further, such differences are related to initial performance levels at the start of the school year. Although a less-studied construct, metamemory may play a meaningful role in academic skills. This emphasizes the importance of examining both domain-general skills, such as memory, in conjunction with domain-specific abilities, such as mathematics.

Notably, children's initial level of metamemory was correlated with mathematical fluency scores at the end of the year; however, it was not a statistically significant predictor in the regression model. It was hypothesized that metamemory at school entry would continue to be associated with performance across Kindergarten. The current study did not look at the correlation between concurrent metamemory and mathematical fluency at the end of the year. One possibility is that metamemory only has a contemporaneous relationship with this skill. Across the school year, children are exposed to numerous other factors that may influence the development of mathematical fluency. It is also possible that other child-level variables or external influences, such as interactions with more knowledgeable members of society (see (Gauvain & Perez, 2015), become more important than metamemory for performance on mathematics tasks.

Cognitive Processing Language and Strategic Sorting

In addition to children's metamemory, this study was also designed to examine the role of contextual factors on cognitive outcomes. Teachers' use of Cognitive Processing Language (CPL) was not predictive of students' sorting ARC scores in Kindergarten. As expected, CPL did not predict students' performance at the start of the school year. However, contrary to the hypothesis, it did not predict sorting at the end of Kindergarten. Past research by Coffman and colleagues (2008) indicates that CPL is related to strategic behaviors on deliberate memory tasks in first grade. There are several possible explanations for the discrepant findings between these studies.

First, the timing of exposure to cognitive-rich instruction may be significant. Morrison and Dow-Ehrensberger (1995) posited the importance of the first-grade school year (compared to Kindergarten) in memory outcomes in a landmark study using the natural cutoff for school entry. Despite notable changes to the organization and focus of Kindergarten (see Bassok et al., 2016), classrooms with higher levels of CPL may be only beneficial to more advanced students. According to sociocultural theory, what children are capable of learning is determined by both their individual abilities and the guidance of a teacher or peer (Vygotsky, 1978). It is likely that students need a certain level of knowledge and proficiency to be able to take advantage of metacognitively rich language. As indicated by the cutoff study, it may not be the age of children that matters for memory development but cumulative experiences. Perhaps children need the Kindergarten year to prime them to take advantage of metacognitively rich language in first grade, or maybe experiences in the later grade involve greater cognitive demands, thus allowing children to reap the benefits of teachers' instructional language. It is also possible that the benefits of high-CPL Kindergarten classrooms are not realized until later. Coffman and colleagues (2018) found that exposure to high levels of CPL in first grade predicted strategic memory behaviors in first, second, and fourth grade. Therefore, early exposure to this type of language may be related to more distal outcomes.

Secondly, the classroom-level measure of teachers' instructional language may have only captured some of the relevant aspects of instruction. The index of Cognitive Processing Language contains five key components (1) *metacognitive questions* (2) *strategy suggestions* (3) deliberate *memory demands* paired with (i) *instructional activities* (ii) *cognitive structuring activities* (iii) and the presentation of *metacognitive information* and has only been used as an aggregated measure. It is likely that some aspects may be more directly related to student outcomes. For example, metacognitive questioning may be more important for children's strategic development than the pairing of memory demands with instructional activities. Direct links between specific components of CPL and students' outcomes have yet to be explored. Other researchers have broken down metacognitive instruction to a more granular level. For example, Zepeda and colleagues (2019) examined four different types of metacognitive talk – metacognitive knowledge (personal, strategy, conditional), skills (planning, monitoring, evaluating), the manner of instruction (directive, prompts, modeling), and metacognitive framing (problem specific, problem general, or domain general). A more detailed examining of metacognitive-focused teacher language may help identify the most important features for promoting students' cognitive skills.

Finally, there may be other relevant aspects of teachers' behavior or instruction that are not captured by this measure. Moreover, other classroom variables may mediate the relationship between CPL and cognitive outcomes. The Classroom Assessment Scoring System (CLASS; Pianta et al., 2008) identifies three significant domains in early education classrooms –

emotional, organizational, and instructional support. It is likely that other aspects of early learning environments work in conjunction with teachers' instructional language. General behavioral management, the nature of teacher-child relationships, and use of strategies for engaging students may play an important role in how much students gain from metacognitive language.

