EPISODIC MEMORY DEVELOPMENT IN CHILDHOOD: CONTRIBUTIONS FROM BRAIN ELECTRICAL ACTIVITY AND EXECUTIVE FUNCTIONS

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(ABSTRACT)

Episodic memory is a critical component of human cognition. Episodic memory involves recollection of the contextual details surrounding an event, the capacity for mental time travel of past and future events, and is characterized by the subjective awareness that an event has been personally experienced. It is fundamental to our understanding of this complex memory system to examine how episodic memory emerges during the course of development. The present investigation explored the developmental improvement in episodic memory processing assessing recollection of factual information and the source of this information (i.e., source memory) between early to middle childhood. The electrophysiological (EEG) correlates of fact and source memory processing and measures of executive function were also examined as potential sources of variation in episodic memory. The focus of Study 1 was to examine source memory development in early childhood in a sample of 4- and 6-year-olds. Results revealed that older children were better able to recall both fact and source information. Source memory measures were correlated to early executive ability, namely measures of working memory, inhibitory control and set-shifting. Frontal EEG accounted for unique variation in fact recall but not source recall, whereas temporal EEG did not predict fact or source recall performance. The focus of Study 2 was to examine source memory development in middle childhood in a sample of 6- and 8-year-olds. Older children were better on fact recall, but both ages were comparable on source recall. Frontal EEG uniquely predicted fact recall performance beyond the contribution of age and language. Both frontal and parietal EEG and executive function predicted variation in source recall performance. In contrast, temporal EEG did not uniquely predict fact or source recall performance. Lastly, Study 3 was a longitudinal investigation of source memory between early and middle childhood. Although age-related increases in performance were evident, Time 1 and Time 2 source memory measures were not correlated. This investigation contributes to our understanding of the developmental changes in source memory processing between early and middle childhood, and identifies that patterns of frontal and parietal brain activity and executive function skills contribute to early episodic memory formation.

DEDICATION

I would like to dedicate this work to my wonderful soon-to-be husband, Robby. You have

always been my biggest supporter and my steady rock throughout all these years. No matter what

the future has in store for us, life is just better when we are together.

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Chapter 1

Introduction

Human memory is a complex cognitive ability. Through varying forms of memory, we are able to learn new skills, learn new facts, retain information about the events that have happened in our lives, relate to past experiences, and establish a unique personal past. Thus, it is generally accepted that memory does not consist of a unitary trait. Rather, evidence from behavioral studies of adult's and children's memory, neuropsychological and neuroimagining investigations support the notion that memory is comprised of multiple systems (Squire, 1987; Tulving, 1972). Within this multiple memory systems perspective, researchers draw a distinction between implicit and explicit memory, although some researchers use the terms non-declarative and declarative memory to refer to these dichotomies (Schacter & Tulving, 1994; Schacter, Wagner, & Buckner, 2000; Sherry & Schacter, 1987; Squire, 1987). Implicit memory is characterized as memory that does not require conscious recollection of previous experience, and it is this memory system that allows organisms to learn stimulus-response associations (Squire 1987; Tulving, 1984). In contrast, explicit memory is conceptualized as memory for which one is consciously aware.

According to Tulving, explicit memory can be broken down further into semantic and episodic memory distinctions. Semantic memory is comprised of our factual knowledge about the world (e.g., I know that butterflies taste with their feet). In general, semantic memory lacks recollection of the specific contextual details that were acquired when the semantic memory was established. In contrast, episodic memories are comprised of contextual detail (e.g., I remember learning that butterflies taste with their feet from my 4th grade elementary school teacher). Episodic memories involve retaining knowledge about personally experienced events and their

spatial and temporal relations, the ability of mental time travel to reflect on past events and anticipate and plan for future events, and a sense of autonoetic consciousness (Tulving, 1983, 1984, 2002; Wheeler, 2000; Wheeler, Stuss, & Tulving, 1997).

Episodic memory and autobiographical memory, which is defined as explicit memory for an event in one's past that can be tagged in a specific time and place, share many of the same characteristics (Nelson & Fivush, 2004). It is possible for an individual to have an episodic memory containing autobiographical information, such as recollecting the time, place, and contextual details associated with one's wedding day. However, similar to what standard source memory paradigms assess, it is also possible to have an episodic memory of impersonal information. For example, a standard source memory test would ask an individual to recollect both item information (e.g., recalling the answer to a fact) and contextual information (e.g., recalling the individual who taught you that fact) associated with the memory episode. The present investigation focused particularly on the development of source memory. Semantic memories can also concern impersonal information (e.g., I know that George Washington was the first president of the United States) or autobiographical information (e.g., I know that I was born in India). It is important to note that this latter example is a clear example of semantic memory (because I cannot personally re-experience this event), thus distinguishing this memory from an episodic self-relevant memory (Newcombe, Lloyd, & Balcomb, 2011; Raj & Bell, 2010). This distinction is important in contrasting episodic memory from other types of explicit memory and was the focus of the present investigation.

In this investigation, I explored the development of episodic memory in childhood, specifically focusing on the role of cognitive and neural mechanisms involved in item and source memory and their contributions to episodic memory formation. A cross-sectional and

longitudinal analysis was employed to examine the improvements observed in item and source memory ability during the transition from early to middle childhood and the neural correlates (through the use of EEG technology) associated with these developmental changes was examined. In addition, I examined the development of other cognitive processes which may support early episodic memory formation, particularly focusing on the role of executive function skills during source monitoring.

Development of Episodic Memory

The present investigation focused specifically on the domain of episodic memory and how improvements in the ability to recollect the source-specifying details of a memory episode contribute to providing a contextualized account to recollection. Episodic memory is believed to be a complex memory system that does not emerge until later in development (Newcombe, Drummey, Fox, Lie, & Ottinger-Alberts, 2000; Newcombe et al., 2011; Newcombe, Lloyd, & Ratliff, 2007; Tulving, 2002). Although infant memory tasks, such as visual paired comparison, conjugate reinforcement, and deferred imitation have demonstrated the presence of early infant memory, there are disagreements concerning which specific memory system is being tapped (Bauer, Deboer, & Lukowski, 2007; Hayne, 2007; Rose, Feldman, & Jankowski, 2007; Snyder, 2007). With regard to deferred imitation, the general consensus is that this task relies on explicit memory (Barr, Dowden & Hayne,1996; Barr, Rovee-Collier & Campanella, 2005; Bauer, 2007; Rovee-Collier & Hayne, 2000). However, it is likely that young infants are primarily forming semantic memory representations (e.g., Hayne, Boniface & Barr, 2000; Hayne, MacDonald & Barr, 1997, Newcombe et al., 2011), and there is no convincing evidence that this memory is *episodic* in nature during infancy.

Children younger than the age of 4 have the capacity to remember some events in the past (MacDonald, Uesiliana, & Hayne, 2000), although their recall of such past memories is generally lacking in specific detail or organization. By the age of 3, children are beginning to display rudimentary episodic memory skills (Hayne, 2007; Hayne & Imuta, 2011; Scarf, Gross, Colombo, & Hayne, 2011), and there is general agreement that by the age of 4 the foundations of an episodic memory system are in place (Gathercole, 1998; Nelson, 1993; Perner & Ruffman, 1995; Rubin, 2000; Tulving, 2002). Once children reach the school age period they are able to demonstrate successful recall about details of past events and have the ability to organize recall of events in a coherent manner. From the age of six years and continuing through the elementary school age period, episodic memory strengthens (Newcombe et al., 2011).

Source monitoring theory, developed by Johnson, Hashtroudi, and Lindsay (1993), can be regarded as one important framework in explaining the development of episodic memory. Specifically, Johnson et al. (1993) discuss that the ability to bind together the qualitative characteristics of memory (i.e., the spatial, temporal, perceptual, and affective details of the event) is what underlies explicit episodic memory ability. Source monitoring judgments can be made between externally generated sources (e.g., distinguishing whether it was your work colleague or spouse that recommended a particular book to read), internally generated sources (e.g., distinguishing between a memory of placing your keys in your purse from one you have of actually completing this action) and from both internal and external sources (i.e., distinguishing between whether a conversation with a friend actually took place or whether you merely imagined it). The present investigation focused on the development of external source monitoring in early and middle childhood.

Investigations into source memory processes can be highly informative to our understanding of episodic memory (Johnson, 2005). According to Johnson (2005), source memory tasks allow researchers to investigate the qualities that give memories their episodic nature. To elaborate, the integrity and successful retrieval of episodic memories depends on the richness of the contextual details associated with that memory. Indeed, many memory researchers believe that recollection of the central content of information (item memory) and its accompanying source information (e.g., the time, place, modality of acquisition, etc.) lays the foundation for episodic memory (Mitchell & Johnson, 2009).

Source Memory Development

Developmental investigations of source memory reveal that children have difficulty recollecting the contextual details associated with an event. Compared to adults, younger children find it more difficult to monitor information between two internal sources (Foley & Johnson, 1985; Foley, Johnson, & Raye, 1983; Sluzenski, Newcombe, & Ottinger, 2004; Welch-Ross, 1995). For instance, when examining memories of performed versus imagined actions (Foley & Johnson, 1985) and spoken versus imagined words (Foley, Johnson, & Raye, 1983), 6-year-olds were worse than 9-year-olds and adults at discriminating between these self-generated memories. Examinations in the eyewitness testimony literature have revealed that children's memories are highly suggestible and that young children are more susceptible to misinformation and are more likely to misattribute sources (Ackil & Zaragoza, 1995; Bruck, Ceci, & Melnyk, 1997; Bruck & Melnyk, 2004). Source confusions are more likely to occur in young children when the source memory test is delayed rather than immediate (Parker, 1995), when the same actors and actions are involved compared to different actors and actions (Day, Howie, & Markham, 1998), and when there is a high degree of perceptual similarity between sources

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(Lindsay, Johnson & Kwon, 1991, Thierry & Pipe, 2009). Relative to old/new item recognition memory judgments, greater age-related deficits in monitoring and retrieving source information has also been found (Cycowicz, Friedman, Snodgrass, & Duff, 2001).

Improvements in source memory have been observed between 4 and 6 years (Drummey & Newcombe, 2002; Lindsay et al., 1991). Drummey and Newcombe (2002) tested 4-, 6-, and 8-year-olds using a modified version of the fictitious fact paradigm developed by Schacter and colleagues (1984). In this task, children were taught novel facts from one of two sources, either the experimenter or a puppet, and were tested on fact recall and source recall after a 1-week delay. The authors found a steady improvement in the ability to remember factual information from 4 to 8 years. However, for source memory, the most pronounced improvement occurred between the ages of 4 and 6, whereas source memory performance between 6- and 8-year-olds was equivalent. Four-year-olds also committed more source memory extraexperimental errors (i.e., incorrectly attributing something learned within the experimental context to something learned outside) compared to intraexperimental errors (i.e., remembering a fact was learned within the experimental context but attributing the fact to the wrong source). Therefore, I focused on examining source memory improvements specifically between the ages of 4 and 8 years, when the most pronounced changes in source monitoring ability were likely to occur.

The Cognitive Neuroscience of Episodic Memory Development

Another aim of the present investigation was to explore the neural correlates of episodic memory development during early and middle childhood. Improvement in children's source memory may be linked to maturation of medial temporal and frontal lobe brain structures (Ofen, 2012; Raj & Bell, 2010). Studies 1 and 2 examined the contribution of brain electrical activity (EEG) to source memory processing.

The medial temporal lobe, which includes the parahippocampal cortex, the hippocampus, amygdala, perirhinal cortex, and entorhinal cortex, plays an important role in episodic memory (Mitchell & Johnson, 2009). In understanding the role of medial temporal lobe functioning during source memory judgments, it is import to determine whether hippocampal involvement is specific to source memory conditions where item and context are bound together, or whether activity in this region is associated with item recognition alone. One approach has been to compare encoding activation leading to subsequent successful or failed item recognition. These investigations have found that hippocampal encoding activation is specifically correlated to item and source memory judgments, and does not distinguish between items correctly recognized and items which have been forgotten (Davachi, Mitchell, & Wagner, 2003). Neuroimaging investigations have also found that activity within the hippocampus is greater for correctly identified source items compared to incorrectly identified source items (Davachi, 2006; Mayes, Montaldi, & Migo, 2007). These findings suggest that the hippocampus is involved during encoding and retrieval of associations among stimuli and their context (Davachi et al., 2003; Davachi & Wagner, 2002; Gabrieli, Brewer, Desmond, & Glover, 1997).

Neuroimaging studies have also implicated the prefrontal cortex in source memory, and have attempted to map the functional specificity of prefrontal cortex regions (Senkfor & Van Petten; 1998; Trott, Friedman, Ritter, & Fabiani, 1997; Wilding & Rugg, 1996). Wilding & Rugg (1996) tested both old/new recognition and external source monitoring judgments during ERP recording. The authors found a frontal ERP effect that was larger for previously studied items that were assigned to the correct source compared to items assigned to an incorrect source. In an event-related fMRI study, Nolde, Johnson, & D'Esposito (1998) contrasted old/new recognition judgments and source memory judgments and found greater activation in the left prefrontal

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cortex for source memory compared to old new item recognition. Subsequent fMRI studies replicated this finding, and in general, have found that in contrast to old/new item recognition, source memory judgments are associated with greater activation in the left prefrontal cortex (Dobbins, Foley, Schacter, & Wagner, 2002; Dobbins, Rice, Schacter, & Wagner, 2003; Mitchell et al., 2008; Nolde, Johnson, & Raye, 1998; Raye, Johnson, Mitchell, Nolde, & D'Esposito, 2000; Rugg, Fletcher, Chua, & Dolan, 1999).

Unfortunately, investigations into the neural correlates of source memory during early childhood have been extremely limited. Cycowicz and colleagues (2000, 2001) examined the relationship between item and source memory for pictures and colors in 7- to 9-year-old children and adults and found that frontal lobe functioning tasks were correlated to source memory performance at both ages. In an ERP study, Cycowicz, Friedman, and Duff (2003) found that children display different scalp topographies (i.e., greater and more widespread frontal brain electrical activity) than adults during retrieval of source information, which may reflect activity from a less refined and more immature brain network (Cycowicz, Friedman, & Duff, 2003; Chastelaine, Friedman, & Cycowicz, 2007). Czernochowski, Mecklinger, Johansson, and Brinkmann (2005) examined ERP correlates of item and source memory development in 6-8 and 10-12-year-old children and young adults. Age-related increases in ERP recollection-based processing (known as the parietal old/new effect) were observed in older children and adults, an effect that has been replicated in young children, adolescents, and young adults (Czernochowski, Mecklinger, & Johansson, 2009; Friedman, de Chastelaine, Nessler, & Malcolm, 2010).

More recently, Sprondel, Kipp, and Mecklinger (2011), examined the ERP correlates of item and source memory processing in children (7-8 years), adolescents (13-14 years) and adults (20-29 years). As expected, behavioral results revealed that children, compared to adolescents

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and adults, exhibited poorer source discrimination. For item memory processing, all three age groups showed the ERP correlate of recollection (parietal old/new effect), but the ERP correlate of source memory processing was only evident in adolescents and adults (indexed as the parietal non-target old/new effect). Taken together, these findings suggest that the ERP correlates of item memory and source memory may be on a different developmental trajectory. ERP correlates of item memory are evident early in development, whereas ERP correlates of source memory may not be evident until adolescence.

Developmental cognitive neuroscience investigations using functional neuroimaging methodology (fMRI) have also been extremely limited. Ofen et al. (2007) examined medial temporal lobe and prefrontal cortex activation in children and adults ranging from 8 to 24 years during recollection and familiarity-based processing, which was assessed using a Remember/Know paradigm. Reliance on recollection-based processing increased with age, and was associated with age-related increases in activation of dorsolateral prefrontal cortex regions, whereas medial temporal lobe activity remained stable across age. This finding is not surprising, given that the prefrontal cortex develops across childhood and adolescence (Casey, Giedd, & Thomas, 2000; Chugani, 1994, 1998; Chugani & Phelps, 1986; Diamond, 2002; Giedd et al., 1999; Huttenlocher, 1997; Jernigan et al., 1991). However, Ghetti, DeMaster, Yonelinas, and Bunge (2010) have found that hippocampal and parahippocampal regions of the medial temporal lobe contribute to age-related improvements in recollection of source-specifying detail, with activity in these brain regions predicting subsequent source memory only in older children and adults. Developmental increases in medial temporal lobe activation have also been found for subsequent recollection of complex scenes but not simple ones (Chai, Ofen, Jacobs, & Gabrieli, 2010), whereas Chiu et al. (2006) found that both hippocampal and left prefrontal cortex activity

predicted subsequent episodic recollection in children 10 and older, but not in younger children. Despite these discrepant findings, these developmental neuroscience investigations confirm that the prefrontal and medial temporal lobe structures play a critical role in supporting episodic memory (Raj & Bell, 2010; Ofen, 2012).

Studies 1 and 2 of the present investigation examined electrophysiological indices of item and source recall memory by collecting EEG, which provides an ongoing continuous measurement of electrophysiological activity during the course of recall. EEG research methodologies are advantageous to use in young developmental populations (Casey & de Haan, 2002), and research investigations utilizing such technologies will be highly informative to investigate early development of neural processes associated with source memory. The present investigation sought to examine the maturation of these brain regions across the transition from early to middle childhood.

Executive Function and Episodic Memory

In addition to examining the electrophysiological indices of item and source memory processing, I was also interested in investigating the extent to which episodic memory may be supported by other cognitive abilities, particularly executive function skills. Executive functions (EF) refer to higher order cognitive processes that organize and coordinate goal-directed actions, and consist of the three core dimensions of working memory, inhibitory control and set-shifting (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Previous research has demonstrated that deficits in source memory ability may be attributed to poorer executive function (Chastelaine, Friedman, & Cycowicz; 2007; Glisky, Polster, & Routhieaux, 1995; Ruffman, Rustin, Garnham, & Parkin, 2001).

Most of the research informing the link between executive function and source monitoring capabilities has come from the adult and aging literature. Spencer and Raz (1994) examined the relation between memory for facts, source, and context to executive function processes in a sample of younger and older adults. Item and source memory was tested using the fictitious fact paradigm immediately after acquisition and over the course of varying delays. Compared to retention of item information, elderly adults showed greater impairment on retention of source information and were less likely to retain contextual information over the varying delays. In addition, poor performance on executive function measures (e.g., Wisconsin Card Sorting Test) predicted poor contextual memory performance, providing support for the claim that age-related impairments in retaining contextual information may depend on frontal executive function (Spencer & Raz, 1994).

Elderly adults also experience difficulties in the component processes that support source memory (Mitchell et al., 2000). To clarify, successful source recollection requires proper processing at encoding, shifting attention between relevant features, reactivating information that may have left the memory trace, and making the right evaluative decisions at test, and each of these component processes may depend on executive abilities. As noted by Mitchell et al. (2000), age-related deficits in working memory ability may be associated with greater difficulty in binding item and context features together. Thus, although older adults demonstrate intact memory for individual features, age-related deficits in source memory were evident when older adults were required to recognize feature combinations. In addition, when comparing memory for feature combinations versus memory for two individual features, older adults still showed poorer performance on combination trials compared to two feature test trials. The authors reasoned that these age-related source memory deficits may be due to inefficient component

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processes, which are supported by working memory, that result in less well bound complex memories (Mitchell et al., 2000).

Dywan, Segalowitz, and Webster (1998) noted a correlation between the executive function dimension of inhibitory control and source memory performance in older adults. Participants were provided with an initial study list of words and performed a recognition task in which study words were interspersed with novel words, which would occasionally repeat. Later, participants were given a source monitoring test in which they had to determine which words were presented from the original study list. Younger adults performed better than older adults at ignoring the distracting material and had better source memory performance. The authors attributed the failures in source memory in older adults to a reduced ability to ignore the irrelevant aspects of an experience. Older adults experienced a failure to inhibit response tendencies, such as a failing to inhibit one's response to familiarity of recently repeated events. Numerous other investigations within the aging literature have revealed that frontal lobe factor scores on tasks of executive function processes are associated with better performance on source memory tests (Davidson & Glisky, 2002; Dywan, Segalowitz, & Webster, 1998; Glisky, Rubin, & Davidson, 2001, Spencer & Raz, 1994) and lower rates of source memory errors (Rubin, Van Petten, Glisky, & Newberg, 1999).

Developmental investigations examining the relation between executive function skills and source memory have been limited and have provided mixed results. Ruffman et al. (2001) examined whether the executive function processes of working memory and inhibitory control were related to children's ability to produce correct source memory judgments and to patterns of false alarms (i.e., incorrectly attributing a new item as old). Results revealed that working memory was related to children's accuracy in source monitoring judgments. Conversely,

inhibitory control uniquely predicted children's ability to avoid making source memory false alarm errors. This specific type of source memory error has been linked to a poorly focused event description at retrieval. To elaborate, false alarm errors may arise because, rather than relying on a conscious verbatim memory, children may be relying on a poorly represented "gist" memory (Brainerd & Reyna, 1998). In this case, inhibitory control is necessary to correctly distinguish and inhibit feelings of familiarity generated from the experimental context in favor of the relevant aspects of the memory episode.

Rhodes, Murphy and Hancock (2011) examined the relation between verbal and spatial memory and episodic memory in children (ages 8, 9, 10, and 11 years) and adults. Participants engaged in tasks tapping the episodic retrieval processes of recollection and familiarity, such as old/new recognition, Remember/Know, and source memory tasks. The authors found that only in the sample of older children was episodic memory processing related to verbal working memory. In a recent investigation, Picard et al. (in press) found that executive function skills (measured by inhibition, shifting, and updating) predicting episodic memory for spatial and temporal context information in a sample of participants aged 4 – 16 years. Picard and colleagues have found that executive function skills predict autobiographical episodic memories as well (Picard, Reffuveille, Eustache, & Piolino, 2009).

However, Drummey and Newcombe (2002) found no correlation between frontal executive function (i.e., Wisconsin Card Sort Test) and source memory performance in their sample of 6-year-old children. For 4-year-olds, source memory was correlated to WCST performance, but only in a subsample of children. Investigations linking executive function abilities to individual differences in children's suggestibility and eyewitness testimony have also found mixed results (Bruck & Melnyk, 2004). For example, some studies have found that greater

inhibitory control is associated with fewer inaccuracies to free recall and yes/no misleading questions (Alexander et al., 2002) and greater resistance to false suggestions (Roberts & Powell, 2005), whereas other studies report a non-significant relation between executive function and suggestibility (Roebers & Schneider, 2005).

Being able to correctly monitor the origin of information requires conscious working memory-dependent strategies for linking content to context. Source monitoring also requires the individual to correctly distinguish and inhibit feelings of familiarity generated from the experimental context in favor of the relevant aspects of the memory episode. It should be noted that the link to executive abilities is most likely evident on tasks that require more episodic traces, and thus an association to free recall (in addition to source recall) would also be seen. Retrieving information from memory using free recall is thought to be more difficult than retrieving information based on recognition, as recall depends more on encoding and retrieval strategies, whereas recognition tasks have minimal strategic demands (Schneider & Pressley, 1997). Free recall tasks have greater strategic demands and participants are required to recall on their own (without the aid of any perceptual cues) information about the item, time or place a stimulus was encountered. As noted by Tulving (1985), free recall tasks contain more episodic traces. Thus, tasks which require greater strategic memory demands are more likely to depend on these executive abilities.

