ABSTRACT

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No previous studies had examined how all constructs of executive functioning (i.e., conflict inhibition, delay inhibition, cognitive flexibility, and working memory) relate to memory for contextual details and false recognition in early childhood controlling for general intelligence. Three and six-year-old children performed a laboratory-based episodic memory task and a battery of neuropsychological tasks. The relation between executive functioning and false recognition was diminished taking general intellectual ability into account. Executive functioning did not predict memory for contextual details in the full sample. However, when children who were at chance at recalling contextual details were excluded from analysis, executive functioning showed a trend for accounting for variance beyond age group and general intellectual

ability. The inability of this effect to reach conventional statistical significance was likely due low statistical power resulting from the sample size reduction. Specifically, accuracy on the day/night task, a measure of conflict inhibition, was a significant predictor.

INFLUENCE OF EXECUTIVE FUNCTIONING ON MEMORY FOR CONTEXTUAL DETAILS AND FALSE RECOGNITION

By

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Table of Contents

List of Tables

Chapter 1: Introduction

Episodic memories, a type of explicit memory, are memories for events. Episodic memories are rich with contextual details including the "*who*, *what*, *where*, *when*, *why*, and *how* of experience (Bauer, 2006)." These types of memories are central to our sense of personal identity because they constitute our knowledge of the world, document our unique pasts, and influence our future actions, cognitions, and emotions. Early childhood is a period of significant development in episodic memory. Specifically, children's memory improves as they are better (a) able to recall contextual details associated with objects and events and (b) resist falsely identifying novel information as previously encountered (i.e., false recognition; Baker-Ward, Gordon, Ornstein, Larus, & Clubb, 1993; Drummey & Newcombe, 2002; Lindsay, Johnson, & Kwon, 1991; Lloyd, Doydum, & Newcombe, 2009; Picard, Cousin, Guillery-Girard, Eustache, & Piolino, 2012; Pillemer, Picariello, & Pruett, 1994; Riggins, Miller, Bauer, Georgieff, & Nelson, 2009; Sluzenski, Newcombe, & Kovacs, 2006).

These developments are likely the result of multiple sources of developmental change. One of these sources is neural development in brain regions known to support memory encoding and retrieval in adults (i.e., the hippocampus, a region of the medial temporal lobe (MTL), and the prefrontal cortex (PFC); Bauer, 2006; Cycowicz, Friedman, Snodgrass, & Duff, 2001; Drummey & Newcombe, 2002; Ofen et al., 2007; Yonelinas, 2002). For example, the PFC is related to memory for contextual details and false recognition in adults (Yonelinas, 2002). In particular, damage to one particular subregion of the PFC (i.e., the dorsolateral prefrontal cortex (DLPFC) leads to performance deficits on memory for contextual details and increases false recognition (Farovik, Dupont, Arce, & Eichenbaum, 2008; Kopelman, Stanhope, & Kingsley, 1997). The PFC (including DLPFC) undergoes significant developmental change during early childhood. This has been demonstrated by at least two metrics: neuroanatomical evidence (e.g., number of cells and synaptic connections) and marker tasks Marker tasks are assessments assumed to tap the functioning of particular brain regions. Support for which brain region is recruited on a given task stems from activation of that region during the task by typical adults and deficits on those tasks by patients with lesions to that region (see Diamond, 2002, for a review).

Marker tasks are particularly useful in developmental populations as they provide one of the only ways to assess the functionality of brain regions during early childhood (de Haan & Johnson, 2003). Executive function tasks serve as marker tasks for prefrontal functioning. These tasks measure effortful goal-directed cognitive operations including inhibition, cognitive flexibility, and working memory (Diamond, 2006; Zelazo, Carlson, & Kesek, 2008). Both inhibition, specifically conflict inhibition, and cognitive flexibility require the DLPFC in adults, the region implicated in memory for contextual details and false recognition (Berlin, Rolls, & Kischka, 2004; Farovik et al., 2008; Kopelman et al., 1997). Therefore, I hypothesized that tasks of conflict inhibition and cognitive flexibility would be related to memory for contextual details and false recognition in early childhood.

Evidence for this association has been found in school age children (Cycowicz et al., 2001; Drummey & Newcombe, 2002; Picard et al., 2012; Ruffman, Rustin, Garnham, & Parkin, 2001) and normal aging. For example, studies in aging have found that better executive functioning is positively related to memory for contextual details (Craik, Morris, Morris & Loewen, 1990; Fabiani & Friedman, 1996; Glisky, Polster, & Routhieux, 1995) and resistance to false recognition (McCabe, Roediger, McDaniel, & Balota, 2009). In young adult populations the influence of executive functioning on memory for contextual details and false recognition is less well supported, perhaps suggesting maturational stability (Manning, Gordon, Pearlson, & Schretlen, 2007). Taken together, these findings suggest that executive functioning may specifically influence memory for contextual details and false recognition during the development and decline of executive functioning.

To date, no studies have systematically examined how all three constructs of executive functioning (i.e., inhibition, cognitive flexibility, and working memory) are related to memory for contextual details and false recognition in early childhood. This represents a critical period of investigation because conflict inhibition and cognitive flexibility show abrupt improvement between 3 and 6 years of age (Crammond, 1992; Diamond, 2006; Garon, Bryson, & Smith, 2008; Luciana & Nelson, 2002, Menna, 1989; Zelazo et al., 2008). Additionally, this is the same developmental period during which memory for contextual details and false recognition improves substantially (Baker-Ward et al., 1993; Drummey & Newcombe, 2002; Lindsay et al., 1991; Lloyd et al., 2009; Picard et al., 2012; Pillemer et al., 1994; Riggins et al., 2009; Sluzenski et al., 2006).

Therefore, the aim of the proposed study was to assess how constructs of executive functioning are related to memory for contextual details and false recognition in 3- and 6-year-olds, while taking into account general intelligence. I expected that, due to the recruitment of the DLPFC, performance on cognitive flexibility and conflict inhibition tasks would be specifically related to memory for contextual details and false recognition whereas other aspects of executive functioning (i.e., working memory and delay inhibition) would not.

Development of Episodic Memory

Initial forms of episodic memory are present in infancy (see Bauer, 2004, for a review). However, research using diverse methods has shown that marked improvement occurs during early childhood. Specifically, advances are present both in children's ability to remember contextual details and to resist false recognition (Baker-Ward et al., 1993; Drummey & Newcombe, 2002; Lindsay et al., 1991; Lloyd et al., 2009; Picard et al., 2012; Pillemer et al., 1994; Riggins et al., 2009; Sluzenski et al., 2006). Memory for contextual details refers to memory for information associated with studied items or events whereas false recognition refers to the acceptance of novel information as previously encountered. In order to understand the development of episodic memory, researchers have begun to use paradigms that allow for the objective assessment of children's accuracy for events and their associated details to examine these developmental changes.

Memory for contextual details. When word cues are used to prompt memories by older children and adults, the number of memories they are able to recall increases substantially throughout the childhood years (Larkina & Bauer, 2011;

Rubin and Schulkind, 1997). In support of this finding, a longitudinal study by Pillemer and colleagues (1994) assessed memory for a unique event to determine age-related changes in memory retrieval. The researchers interviewed 3- and 4-year-old children following an emergency preschool evacuation at two time points. No differences in memory recall were present 2 weeks after the event. However, 7 years following the event, children who were 4-years-old during the time of the event freely recalled significantly more details about the emergency than 3-year-old children. This study suggested that even though young children are able to encode and describe events in detail, age-related differences in memory processes influence long-term memory for events. However, recall paradigms such as the one just described may underestimate children's memory for events due to age-related differences in language ability and narration style (Bauer, 2006; Hamond & Fivush, 1991).

To limit the constraints of language ability on memory assessment performance, researchers often employ association paradigms. Association paradigms require participants to pair items with contextual details. Then, behavioral responses are used as indices of memory performance. Research utilizing association paradigms supports a differential increase in children's memory for contextual details compared to item memory between 3 and 6 years of age (Drummey & Newcombe, 2002; Lindsay et al., 1991; Lloyd et al., 2009; Riggins et al., 2009; Sluzenski et al., 2006). To assess developmental changes related to memory for temporal relations, Riggins and colleagues (2009) utilized a modified elicited imitation paradigm commonly used in infancy research (see Bauer, 2006 for a review). Children learned themed event sequences. Then, item memory was assessed by the performance of individual actions (e.g., trying to catch the fish) whereas contextual memory was determined by the number of temporal relations recalled (e.g., baiting the hook then catching the fish). The investigation revealed that item memory was similar between 3- and 4-year-olds but that 4-year-olds recalled significantly more temporal relations.

Children’s memory for the source of learned information has also been shown to improve in early childhood (Drummey & Newcombe, 2002; Lindsay et al., 1991). To determine the depth of children’s deficits in retrieving contextual details, Drummey and Newcombe (2002) used an open-ended response paradigm. Children 4-, 6-, and 8-years-old were taught novel facts in the laboratory by a puppet or experimenter. During retrieval a week later, children were asked to freely recall fact knowledge and fact source, measures of item and context memory, respectively. If the fact or associated source was incorrect, forced-choice follow-up questions were administered. The results suggested that fact knowledge increased incrementally from 4 to 8 years but fact source specifically increased between 4 and 6 years.

Similar contextual memory transitions between 4- and 6-year-olds have been documented by assessing children’s memory for item combinations (Lloyd et al., 2009; Sluzenski et al., 2006). Sluzenski and colleagues (2006) found that 4-year-old children had poorer memory performance for item and background combinations in comparison to 6-year-olds. The data analysis method used in that study did not allow for the differentiation of whether older children were better at identifying combinations or whether younger children falsely accepted novel combinations as old, a form of false recognition.