Cognitive Processing Language and Mathematical Fluency

Cognitive Processing Language was not linked to mathematical fluency at either the beginning (as anticipated) or the end of Kindergarten. Two past studies report associations between CPL and math outcomes. First, Grammer et al. (2016) discovered that in second grade, students who were exposed to higher levels of CPL (compared to peers in classrooms where teachers used less CPL) had higher mathematical fluency scores at the end of the school year. This begs the question of why mathematics performance and CPL were not related in this sample. One possibility is the significance of timing, similar to the proposed explanations of sorting scores. Students may only benefit from CPL in later grades. However, a previous study by Hudson and colleagues (2018) found that CPL was a significant predictor of mathematical accuracy and strategy use on a 10-problem addition task at the end of Kindergarten. Therefore, it may be a combination of timing and the nature of the task. Mathematical fluency is a time-dependent task, requiring both accuracy and speed. Meanwhile, the addition task used by Hudson et al. (2018) is untimed and focuses on effective strategy use. The differences in the cognitive-demands between these two tasks may account for the varied results. Therefore, it is possible that CPL exposure is more related to strategy use than fluency performance until later grades. Differences between these studies may be related to the measures used and age of the samples.

Other possible explanations mirror those of the role of CPL in children's strategic sorting. The null finding may be related to the conceptualization of CPL or uncaptured classroom environment factors. For example, researchers have linked teachers' understanding of children's mathematical thinking to student outcomes (Fennema et al., 1996). Teachers' knowledge may impact their ability to provide effective metacognitively rich mathematics instruction.

Limitations

This study has several notable limitations. First, it used a relatively small sample size of students (72 children in 10 classrooms). There were approximately 7 students from each classroom. It is possible that the results are partially due to insufficient statistical power based on the limited number of participants. All students came from three schools within one district. A larger sample from multiple school districts or regions would allow for a more diverse student population and greater generalizability. A larger number of classrooms would also allow for more complex analyses such as hierarchical linear modeling. Additionally, observations of only mathematics whole-class lessons were used in this study. Other relevant language may happen during small-group or individual instruction that was not captured in this data set.

This study also did not control for differences in mathematics curriculum between classrooms or across schools. Findings from past research suggest linkages between curricula and students' academic achievement (e.g., Baroody & Ginsburg, 1983; Starkey et al., 2004). Researchers have found that teachers using the same curriculum display variability in language (see Murata et al., 2017). However, without controlling for educational content it is difficult to determine if between classroom differences reflect distinctive teacher behaviors or merely curricular differences.

As discussed above, alternative measures might more comprehensively capture the desired constructs. The metamemory scale (see Schlagmueller et al., 2001) used in this study is shorter than those used previously, and thus may not provide as accurate a measure as other more comprehensive tasks. Similarly, to truly understand the relationship between Cognitive Processing Language, metamemory, and cognitive skills, additional measures of memory and mathematics need to be included. Additional deliberate memory tasks would further elucidate which skills are most directly tied to CPL. Mathematical abilities, such as strategy use or conceptual knowledge, were not included in this study and may warrant further exploration.

Future Directions

Despite null findings for three of the four hypotheses, this study provides a groundwork for several key directions of future research. First, the discrepant findings between this and other studies using CPL (e.g., Coffman et al., 2008; Hudson et al. 2018) suggest the importance of further exploring timing. Additional work should examine comparisons between exposure to higher levels of CPL in Kindergarten compared to first grade. Moreover, researchers should explore long-term and distal impacts of CPL. The benefits from high levels of metacognitively rich instruction may not be apparent until first or second grade.

The finding that metamemory is related to strategic sorting at the start of the year also indicates the importance of looking at factors prior to school entry. Hudson et al. (2018) found that mothers' use of elaborative metamemory talk during reminiscing conversations predicted students' mathematical accuracy and strategy use at the start of Kindergarten. Home experiences before Kindergarten may help children better take advantage of teachers' language and predict initial performance levels.

Other child-level metacognitive skills and aspects of the classroom context may predict cognitive abilities during Kindergarten. Future work can expand on the current literature by exploring metacognitive monitoring and regulating skills in young children during mathematics tasks. Sociocultural theorists note that peer interactions also shape cognitive development (Gauvain & Perez, 2015; Rogoff, 1990). Student responses to memory demands or metacognitive questions may influence learning. Future work might investigate children's responses to metacognitively rich language. Similarly, additional components of teachers' language, beliefs, and individual components of CPL can be examined in relation to these child outcomes.