In the present investigation, I predicted that executive function would be associated with fact recall, source memory accuracy and lower rates of false alarms errors. More specifically, I examined whether the different dimensions of executive function (working memory, inhibitory control, and set-shifting) were correlated to fact recall and source memory performance (Study 1), whether a composite of executive abilities uniquely predicted the variance in fact and source

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recall performance (Study 2), and whether, in a longitudinal investigation, executive function skills at Time 1 were correlated with fact recall and source memory measures at Time 2.

Overview of the Present Investigation

In summary, all of the previously highlighted research indicates that substantial improvements in children's source monitoring abilities occur between the early to middle childhood periods, most notably between the ages of 4 and 8 years of age. In Study 1, I examined source memory development during early childhood, specifically focusing on the improvements that occur between 4 and 6 years. I also examined the correlation between working memory, inhibitory control and set-shifting executive function tasks and children's fact recall, source recall, and false alarm error rates. In addition, I examined electrophysiological indices of item and source recall memory through the use of EEG technology. Specifically, I hypothesized that frontal and temporal brain electrical activity observed during item and source memory processing would predict behavioral performance on fact and source recall, beyond the contribution of age and language. In Study 2, I sought to expand upon the findings from Study 1. In Study 2, I modified the experimental protocol to include a more difficult source discrimination so that I could examine whether improvements in source memory continue to occur in middle childhood, specifically between 6 and 8 years. I also examined whether frontal, temporal, and parietal EEG activity and a composite score of executive function uniquely predicted the variance in children's fact and source recall, above and beyond the contribution of age and language. Lastly, in Study 3 I implemented a longitudinal investigation to examine whether Time 1 source memory and executive function measures (at 4 and 6 years of age) were correlated with Time 2 source memory and executive function measures (at 6 and 8 years of age).

Chapter 2

Study 1

In the first known investigation of its kind, I explored the association between source memory and executive function performance, and examined whether frontal and temporal brain electrical activity predicted source monitoring performance, above and beyond the contribution of age and language. I controlled for language in the present analyses because the source memory task used in this study was highly dependent on word retrieval and recruited the use of free verbal recall demands. However, beyond this link to early language ability, I sought to examine the added contributions of frontal and temporal electrophysiology in predicting item and source memory performance.

Hypotheses

1. Improvement on measures of fact memory and source memory will be observed between 4 and 6 years. As noted previously, both free recall memory and children's source monitoring abilities undergo a dramatic shift between 4 and 6 years of age. Therefore, I hypothesized that 6-year-olds would recall more factual and source information than 4-year-olds.

2. Source memory measures will be correlated with executive function. I hypothesized that children's fact recall, source recall, and source memory errors would be correlated with measures of executive function (tasks assessing working memory, inhibitory control, and set-shifting).

3. Frontal and temporal brain electrical activity will predict unique variance in fact recall and source recall performance. I hypothesized that, after controlling for age and language ability, patterns of frontal and temporal brain electrical activity would predict performance on children's fact recall and source recall.

Method

Participants

Twenty-six 4-year-old children (range: 3 years 10 months – 4 years 3 months; 11 boys, 15 girls; 25 Caucasian, 1 African American) and 26 6-year-old children (range: 5 years 9 months – 6 years 5 months; 11 boys, 15 girls; 24 Caucasian, 2 African American) were participants in this study. Children were seen in the research lab 5 months before or after their respective birthdays. Children were eligible for participation if they were born within 4 weeks of their expected due date, experienced no prenatal or birth complications, were healthy and medication free at the time of testing, and had no developmental or neurological diagnoses. Of the original sample, two 4-year-old children were excluded, one due to developmental diagnosis and the other due to refusal to play games. Thus, all analyses are reported on a sample of 50 children (4-year-olds: $n = 24$; 6-year-olds: $n = 26$).

Children were recruited using a database compiled from commercial mailing lists and email contact via a local Working Mother's listserve. Recruitment letters were mailed to parents of eligible participants (see Appendix A) and subsequent phone conversations took place with those interested in participation, during which specific details of the research design were further explained and a lab visit scheduled. All parents had at least a high school diploma (mothers: 48% bachelor's degree, 42% graduate degree; fathers: 29% bachelor's degree, 49% graduate degree). Average maternal age was 35 years (range: 27 – 44) and average paternal age was 38 years (range: 26 – 54) at the time of the laboratory visit. As compensation for participation, children received a gift bag filled with arts and crafts supplies and parents were entered into a lottery drawing for one $50 gift certificate.

Procedure

Upon arrival to the research laboratory, signed parental consent (see Appendix B) and verbal child assent (see Appendix C) were obtained prior to the introduction of study procedures. The order of task administration was as follows: source memory encoding phase, EF tasks, and source memory test phase. All tasks were videotaped and later scored for accuracy. The parent was seated in the room with the child at all times.

EEG recording and analysis. EEG recordings were accomplished during baseline and during all task procedures. Baseline EEG was recorded for a duration of 60 seconds. During this task, each child was shown a brief video presentation of a screensaver. Use of this procedure was intended to minimize eye movements and gross motor activity (Wolfe & Bell, 2004). Parents were seated next to their children during this time and were instructed not to talk to their children.

Recordings were made from 16 left and right scalp sites, with hypothesis testing focused on medial frontal (F3, F4) and posterior temporal (T7, T8) regions (Pivik et al., 1993). All electrode sites were referenced to Cz. EEG was recorded using a stretch cap (Electro Cap, Inc.) with electrodes placed according to the International 10/20 system pattern (Jasper, 1958). NuPrep and EEG Gel conductor were inserted into each recording site and the scalp gently rubbed. Electrode impedances were measured and accepted if below 10 kΩ. The electrical activity from each lead was amplified using separate SA Instrumentation Bioamps and bandpassed from .1 to 100 Hz. Activity for each lead was displayed on the monitor of an acquisition computer. The EEG signal was digitized online at 512 samples per second for each channel so that the data were not affected by aliasing. The acquisition software was Snapshot-Snapstream (HEM Data Corp.) and the raw data were stored for later analyses. Power was

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computed using the 6-10 Hz frequency band because previous research has demonstrated that this frequency band is most informative during early childhood because it is the dominant frequency (Marshall, Bar-Haim, & Fox, 2002). This particular frequency band also discriminates correct from incorrect responses on an infant working memory task (Bell, 2002) and between baseline EEG and task EEG during preschool working memory (Bell & Wolfe, 2007; Wolfe & Bell, 2007) and infant recall memory (Morasch & Bell, 2008).

EEG data were examined and analyzed using EEG Analysis System software developed by James Long Company. First, the data were re-referenced via software to an average reference configuration. Average referencing, in effect, weighted all the electrode sites equally and eliminated the need for a noncephalic reference. Active (F3, F4, etc.) to reference (Cz) electrode distances vary across the scalp. Without the re-referencing, power values at each active site may reflect inter-electrode distance as much as electrical potential.

The average reference EEG data were artifact scored for eye movements using a peak-to-peak criterion of 100µV or greater. Artifact associated with gross motor movements over 200 µV peak-to-peak was also scored. These artifact scored epochs were eliminated from all subsequent analyses. The data were then analyzed with a discrete Fourier transform (DFT) using a Hanning window of 1-second width and 50% overlap. Power values were computed at each scalp site during each task within the 6 to 10 Hz frequency band. Power was expressed as mean square microvolts and the data were transformed using the natural log (ln) to normalize the distribution.

Source memory task – encoding phase. This task was originally developed by Drummey and Newcombe (2002) for use with children, and was adapted from the fictitious fact paradigm developed by Schacter and colleagues (1984; see Appendix D). The source memory

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task was divided into two phases. The first phase was the source memory encoding phase in which children were taught a series of 10 novel and interesting facts. Each fact was presented by one of two sources, either the experimenter or a puppet (operated by a research assistant), both of which were introduced to the child at the beginning of the session.

For the source memory task, it was necessary that each fact presented to the child was a novel fact, and that children had not learned these facts prior to the experimental session. In order to ensure these facts had not been encountered prior to the encoding phase, each fact was asked in the form of a question. This procedure allowed the experimenter to gauge each child's prior knowledge of the presented facts. For example, a child was asked the question "What do butterflies taste with?" If an answer was not given, then it was assumed the child had no prior knowledge of this fact and the answer was provided to them. "Their feet. Butterflies taste with their feet." If the child responded with a correct answer, however, then it was assumed the child learned the fact outside of the experimental situation and these trials were discarded, and an alternative fact of equal difficulty was asked in its place. This process continued until it was clear the child had been presented with a total of 10 novel facts, five from the experimenter and five from the puppet. Facts were presented from these sources in a blocked (i.e., first five facts from one source, and second five facts from other source) rather than random sequence, and the order of presentation was counterbalanced (Drummey & Newcombe, 2002). After 10 novel facts were presented, each fact was then repeated to the child in a random sequence by the same previous source.

Source memory task – test phase. After a delay of approximately 20 minutes, children's memory for the previously taught facts was tested along with their ability to correctly attribute the source from which this information came. During this test phase, children were

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presented with the 10 facts they previously heard during the source memory encoding phase, along with five novel facts which were intended to be of equal difficulty because it was presumed the children did not have prior exposure to these novel facts (e.g., "What animal walks on its tippy toes?"). An additional five facts were also presented at test, but these questions were intended to be relatively easy for the child to answer (e.g., "What do you use to brush your teeth?"), and were likely to be facts the child learned prior to the experimental session. Inclusion of these questions allowed for each child to provide some answers with relative ease, and also allowed for a variety of source responses. Therefore, a total of 20 questions (10 old, 10 new) were asked during the test phase. All facts were presented in a random sequence.

For each test question, the procedure was as follows: First, the experimenter tested each child's verbal recall memory (i.e., fact recall) for each of the previously heard facts along with the novel and easy facts introduced at test. If a child answered the fact recall question correctly, then the source test question was administered. However, if a child failed to demonstrate fact recall (either by failing to produce a response or by answering incorrectly), a four-alternative forced choice recognition test was given. The recognition question was administered to ensure that children would provide an answer to every trial and allowed for the follow-up source question to then be administered. Children were asked the follow-up source question regardless of how they answered the fact recognition memory assessment (i.e., whether correct or incorrect).

After this assessment of fact recall/recognition, children were then asked to recall how this information was learned and identify the source of this information (i.e., source recall) for all of the facts, including old and new, presented at test. If the child produced some type of source recall response (whether correct or incorrect), then the experimenter moved on to the next test

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question. Only if the child failed to provide a source response was a four-alternative forced choice test given. In this case, children were instructed to choose from one of four options: the experimenter, the puppet, a parent, or a teacher. Prior to the administration of the test, children were given practice trials of sample questions similar to the ones given during test to ensure they understood the format of the test procedure. Practice trials were praised or corrected and testing only began once children demonstrated understanding of the task. The total administration for the test phase lasted approximately 10 minutes. This task was videotaped and later scored for accuracy. The proportion correct was calculated as the dependent measure of interest for Fact Recall, Fact Knowledge (recall plus recognition), and Source Recall. The percentage of agreement between two coders for 20 % of the sample was calculated, and interrater reliabilities ranged from .92 – 1.00. EEG was recorded continuously throughout the encoding and test phases of the source memory task. A research assistant placed event marks on the EEG record associated with the specific *test* stages of the task: fact recall and source recall.

EF tasks. Three EF tasks were administered during the delay period and each child received the tasks in the following order. First, set-shifting ability was assessed using the standard and border versions of the Dimensional Change Card Sort (DCCS; Zelazo, Muller, Frye, & Marcovitch, 2003). For this task, children were instructed to sort cards based on two different dimensions (i.e., color or shape). The order of the first sorting dimension (e.g., color first versus shape first) was counterbalanced. Two sorting trays were used which contained target cards (i.e., a red flower and a blue car) affixed to the top of each tray that remained visible during administration of both versions of the sorting task. Test cards displayed the same shape but had colors opposite to the target cards (i.e., blue flowers and red cars). The experimenter began by teaching children a pair of rules based on the sorting game they were playing (e.g., shape game

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rules or color game rules). For example, if the task began with the "color game" children were instructed that all the blue things go in the blue tray and all red things go in the red tray. Before the preswitch phase began, children were given two practice trials in which the experimenter sorted two test cards facedown in the appropriate tray in order to demonstrate the rules of the game.

After these demonstration trials, the preswitch phase of the sorting task began. During the preswitch phase, the child was randomly presented with seven test cards, with the constraint that the same card type was not presented on more than two consecutive trials. For each trial, the experimenter stated the relevant sorting rules, labeled each card by the relevant dimension, and had the child sort each card by asking "Where does this card go?" Children were instructed to place the card facedown in the tray. No feedback was provided after sorting trials. After all 7 preswitch trials were completed, children were then instructed to stop playing the color game and switch to the shape game. In the "shape game" children were instruced that all flower things go in the flower tray and all car things go in the car tray. Seven post-switch trials were adminstered in an identical manner to the preswitch trial, with the exception that children were now told the rules for sorting according to the shape dimension. The proportion correct during the postswitch condition was used as the measure of interest. The percentage of agreement between two coders for 20% of the sample for the preswitch and postswitch versions of the standard DCCS task were 100% and 99%, respectively.

Children who passed the post-switch phase of the DCCS standard version were given a more difficult border version of the task, which has been administered in children ages 3 to 5 years (Hongwanishkul, Happaney, Lee, & Zelazo, 2005). This was done in order to fully capture the developmental changes in set-shifting ability across the entire age range of interest. This

version of the task contained two different types of test cards: ones that were identical to those used in the standard version, and ones that were similar to those used in the standard version with the exception that they were surrounded by a black border. In the rules for the border version, the experimenter explained that if there is a black border on the card the child must sort according to a particular game (e.g., If there is a black border, you have to play the shape game; if there is no black border then you have to play the color game). The sorting dimension according to the black border was counterbalanced across all participants. Children were then administered 12 test trials, which were randomly presented to the child (with the constraint that no more than two consecutive cards of each type - border or non-border- were presented). For each trial, the experimenter stated the rules, labeled the card according to the relevant dimension, and asked the child to sort each card facedown in the tray by asking, "Where does this card go?" No feedback was provided. The proportion correct was used as the dependent measure of interest. The percentage of agreement between two coders for 24% of the sample for the DCCS Border version task was 99%.

Next, inhibitory control was assessed using the Day-Night Stroop-Like task which has been been used as a measure of working memory and inhibitory control in 3 ½-to 7-year-olds (Gerstadt, Hong, & Diamond, 1994) and more recently in older children ranging from 4- to 11-years (Lagatutta, Sayfan, & Monsour, 2011). For this task, the child is presented with a series of cards (10cm x 15cm) containing two different pictures, either a yellow sun on a white background or a yellow moon and stars on a black background. The experimenter instructed the child to say "day" when shown the picture of the moon and stars and to say "night" when shown the picture of the sun. Two practice trials were administered in order to ensure the children comprehended the rules of the game, and children were either praised or corrected during these

learning trials. Sixteen test trials were then administered, with eight sun cards and eight moon cards presented in a random order (with the constraint that cards of the same type were not presented on more than two consecutive trials). No feedback was provided during testing. A trial was considered correct if the child gave the correct verbal response as their only answer. A trial was considered incorrect if the child produced the wrong verbal response, or if the child initially produced the wrong verbal response and self-corrected. The proportion correct was calculated as the measure of interest. The percentage of agreement between two coders for 20% of the sample for the Day-Night task was 99%.

Last, working memory was assessed using the Forward Digit Span recall test. According to Garon, Bryson, and Smith (2008), the Forward Digit Span task can be classified as a simple working memory task that can be administered to children 3 years and older. For this task, children were presented with a series of digits and were instructed to repeat the sequence in the same order (e.g., If a child hears the digit sequence "2..5..9" they were instructed to repeat the same sequence, "2..5..9"). Two practice trials, each containing a two-digit sequence, were given in order to ensure that the child understood the rules of the game. Following successful comprehension of the task rules, test trials commenced and always began with two digits. Children were required to recall the same digit sequence length for two trials (i.e., two trials using a two-digit sequence, two trials using a three-digit sequence, etc.). The experimenter lengthened the sequence by adding one extra digit to the series until the child erred on two consecutive trials. The highest span in which children could repeat the entire digit sequence in correct order was used as the variable of interest. The percentage of agreement between two coders for 31% of the sample for the Forward Digit task was 98%.

Language assessment. The Expressive Vocabulary Test (EVT) was administered to examine expressive vocabulary and word retrieval. The EVT consists of two types of items: labeling and synonyms (Williams, 1997). It has been normed for ages 2½ through 90[+] years and is co-normed with the Peabody Picture Vocabulary Test – III (PPVT; Dunn & Dunn, 1997). The EVT is a nationally standardized instrument.

Results

Behavioral Results

Descriptive statistics on the dependent variables of fact recall, fact knowledge (fact recall plus recognition; Drummey & Newcombe, 2002), and source recall for both 4- and 6-year-old children are presented in Table 1. In order to compare the differences in item and source memory between 4- and 6-year-old children, independent samples t-tests were conducted. As predicted, 6-year-olds had a higher proportion of correct responses than 4-year-olds on fact recall, $t(48) = 4.47$, $p < .001$, $\eta^2 = .29$, fact knowledge, $t(48) = 4.72$, $p < .001$, $\eta^2 = .32$, and source recall $t(48) = 4.16$, $p < .001$, $\eta^2 = .26$ (see Figure 1). Taken together, these results indicate that 4-year-old children are worse at both recalling fact information and attributing the source of such information.

Descriptive statistics on the types of responses made during the source memory test (e.g., intraexperimental errors and false alarms) are also presented in Table 1. When comparing the types of source monitoring errors produced at test, children were more likely to commit intraexperimental errors ($n = 38$) compared to extraexperimental errors ($n = 15$). As previously mentioned, intraexperimental errors refer to incorrectly attributing something learned within the experimental context to the wrong source (e.g., mistaking something learned from the puppet and claiming it was learned by the experimenter) whereas extraexperimental errors refer to

incorrectly attributing something learned within the experimental context to something learned

outside (e.g., attributing something learned from the experimenter and claiming it was learned by

a parent or teacher). Because so few children committed extraexperimental errors, I chose not to

include this measure in the analyses and focused on intraexperimental errors. Source responses

can also vary in that new test items can be erroneously identified as old (false alarms, e.g., when

a child erroneously attributes a new test item as having been taught by either the experimenter or

puppet). No differences were found between these two age groups on the percentage of

intraexperimental errors, $t(36) = -1.08$, $p = .290$, $n.s$, produced during the source memory test.

However, 4-year-olds had a higher rate of false alarms compared to 6-year-olds, $t(31) = -4.55$, p

$< .001$, $\eta^2 = .40$ (see Table 1).

Table 2 displays the means and standard deviations for each EF measure by age. Some

children had missing data on some of the EF tasks. Two 4-year-old children were missing data

on the DCCS standard and Border versions because they failed to master the pre-switch phase

and thus the task was not administered. For the DCCS Border version, eight 4-year-olds and

three 6-year-olds failed the post-switch phase of the task, and thus the Border version was not

administered. Analyses were conducted on all available data.

Independent samples t-test results revealed that 6-year-olds performed better than 4-year-

olds on Forward Digit Span, $t(46) = 3.11$, $p = .003$, $\eta^2 = .17$, Day Night, $t(48) = 2.64$, $p = .011$, η^2

$= .13$, and DCCS standard task, $t(46) = 2.16$, $p = .036$, $\eta^2 = .09$, but no significant difference was

found on the DCCS Border task, $t(35) = 1.76$, $p = .088$. Pearson correlations were calculated

among the source memory, EF, and language measures (see Table 3). The source memory

measures of fact recall, fact knowledge, and source recall were positively correlated with one

another. As hypothesized, fact recall, fact knowledge and source recall were positively correlated

with the EVT standard score of langauge. In addition, all three of these measures were also positively correlated to the Forward Digit Span, Day Night, DCCS, and DCCS Borders EF tasks. Source memory false alarm errors were negatively correlated to the Forward Digit Span and DCCS tasks. However, false alarm errors were not significantly correlated with the Day Night task, which is regarded as a measure of inhibitory control.

Predicting Fact and Source Recall Performance

A series of hierarchical regressions were performed in order to determine whether frontal and temporal brain electrical activity would predict performance on fact recall and source recall after controlling for age and language. Separate regression analyses were performed for the medial frontal and posterior temporal regions of interest for the dependent measures of fact recall and source recall. These specific scalp locations were analyzed based on previous neuropsychological and electrophysiological research suggesting that fact recall and source memory judgments rely more on the frontal and medial temporal lobe structures of the brain. With the inclusion of frontal and temporal EEG as a predictor of fact and source recall performance, there was a further reduction in sample size. Forty children contributed electrophysiological data to the following analyses. The reason for missing data was a result of too much movement artifact within the EEG record.

Fact Recall. Separate hierarchical regressions were performed for the medial frontal and posterior temporal regions of interest in order to determine whether frontal and temporal EEG would predict performance on fact recall above and beyond the contribution of age and language. Table 4 provides the results from the regression analyses investigating age, language, and frontal EEG as predictors of fact recall. Taken together, the variables of age, language, and frontal EEG account for 63% of the variance in children's fact recall performance. The first step in the model

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included age as the predictor variable. In this model, age accounted for 45% of the variance in fact recall performance (Table 4, step 1). Model 2 included age and EVT standard scores as the first and second predictor variables, respectively. Language ability accounted for an additional 13% of the variance in fact recall performance (Table 4, step 2). Model 3 included age, language, and frontal EEG as the first, second, and third predictor variables, respectively. Above and beyond the contributions of age and language ability, F3/F4 EEG accounted for an additional 5% of the variance in fact recall performance (see Table 4, step 3). More specifically, an examination of the regression weights indicates that for every one unit increase in EEG power at F3/F4 electrode sites, fact recall performance increases by .23 units.

Table 5 provides the results from the regression analyses investigating age, language, and temporal EEG as predictors of fact recall. Age, language, and temporal EEG accounted for 58% of the variance in performance. In model 1, 45% of the variance in fact recall was accounted for by age (Table 5, step 1). In model 2, language ability accounted for an additional 13% of the variance in performance (Table 5, step 2). Although model 3 was signficant (explaining 58% of the variance), the inclusion of T7/T8 EEG did not contribute unique variance, although age and language retained a significant contribution to fact recall performance (see Table 5, step 3).

Source Recall. Table 6 provides the results from the regression analyses investigating age, language, and frontal EEG as predictors of source recall. Age, language, and frontal EEG accounted for 52% of the variance in performance. In model 1, 23% of the variance in source recall was accounted for by age (Table 6, step 1). In model 2, language ability accounted for an additional 28% of the variance in performance (Table 6, step 2). Although model 3 was signficant (explaining 52% of the variance), the inclusion of F3/F4 EEG did not contribute

unique variance, although age and language retained a significant contribution to source recall performance (see Table 6, step 3).

Table 7 provides the results from the regression analyses investigating age, language, and temporal EEG as predictors of source recall. Age, language, and temporal EEG accounted for 51% of the variance in performance. In model 1, 27% of the variance in source recall was accounted for by age (Table 7, step 1). In model 2, language ability accounted for an additional 23% of the variance in performance (Table 7, step 2). Although model 3 was signficant (explaining 51% of the variance), the inclusion of T7/T8 EEG did not contribute unique variance, although age and language retained a significant contribution to source recall performance (see Table 7, step 3).