False recognition. To address this question, Lloyd and colleagues (2009) used a similar paradigm in a subsequent study. When accurate item combination recognition and false recognition of new combinations were assessed separately, 4-year-olds incorrectly accepted more novel item and background pairings than 6-year-olds (Lloyd et al., 2009). However, 4-year-olds recognized previously studied pairs as well as 6-year-olds. This suggests that 4-year-olds may rely on a sense of stimulus familiarity rather than specific details when making recognition judgments about items.

Two additional studies provide support that younger children are particularly susceptible to instances of false recognition. Baker-Ward and colleagues assessed 3-, 5-, and 7-year-old children's memory following a routine visit to the doctor (Baker-Ward et al., 1993). During interviewing, 3-year-old children were more likely than 5- and 7-year-old children to accept that events which did not happen during their visit occurred. This effect was present for routine check-up related events their nurse did not perform (e.g., "Did the nurse give you a shot?") and non-check-up related events (e.g., "Did the nurse cut your hair?"). Likewise, in another study 4- and 6-year-old children listened to stories and were presented with questions about details that were either thematically similar or dissimilar to the story (Lindsay et al., 1991). Younger children were more likely than older children and adults to accept novel but thematically associated details as previously heard. These studies suggest that 3- and 4-year-olds are more susceptible to false recognition in comparison to older children, particularly when the distractor items are similar to previously encoded events.

Taking together, studies on the development of episodic memory have shown that children's memory for contextual details and ability to resist false recognition show significant improvement in early childhood.

What develops? Multiple sources of developmental change potentially contribute to advances in children's episodic memory (see Bauer, 2006, for a review). These sources include skills that are tangential to memory as well as maturation of brain structures that subserve memory processes. Each of these factors is described below.

Many abilities develop in early childhood and scaffold the structure of children's episodic memories, some of which include language, the concept of time, and theory of mind. The development of language and narrative skills plays a crucial role in memory retention (Bauer, 2006). For example, Peterson and Rideout (1998) demonstrated that young children with narrative skills when they visited an emergency room were more likely to remember the event than non-narrative children. Understanding the concepts of time and self may also bolster children's episodic memories by allowing them to organize events sequentially and relate them to the self (Bauer, 2006). Similarly, theory of mind, the understanding of others' desires and knowledge, may also help children recall events (Bright-Paul, Jarrold, & Wright, 2008; Welch-Ross, Diecidue, & Miller, 1997). Theory of mind understanding may structure events causally and provide children with an understanding about what information should be provided to others to fill gaps in their knowledge.

Specifically related to memory performance, children's increased abilities on memory tasks may improve due to developments in the processes of memory encoding, consolidation, storage, and retrieval. The increased proficiency of these processes across development has been attributed to the development of the MTL and PFC regions (see Bauer, 2006 for a review; Cycowicz et al., 2001; Drummey & Newcombe, 2002; Ghetti, DeMaster, Yonelinas, & Bunge, 2010; Ofen et al., 2007).

Although most regions of the MTL become functionally mature by the second postnatal year, the dentate gyrus, a region of the hippocampus, follows an extended developmental trajectory (Eckenhoff & Rakic, 1991). The hippocampus is required for memory formation, and anatomical studies with nonhuman primates suggest that the synaptic density of the dentate gyrus peaks during the second year but that synaptic pruning continues until at least 4 to 5 years (Eckenhoff & Rakic, 1991; Gabrieli, Cohen, & Corkin, 1988; Goldman-Rakic, 1987). In fact, recent functional neuroimaging evidence suggests that the medial temporal system continues developing even into adolescence (Ghetti et al., 2010). The prolonged developmental trajectory of the hippocampus specifically influences memory for contextual information since items and their contexts have been hypothesized to bind within the hippocampus (Diana, Yonelinas, & Ranganath, 2007; Eichenbaum, Yonelinas, & Ranganath, 2007). Given the developmental trajectory of the hippocampus along with its role in processing contextual details, neural development of the hippocampus may underlie the documented performance improvement on associative memory paradigms in early childhood.

Maturation of the PFC may also contribute to children's improved memory for contextual details and resistance to false recognition since this region has been shown to be related to these constructs in adults (Yonelinas, 2002). As with the hippocampus, the PFC shows an extended developmental trajectory with pruning continuing until early adulthood. However, significant reductions in neuronal and synaptic density occur in the PFC between 2 and 7 years of age, the same time frame when children's memory for contextual details and resistance to false recognition improve (Diamond, 2002; Huttenlocher, 1990).

Diana and colleagues' (2007) binding of item and context model provides support for the role of the PFC in memory for contextual details. The perirhinal and parahippocampal cortices, regions of the MTL hypothesized to underlie memory for items and contexts, respectively, receive projections from functionally distinct neural regions (Diana et al., 2007; Suzuki & Amaral, 1994). The perirhinal cortex primarily receives input from unimodal visual association areas although weaker connections are present between this region and the insula, orbitofrontal cortex, and parahippocampal cortex (Suzuki & Amaral, 1994). Conversely, the parahippocampal cortex receives its strongest projections from the polymodal sensory association areas, the parietal cortex, insula, cingulate cortex, and DLPFC (Suzuki & Amaral, 1994). Since the parahippocampal cortex receives strong input from the DLPFC, memory for contextual details may be particularly influenced by maturation of this region and in the strengthening of connections between the DLPFC and parahippocampal cortex.

Although the neural substrates underlying false recognition are not as well defined, resistance to false recognition may also be influenced by the development of the DLPFC since this region has been implicated in adult neuroimaging and lesion studies as discussed below. Therefore, development of the PFC, specifically the

DLPFC, may contribute to the documented increases in children's memory for contextual details and resistance to false recognition. This relation is supported by research in adults with evidence from neuroimaging, lesion, and aging studies.

Relation between Memory and Prefrontal Functioning in Adults

Memory for contextual details. In adults neuroimaging studies support the active engagement of the PFC during memory encoding and retrieval (Cabeza & Nyberg, 2000; Yonelinas, 2002). Prefrontal activation is commonly reported during associative memory tasks that require memory for contextual details surrounding an event (Cansino, Maquet, Dolan, & Rugg, 2002; Kirwan, Wixted, & Squire, 2008; Slotnick, Moo, Segal, & Hart, 2003). However, determining which specific regions of PFC are involved for memory of contextual details is currently a topic of empirical inquiry.

The role of the PFC in memory for contextual details is further supported by lesion studies. Patients with lesions to the PFC exhibit deficits in memory for contextual details (Duarte, Ranganath, & Knight, 2005; Janowsky, Shimamura, & Squire, 1989; Jurado, Junque, Pujol, Oliver, & Vendrell, 1997; Kopelman et al., 1997; Shimamura, Janowsky, & Squire, 1990). Prefrontal lobe patients have been shown to have poorer memory for temporal order (Shimamura et al., 1990), frequency estimations (Jurado et al., 1997), task performed at encoding (Duarte et al., 2005), and the source of learned information (Janowsky et al., 1989). Few studies have assessed the role of focal prefrontal lesions to determine the influence of specific regions on memory performance. However, one study found that lesions of the DLPFC impaired memory for contextual details whereas lesions to other regions of the PFC did not (Kopelman et al., 1997). Thus, convergent evidence from neuroimaging and lesion studies suggests that the PFC is implicated in memory for contextual details.

False recognition. In addition to memory for contextual details, resistance to false recognition has also been shown to require the PFC, specifically DLPFC. An fMRI study revealed that DLPFC was recruited more during a novelty assessment paradigm than an associative memory task supporting the role of this region in recognizing new items (Dobbins et al., unpublished data as discussed in Dobbins, Simons, & Schacter, 2004). Moreover, Rossi and colleagues (2001) showed that transcranial magnetic stimulation (TMS) over right DLPFC led to an increase in false recognition during a picture recognition paradigm.

Lesion studies further support the role of the DLPFC in false recognition. A number of patients with prefrontal damage have been shown to falsely recognize novel stimuli and attribute high confidence ratings to these judgments (Schacter, Norman, & Koutstaal, 1998). Some research suggests that the DLPFC may specifically play an important role in false recognition. Compared to controls and patients with lesions to other regions of the PFC, patients with lesions to the left DLPFC were twice as likely to misidentify novel words as previously viewed on a word recognition task (Alexander, Stuss & Fansabedian, 2003; although see Schacter, Curran, Galluccio, Milberg, & Bates, 1996 for increased false recognition following damage to the right hemisphere). Consistent with this finding, lesions to the rat medial PFC, a region hypothesized to be functionally homologous to human DLPFC, led to false recognition of novel stimuli (Farovik et al., 2008).

In sum, the PFC, specifically the DLPFC, is implicated in processing memory for contextual details and false recognition in adults. In addition to neuroimaging and lesion studies, marker tasks have been instrumental in revealing how the functioning of the prefrontal cortex is related to memory for contextual details and false recognition.

Executive Functioning

Marker tasks are child-appropriate versions of neuropsychological assessments shown to be dependent on specific brain regions in adults (see de Haan & Johnson, 2003 for discussion of marker tasks). As Zelazo and colleagues (2008) have argued, functioning of the PFC, although not synonymous with executive functioning, is central during the implementation of executive functions. Executive functions are a set of effortful goal-directed cognitive operations (Best, Miller, & Jones, 2009; Diamond, 2006). Inhibition, cognitive flexibility, and working memory are the core components of executive functioning and support higher order cognitive processing such as problem solving, planning, and decision making (Diamond, 2006). Inhibition refers to ignoring distracting information or resisting a dominant response. Cognitive flexibility is the ability to switch attention, cognitions, or behaviors. Working memory involves maintaining and fluidly employing information. Because the PFC is recruited during inhibition, cognitive flexibility, and working memory tasks, performance on such tasks may be used as an index of prefrontal functioning. Evidence for the influence of executive functioning on memory for contextual details and false recognition has been shown in school-aged children and normal aging.