Conclusion

Using data from a larger longitudinal study, this investigation was designed to examine children's cognition during Kindergarten. The findings present evidence for the importance of concurrently exploring child- and classroom-level influences on memory and mathematics skills. It is one of the first studies to look at children's metamemory and teachers' instructional language simultaneously. Despite results that were contrary to past research, it raises several important directions for future work – specifically, the need to better understand the timing of developing cognitive skills and the interplay of the classroom context and children's individual abilities.

REFERENCES

Ashcraft, M. H. (1982). The development of mental arithmetic: A chronometric approach. *Developmental Review*, *2*(3), 213-236. https://doi.org/10.1016/0273-2297(82)90012-0

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. *Psychology of Learning and Motivation, 2*(4), 89-195. https://doi.org/10.1016/S0079-7421(08)60422-3

Baker-Ward, L., & Ornstein, P. A. (2014). The coaction of theory and methods in the study of the development of memory. In P. J. Bauer & R. Fivush (Eds.), *The Wiley handbook on the development of children's memory* (pp. 41–64). Wiley Blackwell.

Baker-Ward, L., Ornstein, P. A., & Holden, D. J. (1984). The expression of memorization in early childhood. *Journal of Experimental Child Psychology, 37*(3), 555-575. https://doi.org/10.1016/0022-0965(84)90076-6

Baroody, A. J. (2011). Learning: A framework. In F. Fennell (Ed.), *Achieving fluency: Special education and mathematics* (pp. 15–58). National Council of Teachers of Mathematics.

Baroody, A. J., & Ginsburg, H. P. (1983). The effects of instruction on children's understanding of the 'equals' sign. *The Elementary School Journal*, *84*, 199–212. https://doi.org/10.1086/461356

Bassok, D., Latham, S., & Rorem, A. (2016). Is kindergarten the new first grade?. *AERA Open*, *1*(4), 1-31. https://doi.org/10.1177%2F2332858415616358

Bebko, J. M., McMorris, C. A., Metcalfe, A., Ricciuti, C., & Goldstein, G. (2014). Language proficiency and metacognition as predictors of spontaneous rehearsal in children. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale, 68*(1), 46–58. https://doi.org/10.1037/cep0000013

Bellon, E., Fias, W., & De Smedt, B. (2019). More than number sense: The additional role of executive functions and metacognition in arithmetic. *Journal of Experimental Child Psychology*, *182*, 38-60. https://doi.org/10.1016/j.jecp.2019.01.012

Bjorklund, D. F., & Zeman, B. R. (1982). Children's organization and metamemory awareness in their recall of familiar information. *Child Development, 53*(3), 799-810. https://doi.org/10.2307/1129394

Bjorklund, D. F., Ornstein, P. A., & Haig, J. R. (1977). Developmental differences in organization and recall: Training in the use of organizational techniques. *Developmental Psychology, 13*(3), 175–183. https://doi.org/10.1037/0012-1649.13.3.175

Boonen, A. J. H., Kolkman, M. E., & Kroesbergen, E. H. (2011). The relation between teachers' math talk and the acquisition of number sense within kindergarten classrooms. *Journal of School Psychology, 49*, 281–299. https://doi.org/10.1016/j.jsp.2011.03.002

Brown, S. C., & Craik, F. I. M. (2000). Encoding and retrieval of information. In E. Tulving & F. I. M. Craik (Eds.), *The Oxford handbook of memory* (pp. 93–107). Oxford University Press.

Carr, M., & Jessup, D. L. (1995). Cognitive and metacognitive predictors of mathematics strategy use. *Learning and Individual Differences, 7*(3), 235-247. https://doi-org.libproxy.uncg.edu/10.1016/1041-6080(95)90012-8

Carr, M., Alexander, J., & Folds-Bennett, T. (1994). Metacognition and mathematics strategy use. *Applied Cognitive Psychology, 8(*6), 583-595. https://doi.org/10.1002/acp.2350080605

Carr, M., Kurtz, B. E., Schneider, W., Turner, L. A., & Borkowski, J. G. (1989). Strategy acquisition and transfer among American and German children: Environmental influences on metacognitive development. *Developmental Psychology, 25*(5), 765–771. https://doi.org/10.1037/0012-1649.25.5.765

Cavanaugh, J. C., & Borkowski, J. G. (1979). The metamemory-memory “connection”: Effects of strategy training and maintenance. *The Journal of General Psychology, 101*(2), 161-174. https://doi.org/10.1080/00221309.1979.9920070

Chapin, S. H., O’Connor, C., & Anderson, N. C. (2009). *Classroom discussions: Using math talk to help students learn, Grades K-6.* Math Solutions.