Discussion

The purpose of Study 1 was to examine developmental improvement in source memory between 4 and 6 years of age, to examine whether source memory was correlated with executive function processes, and whether frontal and temporal brain electrical activity uniquely predicted performance in fact and source recall beyond the contribution of age and language. With regard to age differences, this specific age range was chosen based on previous research within the developmental literature that suggests that the most pronounced improvement in source monitoring ability occurs between 4 and 6 years (Drummey & Newcombe, 2002). With regard to children's behavioral performance on the source memory task, my hypothesis that 4-year-olds would perform worse relative to 6-year-olds on the measures of fact recall, fact knowledge, and source recall was supported. These results suggest that younger children have greater difficulty recalling fact information and monitoring the source of such information and replicate the findings observed in Drummey and Newcombe (2002).

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A comparison of the types of source monitoring errors that children made also revealed significant age differences, with 4-year-olds committing a higher rate of false alarm errors compared to 6-year-olds. As noted by Ruffman and colleagues (2001), younger children tend to produce a higher rate of false alarms, which may be indicative of a poorly focused event description at retrieval. In Study 1, children were more likely to commit intraexperimental rather than extraexperimental errors, and the proportion of intraexperimental errors committed did not significantly differ between both age groups. These results differed from Drummey and Newcombe's observation that 4-year-olds committed more extraexperimental errors than 6-year-olds. However, I adopted a significant change in the methodology by implementing a much shorter delay (i.e., 20 minutes) compared to the 1-week delay between encoding and testing phases of Drummey and Newcombe (2002). A longer delay period could have allowed for greater interference or intrusion between multiple sources. To elaborate, children could have discussed these facts with a parent, sibling, etc. during this delay, thus increasing the likelihood that they would misattribute learning the fact information to an outside source. Previous research supports this notion and has found that children's source memory performance is best when an immediate test, compared to a 2-week delay, is administered (Parker, 1995). As noted by Parker (1995), forgetting increases more dramatically immediately after the testing period because of the greatest effect of interference.

Although limited, there is evidence to suggest that executive function skills in children and adults is linked to greater source memory accuracy (Davidson & Glisky, 2002; Dywan, Segalowitz, & Webster, 1998; Glisky, Rubin, & Davidson, 2001, Spencer & Raz, 1994) and lower rates of source memory errors, particularly false alarm rates (Rubin, Van Petten, Glisky, & Newberg, 1999, Ruffman et al., 2001). Thus, another aim of Study 1 was to examine the relation

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between executive function performance and source monitoring ability. When comparing age differences on executive function skills, independent samples t-test results revealed that 6-year-olds performed better than 4-year-olds on working memory, inhibitory control, and set-shifting tasks. These findings are not surprising, given that previous investigations have documented tremendous growth in executive function skills between 3 to 5 years (Carlson, 2005; see Garon, Bryson, & Smith, 2008 for a review). The hypothesis that source memory accuracy would be positively correlated with performance on the executive function tasks was supported. Specifically, the source memory measures of fact recall, fact knowledge, and source recall were positively correlated with the working memory, inhibitory control and set-shifting executive function tasks. In addition, source memory false alarm errors were negatively correlated with working memory. Thus, these results support the claim that source monitoring accuracy and the ability to avoid source memory errors depends on executive processes.

Evidence from the aging literature (Glisky & Kong, 2008; Glisky, Rubin, & Davidson, 2001), neuropsychological investigations (Schacter, 1987; Schacter, Harbluck, & McLachlan, 1984), and cognitive neuroscience investigations (Davachi, Mitchell, & Wagner, 2003; Hannula & Ranganath, 2008; Mitchell, Johnson, Raye & Greene, 2004; Nolde, Johnson, & Raye, 1998; Ranganath, Johnson, & D'Esposito, 2000) implicate medial temporal and frontal lobe brain structures in supporting episodic memory ability. In Study 1, I examine whether frontal and temporal brain electrical activity would significantly predict children's fact recall and source recall performance, above and beyond the contributions of age and language ability. I hypothesized that both frontal and temporal EEG would uniquely predict children's fact recall and source recall performance, after controlling for age and language. A series of hierarchical regression analyses were used to test this hypothesis.

As evident in Tables 4 through 7, age and language ability uniquely accounted for a significant proportion of the variance in all fact recall and source recall performance. The inclusion of age, language ability, and medial frontal (F3/F4) EEG accounted for 63% of the variance in children's fact recall performance. Specifically, medial frontal EEG accounted for an additional 5% of the variance in performance above and beyond the contribution of age and language. These results replicate other functional neuroimaging studies which have established a link between recall performance and the activation of right prefrontal cortex areas of the brain (Cabeza et al., 1997). In addition, retrieving information using free recall contains more episodic traces compared to retrieving information based on recognition (Tulving, 1985). Contrary to what I originally hypothesized, the inclusion of posterior temporal (T7/T8) EEG did not uniquely predict fact recall performance above and beyond the contribution of age and language. Likewise, neither the inclusion of frontal EEG nor temporal EEG uniquely predicted source recall performance. These results suggest that, although patterns of brain electrical activity at frontal electrode sites predict children's recall of factual information, for recall of source information age and language are better predictors of performance compared to patterns of frontal and temporal brain electrical activity.

Thus, on free recall tasks (which contain more episodic traces), age, language, and frontal brain electrical activity all significantly predict performance, and age and language are unique predictors of source recall during early childhood. In Study 1, I chose to focus specifically on the transition between 4 and 6 years of age, based on Drummey and Newcombe's (2002) findings that a steady improvement in fact recall was evident between 4, 6, and 8 years of age, but that the most pronounced improvement in source recall occurred between 4 and 6 years, whereas source recall at 6 and 8 years was equivalent. Although the authors found comparable performance

between 6- and 8-year-olds, previous research has established that source monitoring skills continue to develop from childhood to adolescence (Chastelaine et al., 2007; Ghetti, DeMaster, Yonelinas, & Bunge, 2010). Thus, the restricted focus on the early childhood period is a limitation to Study 1. In Study 2, I sought to address this limitation by exploring improvement in source memory ability during a later time point in development, specifically between 6 and 8 years.

Chapter 3

Study 2

In Study 2, I examined source memory development during middle childhood, specifically focusing on the 6- to 8-year transition. Since previous research has established comparable performance on an external source monitoring paradigm (Drummey & Newcombe, 2002), it was necessary to modify the nature of the source monitoring judgment to make it more difficult for older children. Past studies have established that when there is a high degree of similarity between sources, children experience a greater degree of difficulty correctly monitoring between sources (Lindsay, Johnson & Kwon, 1991, Thierry & Pipe, 2009). Lindsay, Johnson, and Kwon (1991) investigated the effect of highly similar sources on external source monitoring judgments in children and adults. In a series of experiments, the perceptual and semantic similarities of two sources of information were manipulated (i.e., presenting two puppets speaking in the same voice versus using different voices for each puppet). Experiment 1 results revealed that 4-year-old children, compared to adults, were affected by the similarity manipulation and had difficulty discriminating between sources in the same voice condition, but performed equally well as adults in the different voice condition. These results indicate that, as the perceptual similarity between sources increases, there is a greater reliance on control processes that select and evaluate that source information, and these memory control processes are not fully developed in childhood.

In Study 1, there were multiple differences in the perceptual characteristics between the two sources (experimenter and pig puppet) that could aid older children on the source discrimination. In Study 2, rather than using a puppet as a source, I manipulated the similarity between external sources by using two female individuals (experimenter and a research

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assistant). This modification in the experimental protocol was intended to allow for a more

developmentally appropriate source discrimination. This modification also allowed me to assess

whether source monitoring ability improvements continue beyond the early childhood period. If

6- and 8-year-olds show comparable performance on a source monitoring task of greater

difficulty, then this would support the notion that the most pronounced changes in source

memory occur during early childhood. However, if modifying the difficulty of the source task

leads to improvement in performance in older children, then it can be concluded that source

memory skills continue to develop into middle childhood and beyond. I hypothesized that source

memory skills would continue to show improvement in middle childhood.

Two additional modifications to Study 2 allowed for a more thorough examination of the

influences of brain electrical activity and executive function skills on children's fact recall and

source recall performance. First, there was a modification to include a larger sample size. A

larger sample allowed me to analyze the influence of several predictors: age, language, EEG, and

executive function on fact recall and source recall performance. Due to the limitation of the small

sample size in Study 1, I could only address the correlational nature of source monitoring ability

and executive function skills. However, in a separate investigation Raj, Cuevas, and Bell (2012)

found that an executive function composite assessing working memory, inhibitory control and

set-shifting skills uniquely predicted the variance in children's fact recall and source recall

performance, above and beyond the contribution of age and language. In Study 2, I sought to

address this limitation by including a larger sample size, so that a direct examination of the

predictive relationship of executive function could also be assessed.

In addition, there was a modification in the EEG system adopted for Study 2.

Specifically, there was a change from the 16-channel system used in Study 1 to a 32-channel

system used in Study 2. Thus, the combination of a larger sample size plus the inclusion of more electrode sites for analysis allowed for a broader EEG hypothesis. In Study 1, the analysis focused specifically on the predictive relationship of frontal and temporal brain electrical activity at single electrode sites. In Study 2, my hypothesis focused instead on *anterior* (including frontal pole, medial frontal, and lateral frontal electrode sites) and *posterior* (including posterior temporal, anterior parietal, and posterior parietal electrode sites) brain regions. In addition to the previously documented association between episodic memory recruiting the use of prefrontal and medial temporal lobe brain regions, the inclusion of multiple electrode sites allowed me to examine the role of parietal brain electrical activity as a predictor of fact recall and source recall performance.

Neuroimaging investigations have linked parietal cortex activity to encoding and remembering source information. Uncapher, Otten, and Rugg (2006) found that the parietal cortex is involved in the perceptual binding of multifeatural representations. Greater activity in the parietal cortex has also been evident in both Remember (thought to rely on recollection) and Know (thought to index familiarity) responses, and is linked to the recollective experience (Vilberg & Rugg, 2007; Wheeler & Buckner, 2004). In a review of the relevant literature, Vilberg and Rugg (2008) concluded that parietal cortex activity may not necessarily be involved in the processes of recollection or familiarity, per se, but may rather be involved in representing and directing attention toward relevant source features. Thus, in Study 2, I examined the contribution of frontal, temporal, and parietal brain electrical activity to fact recall and source recall ability.

Hypotheses

1. Improvement on measures of fact memory and source memory will be observed between 6 and 8 years. By modifying the source discrimination to be more challenging in nature, I hypothesized that improvement on this task would be evident in middle childhood, and that 8-year-olds would recall more factual and source information than 6-year-olds.

2. Source memory measures will be correlated with executive function. I hypothesized that children's fact recall, source recall, and source memory errors would be correlated with measures of executive function (tasks assessing working memory and inhibitory control).

3. Both anterior and posterior brain electrical activity and children's executive function will predict unique variance in fact recall and source recall performance. I hypothesized that, after controlling for age and language ability, patterns of frontal, temporal and parietal brain electrical activity and executive function would account for unique variance in children's fact recall and source recall.

Method

Participants

Forty 6-year-old children (range: 5 years 7 months – 6 years 8 months; 16 boys, 24 girls; 39 Caucasian, 1 African American) and 39 8-year-old children (range: 7 years 5 months – 8 years 8 months; 21 boys, 18 girls; 34 Caucasian, 3 African American, 1 Asian, 1 American Indian/Alaska Native) were participants in this study. Children were eligible for participation if they were born within 4 weeks of their expected due date, experienced no prenatal or birth complications, were healthy and medication free at the time of testing, and had no developmental or neurological diagnoses. Of the original sample, five 6-year-old children were excluded, four due to developmental diagnosis and one due to premature birth. Two 8-year-olds were excluded,

one due to premature birth and one due to being too old for the sample. Thus, analyses are reported on a sample of 72 children (6-year-olds: $n = 35$; 8-year-olds: $n = 37$).

Children were recruited using the same procedures detailed in Study 1 (see Appendix E). With the exception of one case, all parents had at least a high school diploma (mothers: 4% high school diploma, 4% technical degree, 44% bachelor's degree, 48% graduate degree; fathers: 11% high school diploma, 8% technical degree, 37% bachelor's degree, 43% graduate degree). Average maternal age was 38 years (range: 26 – 50) and average paternal age was 40 years (range: 29 – 53). As compensation for participation, all children received a $10 gift card and parents were entered into a lottery drawing for one $50 gift certificate to a local store of their choice.

Procedure

Upon arrival to the research laboratory, signed parental consent (see Appendix F) and signed child consent (see Appendix G) was obtained prior to the introduction of study procedures. After consent was obtained from both parties, the electroencephalogram (EEG) electrodes was applied on the child's scalp and maintained during the task procedures.

EEG recording and analysis. EEG recordings were accomplished during baseline and during all task procedures. Baseline EEG was recorded for an entire duration of 60 seconds. In which children were shown a brief video presentation. Use of these baseline procedures were intended to minimize eye movements and gross motor activity (Wolfe & Bell, 2004). Parents were seated next to their children during this time and were instructed not to talk to their children.

The EEG application, recording, and analysis procedures were identical to Study 1, with the exception that for Study 2, EEG recordings were made from 32 left and right scalp sites. For

this study, hypothesis testing focused on five regions: frontal pole (Fp1, Fp2), medial frontal (F3, F4), lateral frontal (F7, F8), anterior temporal, (T7, T8), anterior parietal (P3, P4), and posterior parietal (P7, P8) (Pivik et al., 1993). Previous research within other laboratories, as well as our own, has demonstrated that the 6-9 Hz frequency band represents the dominant frequency from 5 months until at least 5 years of age (Bell & Wolfe, 2007; Marshall, Bar-Haim, & Fox, 2002; Wolfe & Bell, 2007). Relatively little is known, however, about which frequency band represents the dominant frequency during periods in middle and late childhood, although our lab has used 8-10 Hz and 11-13 Hz with EEG data from 8-year-old children (Roberts & Bell, 2000, 2002). In adults, the 8-13Hz alpha band has been divided into lower (i.e., 8-10Hz) and upper (i.e., 11-13Hz) frequency bands. In general, studies have found that lower band alpha is associated with attentional processes, whereas upper band alpha is associated with memory processing (Klimesch, 1997, 1999; Klimesch, Pfurtscheller, & Schmike, 1993). Based on this functional difference in upper and lower alpha bands, all EEG analyses reported focused on the upper alpha band (i.e., 11-13Hz). Power was expressed as mean square microvolts and the data were transformed using the natural log (ln) to normalize the distribution.

   Source memory task. The source memory encoding and test administration was identical to Study 1, with the following exceptions: (1) Rather than using the experimenter and a puppet as the 2 potential sources during the encoding phase, Study 2 used the experimenter and another research assistant as the 2 potential sources (2) The specific facts that were taught to children during encoding and the items presented during test were changed (see Appendix H). This task was videotaped and later scored for accuracy. Proportion correct was calculated as the dependent measure of interest for Fact Recall, Fact Knowledge (recall plus recognition) and Source Recall. The percentage of agreement between two coders for 28 % of the sample was

calculated, and interrater reliabilities ranged from .98 – 1.00. EEG was recorded continuously

throughout the encoding and test phases of the source memory task. A research assistant placed

event marks on the EEG record associated with the specific *test* stages of the task: fact recall and

source recall.

EF tasks. Working memory was assessed using the Forward and Backward Digit Span

tasks, which have been widely considered a measure of the central executive component of

working memory, and have been included in many standardized test batteries, such as the

Weschler Intelligence Scale for Children – Revised (WISC-R; Wechsler, 1986). Administration

of the Forward Digit Span task was identical to Study 1. The Backward Digit Span task was also

administered in the same manner, with the exception that children were presented with a series of

digits and were instructed to repeat the sequence in reverse order (e.g., If a child hears the digit

sequence "2..5..9" they will be instructed to repeat it in reverse order, "9..5..2"). For both the

Forward and Backward Digit Span, the highest span in which the child could repeat the entire

digit sequence in correct order/correct reverse order was used as the variable of interest. The

percentage of agreement between two coders for 28% of the sample was calculated, and

interrater reliability was .97 for the Forward Digit task and 1.00 for the Backward Digit task.

Inhibitory control was assessed using the same Stroop-like task procedure utilized by

Ruffman et al. (2001), which is appropriate for use in middle childhood. In the conflict

condition, children were presented with a row of digits presented on a computer screen and were

instructed to count the number of digits presented and press this corresponding number on the

computer keypad. For example, a child was shown the following series of digits "3 3 3 3," and

the correct response for this trial was to press the number "4" on the keypad, as this string

contains 4 digits. Therefore, children need to inhibit the automatic tendency of decoding the

presented digit on the screen (e.g., "3") for the appropriate response, which is to count the number of digits presented. In the control condition, no such level of conflict is available. For this condition, children were presented with with a row of letters presented on the computer screen and were instructed to count the number of letters presented and press this corresponding number on the computer keypad. For example, a child was shown the following set of letters "B B B," and the correct response for this trial was to press the number "3" on the keypad, as this string contains 3 letters. Therefore, in the control condition, children did not experience the same level of conflict because they did not experience the same automatic tendency to decode the information presented on the screen. Reaction times for both non-conflict and conflict trials were recorded. The Stroop interference score was used as the dependent variable of interest, and was calculated by subtracting the mean reaction time of the non-conflict condition from the mean reaction time of the conflict condition.

Language assessment. The Expressive Vocabulary (EVT), which was used in Study 1, was administered to examine expressive vocabulary and word retrieval (Williams, 1997).

Results

Behavioral Results

Descriptive statistics on the dependent variables of fact recall, fact knowledge, and source recall for both 6- and 8-year-old children are presented in Table 8. Independent samples t-tests revealed that 8-year-olds had a higher proportion of correct responses than 6-year-olds on fact recall, $t(70) = 7.82$, $p < .001$, $\eta^2 = .47$, and fact knowledge, $t(70) = 5.02$, $p < .001$, $\eta^2 = .26$. However, 6- and 8-year-olds did not significantly differ on source recall $t(70) = 1.60$, $p = .11$, $n.s$ (see Figure 2). Descriptive statistics on the types of source memory errors (e.g., intraexperimental errors and false alarms) are also presented in Table 8. Similar to the pattern

observed in Study 1, children were more likely to commit intraexperimental errors ($n = 69$)

compared to extraexperimental errors ($n = 3$), and thus this latter variable was excluded from

analyses. No differences were found between these two age groups on the percentage of

intraexperimental errors, $t(67) = .61$, $p = .55$, *n.s,* and false alarms $t(31) = -1.43$, $p = .16$, *n.s.,*

committed during the source memory test (see Table 8).

Table 9 displays the means and standard deviations for each EF measure by age. There

was a slight reduction in sample size due to missing data on the Forward and Backward Digit

Span tasks. Due to experimenter error, the Forward Digit and Backward Digit span tasks were

not adminstered to one 8-year-old child. One 6-year-old was missing data on the Backward Digit

Span task due to failure to understand the rules of the game. Analyses were conducted on all

available data.

Independent samples t-test results revealed that 8-year-olds performed better than 6-year-

olds on Forward Digit Span, $t(69) = 2.38$, $p = .020$, $\eta^2 = .08$, and Backward Digit Span tasks,

$t(68) = 6.23$, $p < .001$, $\eta^2 = .36$. No significant age difference was found between Stroop

interference score $t(70) = -1.05$, $p = .299$, *n.s*. Pearson correlations were calculated among the

source memory, EF, and language measures (see Table 10). Fact recall was positively correlated

with fact knowledge and source recall, whereas the correlation between source recall and fact

knowledge was not significant. Contrary to what I originally hypothesized, fact recall and fact

knowledge were not significantly correlated to the EVT standard score of language, although

source recall was positively correlated. In general, fact recall, fact knowledge, and source recall

were all positively correlated to the Forward and Backward Digit Span EF tasks, with the

exception that the correlation between source recall and Backward Digit Span was not

significant. Neither fact recall nor fact knowledge was correlated with the Stroop interference

score. However, the Stroop interference score was negatively correlated to source recall performance, indicating that children with lower interference scores tended to perform better on the source memory task.

As previously mentioned, measures of working memory and inhibitory control tap into a common EF construct. Therefore, due to the conceptual relations among the EF measures, the Stroop Intereference score, Forward Digit highest span, and Backward Digit highest span scores were aggregated into a single EF composite score, a method which has been used in prior research (Picard, Reffuveille, Eustache, & Piolino, 2009). The Stroop Interference score was multiplied by -1, so that lower scores on all variables indicate poorer performance. Then, I converted the raw scores of these variables into standardized z-scores and took the mean of these z-scores to create a composite EF score. To retain as much data as possible, if children were missing data from one or two EF tasks, their composite score was aggregated based on data from the other available tasks. For 70 children the EF composite score represents an aggregrate of all three EF measures. One child failed to pass the learning criterion for the Backward Digit Span task, and thus the EF composite score for this child represents an aggregate of the remaining two EF measures. Due to experimenter error, one child was not administered the Forward and Backward Digit Span tasks, and thus for this child the EF score represents their Stroop interference z-score.

Predicting Fact and Source Recall Performance

A series of hierarchical regressions were performed in order to determine whether anterior and posterior brain electrical activity and EF would predict performance on fact recall and source recall after controlling for age and language. As noted previously, rather than focusing on a single electrode region, the inclusion of a larger sample and the switch to a 32

channel system allowed us to analyze anterior and posterior regions of interest that included

multiple electrode sites. Therefore, separate regression analyses were performed for the anterior

(that included Fp1/Fp2, F3/F4, F7/F8 electrode sites) and posterior (that included T7/T8, P3/P4,

P7/P8 electrode sites) regions of interest for the dependent measures of fact recall and source

recall. With the inclusion of anterior and posterior EEG as a predictor of fact and source recall

performance, there was a further reduction in sample size. Sixty-three children contributed

electrophysiological data to the following analyses. The primary reason for missing data was too

much movement artifact within the EEG record.

Fact Recall. To determine the amount of variance in children's fact recall performance

explained by age, language, EEG and EF, separate hierarchical regressions were performed for

anterior (frontal electrode sites: Fp1/Fp2, F3/F4, F7/F8) and posterior (temporal and parietal

electrode sites: T7/T8, P3/P4, P7/P8, respectively) brain regions. I was particularly interested in

determining whether the inclusion of anterior EEG and EF and posterior EEG and EF would

uniquely predict the variance explained in children's fact recall, above and beyond the

contribution of age and language. Table 11 provides the results from the regression analyses

investigating age, language, and anterior EEG and EF as predictors of fact recall. Taken together,

the variables of age, language, and anterior EEG account for 63% of the variance in children's

fact recall performance. The first step in the model included age as the predictor variable. In this

model, age accounted for 46% of the variance in fact recall performance (Table 11, step 1).

Model 2 included age and EVT standard scores as the first and second predictor variables,

respectively. Language ability accounted for an additional 9% of the variance in fact recall

performance (Table 11, step 2). Model 3 included age, language, anterior EEG and EF. Above

and beyond the contributions of age and language ability, anterior EEG and EF accounted for an

additional 8% of the variance in fact recall performance (see Table 11, step 3). An examination of the beta coefficients revealed that F7/F8 EEG was significant in explaining children's fact recall. An examination of the regression weights indicates that for every one unit increase in EEG power at the F7/F8 electrode sites, fact recall performance decreases by .22 units. EEG activity at Fp1/Fp2 and F3/F4 electrode sites and the EF composite score were not significant in predicting fact recall performance.

Table 12 provides the results from the regression analyses investigating age, language, posterior EEG and EF as predictors of fact recall. Age, language, posterior EEG and EF accounted for 54% of the variance in performance. In model 1, 43% of the variance in fact recall was accounted for by age (Table 12, step 1). In model 2, language ability accounted for an additional 8% of the variance in performance (Table 12, step 2). Although model 3 was signficant (explaining 54% of the variance), the inclusion of posterior EEG and EF did not contribute unique variance, although age and language retained a significant contribution to fact recall performance (see Table 12, step 3).