Associations between executive function and memory in adults. Studies in normal aging populations show that memory for contextual details and resistance to false recognition decreases markedly with age (Craik et al., 1990; Fabiani & Friedman, 1996; Glisky et al., 1995; McIntyre & Craik, 1987; Norman & Schacter, 1997; Parkin, Walter, & Hunkin, 1995; Spencer & Raz, 1995). Performance deficits may be due to age-related declines in the functioning of the PFC due to decreases in prefrontal white and gray matter (O'Sullivan et al., 2001; Raz et al., 1997). Neuropsychological studies support this notion by showing that executive functioning is positively related to memory for contextual details and resistance to false recognition.

Many aging studies document a positive relation between performance on associative memory and executive function tasks (Craik et al., 1990; Fabiani & Friedman, 1996; Glisky et al., 1995). Source and recency judgments are related to performance on the Wisconsin Card Sort Task (WCST), a task assumed to require inhibition, cognitive flexibility, and working memory (Craik et al., 1990; Fabiani & Friedman, 1996). Similarly, Glisky and colleagues (1995) found that older adults who displayed higher executive functioning judged source more accurately. These results jointly support the notion that age-related decrements in executive functioning are related to memory for contextual details.

In contrast to the research with older adults, an extensive literature search revealed only one study conducted with younger adults that assessed the relation between memory for contextual details and executive functioning (Manning et al., 2007). This study provided only weak evidence for a relation between recency judgments and executive functioning. This suggests that executive functioning may specifically influence memory for contextual details during the development and decline of executive functioning.

Fewer studies have assessed how executive functioning is related to false recognition. McCabe and colleagues (2009) documented a relation between executive functioning and false recognition in 18-90-year-old adults. Path analysis revealed that false recognition was related to marker tasks of PFC but not MTL functioning whereas accurate subjective recollection was related to marker tasks of MTL but not PFC functioning. This study provides support for a relation between executive functioning and false recognition. However, this study did not investigate whether the relation differed across development.

Collectively these studies suggest that executive functioning influences memory for contextual details and false recognition in adult populations, particularly in aging. Analogous to the relation between executive functioning and memory for contextual details in aging populations, the influence of executive functioning on memory for contextual details and false recognition may be robust in early childhood when executive functioning shows significant development.

Development of executive functioning. Inhibition and cognitive flexibility show abrupt improvement in the preschool years, particularly after the age of 3 (Diamond, 2006; Garon et al., 2008; Zelazo et al., 2008). Carlson and Moses (2001) differentiated between inhibition tasks that require delayed versus conflicting responses. Whereas delayed tasks primarily recruit the orbitofrontal cortex, conflict tasks require activation of lateral regions, such as the DLPFC (Berlin et al., 2004).

The orbitofrontal cortex and DLPFC reach functional maturity at different rates. Adult levels of gray matter volume are reached sequentially for the orbitofrontal, ventrolateral, and dorsolateral prefrontal cortices (Giedd et al., 1999). Thus, optimal performance on tasks recruiting those regions is likely reached at different time points.

Consistent with this supposition, many studies have failed to find age-related differences on assessments of delayed inhibition, such as the delay of gratification task (Carlson, 2005; Mischel, Shoda, & Rodriguez, 1989). Most studies that have examined delayed inhibition consider individual differences in performance rather than the developmental trajectory of this ability. However, conflict inhibition improves suddenly between 3 and 6 years of age on tasks such as the day/night Stroop task (Gerstadt, Hong, & Diamond, 1994) and grass/snow task (Carlson & Moses, 2001; Carlson, 2005). Such tasks require the inhibition of a prepotent response in favor of a conflicting response rather than the delay of a typical response. For example, during the grass/snow task children must point to a green stimulus when the experimenter says “snow” and to a white stimulus when the experimenter says “grass” (Carlson & Moses, 2001).

Cognitive flexibility also increases substantially in early childhood as illustrated by children’s abilities to use a new set of rules (Carlson, 2005; see Zelazo & Jacque, 1997, for a review) or take a novel perspective (Gopnik & Rosati, 2001; Perner, Leekam, & Wimmer, 1987). For example, during the dimensional change card sort (DCCS) task children must sort two types of target cards by one dimension (i.e., color; Zelazo, Resnick, & Piñon, 1995). Then, children are asked to sort by another dimension (i.e., shape). Generally, 3-year-old children perseverate and continue to sort by the original dimension, 4-year-olds switch more readily, and 5-year-olds perform optimally (Zelazo, 2006; Zelazo et al., 1995). This effect is present regardless of the dimension enacted first, and working memory demands associated with this task are minimal since sorting instructions are presented for every trial. Diamond (2006) explained that "once a child of 3 years has focused on the 'redness' of a red truck, it is difficult for the child to switch mindsets and focus on its 'truckness (pp. 81).'"

In opposition to the prominent developmental advances on conflict inhibition and cognitive flexibility tasks, working memory develops gradually. Performance on working memory tasks, such as spatial or digit span tasks, linearly increases from the preschool years into adolescence (Crammond, 1992; Diamond, 2006; Luciana & Nelson, 2002; Menna, 1989). Collectively, this research suggests that significant developments in executive functioning occur in early childhood for the domains of conflict inhibition and cognitive flexibility whereas working memory performance increases incrementally. Since prominent developments are present in the domains of conflict inhibition and cognitive flexibility, when advances are seen in children's memory for contextual details and false recognition, relations may be present between these constructs. Furthermore, conflict inhibition and cognitive flexibility likely require DLPFC functioning, the same region implicated in memory for contextual details and false recognition.

Associations between memory and executive functioning in children. Developmental researchers have begun to examine the relation between executive functioning and memory in childhood (Cycowicz et al., 2001; Drummey & Newcombe, 2002; Picard et al., 2012; Ruffman et al., 2001). Memory for contextual details and false recognition are related to measures of executive functioning (Cycowicz et al., 2001; Drummey & Newcombe, 2002; Picard et al., 2012; Ruffman et al., 2001). Picard and colleagues (2012) recently found that for 4-16-year-olds executive functioning skills, as indexed by updating, cognitive flexibility, and conflict inhibition tasks, predicted memory for spatial and temporal information. Cognitive flexibility was most related to memory for these contextual details. In contrast, item recognition was solely accounted for by feature binding abilities.

Similarly, in a sample of 6-, 8-, and 10-year-olds Ruffman and colleagues (2001) found a relation between conflict inhibition, as measured by performance on a Stroop task, and two measures of memory performance. Children with better inhibitory abilities were more likely to remember the source of learned information and less likely to falsely recognize new information as old. However, working memory performance, as assessed by a digit span task, was indiscriminately related to memory performance. Working memory was related to both the identification of items as old and correct source judgments. This research suggests that inhibition may specifically contribute to memory for contextual details and false recognition whereas working memory supports memory more generally.

The majority of research examining how executive functioning influences false recognition has been conducted by determining the relations between executive functioning and suggestibility. Although not synonymous with false recognition, suggestibility is closely related. Suggestibility refers to the acceptance of information as belonging to the original encoding experience although it was encountered after initial learning. A few developmental studies have reported a relation between increased inhibitory control and resistance to suggestibility in early childhood (Melinder, Endestad, & Magnussen, 2006; Roberts & Powell, 2005). Although working memory and inhibition skills have been associated with false recognition, to my knowledge, no research has assessed whether the third core component of executive function, cognitive flexibility, is related to false recognition.

Some recent research has begun to assess how executive functioning, is related to memory for contextual details and false recognition utilizing associative memory paradigms. In a study of children 4-, 6-, and 8-years-old, researchers assessed memory for the source of learned information and how memory was related to performance on a two executive function tasks, a child friendly version of the WCST and the day/night task (Diamond & Boyer, 1988; Drummey & Newcombe, 2002; Gerstadt et al., 1994). The WCST and day/night tasks require a combination of working memory and inhibitory control. Although fact memory improved for each age group, memory for source specifically increased between 4 and 6 years of age. Controlling for general intellectual ability, 4-year-old children who performed better on the WCST were less likely to judge learning information from an extraneous source outside the experimental paradigm (Drummey & Newcombe, 2002). The inclusion of general intellectual ability dampened the relation between verbal fluency and extra-experimenter errors. This finding suggests that some executive function-episodic memory relations may be influenced by general intellectual ability. Since only 4-year-old children completed measures of general intellectual ability, the relation between memory for contextual details and executive function controlling for intelligence were unable to be completed for the older age groups. This study also suggests that false recognition may be related to inhibition in young children. The inability of this study to discern a relation between memory performance and the day/night task, a task classically used with preschoolers as a measure of inhibition, may be because the children were 4-years-old. Significant improvements on this task occur between 3 and 4 years of age with 6-year-old children performing at ceiling on this task (Diamond, 2006).

A similar inability to discern a relation between conflict inhibition and memory was reported by Roberts and Powell (2005) in which only one out of four measures of inhibition was related to suggestibility. As with the Drummey and Newcombe (2002) study, the additional three measures used by Roberts and Powell (2005) may have been inappropriate due to the age of the participants. As discussed by Roberts and Powell (2005), the children in their sample performed at high levels which may have masked a relation between performance on the executive function tasks and suggestibility. These findings illustrate the importance of selecting executive function measures that are sensitive to the cognitive capacities of the participants.