Christian, K., Bachman, H. J., & Morrison, F. J. (2001). Schooling and cognitive development. In R. J. Sternberg & R. L. Grigorenko (Eds.) *Environmental effects on cognitive abilities* (pp. 287- 335). Lawrence Erlbaum Associates.

Clarke, B., Nelson, N., & Shanley, L. (2016). Mathematics fluency—More than the weekly timed test. In K. D. Cummings & Y. Petscher (Eds.), *The fluency construct: Curriculum-based measurement concepts and applications* (pp. 67–89). Springer Science + Business Media. https://doi.org/10.1007/978-1-4939-2803-3_3

Coffman, J. L. & Cook, O. K. (2021). Overview: The development of memory in the elementary classroom context. In L. E. Baker-Ward, D. F. Bjorklund, & J. L. Coffman (Eds.), *The* *development of children's memory: The scientific contributions of Peter A. Ornstein* (pp. 237-257). Cambridge University Press.

Coffman, J. L., Grammer, J. K., Hudson, K. N., Thomas, T. E., Villwock, D. & Ornstein, P. A. (2018). Relating children's early elementary classroom experiences to later skilled remembering and studying. *Journal of Cognition and Development, 20*(2), 203-221. https://doi.org/10.1080/15248372.2018.1470976

Coffman, J. L., Ornstein, P. A., McCall, L. E., & Curran, P. J. (2008). Linking teachers' memory-relevant language and the development of children's memory skills. *Developmental Psychology, 44*(6), 1640–1654. https://doi.org/10.1037/a0013859

Cornoldi, C., Gobbo, C., & Mazzoni, G. (1991). On metamemory-memory relationship: Strategy availability and training. *International Journal of Behavioral Development, 14*(1), 101-121. https://doi.org/10.1177/016502549101400106

Craik, F. I., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior, 11*(6), 671-684. https://doi.org/10.1016/S0022-5371(72)80001-X

Cristofaro, T. N., & Tamis-LeMonda, C. S. (2012). Mother-child conversations at 36 months and at pre-kindergarten: Relations to children's school readiness. *Journal of Early Childhood Literacy, 12*(1), 68-97. https://doi.org/10.1177%2F1468798411416879

Cross, C. T., Woods, T. A., & Schweingruber, H. (Eds.). (2009). *Mathematics learning in early childhood: Paths toward excellence and equity.* National Academies Press.

DeLoache, J. S., Cassidy, D. J., & Brown, A. L. (1985). Precursors of mnemonic strategies in very young children's memory. *Child Development, 56*(1), 125-137. https://doi.org/10.2307/1130180

Engel, M., Claessens, A., & Finch, M. A. (2013). Teaching students what they already know? The (mis) alignment between mathematics instructional content and student knowledge in kindergarten. *Educational Evaluation and Policy Analysis*, *35*(2), 157-178. https://doi.org/10.3102%2F0162373712461850

Fabricius, W. V., & Hagen, J. W. (1984). Use of causal attributions about recall performance to assess metamemory and predict strategic memory behavior in young children. *Developmental Psychology, 20*(5), 975–987. https://doi.org/10.1037/0012-1649.20.5.975

Fennema, E., Carpenter, T. P., Franke, M. L., Levi, L., Jacobs, V. R., & Empson, S. B. (1996). A longitudinal study of learning to use children's thinking in mathematics instruction. *Journal for Research in Mathematics Education*, *27*(4), 403-434. https://doi.org/10.5951/jresematheduc.27.4.0403

Fivush, R. (2011). The development of autobiographical memory. *Annual Review of Psychology, 62,* 559-582. https://doi.org/10.1146/annurev.psych.121208.131702

Fivush, R. (2019). Sociocultural developmental approaches to autobiographical memory. *Applied Cognitive Psychology, 33*(4), 489-497. https://doi.org/10.1002/acp.3512

Fivush, R., Haden, C. A., & Reese, E. (2006). Elaborating on elaborations: Role of maternal reminiscing style in cognitive and socioemotional development. *Child Development, 77*(6), 1568-1588. https://doi.org/10.1111/j.1467-8624.2006.00960.x

Flavell, J. H. (1971). First discussant's comments: What is memory development the development of? *Human Development, 14*(4), 272–278. https://doi.org/10.1159/000271221

Flavell, J. H. & Wellman, H. M. (1977). Metamemory. In Kail, R. V. & Hagin, J. W. (Eds.), *Perspectives on the development of memory and cognition* (pp. 3–33). Lawrence Erlbaum Associates.