Source Recall. Table 13 provides the results from the regression analyses investigating age, language, anterior EEG and EF as predictors of source recall. Age, language, anterior EEG and EF accounted for 23% of the variance in performance. In model 1, age was not a significant predictor of source recall (Table 13, step 1). Likewise, in model 2 language ability was not a significant predictor of source recall (Table 13, step 2). Model 3 included age, language, anterior EEG and EF. After controlling for age and language ability, anterior EEG and EF uniquely accounted for 16% of the variance in source recall performance (see Table 13, step 3). An examination of the beta coefficients revealed that F7/F8 EEG and the EF composite score were significant in explaining children's source recall. Specifically, for every one unit change in EEG

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power at F7/F8 electrode sites, source recall performance increased by .33 units. Likewise, for every 1 unit change in EF performance, source recall performance increased by .39 units. Age, language, and EEG activity at Fp1/Fp2 and F3/F4 electrode sites were not significant in predicting source recall.

Table 14 provides the results from the regression analyses investigating age, language, posterior EEG and EF as predictors of source recall. Age, language, posterior EEG and EF accounted for 26% of the variance in performance. In model 1, age was not a significant predictor of children's source recall (Table 14, step 1). In model 2, after controlling for age, language ability accounted for an additional 7% of the variance in performance (Table 14, step 2). Model 3 included age, language, anterior EEG and EF. After controlling for age and language ability, posterior EEG and EF uniquely accounted for 16% of the variance in source recall performance (see Table 14, step 3). An examination of the beta coefficients revealed that P7/P8 EEG was significant in explaining children's source recall, and that EF ability was marginally significant ($p = .05$). To specifiy, a 1 unit increase in EEG power at P7/P8 electrode sites resulted in a .39 unit increase in source recall performance. Likewise, a 1 unit increase in EF performance resulted in a .29 unit increase in source recall performance. However, age, language, and EEG activity at T7/T8 and P3/P4 electrode sites were not significant in predicting source recall.

Discussion

In Study 2 I sought to examine whether improvements in source monitoring ability would be evident beyond the early childhood period, and whether brain electrical activity and executive function uniquely predict performance in fact and source recall beyond the contribution of age and language. With respect to age differences, if source monitoring ability shows the most improvement in early childhood and truly is comparable in middle childhood (i.e., by 6 and 8

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years), then administering a more difficult source discrimination should not have an effect on performance among children in this age group. However, if source monitoring skills continue to show improvement in the middle childhood years and beyond, then this should be evident when a more difficult source task is used. Although this latter statement is what I originally hypothesized, the results from Study 2 tell a slightly different picture. Results from independent samples t-tests revealed that 8-year-olds performed better on the measures of fact recall and fact knowledge. However, source recall performance was comparable between 6- and 8-year-olds. Source memory errors (both intraexperimental and false alarms) were also equivalent between both age groups. Although 6- and 8-year-olds' level of source recall was comparable, performance was far from ceiling levels. These results suggest that there is still considerable room for improvement in source monitoring beyond this early childhood period, a point which I address further in the General Discussion.

As hypothesized, 8-year-olds performed better than 6-year-olds on some tasks of executive function, specifically the Forward and Backward Digit Span tasks. In contrast, 6- and 8-year-olds did not differ on Stroop interference scores, which could either indicate that levels of inhibitory control are comparable by middle childhood or that this particular measure of inhibitory control was not sensitive enough to detect age differences in this cognitive ability. In examining the relation between source memory and executive function, all three dependent measures of fact recall, fact knowledge, and source recall were correlated to working memory ability, as hypothesized. Source recall was also negatively correlated with Stroop interference scores, as children with lower interference scores (indicating better performance) tended to perform better on source recall.

In order to determine whether brain electrical activity and executive function ability predict fact recall and source recall performance above and beyond the contribution of age and language ability, a series of hierarchical regression analyses were performed. Specifically, separate regressions were performed that included either anterior (Fp1/Fp2, F3/F4, F7/F8) or posterior (T7/T8, P3/P4, P7/P8) regions of interest for the dependent measures of fact recall and source recall. For fact recall, the inclusion of age, language, anterior EEG, and EF explained 63% of the variance in performance. The inclusion of anterior EEG and EF uniquely contributed to 8% of the variance in performance after controlling for age and language ability. An examination of the regression coefficients revealed that lateral frontal EEG retained significance, whereas EF ability did not. The inclusion of age, language, posterior EEG and EF ability accounted for 54% of the variance in performance in fact recall. However, an examination of the regression coefficients revealed that only age and language retained a significant contribution to fact recall performance. Thus, similar to the results observed in Study 1, age, language and patterns of brain electrical activity from anterior regions significantly predicted performance in children's fact recall in middle childhood. Although EF ability was correlated with fact recall, it failed to uniquely predict performance in fact recall above and beyond the contribution of age and language. Thus, although free recall tasks contain more episodic traces than tasks assessing recognition memory (thus more likely depending on executive abilities), age, language, and frontal brain electrical activity are better predictors of performance.

A different pattern emerged when exploring the factors that contribute to source recall performance. For source recall, age, language, anterior EEG and EF accounted for 23% of the variance in performance. Specifically, the addition of anterior EEG and EF accounted for an additional 16% of the variance in performance beyond the contribution of age and language. An

examination of the regression coefficients revealed that both lateral frontal EEG and EF ability retained a significant contribution. Likewise, age, language, posterior EEG and EF accounted for 26% of the variance in performance. Posterior EEG and EF accounted for an additional 16% of the variance in performance beyond age and language. An examination of the regression coefficients revealed that posterior parietal EEG retained a significant contribution. However, when anterior or posterior EEG and EF were added to the model, age and language ability no longer retained unique contributions to source recall performance. Although I hypothesized age-related improvement would be evident between 6 to 8 years, these results indicate that 6 and 8 years demonstrate comparable performance in source recall. Likewise, language itself was not sufficient as a predictor of children's source recall in a model containing EEG and executive function. Thus, it appears that patterns of frontal and parietal brain electrical activity and executive function performance are better predictors of source recall performance in middle childhood. These findings are consistent with the neuroimaging literature that links increased activity to prefrontal (Dobbins, Rice, Wagner, & Schacter, 2003; Ofen et al., 2007) and parietal brain areas (Vilberg & Rugg, 2008) in supporting episodic memory judgments and behavioral investigations that have demonstrated that source monitoring may be supported by various executive function abilities, such as working memory and inhibitory control (Dywan, Segalowitz, & Webster, 1998; Ruffman et al., 2001).

The finding that parietal EEG predicted source recall performance provides additional evidence that the parietal cortex plays a role in episodic memory. Neuroimaging studies implicate that the parietal cortex is involved with the allocation of attention and cognitive control processes that aid in successful memory performance (Cabeza, 2008; Ofen, 2012; Vilberg & Rugg, 2008). Patterns of brain electrical activity at temporal electrode sites did not predict fact

and source recall memory. As previously mentioned, although medial temporal lobe processing plays an important role in episodic memory, it may be that this process is most likely to occurr during encoding. It is specifically during encoding that item and feature information become bound together to form a unified memory representation, and fMRI comparisons during encoding of source items subsequently recalled correctly versus incorrectly reveal greater hippocampal activity on correct responses (Davachi et al., 2003). Although this present investigation focused on patterns of brain electrical activity during retrieval, it would be worthwhile for future investigations to examine EEG activity during encoding.

These results suggest that a developmental shift occurs within the factors that contribute to source memory performance between the early childhood and middle childhood periods. In early childhood, age and language are better predictors of source recall ability whereas in middle childhood, a greater proportion of the variance in source recall is actually explained by frontal and parietal brain electrical activity and executive function performance. As previously stated, approximately 23 – 26% of the variance in performance is accounted for by age, language, anterior or posterior EEG and executive function. Although these results provide some initial insight as to the factors that support source memory ability in middle childhood, there is still a large proportion of the variance in source recall that is left unaccounted for. I address this point further in the General Discussion, and highlight the fact that future research should explore the role of other factors (e.g, memory binding and retrieval strategies) in order to obtain a more comprehensive picture of early episodic memory development.

Chapter 4

Study 3

All of the previously highlighted research, along with the findings from Study 1 and Study 2, indicate that substantial improvements in children's source monitoring abilities occur between the early and middle childhood periods, specifically between the ages of 4 and 8 years, and possibly beyond into adolescence. One significant limitation to the previous research cited is that almost all of have employed cross-sectional methodologies. In order to understand the developmental trends which occur in source monitoring ability during the early and middle childhood periods, it is necessary for researchers to employ a longitudinal technique. Such a technique would allow researchers to chart the developmental improvements in source monitoring implicated in episodic memory, and provide more concrete conclusions about the processes of developmental change that occur from early to middle childhood. The purpose of Study 3 was to address this gap in the literature by conducting a longitudinal analysis to explore the developmental progression of fact recall and source memory recall ability from early to middle childhood.

My longitudinal predictions originally focused on examining the following research questions: (1) Does 4 year fact and source recall performance predict later 6 year fact and source recall performance? (2) If I control for 4 year fact and source recall performance, does frontal and temporal brain electrical activity and individual differences in executive function ability also uniquely predict fact and source recall performance at 6 years? (3) Does 6 year fact and source recall performance predict later 8 year fact and source recall performance? (4) If I control for 6 year fact and source recall performance, does frontal and temporal brain electrical activity and

individual differences in executive function ability also uniquely predict fact and source recall performance at 8 years?

Unfortunately, due to a high subject attrition rate, I was unable to obtain a large enough sample to conduct my intended analyses. Therefore, I was left to re-frame the research questions in Study 3. Instead, I focus on exploring the correlations between 4- to 6- year and 6- to 8-year fact recall, source recall, and executive function performance to obtain a marker of longitudinal stability within these cognitive measures. My revised research questions focus on addressing the following:

Hypotheses

(1) *Are 4 year source memory measures and executive function performance correlated with 6 year source memory measures and executive function performance, respectively?* I hypothesized that that 4 year source memory and executive function would be correlated with 6 year source memory and executive function.

(2) *Are 6 year source memory measures and executive function performance correlated with 8 year source memory measures and executive function performance, respectively?* I hypothesized that 6 year source memory and executive function would be correlated with 8 year source memory and executive function.

(3) *Is executive function performance at Time 1 (i.e., 4 and 6 years) correlated with source memory measures at Time 2 (i.e., 6 and 8 years)?* I hypothesized that Time 1 executive function measures would be correlated with Time 2 source memory.

Method

Participants

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As part of a longitudinal investigation, 27 children out of the original eligible sample of 50 children who participated in Study 1 returned for participation in Study 2. For the 4- to 6-year comparison, 12 children returned for participation (4 boys, 8 girls; 11 Caucasian, 1 African American) and 15 children returned for the 6- to 8-year comparison (5 boys, 10 girls; 14 Caucasian, 1 African American). In general, the follow-up visit was scheduled 2 years after initial participation in Study 1 (range: 1 year 10 months to 2 years 6 months). All efforts were made to contact the original sample and limit the amount of missing data in this longitudinal investigation. Unfortunately, despite these efforts, subject attrition rate was rather high, with 23 children not returning for participation for the following reasons: Moved away ($n = 3$), Too Busy ($n = 6$), Not Interested ($n = 1$), and Could Not Locate ($n = 13$).

Procedure

The procedure for the source memory and executive function tasks has already been outlined in Studies 1 & 2. For the source memory task, the main dependent measures of interest were the proportion correct for Fact Recall, Fact Knowledge (recall plus recognition), and Source Recall. For the measures of EF skills, I focused specifically on working memory and inhibitory control because these two skills were assessed at both time points. To elaborate, I used Forward Digit Span performance (operationalized as the highest span achieved) as the indicator of working memory ability during Time 1 and Time 2. Inhibitory control was assessed at Time 1 using the Day/Night Stroop-like task. The Day/Night task is not developmentally appropriate to use with children older than 6 years (Gerstadt, Hong, & Diamond, 1994), thus I incorporated a different developmentally appropriate measure of inhibitory control during the Time 2 assessment, known as the Number Stroop. Both scores were operationalized as proportion correct.

Results

4 to 6 year comparison

First, a mean comparison on children's expressive vocabulary ability was conducted

between those children who returned for participation (n =12) and those who did not (n = 12).

No differences in expressive language ability were observed between these two groups, $t(22) =$

.476, p = .64. Descriptive statistics on the source memory and executive function measures at 4

and 6 years of age presented in Table 15. Paired samples t-tests revealed changes in fact recall,

$t(11) = 3.84$, p = .003, η^2 = .57, and fact knowledge performance, $t(11) = 5.00$, $p < .001$, η^2 = .69,

with significant increases in performance at 6 years. No significant changes in performance were

evident for source recall, $t(11) = 1.51$, p = .16, $n.s$ (see Figure 3). For the executive function

tasks, paired samples t-tests revealed changes in Forward Digit Span, $t(11) = 4.01$, p = .002, η^2 =

.59, and Stroop performance, $t(11) = 3.62$, p = .004, η^2 = .54, with significant increases in

performance at 6 years (see Table 15).

Pearson correlations were calculated among 6 year source memory measures and 4 year

source memory and executive function measures (see Table 16). There was a marginally

significant correlation between fact knowledge and source recall at 4 years and fact knowledge

and source recall at 6 years. Fact recall at 4 years was not correlated to fact recall performance at

6 years. Contrary to my prediction, none of the EF tasks at 4 years were correlated with 6 year

fact recall, fact knowledge, or source recall.

6 to 8 year comparison

A mean comparison on children's expressive vocabulary ability was conducted between

those children who returned for participation (n =15) and those who did not (n = 11). No

differences in expressive language ability were observed between these two groups, $t(24) =$

-1.70, $p = .10$. Descriptive statistics on the source memory and executive function measures at 6 and 8 years of age presented in Table 17. Paired samples *t*-tests revealed changes in fact recall, $t(14) = 4.67$, $p < .001$, $\eta^2 = .61$, with significant increases in performance at 8 years. No significant changes in performance were evident for fact knowledge, $t(10) = .56$, $p = .59$, *n.s.* A marginally significant change was evident in source recall, although in the opposite direction as predicted, $t(14) = -1.85$, $p = .09$ (see Figure 4). For the executive function tasks, paired samples *t*-tests revealed changes in Stroop performance, $t(14) = 2.58$, $p = .02$, $\eta^2 = .32$, with significant increases in performance at 8 years. No significant changes were observed in Forward Digit Span performance, $t(13) = -.89$, $p = .385$, *n.s.*(see Table 17).

Pearson correlations were calculated among 8 year source memory measures and 6 year source memory and executive function measures (see Table 18). There was a marginally significant correlation between source recall at 6 years and source recall at 8 years. Fact recall and fact knowledge at 6 years was not correlated to fact recall and fact knowledge performance at 8 years. Contrary to our prediction, none of the EF tasks at 6 years were correlated with 8 year fact recall, fact knowledge, or source recall.

Discussion

Study 3 attempted to directly assess the developmental shift in source memory ability between early and middle childhood periods by implementing a longitudinal study design. In examining the transition between 4 and 6 years, there was a change in fact recall and fact knowledge, with significant increases evident by 6 years. However, no such change was observed in source recall performance. There was also a significant increase in working memory and inhibitory control performance at 6 years. A similar pattern of results was also observed for the 6 to 8 year transition. Fact recall and working memory performance significantly increased

by 8 years of age. However, no such improvement was observed for fact knowledge, source recall, and inhibitory control measures.

The revised hypotheses focused on examining whether (1) Time 1 (i.e., 4 and 6 year) source memory measures were correlated with Time 2 (i.e., 6 and 8 year) source memory (2) Time 1 executive function skills were correlated with Time 2 executive function (3) Time 1 executive function skills were correlated with Time 2 source memory measures. Study 3 provided very minimal support for these hypothesis. Only a marginally significant correlation was observed between Time 1 and Time 2 source recall. No other source memory measures were correlated between Time 1 and Time 2. In addition, Time 1 executive function measures were not correlated with Time 2 source memory measures.

Unfortunately, the results from this longitudinal investigation on the stability of source memory and executive function processes are inconclusive. There exist two important limitations in the present methodology that render these results difficult to interpret. First, due to the high subject attrition rate, there was a marked reduction in sample size. Thus, there could be key differences in sample characteristics between those participants who returned for participation and those who did not. This reduction in sample size prevented me from addressing the originally intended hypotheses that patterns of frontal and temporal brain electrical activity and individual differences in executive function performance at Time 1 would predict fact recall and source recall performance at Time 2. In addition to this, a change in the experimental methodology also significantly limits the interpretation of results. To elaborate, the type of source discrimination that children had to make differed between Time 1 and Time 2 testing. Time 2 source memory testing was made harder because two female researchers served as the external sources, providing a great deal more similarity in perceptual characteristics compared to

the external sources used during Time 1 (female researcher and pig puppet). Thus, it is likely that the lack of a significant increase in source recall performance between Time 1 and Time 2 assessments is more a reflection of this change in methodology rather than stagnant performance between these two time periods. Due to these substantial flaws in methodology, the interpretation of these preliminary longitudinal results should be met with caution. Future investigations should expand upon these findings and implement a more comprehensive and consistent assessment to better understand the developmental improvements in source monitoring ability that occur early in life, spanning from early childhood to adolescence.

Chapter 5

General Discussion

The purpose of this investigation was to examine the development of children's source monitoring abilities between the early to middle childhood periods, specifically between the ages of 4 and 8 years. In Study 1, I focused on early childhood (i.e., 4 to 6 years) source memory development. Improvement in the ability to recall factual information and monitor the source of such information was seen. Source memory measures (i.e., fact recall, source recall, and source memory errors) were also correlated to early executive function skills (i.e., working memory, inhibitory control and set-shifting). In addition, I examined electrophysiological indices of item and source recall memory through the use of EEG technology and found that frontal brain electrical activity accounted for unique variance in children's fact recall performance, beyond the contribution of age and language. In contrast, for source recall, age and language accounted for the most variance. In Study 2, I sought to expand upon these findings. I modified the source task to include a more difficult source discrimination and examined whether improvements in source memory continue to occur in middle childhood, specifically between 6 and 8 years. Increases in fact recall were evident between 6 and 8 years, but I found comparable performance in source recall. However, source recall performance was far from ceiling levels, indicating that there is still substantial room for improvement in source monitoring ability during middle childhood and beyond. In trying to understand the factors that contribute to source memory development, frontal and parietal brain electrical activity and executive function skills were better predictors of the variance in source recall compared to age and language ability. Lastly, in a longitudinal investigation in Study 3, I examined whether Time 1 source memory and executive function

measures (at 4 and 6 years of age) were correlated with Time 2 source memory and executive function measures (at 6 and 8 years of age), but did not find support for this.

Developmental Improvement in Episodic Memory

Although it is important to identify age-related improvement in various indices of episodic memory (e..g, free recall of factual information, source memory, etc.) it is also worthwhile to investigate the mechanisms that contribute to these age-related differences. In this respect, I found that a developmental shift occurs within the factors that contribute to source memory performance between the early childhood and middle childhood periods. In early childhood, age and language are better predictors of source recall ability whereas in middle childhood, a greater proportion of the variance in source recall is explained by frontal and parietal brain electrical activity and executive function performance. As other developmental researchers have proposed, age can be considered a proxy variable for normative neurological maturation (Ceci, Fitneva, & Williams, 2010). Thus, it appears that at younger ages, this proxy variable of neural maturation, along with early expressive vocabulary ability, serves as a better predictor of source monitoring ability. However, by middle childhood, brain-electrical activity during task-specific processing at frontal and parietal electrode sites and executive function skills better account for the variance in performance relative to neurological maturation and expressive language ability. However, it is important to acknowledge that interpretations about the role of neural maturation should be met with caution. As noted by Newcombe et al. (2007) and echoed by other developmentalists (see Ceci, Fitneva, & Williams, 2010), researchers have yet to determine the appropriate level of maturation needed to support episodic memory processes. Future investigations should explore the role of these cognitive and brain-behavior processes in more detail.

It is also important to acknowledge that source monitoring skills continue to develop beyond this early childhood period, with improvements occurring throughout later childhood and adolescence. Specifically, younger children perform worse than adolescents on source discrimination tasks, who in turn demonstrate an intermediate level of performance compared to adults (Chastelaine, Friedman, & Cycowicz, 2007; Ghetti, DeMaster, Yonelinas, & Bunge, 2010). Ghetti and Angelini (2008) note that continued age-related improvements from childhood to adolescence in the ability to recollect the qualitative details associated with a memory episode are related to the use of semantic processing during encoding. Older children, adolescents, and adults are able to engage in such semantic processing to aid in retrieval of item and context associations (Ghetti & Angelini, 2008).

Researchers have observed age-related improvements in recollection of contextual details from childhood to adulthood, whereas familiarity-based processing remained relatively stable during this time frame (Billingsley et al., 2002; Ofen, Kao, Sokol-Hessner, Kim, Whitfield-Gabrieli, & Gabrieli, 2007). Similarly, Ofen et al. (2007) also found that recollection-based recognition responses improved from the ages of 8 to 24 years, whereas familiarity-based recognition did not change with age. It is important for future research investigations to examine the transitional stages between early childhood, middle childhood, and adolescence and adopt longitudinal research methodologies in order to better understand the developmental changes in source memory ability.

One question that remains to be answered is: When do episodic memory processes become equated to that of adults? A recent investigation by Picard et al. (in press) may shed some light on this answer. The authors examined the link between feature-binding abilities and executive function skills to the development of three different components of episodic memory

(i.e., factual content, spatial context, and temporal context) within a comprehensive developmental sample (i.e., participants between 4 and 16 years of age). The authors found that these different components of episodic memory may develop at different rates, with memory for factual content emerging earlier than memory for contextual information. To specify, the authors found a pronounced increase in memory for factual content during the preschool years, continued to show slight improvement between 6 and 9 years, and reached maturity approximately at 9 years. These results mirror what I found in the present investigation, with children's fact recall memory showing a steady increase between 4 and 8 years of age.

In contrast, Picard et al., (in press) found that children under the age of 8 found it difficult to retrieve contextual information (both spatial and temporal). This same trend was found in the present study. Although a slight improvement was evident between 4 and 8 years, it was still evident that children did not reach full maturity on their level of source recall by age 8. Indeed, Picard et al. found that contextual memory continued to improve from childhood to adolescence. Thus, there is evidence to suggest that source memory skills may not reach maturity until much later in development, approximately by adolescence.

Although it is important to understand these developmental trends, one caveat should be noted. The relationship between source memory and age is quite complex and the development of source memory skills may not necessarily be linear (Roberts, 2002). In some situations, young preschool-aged children have difficulty with internal source monitoring judgments (e.g., distinguishing between memories of imagined self-generated versus performed actions) , but demonstrate competence on external source monitoring judgments (e.g., distinguishing between memories of self-performed versus other-performed actions; Foley & Johnson, 1985; Welch-Ross, 1995). The specific nature of the task may also influence children's source monitoring

skills. For example, if 3- and 4-year-old children are tested nonverbally, then they are able to discriminate between memories of performed versus imagined actions (Roberts & Blades, 1995). Children also make fewer source errors when allowed to freely recall events compared to answering individual questions (Roberts & Blades, 1998; 1999). Taken together, these research investigations seem to suggest that source memory should not be conceptualized as a single skill that can be acquired abruptly at one specific period in development. Rather, it is more appropriate to view source memory development as gradual and situation specific (Lindsay, 2002; Roberts, 2002).