A relation between inhibition and memory for contextual details has also been discerned in school aged children (Cycowicz et al., 2001). Memory for the color of previously viewed line drawings was assessed in 7- to 8-year-old children and adults. Performance increases with age were observed in participants' memory for items and their color. More pronounced improvements were detected for memory of the contextual detail rather than the individual items. This study discerned a relation between source accuracy and a competing programs task, a measure of conflict inhibition. All together, these studies suggest that select measures of executive functioning may be related to memory for contextual details and false recognition.

Current Study

The aim of the current study was to examine how the core components of executive function were related to memory for contextual details and false recognition. Furthermore, this study examined if these relations were no longer present after controlling for general intellectual ability. Three- and 6-year-old children participated given that significant improvements in the executive function domains of conflict inhibition and cognitive flexibility occur between these ages (Diamond, 2006; Zelazo et al., 2008). Similarly, previous research shows that although young children have similar levels of accuracy for item memory, memory for contextual and resistance to false recognition increases during early childhood (Lloyd et al., 2009; Riggins et al., 2009; Sluzenski et al., 2006).

Children performed a laboratory-based associative memory paradigm designed to resemble the rich episodic memories of children's daily lives. 6-year-old children were expected to more accurately identify previously viewed items and contextual details in comparison to 3-year-old children (Drummey & Newcombe, 2002; Riggins et al., 2009; Sluzenski et al., 2006). Additionally, I hypothesized that 6-year-olds would falsely recognize fewer novel items (Lloyd et al., 2009).

Children also completed a battery of executive function measures examining conflict inhibition, delay inhibition, cognitive flexibility, and working memory.

Specific relations were expected between memory and executive function measures due to previous developmental, neuroanatomical, gerontological, and lesion studies. Children's memory for contextual details and false recognition were expected to be related to measures of conflict inhibition and cognitive flexibility, as assessed by the day/night and DCCS tasks (Cycowicz et al., 2001, Drummey & Newcombe, 2002; Passler, Isaac, & Hynd, 1985; Suzuki & Amaral, 1994; Zelazo, 2006). This relation was expected since the DLPFC is implicated in memory for contextual details, false recognition, conflict inhibition, and cognitive flexibility (Farovik et al., 2008; Kopelman et al., 1997; Berlin et al., 2004). However, memory for contextual details and false recognition were not expected to be related to delay inhibition or working memory, as assessed by the delay of gratification and digit span tasks (Ruffman et al., 2001; Zelazo et al., 2008). Based on the finding by Drummey & Newcombe (2002) that when general intelligence was accounted for in a sample of 4-year-olds the relations between memory and executive functioning differed, the current study also assessed how general intellectual ability influenced the relations between executive functioning and memory constructs. I hypothesized that general intellectual ability would not influence the relations between executive functioning, memory for contextual details, and false recognition. Whether these relations differed as a function of age was also examined. The current literature was insufficient to formulate a specific hypothesis about whether the relation between executive function and memory would exhibit an age-related difference. Since executive functioning continues to develop into adolescence the relation could have been similar across age groups (Luciana & Nelson, 2002). However, since 3-year-olds in particular exhibit deficits on executive function tasks compared to older children, the relation between memory and executive function could differ (Diamond, 2006; Zelazo et al., 2008).

Contributions to Current Literature

The proposed study significantly contributes to current knowledge in three separate ways. First, the influence of executive functioning on memory for contextual details and false recognition in 3-year-old children represents a critical gap in the literature. Although Drummey & Newcombe (2002) targeted 3-year-old children as an age group of interest due to profound deficits on executive function tasks, they conducted their study with 4- and 6-year-old children.

In addition to assessing these two age groups of theoretical interest, the current study provides a systematic assessment of executive functioning. Previous studies interested in the relation between memory and executive function have not assessed all of the core executive functions including inhibition, cognitive flexibility, and working memory (Cycowicz et al., 2001; Drummey & Newcombe, 2002; Ruffman et al., 2001; cf. Picard et al., 2012). The current study included assessments that measured each of these constructs.

Finally, this study allowed for the assessment of how executive functioning is related to memory for contextual details and false recognition independent of general intellectual ability for both 3- and 6-year-olds. Drummey & Newcombe (2002) showed that controlling for general intellectual ability influences the relation between memory and executive function (Drummey & Newcombe, 2002). Altogether, this study fulfills three major gaps in the current literature by (a) recruiting 3- and 6-year-old children, (b) assessing working memory, cognitive flexibility, and inhibition, and (c) controlling for general intellectual ability.

Chapter 2: Methods

Participants

Participants were recruited from a database maintained by the University of Maryland Infant and Child Studies Consortium. The current study was cross-sectional and included 19 3-year-olds (6 females, $M = 3.26$, range 3.05 – 3.47 years) and 19 6-year-olds (10 females, $M = 6.22$, range 6.0 – 6.52 years). The sample included 2 Asian, 5 Black/African American, 7 multiracial, 19 White/Caucasian, and 5 Hispanic children. An additional 21 participants were excluded from participation due to non-compliancy ($n = 8$ 3-year-olds, $n = 1$ 6-year-old), equipment failure ($n =1$ 3-year-old), and failures to meet language criteria ($n = 1$ 3-year-old), full term criteria ($n = 2$ 6-year-olds), complete all three behavioral sessions ($n = 5$ 3-year-olds, $n = 1$ 6-year-old), and an inability to understand task instructions ($n = 1$ 3-year-old), and missing behavioral data from 1 assessment ($n = 1$). Children included in the current sample did not differ from those excluded from their own age group in age or gender. Parents provided informed consent for their children, and the study was ended if children verbally dissented. Children received a small toy after each session and a certificate for participation.

Stimuli

Behavioral stimuli for the memory paradigm included 81 age-appropriate, store-bought items (i.e., a book about lions and a policeman's hat). Each item was visually distinct and identified with a unique verbal label. Additionally, each stimulus was associated with one of three novel actions (i.e., each item was either placed the head, drummed on, or hugged). Actions attributed to stimuli were selected to be novel in that they were typically not associated with that stimulus (i.e., the policeman's hat would not be placed on my head). The items were separated into nine sets of nine items, and each action was performed three times per set.

Procedures

This study included two components, an experimental memory paradigm and a battery of neuropsychological assessments. The study took place over three visits at the Neurocognitive Development Lab. During the first session which lasted approximately 1 hour, children encoded information for the memory task and completed the Receptive Vocabulary assessment. Children completed the retrieval portion of the memory task during the second session 24 to 48 hours later. There was no difference in the average delay for 3-year-old (*M* = 1.2 days) and 6-year-old children (*M* = 1.26 days), $t(36) = -.37$, $p = .71$. The retrieval portion assessed children's memory for individual items and their associated contextual details. This session lasted approximately 1.5 hours. During the third session children completed a battery of neuropsychological assessments measuring general intellectual ability, memory, and executive functioning. The third session occurred within 3 weeks of the second session and lasted approximately 1 hour. There was no difference in the average delay for 3-year-old (*M* = 6.11 days) and 6-year-old children (*M* = 6.37 days), $t(36) = -.31$, $p = .76$. All procedures were approved by the University of

Maryland Institutional Review Board prior to the beginning of the study (see Appendix A).

Memory paradigm.

Encoding. Children were not informed that their memory would be subsequently measured to reduce age-related differences in strategy use (Siegler & Alibali, 2005). During encoding each child was introduced to two different locations and a distinct character that "belonged" in that location. Three sets of nine items were presented in each location for a total of 27 items viewed per location. Order of set presentation was counterbalanced between participants at encoding and randomly presented at retrieval to reduce the likelihood of memory effects being attributable to characteristics of individual items or their sequential relations. Within each set, the order of item presentation was random. Locations were blocked such that all items associated with one location were presented prior to the second location. A 5 to 10 minute delay was introduced between locations to temporally separate the encoding of items in each context. Baseline assessments of action performance were provided. The experimenter prompted the child to explore the object by saying "What you would do with it?" or "How would you play with it?" The experimenter noted if the child performed the target action.

Following the baseline assessment, the experimenter verbally labeled the stimulus, associated the item with the location's character, and performed the action associated with that item. For example, the experimenter said "This is Blicket's police hat. Blicket does something special with it. Blicket hugs it. Squeeze it tight!" and performed the action. To ensure encoding, the child was asked to behaviorally reproduce the novel action associated with the item since action imitation supports subsequent memory performance more than event observation (Lukowski et al., 2005). The play-like setting was designed to be an ecologically valid approximate of the child's daily encoding experiences by providing a multifaceted and rich environment for the encoding of the item and the surrounding contextual details.

Retrieval. Memory retrieval was assessed following a 24 to 48 hour delay using both electrophysiological and behavioral assessments. Event-related potentials (ERPs) associated with each stimulus were recorded prior to the behavioral retrieval session. Three 3-year-olds refused to comply with the ERP portion of the study. The discussion of the ERP data is beyond the scope of the current study and is not discussed further in the present report.

During the behavioral assessment, each child was presented with the 54 items from the previous session ("old") as well as 27 "new" items. This design is similar to those used in studies of older children and adults (Cycowicz et al., 2001; Ghetti et al., 2010; Ofen et al., 2007; Marshall, Drummey, Fox, & Newcombe, 2002). First, the child was asked to judge if the item was "old" or "new." If the child said the item was "new," the item was placed in the "new" bin. If the child said the item was "old", a forced choice assessment was given regarding the associated contextual details, (a) action and (b) location. For example, the child was asked "Did we play with this before?" and, if yes, "Did we make noise with it, hug it, or put it on our head?" After the child performed the action the experimenter asked "Which room does it go in?" The presentation of action and location were held constant for all participants in order to keep the child in the video camera's visibility for subsequent action coding. The sequential order of the action prompt was counterbalanced between participants to reduce order effects. If the child responded verbally but did not automatically perform the action, the experimenter prompted the child to produce the action to aid coding accuracy. Then, the child was asked to place the item in the appropriate location.