Folds, T. H., Footo, M. M., Guttentag, R. E., & Ornstein, P. A. (1990). When children mean to remember: Issues of context, specificity, strategy. In D.F. Bjorklund (Ed.) *Children's strategies: Contemporary views of cognitive development* (pp. 67-91). Lawrence Erlbaum Associates.

Gauvain, M. (1998). Cognitive development in social and cultural context. *Current Directions in Psychological Science, 7*(6), 188-192. https://doi.org/10.1111%2F1467-8721.ep10836917

Gauvain, M. (2001). *The social context of cognitive development.* Guilford Press.

Gauvain, M., & Perez, S. M. (2015). The socialization of cognition. In J. E. Grusec & P. D. Hastings (Eds.), *Handbook of socialization: Theory and research* (pp. 566–589). The Guilford Press.

Geary, D.C. (2006). Development of mathematical understanding. In D. Kuhl, R.S. Siegler (Vol. Eds.), W. Damon (Series Ed.), *Handbook of child psychology: Vol. 2. Cognition, perception, and language* (6th ed., pp. 777–810). John Wiley & Sons.

Goldhaber, D. E. (2000). *Theories of human development: Integrative perspectives.* Mayfield Publishing Company.

Grammer, J. K., Coffman, J. L., Sidney, P. G., & Ornstein, P. A. (2016). Linking teacher instruction and student achievement in mathematics: The role of teacher language. *Journal of Cognition and Development, 17*(3), 468–485. https://doi.org/10.1080/15248372.2015.1068777

Grammer, J. K., Purtell, K. M., Coffman, J. L., & Ornstein, P. A. (2011). Relations between children's metamemory and strategic performance: Time-varying covariates in early elementary school. *Journal of Experimental Child Psychology, 108*(1), 139-155. https://doi.org/10.1016/j.jecp.2010.08.001

Grammer, J., Coffman, J. L., & Ornstein, P. (2013). The effect of teachers' memory-relevant language on children's strategy use and knowledge. *Child Development, 84*(6), 1989-2002. https://doi.org/10.1111/cdev.12100

Groen, G. J., & Parkman, J. M. (1972). A chronometric analysis of simple addition. *Psychological Review, 79*(4), 329–343. https://doi.org/10.1037/h0032950

Haden, C. A. (2021). *Memory* development or the *development* of memory? An update. In L. E. Baker-Ward, D. F. Bjorklund, & J. L. Coffman (Eds.), *The development of children's memory: The scientific contributions of Peter A. Ornstein* (pp. 29-44). Cambridge University Press.

Haden, C. A., Ornstein, P. A., Eckerman, C. O., & Didow, S. M. (2001). Mother–child conversational interactions as events unfold: Linkages to subsequent remembering. *Child Development, 72*(4), 1016-1031. https://doi.org/10.1111/1467-8624.00332

Huber, P. J. (1967). The behavior of maximum likelihood estimates under nonstandard conditions. In *Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability* (Vol. 1, pp. 221–233). University of California Press.

Hudson, K. N., Coffman, J. L., & Ornstein, P. A. (2018). Addition in kindergarten: The role of mothers' and teachers' language. *Journal of Cognition and Development, 19*(1), 65–86. https://doi.org/10.1080/15248372.2017.1415900

Hudson, K. N., Wiley, K. C., Coffman, J. L. (2021). Children's accuracy and strategy use in the context of addition: Extending the impacts of metacognitive language to children's academic skills. In L. E. Baker-Ward, D. F. Bjorklund, & J. L. Coffman (Eds.), *The development of children's memory: The scientific contributions of Peter A. Ornstein* (pp. 258-272). Cambridge University Press.

Jacobs, J. (1887). Experiments on" prehension". *Mind, 12*(45), 75-79. https://doi.org/10.1093/mind/os-12.45.75

Kerkman, D. D., & Siegler, R. S. (1997). Measuring individual differences in children's addition strategy choices. *Learning and Individual Differences, 9*(1), 1-18. https://doi.org/10.1016/S1041-6080(97)90017-0

Klibanoff, R. S., Levine, S. C., Huttenlocher, J., Vasilyeva, M., & Hedges, L. V. (2006). Preschool children's mathematical knowledge: The effect of teacher "math talk." *Developmental Psychology, 42*(1), 59–69. https://doi.org/10.1037/0012-1649.42.1.59

Kreutzer, M. A., Leonard, C., Flavell, J. H., & Hagen, J. W. (1975). An interview study of children's knowledge about memory. *Monographs of the Society for Research in Child Development*, *40*(1), 1-60. https://doi.org/10.2307/1165955

Kurtz, B. E., Schneider, W., Carr, M., Borkowski, J. G., & Rellinger, E. (1990). Strategy instruction and attributional beliefs in West Germany and the United States: Do teachers foster metacognitive development? *Contemporary Educational Psychology, 15*(3), 268–283. https://doi.org/10.1016/0361-476X(90)90024-U

Lange, G. (1978). Organization-related processes in children's recall. In P. A. Ornstein (Ed.), *Memory development in children* (pp. 101–128). Lawrence Erlbaum Associates.