Neural Correlates of Episodic Memory

In the present investigation, patterns of brain electrical activity at frontal and parietal electrodes sites significantly accounted for variance in children's fact and source recall memory, providing further support to a growing body of literature that episodic memory systems depend on these brain regions (Ofen, 2012). Unfortunately, the sole reliance on cross-sectional studies means that comparisons across age are also confounded by individuals who differ from one another on variables other than age. Thus, longitudinal designs are necessary to relate the structural and functional changes within a specific individual's brain to changes in episodic memory ability over the course of development.

Although the present focused specifically on the electrophysiological indices of item and source memory processing during retrieval, future studies should examine the EEG correlates of item and source memory during encoding. Contrary to what I originally hypothesized, patterns of brain electrical activity at temporal electrode sites did not predict fact and source recall memory. As previously mentioned, it may be that temporal lobe brain electrical activity during encoding, rather than retrieval, serves as a better predictor of fact and source recall memory. It is

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specifically during encoding that binding processes connect item and source information together into a unified memory representation. Therefore, it would be worthwhile for future investigations to examine EEG activity during encoding of source items subsequently recalled correctly versus incorrectly to reveal the role of temporal brain electrical activity during encoding of episodic information.

Additional research is also needed to understand the extent to which the prefrontal cortex interacts with posterior regions of the brain during encoding and retrieval of item and source memory judgments. For example, in adults, there is evidence that suggests that the prefrontal cortex regulates top-down processing of posterior brain activity, and that this regulation supports later source memory. Summerfield et al. (2006) examined the functional connectivity of brain regions that were active during the encoding of face-house pairs, and found that correlations between face and place voxels in the left dorsolateral prefrontal cortex and posterior regions was linked to successful binding of face-house pairs. In addition, maintaining focused selective attention during monitoring of source information may also require coordinated activity from parietal and prefrontal brain areas (Mitchell & Johnson, 2009). Unfortunately, very little is known about the developmental trends in functional brain connectivity that support memory formation, which should be the focus of future research. In the future, I plan to examine measures of functional connectivity using EEG coherence, defined as the frequency-dependent squared cross correlation between two electrode sites (Nunez, 1981; Thatcher, Walker, & Giudice, 1987). I am specifically interested in examining whether task-related changes in frontal-parietal and frontal-temporal EEG coherence are evident during episodic memory processing, as previous investigations in our research laboratory have documented these changes during infant (Bell, 2012; Cuevas, Raj, & Bell, 2012) and child working memory (Bell & Wolfe, 2007).

Cognitive Processes Supporting Episodic Memory

The findings from this investigation suggest a link between episodic memory and executive function. Being able to correctly monitor source information and link feature information together requires working memory-dependent strategies. These executive function skills can support episodic memory through processes that occur during encoding and retrieval. For example, it may be the case that children with better executive function skills are better at integrating item and source information together during encoding, resulting in a more integrated memory representation. Executive function skills may also guide retrieval processes. Children with better executive function skills may be more efficient at engaging in search and monitoring processes at test, and may be better at retrieving the correct pair of item and source information or more efficient at making a decision regarding whether the match that is retrieved is correct or not. Executive function skills are also related to the ability to avoid making source memory errors. Ruffman et al. (2001) found children with greater inhibitory control were more likely to *avoid* making false alarm errors. Successful source monitoring requires the individual to correctly distinguish and inhibit feelings of familiarity that may have been generated in the experimental context in favor of the relevant aspects of the memory episode, all of which may be supported by greater inhibitory control. Therefore, these processes during encoding and retrieval are likely to depend on executive abilities (Raj & Bell, 2010).

Picard et al. (in press) found that both feature binding abilities and executive functions are critical to the encoding of rich episodic memory representations and their subsequent recall. Specifically, executive function was linked to recall of both the temporal and spatial context associated with item information and that feature-binding was linked to recall of factual content, temporal context, and spatial context. These findings support recent claims that episodic

memory functioning can be conceptualized as containing two components, an associative component that binds the features of a memory trace together into a cohesive episode and a strategic component that organizes and manipulates the elements of a memory episode. Shing, Werkle-Bergner, Li, and Lindenberger (2008) found that these two components of episodic memory follow different trajectories throughout the lifespan. Specifically, the associative abilities of young children are relatively intact by 6 years of age (Lloyd, Doydum, & Newcombe, 2009; Sluzenski, Newcombe, & Kovacs, 2006), and difficulties in older children's episodic memory can primarily be attributed to lower strategic functioning, which is dependent on executive abilities (Shing et al., 2008).

Thus, future investigations should examine the role these cognitive factors play in explaining developmental changes and variability in children's source monitoring. In examining this associative component, research investigations have established that *binding,* which refers to a process that encodes the relations among separate stimuli into a cohesive unit, is important for retaining the contextual details of a memory episode (Chalfonte & Johnson, 1996; Sluzenski, Newcombe, & Kovacs, 2006). Failures in feature binding may result in incomplete episodic memory representations. Research investigations exploring the development of binding in children have been extremely limited.

Sluzenski et al. (2006) investigated the development of binding ability in early childhood and its relation to episodic memory. Four and six-year-old children were shown single features (either animals or backgrounds) and were then shown the combination of both animal and background paired together. Memory for single features was intact in both younger and older children, but 4-year-olds performed worse in the combination condition (i.e., the binding task). Additionally, 4-year-old performance in the combination condition predicted later episodic

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memory for a complex event, even after controlling for intelligence (Sluzenski et al., 2006).

Lloyd, Doydum, and Newcombe (2009), investigated young children's memory performance on

a similar binding task, testing single feature and combination items as a function of list length.

When there was a long list of items to be remembered, 4-year-olds experienced greater difficulty

remembering bound items, whereas memory for individual features was comparable in younger

and older children (Lloyd et al., 2009). Given that binding processes hold feature information

together and have been linked to episodic memory in early childhood, future investigations need

to examine how the development of binding processes supports source monitoring ability.

Age-related changes in episodic memory may also be related to children's use of retrieval

strategies, which improve during childhood (Chinsky, 1966; Kail, 1979; Ornstein, Naus, &

Liberty, 1975). In the early literature examining the development of mnemonic strategies, it was

found that children under the age of five do not rely on rehearsal as a memory strategy for

storing information, whereas older children use rehearsal in a rudimentary way (Flavell, Beach,

and Chinsky, 1966; Kail, 1979; Ornstein, Naus, & Liberty, 1975). By 8 years, children use

category information as a retrieval strategy. Thus, one possible explanation for age-related

changes in source memory performance may be the use of mnemonic strategies. If adults

experience difficulty trying to recollect the source of a memory, they may engage in more

strategic search processes and can infer source based on reasoning abilities. Young children, on

the other hand, may not automatically employ such strategies or may perform such strategies less

efficiently (Lindsay, 2002). In trying to gain a comprehensive understanding of the cognitive

factors that contribute to early episodic memory formation, it is important for future

investigations to examine the development of these associative and strategic components.

Limitations

Although these results provide promising insight into source memory development in early childhood, several limitations should be addressed. First, the generalizability of these findings is rather restricted, as the majority of participants were European-Caucasian and had older and well-educated parents, which restricts the application of these results. Another limitation is that statements about developmental changes in source monitoring ability should be interpreted with caution, given that the longitudinal sample was very small and offered inconclusive results. In order to understand the developmental trends which occur in source monitoring ability, future investigations need to employ a longitudinal technique spanning early childhood to adolescence.

As previously mentioned, EEG is advantageous to use in developmental populations because it is relatively non-invasive. However, this neuroimaging technique does have certain limitations. For instance, it is not possible to localize cortical versus subcortical brain activity using EEG. EEG offers poorer spatial resolution compared to other neuroimaging techniques which are dependent on changes in blood flow or the metabolic processes of the brain. In addition to this, the science of mapping the functions of item and source memory processes to specific brain regions is still complicated, and interpretations about functional specificity of prefrontal, medial temporal, and parietal cortex brain regions should be made with caution. Therefore, it is necessary for future investigations to document convergent findings across multiple neuroimaging techniques (such as comparisons among fMRI, ERP, and EEG studies, etc.) in order to increase the generalizability of these findings.

Future Directions

There are a number of issues that remain to be addressed regarding the development of episodic memory and the factors that contribute to its formation. Future studies should

implement longitudinal research designs in order to chart the maturation of these brain regions across early childhood and adolescence. This approach could allow researchers to determine when these brain-behavior processes in episodic memory become equated to those of adults. Convergence from multiple neuroimaging techniques is also needed to in order to better understand the role of neural maturation in the brain structures that support episodic memory. With respect to future electrophysiological investigations, measures of EEG coherence can provide an index of the degree of functional connectivity between prefrontal and posterior brain regions and how episodic memory processing functions as an interaction between these brain regions. Developmental studies spanning a longer time period (i.e., early childhood through adolescence and adulthood) are necessary to obtain a clearer understanding about the trajectories of the varying components of episodic memory (i.e., binding and strategic processes). Each of these avenues of investigation are critical to expanding our knowledge about the emergence and development of this complex memory system.

References

Ackil, J. K., & Zaragoza, M. S. (1995). Developmental differences in eyewitness suggestibility and memory for source. *Journal of Experimental Child Psychology, 60,* 57-83.

Alexander, K. W., Goodman, G. S., Schaaf, J. M., Edelstein, R, S., Quas, J. A., & Shaver, P. R. (2002). The role of attachment and cognitive inhibition in children's memory and suggestibility for a stressful event. *Journal of Experimental Child Psychology, 83,* 262-290.

Barr, R., Dowden, A., & Hayne, H. (1996). Developmental changes in deferred imitation by 6- to 24-month-old infants. *Infant Behavior & Development, 19,* 159-170.

Barr, R., Rovee-Collier, C., & Campanella, J. (2005). Retrieval protracts deferred imitation by 6-month-olds. *Infancy, 7,* 263-283.

Bauer, P. J. (2007). Recall in infancy: A neurodevelopmental account. *Current Directions in Psychological Science, 16,* 142-146.

Bauer, P. J., Deboer, T., & Lukowski, A. F. (2007). In the language of multiple memory systems: Defining and describing developments in long-term declarative memory. In L. M. Oakes & P. J. Bauer (Eds.), *Short and long-term memory in infancy and early childhood: Taking the first steps toward remembering* (pp.240-270). New York: Oxford University Press.

Bell, M. A. (2002). Power changes in infant EEG frequency bands during a spatial working memory task. *Psychophysiology, 39,* 450-458.

Bell, M. A. (2012). A psychobiological perspective on working memory performance at 8 months of age. *Child Development, 83,* 251-265.

Bell, M. A. & Wolfe, C. D. (2007). Brain reorganization from infancy to early childhood: Evidence from EEG power and coherence during working memory tasks. *Developmental*

Neuropsychology, 31, 21-38.

Billingsley, R. L., Lou Smith, M., & McAndrews, M. P. (2002). Developmental patterns in
priming and familiarity in explicit recollection. *Journal of Experimental Child
Psychology, 82,* 251-277.

Brainerd, C. J., & Reyna, V. F. (1998). Fuzzy-trace theory and children's false memories.
Journal of Experimental Child Psychology, 71, 81-129.

Bruck, M., Ceci, S. J., & Melnyk, L. (1997). External and internal sources of variation in the
creation of false reports in young children. *Learning and Individual Differences, 9,* 289-
316.

Bruck, M., & Melnyk, L. (2004). Individual differences in children's suggestibility: A review
and synthesis. *Applied Cognitive Psychology, 18,* 947-996.

Cabeza, R., Kapur, S., Craik, F. I. M., McIntosh, A. R., Houle, S., & Tulving, E. (1997).
Functional neuroanatomy of recall and recognition: A PET study of episodic memory.
Journal of Cognitive Neuroscience, 9, 254-265.

Carlson, S. M. (2005). Developmentally sensitive measures of executive function in preschool
children. *Developmental Neuropsychology, 28,* 595-616.

Casey, B.J. & de Haan, M. (2002). Introduction: new methods in developmental science.
Developmental Science, 5, 265-267.

Casey, B. J., Giedd, J. N., & Thomas, K. M. (2000). Structural and functional brain development
and its relation to cognitive development. *Biological Psychology, 54,* 241-257.

Ceci, S. J., Fitneva, S. A., & Williams, W. M. (2010). Representational constraints on the
development of memory and metamemory: A developmental-representational theory.
Psychological Review, 117, 464-495.

Chai, X. J., Ofen, N., Jacobs, L. F., & Gabrieli, J. D. (2010). Scene complexity: Influence on
perception, memory, and development in the medial temporal lobe. *Frontiers in Human
Neuroscience, 4,* 21.

Chiu, C. Y.P., Shmithorst, V. J., Brown, R. D., Holland, S. K., & Dunn, S. (2006). Making
memories: A cross-sectional investigation of episodic memory encoding in childhood
using fMRI. *Developmental Neuropsychology, 29,* 321-340.

Chalfonte, B. L. & Johnson, M. K. (1996). Feature memory and binding in young and older
adults. *Memory & Cognition, 24,* 403-416.

Chastelaine, M., Friedman, D., & Cycowicz, Y. M. (2007). The development of control
processes supporting source memory discrimination as revealed by event-related
potentials. *Journal of Cognitive Neuroscience, 19,* 1286-1301.

Chugani, H. T. (1994). Development of regional brain glucose metabolism in relation to
behavior and plasticity. In G. Dawson & K. Fischer (Eds.), *Human behavior and the
developing brain* (pp. 153-175). New York: Guilford Press.

Chugani H. T. (1998). A critical period of brain development: Studies of cerebral glucose
utilization with PET. *Preventive Medicine, 27,* 184-188. doi:10.1006/pmed.1998.0274

Chugani, H. T. & Phelps, M. E. (1986). Maturational changes in cerebral function in infants
determined by 18FDG positron emission tomography. *Science, 231,* 840-843.
doi:10.1126/science.3945811

Cuevas, K., Raj, V., & Bell, M. A. (in press). Functional connectivity and infant spatial working
memory: A frequency band analysis. *Psychophysiology.* DOI: 10.1111/j.1469-
8986.2011.01304.x

Cycowicz, Y. M. (2000). Memory development and event-related brain potentials in children.

Biological Psychology, 54, 145-174.

Cycowicz, Y. M., Friedman, D., & Duff, M. (2003). Pictures and their colors: What do children remember? *Journal of Cognitive Neuroscience, 15,* 759-768.

Cycowicz, Y. M., Friedman, D., Snodgrass, J. G., & Duff, M. (2001). Recognition and source memory for pictures in children and adults. *Neuropsychologia, 39,* 255-267.

Czernochowksi, D., Mecklinger, A., & Johansson, M. (2009). Age-related changes in the control of episodic retrieval: An ERP study of recognition memory in children and adults. *Developmental Science, 12,* 1026-1040.

Czernochowski, D., Mecklinger, A., Johansson, M., & Brinkmann, M. (2005) Age-related differences in familiarity and recollection: ERP evidence from a recognition memory study in children and young adults. *Cognitive, Affective, & Behavioral Neuroscience, 5,* 417-433.

Davachi, L. (2006). Item, context and relational episodic encoding in humans. *Current Opinion in Neurobiology, 16,* 693-700.

Davachi, L., Mitchell, J. P., & Wagner, A. D. (2003). Multiple routes to memory: Distinct medial temporal lobe processes build item and source memories. *Proceedings of the National Academy of Sciences, 100,* 2157-2152.

Davachi, L., & Wagner, A. D. (2002). Hippocampal contributions to episodic encoding: Insights from relational and item-based learning. *Journal of Neurophysiology, 88,* 982-990.

Davidson, P. S. R. & Glisky, E. L. (2002). Neuropsychological correlates of recollection and familiarity in normal aging. *Cognitive, Affective, & Behavioral Neuroscience, 2,* 174-186.

Day, K., Howie, P., & Markham, R. (1998). The role of similarity in developmental differences in source monitoring. *British Journal of Developmental Psychology, 16,* 219-232.

Diamond, A. (2002). Normal development of prefrontal cortex from birth to young adulthood: Cognitive functions, anatomy, and biochemistry. In D. T. Stuss & R. T. Knight (eds.), *Principles of frontal lobe function* (pp. 466-503). London: Oxford University Press.

Dobbins, I. G., Foley, H., Schacter, D. L., & Wagner, A. D. (2002). Executive control during episodic retrieval: Multiple prefrontal processes subserve source memory. *Neuron, 35,* 989-996.

Dobbins, I. G., Rice, H. J., Wagner, A. D., & Schacter, D. L. (2003). Memory orientation and success: Separable neurocognitive components underlying episodic recognition. *Neuropsychologia, 41,* 318-333.

Drummey, A. B. & Newcombe, N. S. (2002). Developmental changes in source memory. *Developmental Science, 5,* 502-513.

Dunn, L.M., & Dunn, L.M. (1997). Peabody Picture Vocabulary Test, Third Edition. Circle Pines, MN: American Guidance Service.

Dywan, J., Segalowitz, S., & Webster, L. (1998). Source monitoring: ERP evidence for greater reactivity to nontarget information in older adults. *Brain and Cognition, 36,* 390-430.

Flavell, J. H., Beach, D. R., & Chinsky, J. M. (1966). Spontaneous verbal rehearsal in a memory task as a function of age. *Child Development, 37,* 283-299.

Friedman, D., de Chastelaine, M., Nessler, D., & Malcolm, B. (2010). Changes in familiarity and recollection across the lifespan: An ERP perspective. *Brain Research, 1310,* 124-141

Foley, M. A. & Johnson, M. K. (1985). Confusions between memories for performed and imagined actions: A developmental comparison. *Child Development, 56,* 1145-1155.

Foley, M. A., Johnson, M. K., & Raye, C. L. (1983). Age-related changes in confusion between

memories for thoughts and memories for speech. *Child Development, 54,* 51-60.

Gabrieli, J. D. E., Brewer, J. B., Desmond, J. E., & Glover, G. H. (1997). Separate neural bases

of two fundamental memory processes in the human medial temporal lobe. *Science, 276,*

264-266.

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review

using an integrative framework. *Psychological Bulletin, 134,* 31-60.

Gathercole, S. E. (1998). The development of memory. *Journal of Child Psychology and Child*

Psychiatry, 39, 3-27.

Gersdadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and

action: Performance of children $3_{1/2} - 7$ years old on a Stroop-like day-night test.

Cognition, 53, 129-153.

Ghetti, A., & Angelini, L. (2008). The development of recollection and familiarity in childhood

and adolescence: Evidence from the dual-process signal detection model. *Child*

Development, 79, 339-358.

Ghetti, S., DeMaster, D. M., Yonelinas, A. P., & Bunge, S. A. (2010). Developmental

differences in medial temporal lobe function during memory encoding. *Journal of*

Neuroscience, 30, 9548-9556.

Giedd, J. N., Blumenthal, J., Jeffries, N. O., Castellanos, F. X., Liu, H., Zijdenbos, A., & Paus, T.

et al. (1999). Brain development during childhood and adolescence: A longitudinal MRI

study. *Nature Neuroscience, 2,* 861-863.

Glisky, E. L., & Kong, L. L. (2008). Do young and older adults rely on different processes in

source memory tasks? A neuropsychological study. *Journal of Experimental Psychology:*

Learning, Memory, and Cognition, 34, 809-822.

Glisky, E. L., Polster, M. R., & Routhieaux, B. C. (1995). Double dissociation between item and source memory. *Neuropsychology, 9,* 229-235.

Glisky, E. L., Rubin, S. R., & Davidson, P. S. R. (2001). Source memory in older adults: An encoding or retrieval problem? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27,* 1131-1146.

Hannula, D. E., & Ranganath, C. (2008). Medial temporal lobe activity predicts successful relational memory binding. *Journal of Neuroscience, 28,* 116-124.

Hayne, H. (2007). Infant memory development: New questions, new answers. In L. M. Oakes & P. J. Bauer (Eds.), *Short and long-term memory in infancy and early childhood: Taking the first steps toward remembering* (pp.209-239). New York: Oxford University Press.

Hayne, H., Boniface, J., & Barr, R. (2000). The development of declarative memory in human infants: Age-related changes in deferred imitation. *Behavioral Neuroscience, 11,* 77-83.

Hayne, H., & Imuta, K. (2011). Episodic memory in 3- and 4-year-old children. *Developmental Psychobiology, 53,* 317-322.

Hayne, H., MacDonald, S., & Barr, R. (1997). Developmental changes in the specificity of memory over the second year of life. *Infant Behavior & Development, 20,* 233-245.

Hongwanishkul, D., Happaney, K. R., Lee, W. S. C., & Zelazo, P. D. (2005). Assessment of hot and cool executive function in young children: Age-related changes and individual differences. *Developmental Neuropsychology, 28,* 617-644.

Huttenlocher, P. R. (1979). Synaptic density in human frontal cortex – developmental changes and effects of aging. *Brain Research, 163,* 195-205.

Jasper, H. H. (1958). The ten twenty electrode system of the International Federation. *Electroencephalography and Clinical Neurophysiology, 10,* 371-375.

Jernigan, T. L., Archibald, S. L., Berhow, M. T., Sowell, E. R., Foster, D. S., & Hesselink, J. R. (1991). Cerebral structure on MRI, part I: Localization of age-related changes. *Biological Psychiatry, 29,* 55-67.

Johnson, M. K. (2005). The relation between source memory and episodic memory: Comment on Siedlecki et al. (2005). *Psychology and Aging, 20,* 529-531.

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological Bulletin, 114,* 3-28.

Kail, R. V. (1979). *The development of memory in children.* San Francisco, CA: W. H. Freeman and Company.

Klimesch, W. (1996). Memory processes, brain oscillation, and EEG synchronization. *International Journal of Psychophysiology, 24,* 61-100.

Klimesch, W. (1997). EEG-alpha rhythms and memory processes. *International Journal of Psychophysiology, 26,* 319-340.

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

Lindsay, D. S. (2002). Children's source monitoring. In H. L. Westcott, G. Davies, & R. H. C. Bull (Eds.), *Children's testimony: Psychological research and forensic practice* (pp.83-98). Sussex, England: John Wiley and Sons.

Lindsay, D. S., Johnson, M. K., Kwon, P. (1991). Developmental changes in memory source monitoring. *Journal of Experimental Child Psychology, 52,* 297-318.

Lloyd, M. E., Doydum, A. O., & Newcombe, N. S. (2009). Memory binding in early childhood: Evidence for a retrieval deficit. *Child Development, 80,* 1321-1328.

MacDonald., S., Uesiliana, K., & Hayne, H. (2000). Cross-cultural and gender differences in

    childhood amnesia. *Memory, 8,* 365-376.

Marshall, P. J., Bar-Haim, Y., & Fox, N. A. (2002). Development of the EEG from 5 months to 4

    years of age. *Clinical Neurophysiology, 113,* 1199-1208.

Mayes, A., Montaldi, D., & Migo, E. (2007). Associative memory and the medial temporal

    lobes. *Trends in Cognitive Sciences, 11,* 126-135.

Mitchell, K. J. & Johnson, M. K. (2009). Source monitoring 15 years later: What have we

    learned about the neural mechanisms of source memory? *Psychological Bulletin, 135,*

    638-677.

Mitchell, K. J., Johnson, M. K., Raye, C. L., & Greene, E. J. (2004). Prefrontal cortex activity

    associated with source monitoring in a working memory task. *Journal of Cognitive*

    Neuroscience, 16, 921-934.