Coding**.** Following the retrieval session, the experimenter coded the location the child placed each item (Location 1, Location 2, or New) as there was no ambiguity in this measure. Actions were coded by four undergraduate students who were blind to the target action associated with each item because the experimenter could not code the action on-line and there may have been some subjectivity regarding which action the child performed. Each observer coded 8-10 sessions independently. Inter-rater reliability was calculated for 18% of the videos (n = 7, coders overlapped with other coders on 4 to 6 videos). The Krippendorff alpha was used to examine reliability since this measure allows for more than 2 observers and does not require that all observers code all instances (Hayes & Krippendorff, 2007). The Krippendorff alpha reliability coefficient was .9965. A 95% confidence interval of .9918 – 1.0 was obtained by using 10,000 bootstrapped samples. The single disagreement that existed re-examined by video and settled by the expert coder.

Behavioral data was used to separate responses based on memory for items and contextual details. Item accuracy was assessed by the number of items identified as old divided by the total number of items viewed at encoding. Accuracy for contextual details was assessed by the total number of details recalled (combined location and action) divided by the number of items identified as old multiplied by two (since two contextual details are associated with each item). False recognition was assessed by the percentage of falsely recognized items out of total new items.

Neuropsychological assessments.

See Table 1 for a list of all tasks including their duration, associated dependent variables used for the current analyses, and score range.

Table 1

Memory Paradigm and Neuropsychological Assessment Dependent Measures

Construct	Task	Time to Complete	Dependent Measures	Range
Memory	Memory Paradigm	1st session: 45 minutes	Percent correctly identified old items	0-100%
		2nd session: 45 minutes	Percent contextual details retrieved	0-100%
			Percent false recognition	0-100%
Intellectual Ability	RV	5 minutes	Sum of identified words (Scaled)	0-38
	Block Design	10 minutes	Sum of designs constructed (Scaled)	0-40
Executive Functioning	Day/Night Task	5 minutes	Original response accuracy	0-16
	DoG	1-6 minutes	Dichotomous success/failure to wait	0, 1
	Digit Span	5 minutes	Total number of sequences recalled	0-28
	DCCS	5-10 minutes	Total response accuracy on standard and bordered versions (if applicable)	0-18

RV = Receptive Vocabulary, DoG = Delay of Gratification, DCCS = Dimensional Change Card Sort

All neuropsychological assessments with the exception of the Receptive Vocabulary task were administered during the third session. Children completed the Receptive Vocabulary task during the first session prior to behavioral encoding to maintain consistency with the larger study. During the third session the task completion order was counterbalanced across participations in blocks to account for fatigue effects. Tasks were blocked into three groups with presentation order within each group the same across all participants. Tasks were blocked as follows, (a) day/night, Block Design, and Verbal Fluency, (b) delay of gratification and Narrative Memory, and (c) digit span and dimensional change card sort. Five minute breaks occurred between blocks of tasks. Performance on the Verbal Fluency task is beyond the scope of the current study and is not described in additional detail.

General intelligence. Children completed two measures of general intellectual ability from the WPPSI-III (Weschler Preschool and Primary Scale of Intelligence, 3rd ed; Weschler, 2002), Receptive Vocabulary and Block Design. The Receptive Vocabulary task required children to identify the picture out of four possible pictures that illustrated multiple target words' meaning. Children received one point for each word correctly identified (see Appendix B for additional information about the administration and scoring of the Receptive Vocabulary task). For the Block Design task an experimenter modeled a block design or showed the child a pictorial representation of a block design. Then, the child was asked to replicate the figure using the blocks. Children received one or two points for each design correctly configured based on the item and whether more than one trial was necessary for accurate performance (see Appendix C for additional information about the administration and scoring of the Block Design task). Scores scaled by age were obtained from the WPPSI-III Scoring Manual. Total scores were used to examine age-related performance differences, and scaled scores from the Receptive Vocabulary and Block Design tasks were summed and used to examine where general intellectual ability influenced the relations between executive functioning and memory constructs.

Narrative memory. Children performed the Narrative Memory task, a subtest from the NEPSY-II (Neuropsychological assessment, 2nd ed., Korkman, Kirk, & Kemp, 2007). Story recall tasks such as this have been shown to recruit the MTL memory system in adults, as evidenced by deficits shown following temporal lobectomy particularly with excisions of the hippocampus (Frisk & Milner, 1990). Thus, in the proposed study, the Narrative Memory task is a marker task of MTL functioning. The 3- and 6-year-old children heard different stories standardized for children of their age. Three-year-olds saw a picture and heard the story, but 6-year-olds only heard the story. Memory was assessed at three levels of difficulty immediately following the narrative. First, children were asked to repeat the story to the experimenter (Free Recall). Then, for details that were not recalled, children were asked prompted questions (Cued Recall). Last, all children were asked a forced choice question for each detail (Recognition). Task performance was coded during administration. Children received two points for each detail retrieved during Free Recall and one point for each detail retrieved during Cued Recall and Recognition. Percent scores were obtained for Free Recall, the summed score of Free and Cued Recall, and Recognition since the number of items differ for stories heard by 3- and 6-year-old children (see Appendix D for additional information about the administration and scoring of the Narrative Memory task). The Free and Cued Recall and Recognition measures were selected for analysis since 3-year-old children performed so poorly on the Free Recall measure although analyses revealed a similar pattern or results when either Free Recall or Free and Cued Recall was used.

***Executive function*.** Multiple measures of executive functioning were utilized in order to determine the relation between memory constructs and working memory, inhibition, and cognitive flexibility.

Day/night task. A modified version of the day/night task was used in the proposed study as a measure of conflict inhibition (Gerstadt et al., 1994; Passler et al., 1985; for a similar task see Carlson & Moses, 2001). Similar to stimuli used by Gerstadt and colleagues (1994), one stimulus was a yellow sun on a white background and the other was a white moon and stars on a dark blue background. The illustration of icons closely associated with representations of day and night are assumed to require more inhibition than solid colored cards used by Passler and colleagues (1985) and Carlson and Moses (2001). However, unlike the design of Gerstadt and colleagues (1994), children were not asked to produce responses upon seeing the stimuli because young 3-year-old children were not able to complete their task. The current procedure more closely resembles that of Passler and colleagues (1985). The children sat in front of a table that has each 8.5” x 11” stimulus placed side by side. The location of the stimuli was counterbalanced across participants. To verify understanding of the pictorial representations, children were asked which picture showed “day” and which showed “night.” Children were asked to point to “night” when the experimenter said “day” and to point to “day” when the experimenter said “night.” Children were given practice trials to ensure they understood the procedure. If children did not understand the practice trials, they were not administered the test trials (n = 1 3-year-old excluded from analyses). Similar to

Gerstadt and colleagues (1994), 16 test trials were given in the same pseudorandom prompt sequence for each child.

Data was coded by an undergraduate student for accuracy of the children's original response using Interact coding software (Mangold, 1998). Based on previous research, 3-year-olds were expected to perform with lower accuracy compared to 6-year-olds (Gerstadt et al., 1994; see Appendix E for additional information about the administration and scoring of the day/night task). Based on previous research, the current study only used the original response accuracy response as the dependent measure (Carlson, 2005). Inter-rater reliability was calculated for 21% of the sessions (n = 8, 4 for each age group). There were no disagreements between coders for the original response accuracy measure.

Delay of gratification. Delay of gratification, a measure of delayed inhibition, was assessed using a paradigm that required children to choose between a small immediate reward or a larger delayed reward (see Mischel et al., 1989, for a review). Children were seated behind a table in a plainly decorated room. Similar to Houck and Lecuyer-Maus (2004), children were asked if they would like marshmallows, goldfish, or M&M's to equate reward desire. Consistent with Carlson (2005), children were shown 2 versus 10 of their chosen item on separate paper plates and asked which amount they preferred. Then, similar to Mischel and Ebbesen (1970) the experimenter explained the task to the child by saying. "I have to go out of the room for a little while. If you wait until I come back you can eat these [point to preferred reward]. Or you can eat these [point to unpreferred reward] and I will come right back. But if you eat these [point to unpreferred reward] then you can't have these [point to preferred reward].” Children’s comprehension of the task was assessed by asking “What will happen if you wait for me to come back?” If necessary, the experimenter explained the task again. Then, the experimenter left the room until the child ate the reward or until 5 minutes elapsed. Consistent with Carlson (2005), when the experimenter returned, the child was asked “What happens now?” and “Why did you wait/not wait?” Then, all children received all 12 snacks. The dependent measure used in the current analyses was dichotomously scored for whether the child waited or ate the marshmallow (see Appendix F for additional information about the administration and scoring of the delay of gratification task).

Digit span. Children performed a digit span task to measure working memory. Previous research has demonstrated that children as young as 34 months are capable of performing this task (Gathercole & Adams, 1993). The current protocol was similar to that of Gathercole & Adams (1993). Children were read digit sequences from four lists spanning from two to seven digits. All children began with sequences of two digits. At each level if children correctly repeated sequences for three out of four lists, they were read lists with the length of the sequences increased by one. If children incorrectly repeat two sequences from the current level, the assessment ended. The children’s score was the total number of sequences correctly identified (see Appendix G for additional information about the administration and scoring of the digit span task). This measure was chosen in order to maximize task variability.