Langley, H. A., Coffman, J. L., & Ornstein, P. A. (2017). The socialization of children's memory: Linking maternal conversational style to the development of children's autobiographical and deliberate memory skills. *Journal of Cognition and Development, 18(*1), 63-86. https://doi.org/10.1080/15248372.2015.1135800

McCarthy, D. (1972). *Manual for the McCarthy scales of children's abilities.* Psychological Corporation.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63*(2), 81–97. https://doi.org/10.1037/h0043158

Moely, B. E., Hart, S. S., Leal, L., Santulli, K. A., Rao, N., Johnson, T., & Hamilton, L. B. (1992). The teacher's role in facilitating memory and study strategy development in the elementary school classroom. *Child Development, 63*(3), 653-672. https://doi.org/10.1111/j.1467-8624.1992.tb01653.x

Morrison, F. J., Smith, L., & Dow-Ehrensberger, M. (1995). Education and cognitive development: A natural experiment. *Developmental Psychology, 31(*5), 789–799. https://doi-org.libproxy.uncg.edu/10.1037/0012-1649.31.5.789

Murata, A., Siker, J., Kang, B., Baldinger, E. M., Kim, H. J., Scott, M., & Lanouette, K. (2017). Math talk and student strategy trajectories: The case of two first grade classrooms. *Cognition and Instruction*, *35*(4), 290-316. https://doi.org/10.1080/07370008.2017.1362408

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

Ornstein P. A., & Naus M.J. (1978). Rehearsal processes in children's memory. In P. A. Ornstein (Ed.), *Memory development in children* (pp. 69–99). Lawrence Erlbaum Associates.

Ornstein, P. A., & Coffman, J. L. (2020). Toward an understanding of the development of skilled remembering: The role of teachers' instructional language. *Current Directions in Psychological Science, 29*(5), 445–452. https://doi.org/10.1177/0963721420925543

Ornstein, P. A., & Haden, C. A. (2001). Memory development or the development of memory? *Current Directions in Psychological Science, 10*(6), 202–205. https://doi.org/10.1111/1467-8721.00149

Ornstein, P. A., Baker-Ward, L., & Naus, M. J. (1988). The development of mnemonic skill. In F. E. Weinert & M. Perlmutter M (Eds.), *Memory development: Universal changes and individual differences* (pp. 31-50). Lawrence Erlbaum Associates

Ornstein, P. A., Coffman, J. L., & Grammer, J. K. (2009). Learning to remember. In O. A. Barbarin & B. Wasik (Eds.), *Handbook of child development and early education: Research to practice* (pp.103-122). Guilford Press.

Ornstein, P. A., Coffman, J. L., Grammer, J. K., San Souci, P. P., & McCall, L. E. (2010). Linking the classroom context and the development of children's memory skills. In J. Meece & J. Eccles (Eds.), *Handbook of research on schools, schooling, and human development* (pp. 42 – 59). Routledge.

Ornstein, P. A., Grammer, J. K., & Coffman, J. L. (2010). Teachers' "mnemonic style" and the development of skilled memory. In H. S. Waters & W. Schneider (Eds.), *Metacognition, strategy use, and instruction* (pp. 23-53). Guilford Publications.