Mitchell, K. J., Johnson, M. K., Raye, C. L., Mather, M., & D'Esposito, M. (2000). Aging and

    reflective processes of working memory: Binding and test load deficits. *Psychology and*

    Aging, 15, 527-541.

Mitchell, K. J., Raye, C. L., McGuire, J. T., Frankel, H., Greene, E. J., & Johnson, M. K. (2008).

    Neuroimaging evidence for agenda-dependent monitoring of different features during

    short-term source memory tests. *Journal of Experimental Psychology: Learning,*

    Memory, and Cognition, 34, 616-626.

Mikaye, A., Friedman, N. P., Emerson, M. J., Witzki, A. J., Howerter, A., & Wager, T. D.

    (2000). The unity and diversity of executive functions and their contributions to complex

    "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41,* 49-100.

Morasch, K.C., & Bell, M.A. (2009). Patterns of frontal and temporal brain electrical activity

    during declarative memory performance in 10-month-old infants. *Brain and Cognition,*

    71, 215-222

Nelson, K. (1993). The psychological and social origins of autobiographical memory.

    Psychological Science, 4, 7-14.

Nelson, K., & Fivush, R. (2004). The emergence of autobiographical memory: A social cultural

    developmental theory. *Psychological Review, 111,* 486-511.

Newcombe, N. S., Drummey, A. B., Fox., N. A., Lie, E., & Ottinger-Alberts, W. (2000).

    Remembering early childhood: How much, how, and why (or why not). *Current*

    Directions in Psychological Science, 9, 55-58.

Newcombe, N. S, Lloyd, M.E, & Balcomb, F. (2011). Contextualizing the development of

    recollection. In S. Ghetti & P. J. Bauer (Eds.). *Origins and Development of Recollection:*

    Perspectives from Psychology and Neuroscience. Oxford University Press.

Newcombe, N. S., Lloyd, M.E, & Ratliff, K .R. (2007). Development of episodic and

    autobiographical memory: A cognitive neuroscience perspective. In R. V. Kail (Ed.).

    Advances in child development and behavior (Vol. 35, pp. 37-85). San Diego, CA:

    Elsevier.

Nolde, S. F., Johnson, M. K., & D'Esposito, M. (1998). Left prefrontal activation during

    episodic remembering: An event-related fMRI study. *NeuroReport, 9,* 3509-3514.

Nolde, S. F., Johnson, M K., & Raye, C. L. (1998). The role of the prefrontal cortex during tests

    of episodic memory. *Trends in Cognitive Sciences, 2,* 399-406.

Nunez, P. (1981). *Electrical fields of the brain*. New York, NY: Oxford.

Ofen, N. (2012). The development of neural correlates for memory formation. *Neuroscience and*

Biobehavioral Reviews. doi:10.1016/j.neurobiorev.2012.02.016

Ofen, N., Kao, Y., Sokol-Hessner, P., Kim, H., Whitfield-Gabrieli, S., & Gabrieli, J. D. (2007). Development of the declarative memory system in the human brain. *Nature Neuroscience, 10,* 1198-1205.

Ornstein, P. A., Naus, M. J., and Liberty, C. (1975). Rehearsal and organizational processes in children's memory. *Child Development, 46,* 818-830.

Parker, J. F. (1995). Age differences in source monitoring of performed and imagined actions on immediate and delayed tests. *Journal of Experimental Child Psychology, 60,* 84-101.

Perner, J. & Ruffman, T. (1995). Episodic memory and autonoetic consciousness: Developmental evidence and a theory of childhood amnesia. *Journal of Experimental Child Psychology, 59,* 516-548.

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

Picard, L., Reffuveille, I., Eustache, F., & Piolino, P. (2009). Development of autonoetic autobiographical memory in school-age children: Genuine age effect or development of basic cognitive abilities? *Consciousness and Cognition, 18,* 864-876.

Pivik, R. T., Broughton, R. J., Coppola, R., Davidson, R. J., Fox, N. A., & Nuwer, M. R. (1993). Guidelines for the recording and quantitative analysis of electroencephalographic activity in research contexts. *Psychophysiology, 30,* 547-558.

Raj, V., & Bell, M. A. (2010). Cognitive processes supporting episodic memory formation in early childhood: The role of source memory, binding, and executive functioning.

Developmental Review, 30, 384-402.

Raj, V., Cuevas, K., & Bell, M. A. (2012). The contribution of executive function to

    source memory development in early childhood. Manuscript submitted for publication.

Ranganath, C., Johnson, M. K., & D'Esposito, M. (2000). Left anterior prefrontal activation

    increases with demands to recall specific perceptual information. *The Journal of*

    Neuroscience, 20, 1-5.

Raye, C. L., Johnson, M .K., Mitchell, K .J., Nolde, S. F., & D'Esposito, M. (2000). fMRI

    investigations of left and right PFC contributions to episodic remembering.

    Psychobiology, 28, 197-206.

Rhodes, S. M., Murphy, D., Hancock, P. J. B. (2011). Developmental changes in the

    development of episodic retrieval processes and their relationship with working memory

    during the period of middle childhood. *British Journal of Developmental Psychology, 29,*

    865-882.

Roberts, J.E., & Bell, M.A. (2000). Sex differences on a mental rotation task: Variations in

    electroencephalogram hemispheric activation between children and college students.

    Developmental Neuropsychology, 17, 199-223.

Roberts, J.E., & Bell, M.A. (2002). The effects of age and sex on mental rotation performance,

    verbal performance, and brain electrical activity. *Developmental Psychobiology, 40,*

    391-407.

Roberts, K. P. (2002). Children's ability to distinguish between memories from multiple sources:

    Implications for the quality and accuracy of eyewitness statements. *Developmental*

    Review, 22, 403-435.

Roberts, K. P., & Blades, M. (1995). Children's discriminations of memories for actual and

pretend actions in a hiding task. *British Journal of Developmental Psychology, 13,* 321-334.

Roberts, K. P., & Blades, M. (1998). The effects of interacting with events on children's eyewitness memory and source monitoring. *Applied Cognitive Psychology, 12,* 489-503.

Roberts, K. P., & Blades, M. (1999). Children's memory and source monitoring for real-life and television events. *Journal of Applied Developmental Psychology, 20,* 575-596.

Roberts, K. P., & Powell, M. B. (2005). The relation between inhibitory control and children's eyewitness memory. *Applied Cognitive Psychology, 19,* 1003-1018.

Roebers, C. M., & Schneider, W. (2005). Individual differences in young children's suggestibility: Relations to event memory, language ability, working memory, and executive functioning. *Cognitive Development, 20,* 427-447.

Rose, S. A., Feldman, J. F., & Jankowski, J. J. (2007). Developmental aspects of visual recognition memory in infancy. In L. M. Oakes & P. J. Bauer (Eds.), *Short and long-term memory in infancy and early childhood: Taking the first steps toward remembering* (pp.153-178). New York: Oxford University Press.

Rovee-Collier, C., & Hayne, H. (2000). Memory in infancy and early childhood. In E. Tulving & F. I. M. Craik (Eds.), *The oxford handbook of memory* (pp.267-282). New York: Oxford University Press.

Rubin, D. C. (2000). The distribution of early childhood memories. *Memory, 8,* 265-269.

Rubin, S. R., Van Petten, C., Glisky, E. L., & Newberg, W. M. (1999). Memory conjunction errors in younger and older adults: Event-related potential and neuropsychological data. *Cognitive Neuropsychology, 16,* 459-488.

Ruffman, T., Rustin, C., Garnham, W., & Parkin, A. J. (2001). Source monitoring and false

memories in children. Relation to certainty and executive functioning. *Journal of Experimental Child Psychology, 80,* 95-111.

Rugg, M. D., Fletcher, P. C., Chua, P., Dolan, R. J. (1999). The role of the prefrontal cortex in recognition memory and memory for source: An fMRI study. *NeuroImage, 10,* 520-529.

Scarf, D., Gross, J., Colombo, M., & Hayne. H. (2011). To have and to hold: Episodic memory in 3- and 4-year-old children. *Developmental Psychobiology.* doi: 10.1002/dev.21004

Schacter, D. L. (1987). Memory, amnesia, and frontal lobe dysfunction. *Psychobiology, 15,* 21-36.

Schacter, D. L., Harbluk, J. L., & McLachlan, D. R. (1984). Retrieval without recollection: An experimental analysis of source amnesia. *Journal of Verbal Learning and Verbal Behavior, 23,* 593-611.

Schacter, D. L., & Tulving, E. (1994). What are the memory systems of 1994? In D. L. Schacter & E. Tulving (Eds.) *Memory systems of 1994* (pp.1-38). Cambridge, MA: MIT Press.

Schneider, W., & Pressley, M. (1997). *Memory development between two and twenty.* Mahwah, NJ: Erlbaum.

Senkfor, A. J. & Van Petten, C. (1998). Who said what? An event-related potential investigation of source and item memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 1005-1025.

Schacter, D. L., Wagner, A. D., & Buckner, R. L. (2000). Memory systems of 1999. In E. Tulving & F. I. M. Craik (Eds.), *The oxford handbook of memory* (pp.627-643). New York: Oxford University Press.

Sherry, F., & Schacter, D. L. (1987). The evolution of multiple memory systems. *Psychological Review, 94,* 439-454.

Shing, Y.L., Werkle-Bergner, M., Li, S.-C., & Lindenberger, U. (2008). Associative and

strategic components of episodic memory: A lifespan dissociation. *Journal of*

Experimental Psychology: General., 137, 496-513.

Sluzenski, J., Newcombe, N., & Kovacs, S. L. (2006). Binding, relational memory, and recall of

naturalistic events: A developmental perspective. *Journal of Experimental Psychology:*

Learning, Memory, and Cognition, 32, 89-100.

Sluzenski, J., Newcombe, N., & Ottinger, W. (2004). Changes in reality monitoring and

episodic memory in early childhood. *Developmental Science, 7,* 225-245.

Snyder, K. A. (2007). Neural mechanisms of attention and memory in preferential looking tasks.

In L. M. Oakes & P. J. Bauer (Eds.), *Short and long-term memory in infancy and early*

childhood: Taking the first steps toward remembering (pp.179-208). New York: Oxford

University Press.

Spencer, W. D., & Raz, N. (1994). Memory for facts, source, and context: Can frontal lobe

dysfunction explain age-related differences? *Psychology and Aging, 9,* 149-159.

Sprondel, V., Kipp, K. H., & Mecklinger, A. (2011). Developmental changes in item and source

memory: Evidence from an ERP recognition memory study with children, adolescents,

and adults. *Child Development, 82,* 1938-1953.

Squire, L. R. (1987). *Memory and brain.* New York: Oxford University Press.

Summerfield et al. (2006). Neocortical connectivity during episodic memory formation. *PLoS*

Biology. doi:10.1371/journal.pbio.0040128

Thatcher, R. W., Walker, R. A., & Giudice, S. (1987). Human cerebral hemispheres develop at

different rates and ages. *Science, 236,* 1110–1113.

Thierry, K. L. & Pipe, M. E. (2009). The susceptibility of young preschoolers to source

similarity effects: Confusing story or video events with reality. *Journal of Experimental Child Psychology, 102,* 392-407.

Trott, C. T., Friedman, D., Ritter, W., Fabiani, M. (1997). Item and source memory: differential age effects revealed by event-related potentials. *NeuroReport, 8,* 3373-3378.

Tulving, E. (1972). *Organization of memory.* Oxford, England: Academic Press.

Tulving, E. (1983). *Elements of episodic memory*. New York: Oxford University Press.

Tulving, E. (1984). Relations among components and processes of memory. *Behavioral Brain Sciences, 7,* 257-268.

Tulving, E. (1985). How many memory systems are there? *American Psychologist, 40,* 385-398.

Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology, 53,* 1-25.

Uncapher, M. R., Otten, L. J., & Rugg, M. D. (2006). Episodic encoding is more than the sum of its parts: An fMRI investigation of multifeatural contextual encoding. *Neuron, 52,* 542-556.

Vilberg, K.L., & Rugg, M.D. (2007). Dissociation of the neural correlates of recognition memory according to familiarity, recollection, and amount of recollected information. *Neuropsychologia, 45,* 2216-2225.

Vilberg, K.L., & Rugg, M.D. (2008). Memory retrieval and the parietal cortex: A review of evidence from a dual-process perspective. *Neuropsychologia, 46,* 1787-1799.

Vilberg, K.L., & Rugg, M.D. (2009). Left parietal cortex is modulated by amount of recollected verbal information. *Neuroreport, 20,* 1295-1299.

Wechsler D. Wechsler Intelligence Scale for Children – Revised (WISC-R). San Antonio, TX:

Psychological Corporation; 1986.

Wheeler, M. E., & Buckner, R. L. (2004). Functional-anatomic correlates of remembering and knowing. *NeuroImage, 21,* 1337-1349.

Welch-Ross, M. K. (1995). Developmental changes in preschoolers' ability to distinguish memories of performed, pretended, and imagined actions. *Cognitive Development, 10,* 421-441.

Wheeler, M. A. (2000). Episodic memory and autonoetic awareness. In E. Tulving & F. I. M. Craik (Eds.), *The oxford handbook of memory* (pp.597-608). New York: Oxford University Press.

Wheeler, M. A., Stuss, D. T., & Tulving, E. (1997). Toward a theory of episodic memory: The frontal lobes and autonoetic consciousness. *Psychological Bulletin, 121,* 331-354.

Wilding, E. L. & Rugg, M. D. (1996). An event-related potential study of recognition memory and with and without retrieval of source. *Brain, 119,* 889-905.

Williams, K.T. (1997). Expressive Vocabulary Test Circle Pines, MN: American Guidance Service.

Wolfe, C.D., & Bell, M.A. (2004). Working memory and inhibitory control in early childhood: Contributions from electrophysiology, temperament, and language. *Developmental Psychobiology, 44,* 68-83.

Wolfe, C. D. & Bell, M. A. (2007). Sources of variability in working memory in early childhood: A consideration of age, temperament, language, and brain electrical activity. *Cognitive Development, 22,* 431-435.

Zelazo, P. D., Muller, U., Frye, D., & Marcovitch, S. (2003). The development of executive

function in early childhood. *Monographs of the Society for Research in Child*

Development, 68(3, Serial No. 274).

Table 1

Study 1: Descriptive Statistics for the Source Memory Task as a Function of Age

	6-year-olds			4-year-olds			
	M	SD	*n*	M	SD	*n*	Mean Difference
Fact Recall	.64	.20	26	.40	.19	24	.24
Fact Knowledge	.92	.12	26	.74	.15	24	.18
Source Recall	.75	.22	26	.49	.23	24	.26
Intraexperimental Error	.26	.12	16	.31	.15	22	-.05
False Alarms	.37	.25	15	.80	.29	18	-.43

Note: All values represent mean proportions.

Table 2

Study 1: Descriptive Statistics for the EF Tasks as a Function of Age

	6-year-olds			4-year-olds			
	M	SD	*n*	M	SD	*n*	Mean Difference
Forward Digit	5.00	.94	26	4.23	.75	22	.77
Day Night	.83	.15	26	.66	.30	24	.17
DCCS	.88	.31	26	.64	.48	22	.24
DCCS Border	.64	.20	23	.54	.12	14	.10

Note: All values represent mean proportion correct, with the exception of Forward Digit (highest span).

Table 3

Study 1: Pearson Correlations among Source Memory, EF and Language Collapsed across Age

	1	2	3	4	5	6	7	8	9	10
1. Fact Recall	--									
2. Fact Knowledge	.859***	--								
3. Source Recall	.606***	.573***	--							
4. Intraexperimental Error	-.207	-.306+	-.228	--						
5. False Alarms	-.415*	-.601***	-.509**	.686***	--					
6. Forward Digit	.392**	.376**	.276+	-.167	-.339+	--				
7. Day Night	.370**	.327*	.461**	-.137	-.280	.302*	--			
8. DCCS	.411**	.502***	.547***	-.191	-.374*	.098	.272+	--		
9. DCCS Border	.528**	.378*	.325*	.076	-.241	.571***	.256	.143	--	
10. EVT	.419**	.391**	.353*	-.016	-.229	.094	.085	.258+	.309+	--

*Note: +p < .10. *p < .05. **p < .01 ***p < 001.*

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Table 4

Study 1: Regression Analysis Investigating Age, Language, and Frontal EEG as Predictors of

Fact Recall

	R	R^2	$R^2\,\Delta$	$F\,\Delta$	F	β	t
Dependent variable: Fact Recall							
Step 1: Age							
Model 1							
Age	.67	.45			31.51**	.67	5.61**
Step 2: Age and EVT							
Model 2							
Age	.76	.58	.13	11.01**	25.41**	.72	6.71**
EVT						.36	3.32**
Step 3: Age, EVT, and Frontal EEG							
Model 3							
Age	.79	.63	.05	4.91*	20.37**	.77	7.36**
EVT						.37	3.56**
F3/F4 EEG						.23	2.22*

*Note: *$p < .05$. **$p < .01$.*

Table 5

Study 1: Regression Analysis Investigating Age, Language, and Temporal EEG as Predictors of

Fact Recall

	R	R^2	$R^2\varDelta$	$F\varDelta$	F	β	t
Dependent variable: Fact Recall							
Step 1: Age							
Model 1							
Age	.67	.45			31.51**	.67	5.61**
Step 2: Age and EVT							
Model 2							
Age	.76	.58	.13	11.01**	25.41**	.72	6.71**
EVT						.36	3.32**
Step 3: Age, EVT, and Temporal EEG							
Model 3							
Age	.76	.58	.00	.36	16.77**	.74	6.58**
EVT						.37	3.34**
T7/T8 EEG						.07	.60

*Note: *p < .05. **p < .01.*

Table 6

Study 1: Regression Analysis Investigating Age, Language, and Frontal EEG as Predictors of

Source Recall

	R	R^2	$R^2 \Delta$	$F \Delta$	F	β	t
Dependent variable: Source Recall							
Step 1: Age							
Model 1							
Age	.48	.23			11.92**	.48	3.45**
Step 2: Age and EVT							
Model 2							
Age	.72	.51	.28	21.93**	20.13**	.56	4.87**
EVT						.53	4.68**
Step 3: Age, EVT, and Frontal EEG							
Model 3							
Age	.72	.52	.00	.49	13.40**	.53	4.37**
EVT						.53	4.55**
F3/F4 EEG						-.08	-.70

*Note: *$p < .05$. **$p < .01$.*

Table 7

Study 1: Regression Analysis Investigating Age, Language, and Temporal EEG as Predictors of

Source Recall

	R	R^2	$R^2 \Delta$	$F \Delta$	F	β	t
Dependent variable: Source Recall							
Step 1: Age							
Model 1							
Age	.52	.27			14.04**	.52	3.75**
Step 2: Age and EVT							
Model 2							
Age	.71	.50	.23	17.25**	18.64**	.56	4.79**
EVT						.48	4.15**
Step 3: Age, EVT, and Temporal EEG							
Model 3							
Age	.72	.51	.01	.65	12.53**	.52	4.13**
EVT						.46	3.81**
T7/T8 EEG						-.10	-.81

*Note: *$p < .05$. ***$p < .01$.*

Table 8

Study 2: Descriptive Statistics for the Source Memory Task as a Function of Age

	8-year-olds			6-year-olds			
		SD	*n*	M	SD	*n*	Mean Difference
Fact Recall	.86	.11	37	.61	.15	35	.25
Fact Knowledge	.99	.03	37	.89	.11	35	.10
Source Recall	.63	.16	37	.57	.19	35	.06
Intraexperimental Error	.34	.12	35	.31	.15	34	.03
False Alarms	.22	.25	13	.38	.35	20	-.16

Note: All values represent mean proportions.

Table 9

Study 2: Descriptive Statistics for the EF Tasks as a Function of Age

	8-year-olds			6-year-olds			
	M	SD	*n*	M	SD	*n*	Mean Difference
Forward Digit	5.42	.87	36	4.94	.80	35	.48
Backward Digit	3.94	.98	36	2.68	.68	34	1.26
Stroop Interference	53.82	604.32	37	206.35	631.77	35	-152.53

Note: Forward and Backward Digit Span values represent highest span achieved. For the Stroop task, higher values represent a greater interference score.

Table 10

Study 2: Pearson Correlations among Source Memory, EF and Language Collapsed across Age

	1	2	3	4	5	6	7	8	9
1. Fact Recall	--								
2. Fact Knowledge	.701**	--							
3. Source Recall	.225+	.196	--						
4. Intraexperimental Error	.057	.044	-.524**	--					
5. False Alarms	-.232	-.367*	-.380*	.267	--				
6. Forward Digit	.398**	.309**	.302*	-.062	-.297+	--			
7. Backward Digit	.545**	.359**	.139	.173	-.341+	.419**	--		
8. Stroop Interference	.043	.012	-.312**	.058	.335+	-.090	-.067	--	
9. EVT	.186	.159	.238*	-.089	-.367*	.204+	.125	-.183	--

*Note: +p < .10. *p < .05. **p < .01 ***p < 001.*

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Table 11

Study 2: Regression Analysis Investigating Age, Language, Anterior EEG and EF as Predictors

of Fact Recall

	R	R^2	$R^2\varDelta$	$F\varDelta$	F	β	t
Dependent variable: Fact Recall							
Step 1: Age							
Model 1							
Age	.68	.46			53.18**	.68	7.29**
Step 2: Age and EVT							
Model 2							
Age	.74	.55	.09	12.45**	37.64**	.73	8.43**
EVT						.31	3.53**
Step 3: Age, EVT, Anterior EEG, EF							
Model 3							
Age	.80	.63	.08	3.34*	16.67**	.70	7.28**
EVT						.31	3.39**
Fp1/Fp2 EEG						.11	1.14
F3/F4 EEG						-.17	-1.77+
F7/F8 EEG						-.22	-2.24*
EF						.06	.66

*Note: +p < .10. *p < .05. **p < .01.*

Table 12

Study 2: Regression Analysis Investigating Age, Language, Posterior EEG and EF as Predictors

of Fact Recall

	R	R^2	$R^2 \Delta$	$F \Delta$	F	β	t
Dependent variable: Fact Recall							
Step 1: Age							
Model 1							
Age	.66	.43			46.55**	.66	6.82**
Step 2: Age and EVT							
Model 2							
Age	.72	.52	.08	10.39**	32.05**	.68	7.59**
EVT						.29	3.22**
Step 3: Age, EVT, Posterior EEG, EF							
Model 3							
Age	.73	.54	.02	.63	10.84**	.65	6.02**
EVT						.30	2.82**
T7/T8 EEG						-.10	-.94
P3/P4 EEG						.03	.29
P7/P8 EEG						-.07	-.54
EF						.03	.29

*Note: *p < .05. **p < .01.*

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Table 13

Study 2: Regression Analysis Investigating Age, Language, Anterior EEG and EF as Predictors

of Source Recall

	R	R^2	$R^2 \varDelta$	$F \varDelta$	F	β	t
Dependent variable: Source Recall							
Step 1: Age							
Model 1							
Age	.10	.01			.56	.10	3.45**
Step 2: Age and EVT							
Model 2							
Age	.27	.07	.06	3.98	2.28	.14	4.87**
EVT						.25	4.68**
Step 3: Age, EVT, Anterior EEG, EF							
Model 3							
Age	.48	.23	.16	2.85*	2.76*	-.00	-.01
EVT						.10	.77
Fp1/Fp2 EEG						-.10	-.71
F3/F4 EEG						-.05	-.34
F7/F8 EEG						.33	2.30*
EF						.39	2.62*

*Note: *$p < .05$. **$p < .01$.