Dimensional change card sort. Cognitive flexibility was recruited using the dimensional change card sort (DCCS) task. The DCCS was administered in accord with the protocol developed by Zelazo (2006). Children sat in front of a table with two target cards (i.e., a blue rabbit and a red boat) situated above a small tray used to sort the test cards (i.e., four red rabbits and four blue boats). For the standard version, children were asked to sort cards by color and shape. The dimension that was presented first was counterbalanced across participants. The experimenter illustrated how to sort by the first dimension using each type of test card. Prior to each trial children were reminded of the dimension being used to sort the card. After six trials, children were taught how to sort based on the second dimension verbally. The experimenter did not demonstrate how to sort by the second dimension. Then the same protocol was used to administer trials during the post-switch phase. The number of correct responses on the post-switch phase was coded offline.

Children who correctly sorted at least five test cards correctly performed a more challenging border version appropriate for children as old as 7 years. The previously sorted cards were removed from the sorting trays. Four red rabbits and three blue boats were combined with bordered test cards (i.e., four bordered red rabbits and three bordered blue boats). Children sorted the bordered cards by color and cards without borders by shape. The experimenter illustrated the rules with red rabbit cards with and without a border. Accuracy was determined by the number of correct responses out of the 12 test trials. Based on previous research, approximately half of the 6-year-olds were expected to correctly sort 9 of 12 test trials (Carlson, 2005; Hongwanishkul, Happaney, Lee & Zelazo, 2005). Performance was scored by undergraduate students using Interact coding software (Mangold, 1998). Inter-rater reliability was calculated for 21% of the sessions (n = 8, 4 for each age group). There were no accuracy disagreements between coders for the pre switch, post switch, or bordered version phases of the DCCS task (see Appendix H for additional information about the administration and scoring of the DCCS task). The dependent measure selected for this task was the total number of accurate responses summed across the standard and bordered versions of the task.

Data Analysis Plan

Prior to analysis, three dependent measures were selected for the memory paradigm, two for the Narrative Memory task, and one dependent measure was selected for each general intellectual ability and executive function measure taking into account the previous literature, the most central measure of the construct of interest, and measure variability (see Table 1 for a list of selected dependent variables). All dependent measures were examined for outliers and normal distribution and accounted for as necessary.

Hypotheses

Please see Table 2 for the condensed list of hypotheses.

Memory paradigm and neuropsychological assessments. For the memory paradigm, I hypothesized that 3-year-old children would be less successful in remembering individual items (Hypothesis 1), recalling their contextual details (Hypothesis 2), and rejecting novel items (Hypothesis 3) than 6-year-old children. Similarly, I expected 3-year-old children to be less successful on the narrative memory task and all executive function tasks (Hypothesis 4). To examine these hypotheses I conducted a multivariate analysis of variance using the 10 dependent measures listed in Table 1.

Table 2

Hypotheses

	Hypothesis	Supported/Not supported
Hypothesis 1	3-year-olds will recognize fewer items than 6-year-olds	Not supported
Hypothesis 2	3-year-olds will remember fewer contextual details than 6-year-olds	Supported
Hypothesis 3	3-year-olds will falsely recognize more items than 6-year-olds	Supported
Hypothesis 4	3-year-olds will perform more poorly on all general intellectual ability, executive function, and standardized memory measures than 6-year-olds.	Supported
Hypothesis 5	General intellectual ability will be related to memory on our paradigm.	Partially supported; false recognition
Hypothesis 6	Recognition on NM task will be related to recognition on our paradigm.	Not supported
Hypothesis 7	Cued recall on NM task will be related to memory for contextual details.	Not supported
Hypothesis 8	Cued recall on NM task will be related to false recognition.	Supported
Hypothesis 9	DN and DCCS performance will be related to memory for contextual details.	Partially supported; DN in high performers
Hypothesis 10	DN and DCCS performance will be related to false recognition.	Partially supported (not controlling for general intellectual ability)
Hypothesis 11	DS and DoG performance will not be related to memory for contextual details.	Supported
Hypothesis 12	DS and DoG performance will not be related to false recognition.	Supported

DCCS = Dimensional Change Card Sort, DN = Day/Night, DoG = Delay of gratification, DS= Digit span, NM = Narrative Memory

Relations between general intellectual ability and memory. General intellectual ability, as assessed by the Receptive Vocabulary and Block Design tasks, was expected to be related to memory performance (Hypothesis 5) at each age.

Separate hierarchical multiple regression analyses were used to predict the percent of items correctly identified as old, percent of contextual details retrieved, and percent of items falsely recognized. Each predictor was entered in a separate block, and the order of entry (age group, composite general intellectual ability score, and an interaction term for age group and the composite general intellectual ability score) was the same for all regressions. Age group was used for all regression analyses rather than exact ages. Since participants were selectively recruited from two age groups age was not normally distributed, and these types of distributions inflate correlation and regression coefficients (Cohen & Cohen, 1983). If general intellectual ability predicted memory for items, details, or false recognition, this factor was used as a control variable for analyses examining the relations between executive functioning and memory.

Relation between performance on Narrative Memory task and memory paradigm. Narrative memory measures were expected to be related to memory on the experimental paradigm. Separate hierarchical multiple regression analyses were used to predict the percent of items correctly identified as old, percent of contextual details retrieved, and percent of items falsely recognized using the cued recall and recognition measures from the Narrative Memory task. The order of entry (age group, general intellectual ability, cued recall and recognition, and the age group x cued recall and age group x recognition interactions) was the same for all regressions. Recognition was expected to be related to memory for individual items (Hypothesis 6) whereas cued recall was expected to be related to memory for contextual details (Hypothesis 7) and false alarms (Hypothesis 8).

Relations between executive functioning and memory. Conflict inhibition and cognitive flexibility were expected to be related to memory for contextual details (Hypothesis 9) and false recognition (Hypothesis 10) as indexed by original response accuracy on the day/night task and performance on the DCCS, respectively. However, performance on the delay of gratification and digit span task, measures of delay inhibition and working memory, were not expected to be related to memory for contextual details (Hypothesis 11) or false recognition (Hypothesis 12). Exploratory analyses were also conducted to examine whether the relation between executive functioning and memory differed as a function of age.

These hypotheses were examined using separate hierarchical multiple regression analyses to predict memory for contextual details and false recognition. Age group was entered in the first block, general intellectual ability was included in the second block, and all four executive function measures were added to the third block.

Chapter 3: Results

Memory Paradigm

Descriptive statistics are provided in Table 3. A multivariate ANOVA revealed a significant group effect, $p < .001$. Contrary to Hypothesis 1, the univariate test showed that 3- and 6-year-old children were equally likely to correctly recognize previously viewed items, $F(1, 36) = .62$, $p = .44$. Further analyses suggested that 3- and 6-year-olds recognition responses may have been influenced by different factors. Three-year-old children's recognition percentage was positively correlated with false alarms, $r(19) = .46$, $p = .049$ whereas 6-year-olds showed a trend in the opposite direction, $r(19) = -.43$, $p = .07$. This suggests that 3-year-olds showed an overall propensity to either accept or reject items. However, 6-year-olds who were better at recognizing previously encountered items were also better at rejecting new items. Consistent with Hypotheses 2 and 3, 3-year-old children were less accurate in identifying contextual details associated with items, $F(1, 36) = 11.71$, $p < .01$, and were more likely to commit false recognition, $F(1, 36) = 5.38$, $p = .03$.

Neuropsychological Assessments

Descriptive statistics are provided in Table 3. In support of Hypothesis 4, 3-year-olds performed worse than 6-year-olds on the Receptive Vocabulary, $F(1, 36) = 36.47$, $p < .001$, and Block Design tasks, $F(1, 36) = 84.3$, $p < .001$, measures of general intellectual ability. Three-year-old children performed more poorly than 6-year-old children on all measures of neuropsychological function. Three-year-olds demonstrated lower levels of narrative memory as well as executive functioning for the constructs of inhibition, working memory, and cognitive flexibility. Younger children demonstrated poorer narrative memory as indexed by lower levels of cued recall, $F(1, 36) = 47.13$, $p < .001$, and recognition, $F(1, 36) = 40.58$, $p < .001$. In terms of conflict inhibition and cognitive flexibility, 3-year-olds also made more errors on the day/night task, $F(1, 36) = 23.21$, $p < .001$, as well as the DCCS task, $F(1, 36) = 26.62$, $p < .001$. Three-year-olds also recalled fewer sequences on the digit span task, $F(1, 36) = 25.19$, $p < .001$, and were less likely to delay gratification $F(1, 36) = 4.69$, $p = .04$.

Table 3

Performance by 3- and 6-year-olds on Memory, General Intellectual Ability, and Executive Function Measures

	3-year-old children (*n* = 19)		6-year-old children (*n* = 19)		MANOVA statistics	
Construct	*M*	*SE*	*M*	*SE*	*F*	*P*
Memory						
Item Recognition (%)	79.63	6.28	85.17	3.25	.62	.44
Contextual Details (%)	49.2	2.19	58.36	1.54	11.7	.002*
False Recognition (%)	34.47	8.97	10.71	4.95	5.38	.03*
Intellectual Ability						
Receptive Vocabulary	21.89	1.01	29.84	.85	36.47	< .001*
Block Design	15.32	.82	27.32	1.02	84.3	< .001*
Narrative Memory						
Cued Recall (%)	20.04	8.97	54.74	4.41	47.13	< .001*
Recognition (%)	65.89	3.27	89.47	1.73	40.58	< .001*
Executive Functioning						
Day/Night Task	6.84	.99	13.21	.87	23.21	< .001*
Delay of Gratification	.68	.11	.95	.05	4.69	.037*
Digit Span	7.53	.731	12.21	.58	25.19	< .001*
DCCS	5.63	1.39	14.37	.97	26.62	< .001*

* Significant at $p \leq .05$

Memory, General Intellectual Ability, and Executive Functioning

General intellectual ability and memory. Contrary to Hypothesis 5, regression analyses revealed that when age group was entered in the model first, neither general intellectual ability nor the interaction between age group and general intellectual ability significantly improved the prediction of memory for individual items or contextual details (see Table 4).