Ornstein, P. A., Haden, C. A., & Elischberger, H. B. (2006). Children's memory development: Remembering the past and preparing for the future. In E. Bialystok & F. I. M. Craik (Eds.), *Lifespan cognition: Mechanisms of change* (pp. 143–161). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195169539.003.0010

Ornstein, P. A., Haden, C. A., & San Souci, P. (2008). The development of skilled remembering in children. *Learning and Memory: A Comprehensive Reference, 2*, 715-744. https://doi.org/10.1016/B978-012370509-9.00136-4

Ornstein, P. A., Naus, M. J., & Liberty, C. (1975). Rehearsal and organizational processes in children's memory. *Child Development, 46*(4), 818–830. https://doi.org/10.2307/1128385

Ornstein, P. A., Naus, M. J., & Stone, B. P. (1977). Rehearsal training and developmental differences in memory. *Developmental Psychology, 13*(1), 15–24. https://doi.org/10.1037/0012-1649.13.1.15

Paris, S. G., Newman, R. S., & Mcvey, K. A. (1982). Learning the functional significance of mnemonic actions: A microgenetic study of strategy acquisition. *Journal of Experimental Child Psychology, 34*(3), 490-509. https://doi.org/10.1016/0022-0965(82)90073-X

Pellegrino, J. W., & Goldman, S. R. (1987). Information processing and elementary mathematics. *Journal of Learning Disabilities*, *20*(1), 23–32, 57. https://doi.org/10.1177/002221948702000105

Pianta, R. C., La Paro, K. M., & Hamre, B. K. (2008). *Classroom Assessment Scoring System™: Manual K-3*. Paul H Brookes Publishing.

Pressley, M. (1986). The relevance of the good strategy user model to the teaching of mathematics. *Educational Psychologist, 21*(1-2), 139-161. https://doi.org/10.1080/00461520.1986.9653028

Pressley, M., Borkowski, J. G., & Schneider, W. (1989). Good information processing: What it is and how education can promote it. *International Journal of Educational Research, 13*(8), 857-867. https://doi.org/10.1016/0883-0355(89)90069-4

Pressley, M. & Van Meter, P. (1993). Memory strategies: Natural development and use following instruction. *Emerging Themes in Cognitive Development, 2*, 128-165.

Reese, E., Haden, C. A., & Fivush, R. (1993). Mother-child conversations about the past: Relationships of style and memory over time. *Cognitive Development, 8*(4), 403-430. https://doi.org/10.1016/S0885-2014(05)80002-4

Roebers, C. M. (2014). Children's deliberate memory development: The contribution of strategies and metacognitive processes. In P. J. Bauer & R. Fivush (Eds.), *The Wiley handbook on the development of children's memory* (pp. 865–894). Wiley Blackwell.

Roenker, D. L., Thompson, C. P., & Brown, S. C. (1971). Comparison of measures for the estimation of clustering in free recall. *Psychological Bulletin, 76*(1), 45–48. https://doi.org/10.1037/h0031355

Rogoff, B. (1981). Schooling and the development of cognitive skills. In H. C. Triandis & A. Heron (Eds.), *Handbook of cross-cultural psychology* (Vol. 4, pp. 233–294). Allyn & Bacon

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context.* Oxford University Press.

Rohwer W. D., Jr (1973). Elaboration and learning in childhood and adolescence. *Advances in Child Development and Behavior, 8*, 1–57. https://doi.org/10.1016/s0065-2407(08)60492-9

Rudd, L. C., Lambert, M. C., Satterwhite, M., & Zaier, A. (2008). Mathematical language in early childhood settings: What really counts? *Early Childhood Education Journal*, *36*, 75–80. https://doi.org/10.1007/s10643-008-0246-3

Schlagmüller, M., & Schneider, W. (2002). The development of organizational strategies in children: Evidence from a microgenetic longitudinal study. *Journal of Experimental Child Psychology, 81*(3), 298-319. https://doi.org/10.1006/jecp.2002.2655

Schlagmüller, M., Visé, M., & Schneider, W. (2001). Zur Erfassung des Gedächtniswissens bei Grundschulkindern: Konstruktionsprinzipien und empirische Bewährung der Würzburger Testbatterie zum deklarativen Metagedächtnis [Assessing metamemory in elementary school children: Construction and evaluation of the Würzburg Metamemory Test]. *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie, 33*(2), 91–102. https://doi.org/10.1026/0049-8637.33.2.91

Schneider, W. (1985). Developmental trends in the metamemory-memory behavior relationship: An integrative review. In D. J. Forrest-Pressley, G. E. McKinnon, & T. G. Waller (Eds.), *Metacognition, cognition, and human performance* (Vol. 1, pp. 57-109). Academic Press.

Schneider, W. (2008). The development of metacognitive knowledge in children and adolescents: Major trends and implications for education. *Mind, Brain, and Education, 2*(3), 114-121. https://doi.org/10.1111/j.1751-228X.2008.00041.x

Schneider, W., & Artelt, C. (2010). Metacognition and mathematics education. *ZDM Mathematics Education, 42*(2), 149-161. https://doi.org/10.1007/s11858-010-0240-2

Schneider, W., & Bjorklund, D. F. (1998). Memory. In W. Damon (Ed.), *Handbook of child psychology: Vol. 2. Cognition, perception, and language* (pp. 467–521). John Wiley & Sons Inc.