Table 14

Study 2: Regression Analysis Investigating Age, Language, Posterior EEG and EF as Predictors

of Source Recall

	R	R^2	$R^2 \Delta$	$F \Delta$	F	β	t
Dependent variable: Source Recall							
Step 1: Age							
Model 1							
Age	.15	.02			1.40	.15	1.18
Step 2: Age and EVT							
Model 2							
Age	.31	.10	.07	4.79*	3.14*	.17	1.35
EVT						.27	2.19*
Step 3: Age, EVT, Posterior EEG, EF							
Model 3							
Age	.51	.26	.16	2.97*	3.16*	.01	.03
EVT						.13	.96
T7/T8 EEG						-.23	-1.70
P3/P4 EEG						-.17	-1.28
P7/P8 EEG						.39	2.56*
EF						.29	1.99+

*Note: +p < .10. *p < .05. **p < .01.*

Table 15

Study 3: Descriptive Statistics for the Source Memory and EF Tasks: 4 to 6 year

Longitudinal Comparison

	6 years		4 years			
	M	SD	M	SD	*n*	Mean Difference
Fact Recall	.64	.14	.41	.20	12	.23
Fact Knowledge	.94	.10	.73	.17	12	.21
Source Recall	.56	.15	.48	.26	12	.08
Forward Digit Span	5.08	1.08	4.17	.94	12	.91
Stroop	.94	.04	.62	.32	12	.32

Note: All values represent mean proportions, with the exception of Forward Digit Span, which represents highest span achieved.

Table 16

Study 3: Correlations among the Source Memory and EF Tasks: 4 to 6 year

Longitudinal Comparison

	6 year Measures		
	Fact Recall	Fact Knowledge	Source Recall
4 year Measures			
Fact Recall	.30	.34	.53+
Fact Knowledge	.24	.51+	.74**
Source Recall	.08	-.06	.50+
Forward Digit Span	.35	.21	-.03
Day Night Stroop	.05	-.10	.28

*Note: +p < .10. *p < .05. **p < .01.*

Table 17

Study 3: Descriptive Statistics for the Source Memory and EF Tasks: 6 to 8 year

Longitudinal Comparison

	8 years		6 years			
	M	SD	M	SD	*n*	Mean Difference
Fact Recall	.87	.12	.68	.15	15	.19
Fact Knowledge	.98	.04	.97	.05	11	.01
Source Recall	.65	.19	.75	.24	15	-.10
Forward Digit Span	4.79	.58	5.00	.88	14	-.21
Stroop	.92	.09	.81	.12	15	.11

Note: All values represent mean proportions, with the exception of Forward Digit Span, which represents highest span achieved.

Table 18

Study 3: Correlations among the Source Memory and EF Tasks: 6 to 8 year

Longitudinal Comparison

	8 year Measures		
	Fact Recall	Fact Knowledge	Source Recall
6 year Measures			
Fact Recall	.33	.04	.03
Fact Knowledge	-.42	.24	-.11
Source Recall	-.04	-.16	.46+
Forward Digit Span	.31	-.15	-.01
Day Night Stroop	.28	.48	.02

Note: +p < .10.

Figure 1. Study 1: Mean Proportion Correct on Fact Recall, Fact Knowledge and Source Recall

Performance in 4- and 6-year-olds.
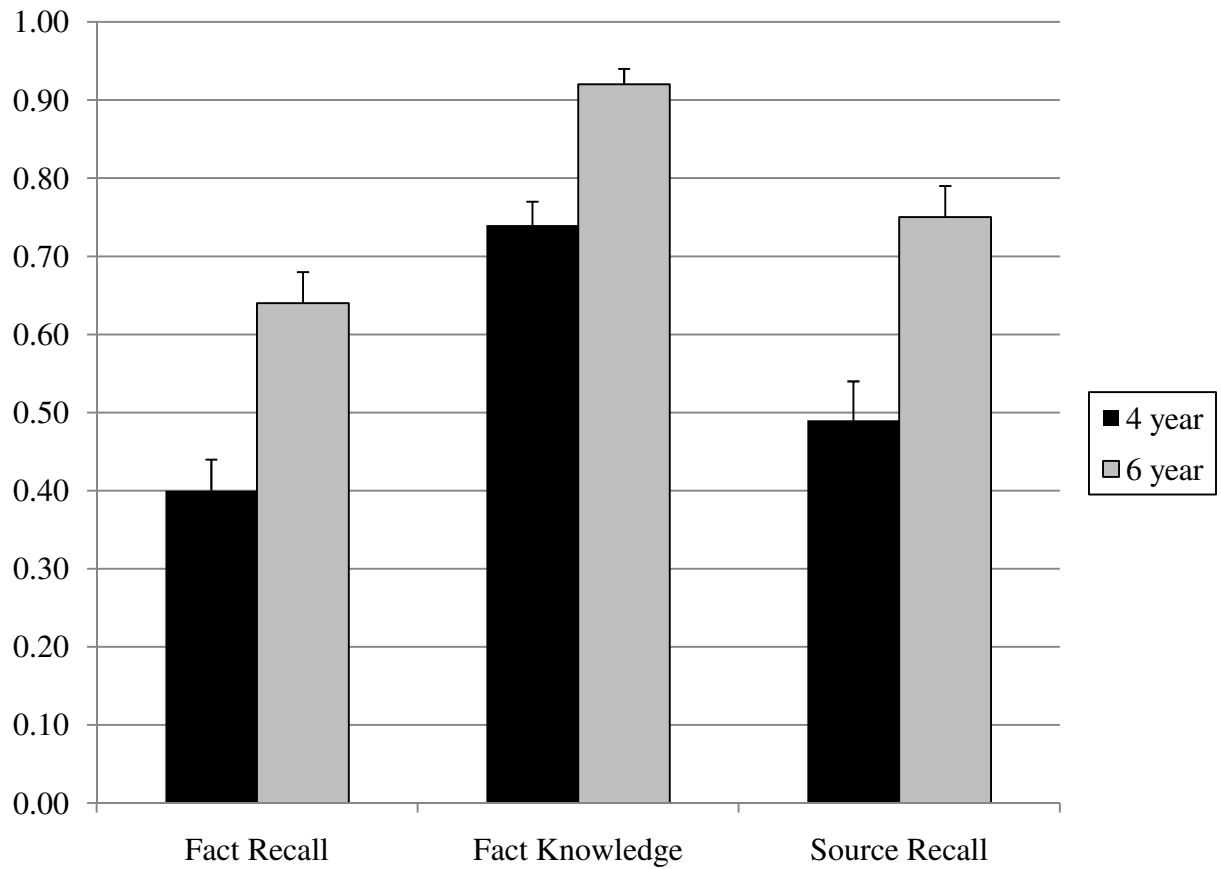
Figure 2. Study 2: Mean Proportion Correct on Fact Recall, Fact Knowledge and Source Recall

Performance in 6- and 8-year-olds.

Figure 3. Study 3 Longitudinal 4- to 6-years: Mean Proportion Correct on Fact Recall, Fact

Knowledge and Source Recall Performance at Time 1 and Time 2.
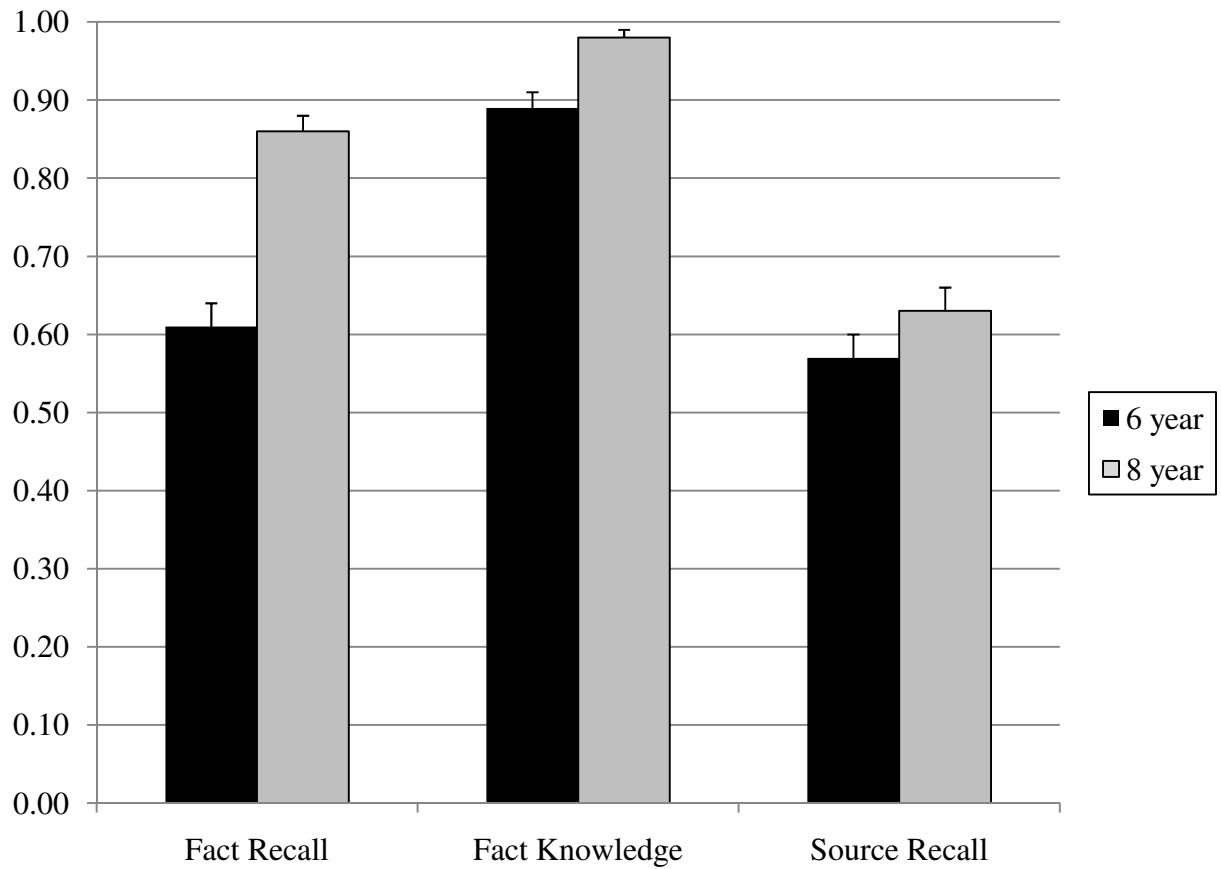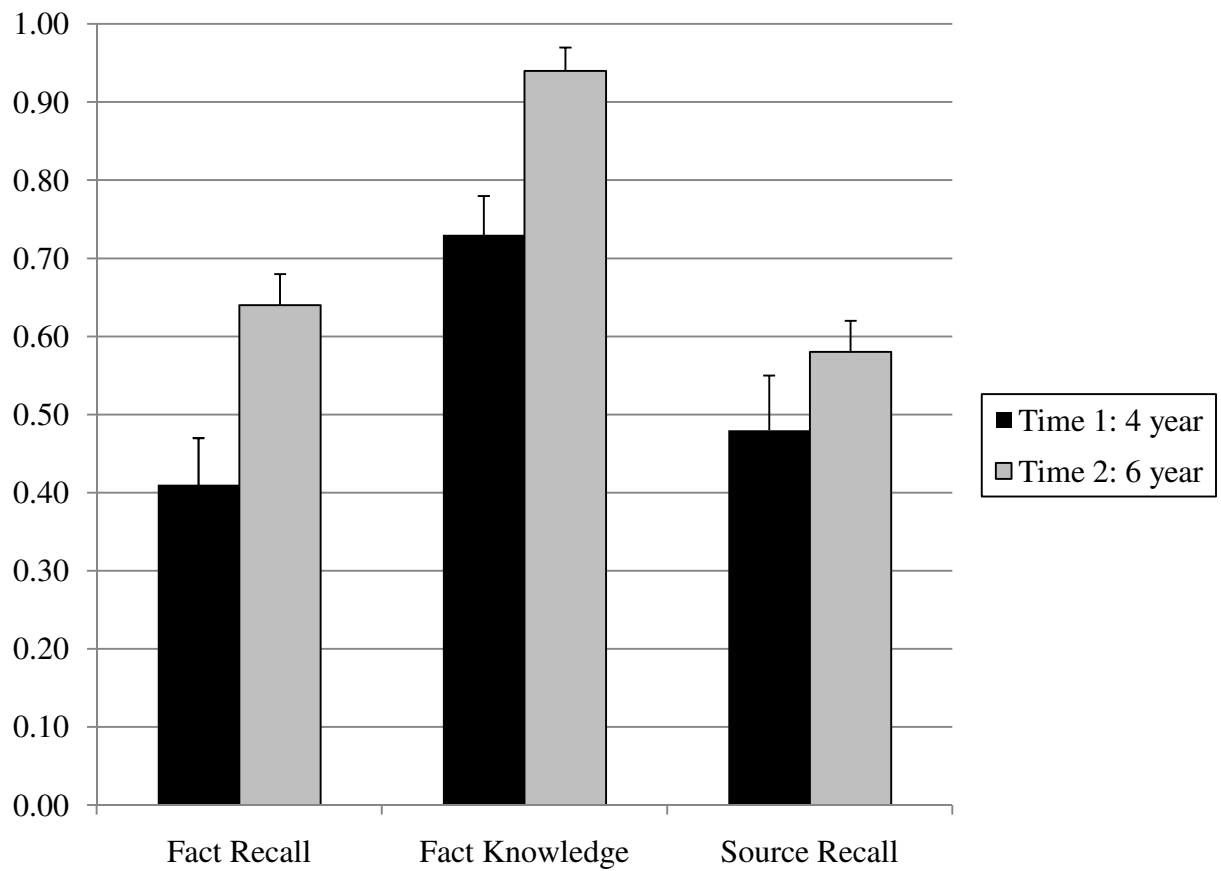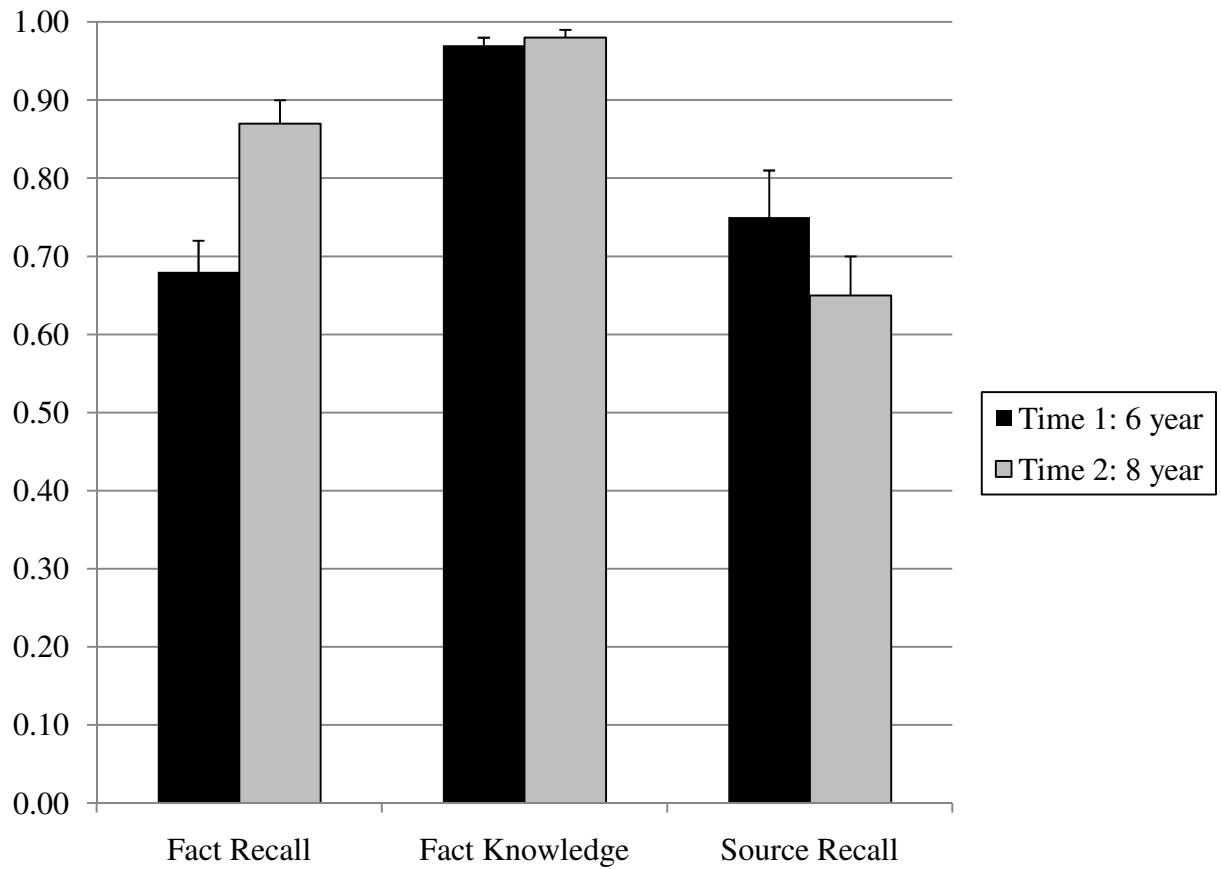
Figure 4. Study 3 Longitudinal 6- to 8-years: Mean Proportion Correct on Fact Recall, Fact

Knowledge and Source Recall Performance at Time 1 and Time 2.

Appendix A. Study 1: Recruitment Letter

Date

Dear Parent,

We hope this letter finds you and your family doing well! We are affiliated with the Psychology Department at Virginia Tech. This letter is to let you know that our latest *C.A.P. Study* is now focusing on the development of memory in early childhood, and we would love to invite you and your child to participate!

In our Early Childhood Memory Project, we would invite you and your child to visit us at the C.A.P. Lab while we play several different games with your child. Some of these games involve your child learning new and interesting facts about animals and objects so that we can later play some memory games with these facts. Other games involve your child to remember some simple rules while playing with cards or numbers. For all of these games, your child will be wearing a stretchy EEG cap so we can see what the brain is doing while your child is playing our games.

For this study, parents and their children will visit the C.A.P. Lab at Virginia Tech and will spend a total of 60 minutes with us. Your child will be given a small gift as a "thank you" gift for participating in the study and your name will be entered into a drawing for a $50 gift certificate to a local store of your choice. Our research lab is in Williams Hall (on the Virginia Tech campus). Williams Hall is located on the drill field next to Buruss Hall and we have reserved parking for participants in our research projects.

Would you be interested in hearing more about this study? One of us will be calling you within the next few days to talk with you about our study. Agreeing to talk with us over the phone does not obligate you to participate. We want to tell you all the details before you decide whether or not you would like to participate. In the meantime, feel free to visit the web site for our research lab. You can read about similar *C.A.P. Studies* that are going on in our lab and see photos of infants and children who have been involved with our studies.

http://www.psyc.vt.edu/devcogneuro

If you wish to call us, we can be reached at (**540)231-2320** (research lab) and by e-mail (Ms. Raj's email address is *vraj318@vt.edu)*. Thank you and we look forward to talking with you!

Sincerely,

Martha Ann Bell, Ph.D.   Vinaya Raj, B.S.
Associate Professor of Psychology   Graduate Student

Appendix B. Study 1: Parental Consent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Parent Consent Form

Title of Thesis Project: Source Memory Development in Early Childhood

Researchers: Martha Ann Bell, PhD. and Vinaya Raj

I. Purpose of this Research
You and your child have been invited to be a part of a research study investigating the development of memory from 4 through 6 years of age. The purpose of this project is to examine how children's memory for source, or the origin of information, develops in early childhood. More specifically, this study will investigate whether children can correctly remember facts that were taught to them during a memory game, and will also examine whether children can correctly remember from which source this information came from (i.e., which individual they learned these facts from). This type of memory will be compared to other types of important cognitive skills, such as working memory and inhibitory control. We are also interested in examining how brain wave activity and heart rate are related to these specific memory skills during early childhood. What we learn from this study will help us better understand how these important cognitive skills develop in early childhood.

II. Procedures
A total of 50 children from the New River Valley area will be asked to participate. This study involves a 60 minute visit to the C.A.P. LAB (Williams 348) at Virginia Tech. You will be asked to remain in the room with your child throughout the entire. This entire session will be videotaped. This study also involves two questionnaires (General Information Questionnaire and Child Behavior Questionnaire). We have asked you to try to complete these brief forms at home prior to your child's visit to our research lab.

In order to measure brain activity during the session, we will place a stretchy cap with sensors on your child's head. The cap looks and fits like a swim cap. Gel will then be applied to your child's hair through little holes in the cap. In addition, we will be placing two small sticky patches on your child's back to help us collect heart rate activity. These procedures are similar to those used in a doctor's office and are not harmful to your child. While brain-wave activity and heart rate activity are being recorded for two minutes, your child will be watching a brief video clip from a popular children's movie. Brain-wave activity and heart rate activity will also be recorded during all of the games noted in the next paragraph.

The first task involves session one of the source memory game in which your child will be taught ten new and interesting facts from one of two different sources (from either the experimenter or a puppet). Next, we will play a series of brief games that are designed to be difficult for your child to remember the simple rules. For example, one game requires your child to say "day" when shown a picture of a nighttime scene and to say "night" when show a picture of a daytime scene. In another game, your child will play a card sorting game in which they will be asked to sort cards by color and shape. A vocabulary game will also be played in which your child will be shown a picture and must correctly name the picture. Finally, session two of the source memory game will occur in which we will ask a series of questions examining your child's memory for the previously learned facts from session one.

III. Risks
There is minimal risk associated with this research project. The brainwave and heart rate procedures are similar to that done in a doctor's office and are not harmful. All brain-wave equipment is disinfected after each use. The heart rate equipment is disposable. If your child has an allergy to skin lotions, please inform us so that we can discuss the allergy and determine if any procedural changes need to be made. Our EEG gels are water based, but do not contain the same preservatives that are used in everyday skin lotions.

IV. Benefits of This Research

There are no tangible benefits for you or your child. No promise or guarantee of benefits has been made to encourage you and your child to participate in this study. In a scientific sense, however, this research study will give psychologists more information about the development of source memory during early childhood.

V. Extent of Confidentiality

Information gathered for this study will be confidential and the information from each individual child will be identified by code number only. Information linking child's name and code number will be kept in a file and locked in a file drawer. Only my professor Dr. Bell and I will have access to the file. Your child will be videotaped during the lab procedure. This allows us to go back at a later date and code your child's behaviors. Videotapes will identify children only by code number. Tapes will be stored in the research lab and will not be accessible to anyone else. Dr. Bell will supervise the confidentiality of the videotapes. Tapes will be erased 5 years after final publications of the results of this study.

If the Investigator (Dr. Bell) should ever become concerned that your child has a developmental delay, you will be told of the concerns. You will be given a list of referrals who will provide your family with a developmental screening of your child. If at any time during the study you request help in dealing with a child, Dr. Bell will provide referrals of both private and public agencies that offer assistance.

Also, if at any time there is a concern that your child is in danger due to abuse or neglect, the Investigator (Dr. Bell) will, after informing you, be obligated to contact the Department of Social Services and report the concern. This is in compliance with the mandatory reporting laws of the state of Virginia.

VI. Compensation

At the end of the session, your child will be given a small toy. Also, your name will be entered into a drawing for a $50.00 gift certificate to a local store of your choice.