Table 4

Hierarchical Multiple Regression Analyses Predicting Episodic Memory Performance Using General Intellectual Ability, Age, and Their Interaction as Predictors

Variable	R^2	*F*	*ΔF*	*β*	*t*
Item Recognition					
Step 1: Age group	.02	.62			
Step 2: General intellectual ability	.03	.49	.37		
Step 3: Age group * general intellectual ability	.07	.79	1.39		
Contextual Details					
Step 1: Age group	.25	11.7*			
Step 2: General intellectual ability	.3	7.43*	2.63		
Step 3: Age group * general intellectual ability	.34	5.82*	2.11		
False Recognition					
Step 1: Age group	.13	5.38*			
Step 2: General intellectual ability	.29	7.04*	7.7*		
Age group				-.45	-3.07*
General intellectual ability				-.41	-2.78*
Step 3: Age group * general intellectual ability	.29	4.65*	.2		

* Significant at $p \leq .05$

However, general intellectual ability and age group significantly predicted false recognition, $F(2, 35) = 7.04$, $p < .01$. The model including both of these factors was better than the model only including age group, $\Delta F(1,35) = 7.7$, $p < .01$. Older children, $\beta = -.45$, $t(37) = -3.07$, $p < .01$, and children with higher general intellectual ability, $\beta = -.41$, $t(37) = -2.78$, $p < .01$, were less likely to falsely recognize novel items.

Relations between performance on the Narrative Memory task and memory paradigm. Contrary to Hypotheses 6-8, regression analyses did not support a relation between memory performance on the Narrative Memory task and memory for individual items, contextual details, or false recognition when controlling for age and general intellectual ability (see Table 5).

Table 5

Hierarchical Multiple Regression Analyses Predicting Episodic Memory Performance Using Narrative Memory Performance Measures as Predictors

Variable	R^2	F	ΔF
Item Recognition			
Step 1: Age group	.02	.62	
Step 2: General intellectual ability	.03	.49	.37
Step 3: Narrative Memory	.07	.64	.8
Step 4: Narrative Memory*age group	.12	.71	.85
Contextual Details			
Step 1: Age group	.25	11.7*	
Step 2: General intellectual ability	.3	7.43*	2.63
Step 3: Narrative Memory	.33	4.06*	.79
Step 4: Narrative Memory*age group	.34	2.6*	.11
False Recognition			
Step 1: Age group	.13	5.38*	
Step 2: General intellectual ability	.29	7.04*	7.7*
Step 3: Narrative Memory	.37	4.93*	2.3
Step 4: Narrative Memory*age group	.39	3.36*	.52

* Significant at $p \leq .05$, Narrative Memory included the Cued Recall and Recognition percentage scores

Relations between executive functioning and performance on the memory paradigm. Analyses were conducted both including and excluding general intellectual ability as a control variable. Analyses excluding general intellectual ability were conducted to be consistent with previous literature. However, the one study that has controlled for general intellectual ability found that doing diminished the relation between some executive function measures and memory for contextual details (Drummey & Newcombe, 2002). Executive functioning did not significantly predict memory for individual items or contextual details, contrary to Hypothesis 9. In contrast, executive functioning did predict false recognition controlling for age group, $\Delta F(4,32) = 3.25$, $p = .03$, and accuracy on the DCCS was the only significant predictor, $\beta = -.46$, $t(37) = -2.25$, $p = .03$, see Table 6. In opposition to Hypothesis 10, when controlling for age group and general intellectual ability, executive functioning no longer accounted for additional variance in false recognition, $F(4, 31) = 1.53$, $p = .22$, see Table 7.

Table 6

Hierarchical Multiple Regression Analyses Predicting Episodic Memory Performance Using Executive Functioning Measures as Predictors (Without General Intelligence)

Variable	R^2	F	ΔF	β	t
Item Recognition					
Step 1: Age group	.02	.62			
Step 2: Executive functioning	.15	1.15	1.28		
Step 3: Age group * Executive functioning	.27	1.16	1.15		
Contextual Details					
Step 1: Age group	.25	11.71*			
Step 2: Executive functioning	.2	2.8*	.68		
Step 3: Age group * Executive functioning	.1	1.47	.17		
False Recognition					
Step 1: Age group	.13	5.38*			
Step 2: Executive functioning	.29	3.95*	.3.25*		
Age group				.24	1.02
Day/Night				-.3	-1.56
Dimensional Change Card Sort				-.46	-2.25*
Delay of gratification				-.16	-1.09
Digit Span				-.08	-.44
Step 3: Age group * Executive functioning	.19	1.97*	.08		

* Significant at $p \leq .05$, DCCS = Dimensional Change Card Sort

Table 7

Hierarchical Multiple Regression Analyses Predicting Episodic Memory Performance Using Executive Functioning Measures as Predictors (Including General Intelligence)

Variable	R^2	F	ΔF
Item Recognition			
Step 1: Age group & general intellectual ability	.03	.49	.49
Step 2: Executive functioning	.2	1.29	1.67
Step 3: Age group * Executive functioning	.31	1.19	1.03
Contextual Details			
Step 1: Age group & general intellectual ability	.3	7.43	
Step 2: Executive functioning	.32	2.47	.29
Step 3: Age group * Executive functioning	.34	1.36	.12
False Recognition			
Step 1: Age group & general intellectual ability	.29	7.04*	
Step 2: Executive functioning	.4	3.51*	1.53
Step 3: Age group * Executive functioning	.41	1.89	.09

* Significant at $p \leq .05$

Given previous studies in older children that have found a relation between executive functioning and memory for contextual information (Cycowicz et al., 2001; Drummey & Newcombe, 2002; Ruffman et al., 2001; Picard et al., 2012), additional analyses were conducted to further probe Hypothesis 9. One potential explanation for the null finding above is that children who performed at or below chance on either the action or location detail may have obscured the relation between memory and executive functioning since any variability in memory for action or location below chance, arguably, could not be accounted for theoretically (see Drummey & Newcombe, 2002 for a similar argument). In order to assess this hypothesis, 9 children with either ≤ 33% action accuracy or ≤ 50% location accuracy (6 3-year-olds, 3 6-year-olds) were excluded from analyses. The same regression analysis as above was conducted to examine the relations among general intellectual ability, executive functioning, and memory for contextual details with this subset of children.

As shown in Table 8, general intellectual ability and age group marginally predicted memory for contextual information, $F(2, 26) = 3.33$, $p = .05$. Including executive functioning the model was significant, $F(6, 22) = 2.69$, $p = .04$. The change in model fit above age group and general intellectual ability did not meet the conventional level of significance. However, because of previous literature, decreased power due to sample size, and my specific a priori hypotheses, I examined whether any of the executive function measures were significant predictors of memory for contextual details. Consistent with a portion of Hypothesis 9, accuracy on the day/night task was the only significant predictor of memory for contextual details, $\beta = .68$, $t(28) = 2.77$, $p = .01$.

Table 8

Hierarchical Multiple Regression Analyses Predicting Memory for Contextual Details Using Executive Functioning Measures as Predictors in Subset of Children Above Chance Performance on Action and Location Detail

Variable	R^2	F	ΔF	β	t
Contextual Details					
Step 1: Age & general	.45	3.33*			
Step 2: Executive Functioning	.65	2.69*	2.09^		
Age group				-.23	-.62
General intellectual				-.08	-.35
Day/Night				.68	2.77*
Dimensional Change				-.01	-.03
Delay of Gratification				.09	.5
Digit Span				.22	.9
Step 3: EF*Age	.68	1.51	.28		

* Significant at $p \leq .05$, ^ $p = .12$, EF = Executive Functioning

Chapter 4: Discussion

This purpose of this study was to conduct a systematic assessment of the relations between episodic memory and executive functioning in early childhood taking into account age and general intellectual ability. Children's memory for contextual information is important because it underlies our personal past and can influence problem solving and decision making about future behaviors. Three- and 6-year-old children were included since significant improvements are present in memory and executive functioning during this developmental period. To fully understand the ways these constructs are related, the current study included measures of children's memory for individual items, contextual details, false recognition, all four core constructs of executive functioning (cognitive flexibility, conflict inhibition, delay inhibition, working memory), and general intellectual ability. The results suggested complex relations between episodic memory, executive functioning, age, and general intelligence. Of particular note was the finding that suggested executive functioning, in particular conflict inhibition, does influence memory for contextual details in early childhood even when controlling for age and general intellectual ability. This relation is discussed in detail below, followed by discussion of the other findings.

Memory for Contextual Details and Executive Functioning

This study adds to the literature the novel finding that performance on the day/night task, a measure of conflict inhibition, significantly predicts memory for contextual information in high performing 3- and 6-year-old children. This finding is important because it 1.) shows that particular executive functioning abilities influence memory for contextual details and 2.) highlights the importance of considering individual differences in cognitive abilities.