Schneider, W., & Sodian, B. (1988). Metamemory-memory behavior relationships in young children: Evidence from a memory-for-location task. *Journal of Experimental Child Psychology, 45*(2), 209-233. https://doi.org/10.1016/0022-0965(88)90030-6

Schneider, W., Borkowski, J. G., Kurtz, B. E., & Kerwin, K. (1986). Metamemory and motivation: A comparison of strategy use and performance in German and American children. *Journal of Cross-Cultural Psychology, 17*(3), 315–336. https://doi.org/10.1177/0022002186017003005

Schneider, W., Schlagmüller, M., & Visé, M. (1998). The impact of metamemory and domain-specific knowledge on memory performance. *European Journal of Psychology of Education, 13*(1), 91-103. https://doi.org/10.1007/BF03172815

Scribner, S., & Cole, M. (1978). Literacy without schooling: Testing for intellectual effects. *Harvard Educational Review, 48*(4), 448-461. https://doi.org/10.17763/haer.48.4.f44403u05l72x375

Short, E. J., Schatschneider, C. W., & Friebert, S. E. (1993). Relationship between memory and metamemory performance: A comparison of specific and general strategy knowledge. *Journal of Educational Psychology, 85*(3), 412–423. https://doi.org/10.1037/0022-0663.85.3.412

Siegler, R. S. (1987). The perils of averaging data over strategies: An example from children's addition. *Journal of Experimental Psychology: General, 116*(3), 250–264. https://doi.org/10.1037/0096-3445.116.3.250

Siegler, R. S. (1996). *Emerging minds: The process of change in children's thinking.* Oxford University Press.

Siegler, R. S., & Robinson, M. (1982). The development of numerical understanding. In H. W. Reese & L. P. Lipsett (Eds.), *Advances in child development and behavior* (Vol. 16, pp. 241–312). Academic Press. https://doi.org/10.1016/s0065-2407(08)60072-5

Sodian, B., Schneider, W. (1999). Memory strategy development: Gradual increase, sudden insight, or roller-coaster? In Weinert, F. E., Schneider, W. (Eds.), *Individual development from 3 to 12: Findings from the Munich Longitudinal Study* (pp. 61–77). Cambridge University Press.

Starkey, P., Klein, A., & Wakeley, A. (2004). Enhancing young children's mathematical knowledge through a pre-kindergarten mathematics intervention. *Early Childhood Research Quarterly*, *19*, 99–120. https://doi.org/10.1016/j.ecresq.2004.01.002

Steffe, L. P., Nesher, P., Cobb, P., Sriraman, B., & Greer, B. (Eds.). (2013). *Theories of mathematical learning.* Routledge.

Van Oers, B. (1990). The development of mathematical thinking in school: A comparison of the action-psychological and information-processing approaches. *International Journal of Educational Research*, *14*(1), 51-66. https://doi-org.libproxy.uncg.edu/10.1016/0883-0355(90)90016-2

Verschaffel, L. (1999). Realistic mathematical modelling and problem solving in the upper elementary school: Analysis and improvement. In J. H. M. Hamers, J. E. H. Van Luit, & B.

Csapo (Eds.), *Teaching and learning thinking skills: Contexts of learning* (pp. 215–240). Swets & Zeitlinger.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Harvard University Press.

Wagner, D. A. (1978). Memories of Morocco: The influence of age, schooling, and environment on memory. *Cognitive Psychology, 10*(1), 1-28. https://doi.org/10.1016/0010-0285(78)90017-8

Weed, K., Ryan, E. B., & Day, J. (1990). Metamemory and attributions as mediators of strategy use and recall. *Journal of Educational Psychology, 82*(4), 849–855. https://doi.org/10.1037/0022-0663.82.4.849

White, H. (1980). A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica, 48*, 817–830. https://doi.org/10.2307/1912934

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). *The Woodcock–Johnson Tests of Achievement: Third Edition.* Riverside Publishing.

Zepeda, C. D., Hlutkowsky, C. O., Partika, A. C., & Nokes-Malach, T. J. (2019). Identifying teachers' supports of metacognition through classroom talk and its relation to growth in conceptual learning. *Journal of Educational Psychology, 111*(3), 522–541. https://doi.org/10.1037/edu0000300