VII. Freedom to Withdraw

Your child may choose to stop playing the games at any time. You may also elect to withdraw your child from participation at any time without penalty. Your child will still be given the toys, and your name will still be entered into the drawing for the gift certificate.

VIII. Approval of Research

This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at VPI&SU and by the Department of Psychology at Virginia Tech.

IX. Parent's Responsibilities

You will be asked to transport and accompany your child to the research laboratory for this visit. We also ask that you complete the questionnaires.

X. Parent's Permission

I have read and understand the Informed Consent and conditions of this research study. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for my child to participate in this project. I understand that I may withdraw my child from participation at any time without penalty. I understand that I will be given a copy of this consent form.

_____   _____
Parent's signature   Date

Should I have any questions about this study, I may contact:

1) Vinaya Raj
    Co-Investigator, Graduate student, 231-2320, vraj318@vt.edu
2) Martha Ann Bell, Ph.D.
    Principal Investigator, Associate Professor of Psychology, 231-2546, mabell@vt.edu
3) David W. Harrison, Ph.D.
    Chair, Psychology Department Human Subjects Committee, 231-4422, dwh@vt.edu
4) David Moore, Ph.D.
    IRB Chair, 1880 Pratt Drive, Suite 2006, Blacksburg, VA 24060, 231-4991, moored@vt.edu

Photographer's Release (optional)

I understand that the photographs taken of my child are the property of Virginia Tech. These photographs will be used to illustrate Department of Psychology research at professional conferences, in professional publications, and/or in university/departmental literature (print and internet).

_____   _____
Parent's signature   Date

Appendix C. Study 1: Child Assent Form

Child Assent Form

Title of Thesis Project: Source Memory Development in Early Childhood
Researchers: Martha Ann Bell, Ph.D., and Vinaya Raj

I. Explanation of Research to Child
We're going to play some fun games today. Some of the games are memory games and some are picture games. For these games, you will get to wear our cool cap that looks like this. (Shows EEG cap to the child). At any time you can decide to stop playing these games. Just tell us, and we will stop.

II. Asking for Child's Verbal Assent
Are you ready to play? Shall we get the games ready?

III. Witness Affirmation
The child verbally agreed to participate in this research study. I understand that the parent will receive a copy of this assent form.

_____
Child's name

_____   _____
Signature of witness   Date

Appendix D. Study 1: Source Memory Task

(Drummey & Newcombe, 2002)

SOURCE MEMORY TASK – ENCODING PHASE

Source 1 – Experimenter (or Puppet)

What are the big cats that can't roar? CHEETAHS. Cheetahs are the only big cats that can't roar.

Bananas grow in bunches called what? HANDS. Bananas grow in bunches called hands.

Do you know what is made from the petals of flowers? PERFUME. Perfume is made from the petals of flowers.

What is glass made from? SAND. Glass is made from sand.

Where does the sun set? IN THE WEST. The sun sets in the west.

Source 2 – Puppet (of Experimenter)

What is the longest river in the world? THE NILE. The Nile is the longest river in the world.

What animal can not make any sounds? A GIRAFFE. A giraffe can not make any sounds.

Do you what the largest state in America is? ALASKA. Alaska is the largest state in America.

What sound do tea kettles make? A WHISTLE. A tea kettle makes a whistle.

What do butterflies taste with? Their feet. Butterflies taste with their feet.

Alternative facts

Who introduces all the acts in a circus? A ringmaster

How many stripes does the American flag have? 13

What do you call a group of lions? A Pride

What do you call a 2 person bicycle? A tandem

What is a baby kangaroo called? A Joey

SOURCE MEMORY TASK – TEST PHASE

Source choices if not recalled, parents, teacher, puppet, experimenter

What is the only big cat that can't roar? Lion, tiger, <u>cheetah</u>, leopard

Answer: _____   Source_____

What is the longest river in the world? Red, Hudson, <u>Nile</u>, Delaware

Answer_____   Source_____

Bananas grow in bunches called? <u>Hands,</u> dozens, group, ton

Answer_____   Source_____

What animal can not make any sounds? Duck, <u>giraffe</u>, zebra, ostrich

Answer: _____   Source_____

Which is the largest state? <u>Alaska,</u> Florida, South Carolina, Utah

Answer_____   Source_____

What is made from the petals of flowers? Juice, shampoo, <u>perfume</u>, gum

Answer_____   Source_____

What is glass made from? Oil, water, paper, <u>sand</u>

Answer: _____   Source_____

What sound do tea kettles make? Slurp, gulp, beep, <u>whistle</u>

Answer_____   Source_____

Where does the sun set? North, south, east, <u>west</u>

Answer_____   Source_____

What do butterflies taste with? Wings, back, <u>feet,</u> nose

Answer_____Source_____

NOVEL FACTS

What substance found in your home is poisonous to most plants?
Salt, cheese, pepper, oil

Answer_____ Source_____

What holiday is February 14th? Christmas, groundhog day, thanksgiving, Valentine's day

Answer_____Source_____

What is the colored part of the eyes called? Corner, iris, honey , eyetip

Answer_____ Source_____

What animal actually walks on his tippy toes? Hippo, bear, lion, elephant

Answer: _____ Source_____

The last tooth in your mouth is called what? Star, big, wisdom, canine

EASY FACTS

What is the color of grass?

Answer_____ Source_____

What sound does a pig make?

Answer_____ Source_____

What room do you cook in?

Answer _____ Source _____

What do you use to brush your teeth?

Answer _____ Source _____

What do monkeys like to eat?

Answer_____ Source _____

EXTRAS

Who is the person that introduces all the acts in the circus?

      Answer_____   Source_____

How many stripes does the American flag have?

      Answer_____   Source _____

What is a group of lions called?

      Answer_____   Source_____

What is a 2 person bicycle called?

      Answer_____   Source _____

What is a baby kangaroo called?

      Answer _____   Source _____

Appendix E. Study 2: Recruitment Letter

Dear Parent,

We hope this letter finds you and your family doing well! We are affiliated with the Psychology Department at Virginia Tech. This letter is to let you know that our latest *C.A.P. Study* is now focusing on the development of memory in early childhood in 6 and 8-year-olds, and we would love to invite you and your child to participate!

In our Early Childhood Memory Project, we would invite you and your child to visit us at the C.A.P. Lab while we play several different games with your child. Some of these games involve your child learning new and interesting facts about animals and objects so that we can later play some memory games with these facts. Another game involves your child looking at pictures of animals and backgrounds so that we can later play a memory game with these pictures. Other games involve your child to remember some simple rules while playing with numbers. For all of these games, your child will be wearing a stretchy EEG cap so we can see what the brain is doing while your child is playing our games.

For this study, parents and their children will visit the C.A.P. Lab at Virginia Tech and will spend a total of 60 minutes with us. Your child will be given a small gift as a "thank you" gift for participating in the study and your name will be entered into a drawing for a $50 gift certificate to a local store of your choice. Our research lab is in Williams Hall (on the Virginia Tech campus). Williams Hall is located on the drill field next to Buruss Hall and we have reserved parking for participants in our research projects.

Would you be interested in hearing more about this study? One of us will be calling you within the next few days to talk with you about our study. Agreeing to talk with us over the phone does not obligate you to participate. We want to tell you all the details before you decide whether or not you would like to participate. In the meantime, feel free to visit the web site for our research lab. You can read about similar *C.A.P. Studies* that are going on in our lab and see photos of infants and children who have been involved with our studies.

http://www.psyc.vt.edu/devcogneuro

If you wish to call us, we can be reached at (*540)231-1116* (office) and or by contacting Ms. Raj directly through email (*vraj318@vt.edu*) or telephone (*201)888-5655*. Thank you and we look forward to talking with you!

Sincerely,

Martha Ann Bell, Ph.D.   Vinaya Raj, M.S.
Associate Professor of Psychology   Graduate Student
Appendix F. Study 2: Parental Consent Form

Appendix F. Study 2: Parental Consent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Parent Consent Form

Title of Project: Source Memory Development in Early Childhood

Researchers: Martha Ann Bell, PhD. and Vinaya Raj

I. Purpose of this Research

You and your child have been invited to be a part of a research study investigating the development of memory from 6 through 8 years of age. The purpose of this project is to examine how children's memory for source, or the origin of information, develops in early childhood. More specifically, this study will investigate whether children can correctly remember facts that were taught to them during a memory game, and will also examine whether children can correctly remember from which source this information came from (i.e., which individual they learned these facts from). This type of memory will be compared to other types of important cognitive skills, such as working memory and inhibitory control. We are also interested in examining how brain wave activity and heart rate are related to these specific memory skills during childhood. What we learn from this study will help us better understand how these important cognitive skills develop in childhood.

II. Procedures

A total of 64 children from the New River Valley area will be asked to participate. This study involves a 60 minute visit to the C.A.P. LAB (Williams 348) at Virginia Tech. You will be asked to remain in the room with your child throughout the entire. This entire session will be videotaped. This study also involves two questionnaires (General Information Questionnaire and Child Behavior Questionnaire). We have asked you to try to complete these brief forms at home prior to your child's visit to our research lab.

In order to measure brain activity during the session, we will place a stretchy cap with sensors on your child's head. The cap looks and fits like a swim cap. Gel will then be applied to your child's hair through little holes in the cap. In addition, we will be placing two small sticky patches on your child's back to help us collect heart rate activity. These procedures are similar to those used in a doctor's office and are not harmful to your child. While brain-wave activity and heart rate activity are being recorded, your child will be watching a brief video clip from a computer screensaver for one minute and will be asked to remain seated still while keeping their eyes open and closed for two minutes. Brain-wave activity and heart rate activity will also be recorded during all of the games noted in the next paragraph.

The first task involves session one of the source memory game in which your child will be taught ten new and interesting facts from one of two different sources (from either the experimenter or another individual). Next, we will play a picture memory game in which your child will be shown pictures of various animals and backgrounds. Next, we will play a series of brief games that are designed to be difficult for your child to remember the simple rules. For example, one game requires your child to count the number of digits or letters shown to them while another game requires your child to remember and repeat the numbers they hear in backwards order. A vocabulary game will also be played in which your child will be shown a picture and must correctly name the picture. Finally, we will test your child on whether they can recognize the previously shown pictures of animals and backgrounds. For the last task of the study, session two of source memory game will occur in which we will ask a series of questions examining your child's memory for the previously learned facts from session one.

III. Risks

There is minimal risk associated with this research project. The brainwave and heart rate procedures are similar to that done in a doctor's office and are not harmful. All brain-wave equipment is disinfected after each use. The heart rate equipment is disposable. If your child has an allergy to skin lotions, please inform us so that we can discuss the allergy and determine if any procedural changes need to be made. Our EEG gels are water based, but do not contain the same preservatives that are used in everyday skin lotions.

IV. Benefits of This Research

There are no tangible benefits for you or your child. No promise or guarantee of benefits has been made to encourage you and your child to participate in this study. In a scientific sense, however, this research study will give psychologists more information about the development of source memory during childhood.

V. Extent of Confidentiality

Information gathered for this study will be confidential and the information from each individual child will be identified by code number only. Information linking child's name and code number will be kept in a file and locked in a file drawer. Only my professor Dr. Bell and I will have access to the file. Your child will be videotaped during the lab procedure. This allows us to go back at a later date and code your child's behaviors. Videotapes will identify children only by code number. Tapes will be stored in the research lab and will not be accessible to anyone else. Dr. Bell will supervise the confidentiality of the videotapes. Tapes will be erased 5 years after final publications of the results of this study.

If the Investigator (Dr. Bell) should ever become concerned that your child has a developmental delay, you will be told of the concerns. You will be given a list of referrals who will provide your family with a developmental screening of your child. If at any time during the study you request help in dealing with a child, Dr. Bell will provide referrals of both private and public agencies that offer assistance.

Also, if at any time there is a concern that your child is in danger due to abuse or neglect, the Investigator (Dr. Bell) will, after informing you, be obligated to contact the Department of Social Services and report the concern. This is in compliance with the mandatory reporting laws of the state of Virginia.

VI. Compensation

At the end of the session, your child will be given a $5 Gift Card to Books A Million. Also, your name will be entered into a drawing for a $50.00 gift certificate to a local store of your choice.

VII. Freedom to Withdraw

Your child may choose to stop playing the games at any time. You may also elect to withdraw your child from participation at any time without penalty. Your child will still be given the toys, and your name will still be entered into the drawing for the gift certificate.

VIII. Approval of Research

This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at VPI&SU and by the Department of Psychology at Virginia Tech.

IX. Parent's Responsibilities

You will be asked to transport and accompany your child to the research laboratory for this visit. We also ask that you complete the questionnaires.

X. Parent's Permission

I have read and understand the Informed Consent and conditions of this research study. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for my child to participate in this project. I understand that I may withdraw my child from participation at any time without penalty. I understand that I will be given a copy of this consent form.

_____   _____

Parent's signature   Date

Should I have any questions about this study, I may contact:

1) Vinaya Raj
      Co-Investigator, Graduate student, 231-2320, vraj318@vt.edu
2) Martha Ann Bell, Ph.D.
      Principal Investigator, Associate Professor of Psychology, 231-2546, mabell@vt.edu
3) David W. Harrison, Ph.D.
      Chair, Psychology Department Human Subjects Committee, 231-4422, dwh@vt.edu
4) David Moore, Ph.D.
      IRB Chair, 1880 Pratt Drive, Suite 2006, Blacksburg, VA 24060, 231-4991, moored@vt.edu

Photographer's Release (optional)
I understand that the photographs taken of my child are the property of Virginia Tech. These photographs will be used to illustrate Department of Psychology research at professional conferences, in professional publications, and/or in university/departmental literature (print and internet).

_____   _____

Parent's signature   Date

Appendix G. Study 2: Child Assent Form

<div align="center">

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Child Assent Form

</div>

Title of Project: "Source Memory Development in Early Childhood"
Investigators: Martha Ann Bell, Ph.D., Vinaya Raj, M. S.

I. Purpose and Procedures

We're going to play some fun games today. Some of the games are memory games and some are picture games. We are also going to see the way your brain and heart look when you play these games. First, we will put a cap that looks like a swim cap on your head and we will put stickers on your chest. Then, we will put some gel through the little holes on the cap so that we can see what your brain and heart look like on our computer. Then we will watch a video, and we will also have you sit quietly with your eyes open and closed. In the next part, we will videotape you while you are playing games. For some of these games you will play with pictures, words, numbers, and you will learn and try to remember new things about animals and science. When we are done, we will wash the gel off your head and take off the stickers. All of this will probably take about one hour.

II. Risks and Benefits

You will get some gel in your hair, but we will wash it out when you are finished playing the game. You will get to help us understand how your brain waves and heart change when you are playing all of our games.

III. Confidentiality

We won't use your name when we report the results of this study. Also, the video of you will only be seen by people who work in our lab.

IV. Compensation

We will give you a $5 Gift Card to Books A Million say thank you for playing our games.

V. Freedom to Withdraw

You can ask questions at any time and you can ask to take off the cap and stickers. You should also let me know if you don't want to answer questions.

VI. Approval of Research

Virginia Tech approved this research.

VII. Participant's Responsibilities

We will ask that you sit still with your eyes open and closed. Also, we will ask you to play word, number, picture, and memory games with us.

VIII. Participant's Permission

I have read and understand this form. I have asked any questions that I had and agree to participate in this study. I understand that I can stop at any time I want. I understand that I will get a copy of this form.

_____   _____
Signature   Date

Should I have any questions about this study, I may contact:
1) Martha Ann Bell, PhD
        Investigator, Associate Professor of Psychology, 231-2546
2) Vinaya Raj
        Co-investigator, Graduate Student of Psychology, 231-2320
3) David W. Harrison, PhD
        Chair, Psychology Department Human Subjects Committee, 231-4422
4) David Moore, PhD
        Chair, IRB, CVM Phase II   231-4991

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Appendix H. Study 2: Source Memory Task

SOURCE MEMORY TASK

Subj. ID:	CAP: Yes / No	Date of Coding:
Sex:	Date of Visit:	Coder Initials:

Source 1 – EXPERIMENTER: First / Second
(1) **Question:** What is the only bird that can fly backwards? (#3 repeating)
   Answer: HUMMINGBIRDS. Hummingbirds are the only birds that can fly backward.

(2) **Question:** What is the only food that does not spoil? (#9 repeating)
   Answer: HONEY. Honey is the only food that does not spoil.

(3) **Question:** What is the largest continent? (# 1 repeating)
   Answer: ASIA. Asia is the largest continent.

(4) **Question:** What animal has three eyelids? (# 8 repeating)
   Answer: CAMELS. Camels have three eyelids.

(5) **Question:** What animal sleeps with one eye open? (#6 repeating)
   Answer: DOPLHINS. Dolphins sleep with one eye open.
****
Source 2 – ASSISTANT: First / Second
(1) **Question:** What animals are left-handed? (#4 repeating)
   Answer: POLAR BEARS. Polar bears are left-handed.

(2) **Question:** What is the strongest muscle in your body? (#10 repeating)
   Answer: YOUR TONGUE. Your tongue is the strongest muscle in your body.

(3) **Question:** What is the largest desert in the world? (#2 repeating)
   Answer: THE SAHARA. The Sahara is the largest desert in the world.

(4) **Question:** How many toes does an ostrich have on each foot? (#7 repeating)
   Answer: TWO. An ostrich has two toes on each foot.

(5) **Question:** What is the longest river in the US? (#5 repeating)
   Answer: THE MISSISSIPPI. The Mississippi River is the longest river in the US.

*******Alternative facts** (Given if child answers question correctly)***********************
(1) **Question:** What animal cannot stick its tongue out?
   Answer: CROCODILES. Crocodiles cannot stick their tongues out.

(2) **Question:** What do you call a group of giraffes?
   Answer: A TOWER. A group of giraffes is called a tower.

(3) **Question:** What is the largest animal in the ocean?
   Answer: THE BLUE WHALE. The blue whale is the largest animal in the ocean.

(4) **Question:** What is the hardest bone in your body?
   Answer: YOUR JAWBONE. Your jawbone is the hardest bone in your body.

(5) **Question:** What is the tallest living thing in the United States?

Answer: A REDWOOD TREE. Redwood trees are the tallest living things in the United States

Practice Trials:

(1) What group of animals have no bones? Answer: **Insects.** Insects do not have bones.
   Ask question again, options: Reptiles, Mammals, <u>Insects,</u> Birds
   Who did you learn this from? Parent, Teacher, Mr. Piggy, Experimenter

(2) What color is a banana? Answer: **Yellow,** Red, Orange, Blue
   Who did you learn this from? _____ Parent, Teacher. Mr. Piggy, Exp.

(3) What sound does a cat make? Answer: moo, bark, **meow,** oink
   Who did you learn this from? _____Parent, Teacher, Mr. Piggy, Exp.

****First see if Child can Recall answer, if not then ask Recognition Questions****

(A) What is the only bird that can fly backwards?
Recall: _____ Recog: parrot, eagle, <u>hummingbird</u>, ostrich
   Who did you learn this from?
S. Recall: _____ S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(B) What animal is left-handed?
Recall: _____ Recog: koala, panda bear, <u>polar bear</u>, grizzly
   Who did you learn this from?
S. Recall: _____ S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(C) What do you use to brush your hair?
Recall: _____Recog: <u>Hairbrush</u>, Toothbrush, Fork, Spoon
   Who did you learn this from?
S. Recall: _____ S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(A) What is the only food that does not spoil?
Recall: _____ Recog: <u>Honey</u>, milk, cheese, bread
   Who did you learn this from?
S. Recall: _____ S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(C) What is the largest planet in our solar system?
Recall: _____ Recog: <u>Jupiter</u>, Saturn, Mars, Venus
   Who did you learn this from?
S. Recall: _____ S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(C) What room do you take a bath in?
Recall: _____ Recog: Kitchen, Bedroom, Living Rm, <u>Bathroom</u>
   Who did you learn this from?
S. Recall: _____ S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(B) What is the strongest muscle in your body?
Recall: _____ Recog: Bicep, <u>Tongue</u>, Calf, Hamstring
   Who did you learn this from?
S. Recall: _____ S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(C) What holiday is always celebrated on a Thursday?
Recall: _____Recog: Xmas, Easter, Valentine's, <u>Thanksgiving</u>   Who did you learn this from?
S. Recall: _____S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(B) What is the largest desert in the world?
Recall: _____   Recog: <u>Sahara</u>, Gobi, Mojave, Colorado
    Who did you learn this from?
S. Recall: _____   S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(A) What is the largest continent?
Recall: _____   Recog: Africa, <u>Asia</u>, Europe, Australia
    Who did you learn this from?
S. Recall: _____   S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(C) What planet is closest to the sun?
Recall: _____   Recog<u>: Mercury,</u> Saturn, Mars, Venus
    Who did you learn this from?
S. Recall: _____   S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(B) How many toes does an ostrich have on each foot?
Recall: _____   Recog: Five, Four, Three, <u>Two</u>
    Who did you learn this from?
S. Recall: _____   S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(A) What animal has three eyelids?
Recall: _____   Recog: Lion, Chimpanzee, Kangaroo, <u>Camel</u>
    Who did you learn this from?
S. Recall: _____   S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(C) How many stars are on the American flag?
Recall: _____   Recog: 25, 13, <u>50</u>, 10
    Who did you learn this from?
S. Recall: _____   S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(C) What part of your body do you use to smell?
Recall: _____   Recog: <u>Nose</u>, Ears, Eyes, Mouth
    Who did you learn this from?
S. Recall: _____   S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(A) What animal sleeps with one eye open?
Recall: _____   Recog<u>: Dolphin</u>, Seal, Turtle, Lizard
    Who did you learn this from?
S. Recall: _____   S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(C) How many oceans does planet Earth have?
Recall: _____   Recog: Seven, <u>Five</u>, Three, Four
    Who did you learn this from?
S. Recall: _____   S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(B) What is the longest river in the US?
Recall: _____ Recog: Nile, Hudson, <u>Mississippi</u>, Delaware
 Who did you learn this from?
S. Recall: _____ S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(C) What animal travels together in a school?
Recall: _____ Recog: <u>Fish</u>, Zebra, Geese, Monkeys
 Who did you learn this from?
S. Recall: _____ S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

 (C) What do birds use to fly?
Recall: _____ Recog: Beak, <u>Wings</u>, Feet, Eyes
 Who did you learn this from?
S. Recall: _____ S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

<u>ALTERNATIVE FACTS</u>
(1) What animal cannot stick its tongue out?
Recall: _____ Recog: Turtle, Giraffe, Goat, <u>Crocodile</u>
 Who did you learn this from?
S. Recall: _____ S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(2) What do you call a group of giraffes?
Recall: _____ Recog: Congress, <u>Tower</u>, Herd, Flock
 Who did you learn this from?
S. Recall: _____ S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(B) What is the largest animal in the ocean?
Recall: _____ Recog: Shark, Octopus, <u>Blue Whale</u>, Turtle
 Who did you learn this from?
S. Recall: _____ S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(4) What is the hardest bone in your body?
Recall: _____ Recog: <u>Jawbone</u>, Spine, Ribs, Pelvis
 Who did you learn this from?
S. Recall: _____ S. Recog: Parent, Teacher, Mr. Piggy, Experimenter

(5) What is the tallest living thing in the United States?
Recall: _____ Recog: Elephant, Kangaroo, Tiger, <u>Redwood Tree</u>
 Who did you learn this from?
S. Recall: _____ S. Recog: Parent, Teacher, Mr. Piggy, Experimenter