There is a growing number of studies that have assessed the relations between executive functioning and memory for contextual details in children. However, these studies have not examined all of the core constructs of executive functioning (Cycowicz et al., 2001; Drummey & Newcombe, 2002; Picard et al., 2012; Ruffman et al., 2010). The present study filled this critical gap in the literature by including measures of four critical executive function domains. Motivated by previous studies that have shown memory for contextual details to be related to conflict inhibition and cognitive flexibility (Cycowicz et al., 2001; Drummey & Newcombe, 2002; Picard et al., 2012; Ruffman et al., 2010) as well as lesion data suggesting that the region (i.e., DLPFC) responsible for these skills plays a role in memory for contextual information (Kopelman et al., 1997), I hypothesized that memory for contextual details would be related to conflict inhibition and cognitive flexibility. In contrast to the multiple studies relating conflict inhibition and cognitive flexibility to memory for contextual information, only one study in children has examined working memory. This study found that working memory was indiscriminately related to memory performance (i.e., was not specifically related to memory for contextual details; Ruffman et al., 2001). No studies to date had included measures of emotional inhibition. Based on the study by Ruffman and colleagues (2001) as well as the developmental trajectory and neural correlates of working memory and delay inhibition (Berlin et al., 2004; Carlson, 2005; Crammond, 1992; Diamond, 2006;

Luciana & Nelson, 2002; Menna, 1989; Mischel et al., 1989), I hypothesized that these constructs would not predict memory for contextual details.

To address the multidimensional nature of children's memories, the current study included measures of children's memory for action and location. In the developmental literature a number of association paradigms have been developed to assess memory for many contextual details, including temporal order (Riggins et al., 2009), spatial context (Picard et al., 2012), the source of learned information (Drummey & Newcombe, 2002), item-item associations (Lloyd et al., 2009; Sluzenski et al., 2006), and item color (Cycowicz et al., 2001). These researchers all discuss the process of recollection as underlying memory these various contextual details. Based on this literature, the current study assessed the relations between executive functioning and children's memory for action and location considered together. When all children were included in the analysis, executive functioning did not predict memory for contextual information beyond age and general intellectual ability. However, I hypothesized that executive functioning would predict memory for details only in children with above chance performance since variability below chance cannot be accounted for theoretically (see Drummey & Newcombe, 2002, for a similar argument). The results were in line with my hypothesis. Executive functioning showed a trend for predicting memory for contextual details above age group and general intellectual ability. This result did not reach the conventional level of statistical significance likely due to the decrease in power associated with the diminished sample size. Based on my a priori hypotheses about how various executive function abilities would be related to memory for contextual details, I examined the individual predictors. Conflict inhibition, as assessed by the day/night task, predicted children's memory for contextual details in the subset of children who performed above chance. This finding underscores the importance of taking individual differences in behavioral performance into account, especially during periods of developmental change when some children may not have acquired proficiency in skills of interest. Furthermore, this result is consistent with the relation between executive functioning, specifically conflict inhibition and cognitive flexibility, and memory for contextual details in older children (Cycowicz et al., 2001; Drummey & Newcombe, 2002; Picard et al., 2012; Ruffman et al., 2001) and normal aging (Craik et al., 1990; Fabiani & Friedman, 1996; Glisky et al., 1995).

The findings discussed above are based on memory for action and location collapsed together. However, the binding of item and context model proposed by Diana and colleagues (2007) suggests that different types of contextual details are subserved by different cognitive and neural processes. Specifically, items and details that are unitized into single events (i.e., red elephant) are processed differently from non- unitized items and details (i.e., the elephant is associated with the color red because it is standing in a barn; Diana et al., 2007; Eichenbaum et al., 2007). Item and contextual information are processed in the perirhinal and parahippocampal cortices, respectively. Unitized details, such as object color, can be processed by the perirhinal cortex and supported by the process of familiarity. In contrast, item and non-unitized contextual information must be bound in the hippocampus and supported by the process of recollection. Motivated by neuroanatomical evidence showing that the parahippocampal cortex receives strong projections from the

DLPFC, I hypothesized that memory for non-unitized details would be more influenced by executive functioning processes than unitized details.

The current study employed memory for action and location as the contextual details of interest. Many researchers have argued that memory for action is "special (Engelkamp, 1998; Zimmer, Cohen, Guynn, Engelkamp, Kormi-Nouri, & Foley, 2001)." Memory is better for self-performed actions in both adults and children (Baker-Ward, Hess & Flannagan, 1990; Engelkamp, 1998; Lukowski et al., 2005; Zimmer et al., 2001). Further, when participants retrieve memory for action, they recruit neural regions responsible for motor activity (i.e., premotor, supplementary motor, and cerebellar areas) in addition to medial temporal lobe regions (Ingvar & Philipsson, 1977; Nyberg, Petersson, Nilsson, Sandblom, Aberg, & Ingvar, 2001; Roland, Larsen, Lassen, & Skinhoj, 1980). The additional recruitment of motor regions may underlie better memory for action than other contextual information and may make memory for actions less reliant on other cognitive processes, such as executive functioning. Memory for location, in comparison, likely requires binding processes described by the binding of item and context model since this is a non-unitized contextual detail (Diana et al., 2007; Eichenbaum et al., 2007) and/or retrieval search processes conducted by the prefrontal cortex (Dobbins, Foley, Schacter, & Wagner, 2002; Wagner, Desmond, Glover, & Gabrieli, 1998). Thus, I expected that memory for location would be more influenced by executive functioning skills than memory for action.

Additional analyses not reported in the results section were conducted to examine whether relations between memory for contextual details and executive functioning differed between memory for action and location. Consistent with my hypothesis, regression analyses revealed that accuracy on the day/night task, the measure of conflict inhibition, significantly predicted memory for location. However, no executive function measure predicted memory for action. These findings are important as they provide support for the argument that contextual details are not all processed similarly. Based on this finding, previous results about the relation between executive functioning and memory for contextual details need to be considered in terms of the binding of item and context model. For example, Manning and colleagues (2007) reported a weak relation between recency judgments (i.e., the selected contextual detail) and executive functioning in young adults. This finding could be due to the use of recency judgments since they can be accurately made by relying on familiarity (Yonelinas, 2002). Additionally, future studies should also be designed with this framework in mind. One weakness of the current study is that action and location are very distinct details and may have differed in multiple respects, once of which includes salience. Future investigations should control for stimulus type, modality, and salience across the unitized and non-unitized conditions (e.g., see Diana, Yonelinas, & Ranganath, 2009 for a paradigm that fits these criteria) and examine how executive functioning relates to these distinct binding processes across development.

False Recognition and Executive Functioning

The current study found that, when not controlling for general intellectual ability, performance on the DCCS task significantly predicted false recognition. Out of the few studies that have assessed the relation between executive functioning and false recognition (McCabe and colleagues, 2009; Melinder et al., 2006; Roberts & Powell, 2005; Ruffman et al., 2001), they have consistently found relations between inhibition and false recognition (Melinder et al., 2006; Roberts & Powell, 2005; Ruffman et al., 2001). Although the DCCS was selected as a measure of cognitive flexibility, this task is not process pure and also requires inhibition, particularly during the bordered version of the task. Thus, our finding is consistent with previous literature documenting a relation between false recognition and executive functioning. However, as discussed below, the relation between false recognition and executive functioning was reduced when controlling for general intellectual ability.

General Intelligence and Memory

In addition to examining how executive functioning was related to memory for contextual details and false recognition, the current study also included measures of general intellectual ability. Previously, Drummey & Newcombe (2002) showed that controlling for general intellectual ability can diminish the relations between executive functioning and memory for contextual details in 4-year-old children. In this study, executive functioning, particularly on the day/night task, predicted memory for contextual details in high performing children even when controlling for age group and general intellectual ability. In line with arguments by other researchers (Herlitz & Yonker, 2002), this suggests that memory for items and their details on this paradigm was domain specific. This finding is consistent with that of Drummey & Necombe (2002) in which 4-year-olds' performance on a child-friendly version of the WCST continued to significantly predict source memory when controlling for general intellectual ability.

In contrast, when controlling for general intellectual ability, the relation between executive functioning and false recognition was diminished. This is important because it suggests that the relation between executive functioning and false recognition is not specific. Rather, more general individual differences in cognitive abilities account for this relation. Whether the relation between false recognition and executive functioning is completely accounted for by general intellectual ability will need to be examined in a large sample since performance on the DCCS still showed a trend to predict false recognition even when general intellectual ability was included in the model.

To my knowledge, the relation between intelligence and false recognition has not been documented in previous studies. This finding provides further support for the separation of true and false recognition as distinct cognitive and neural processes (Farovik et al., 2008; Garoff-Eaton, Slotnick, & Schacter, 2005) since true recognition was not related to intelligence. Although numerous explanations could explain this relation, one possibility is that the Receptive Vocabulary and Block Design measures used to assess general intellectual ability may have been tapping skills that influence false recognition. For example, problem solving, persistence, and task-focused maintained attention which are necessary for optimal performance on the Block Design task may also have been necessary while performing our task since many items were encountered at encoding and retrieval. Similarly if children with better Vocabulary performance were more likely to encode the object labels they may have been less likely to falsely endorse seeing novel items.

General Findings

Generally, this study also examined age-related differences in cognitive abilities, whether the relations between executive functioning and memory constructs differed as a function of age, and relations between our experimental paradigm and a standardized measure of memory. Three-year-olds performed more poorly than 6-year-olds on all but one measure of memory, executive functioning, and general intellectual ability. This finding is consistent with previous studies documenting age-related changes in these abilities in early childhood (see Diamond, 2006, and Zelazo, 2008, for reviews on executive functioning development and Bauer, 2006, for a review on memory development). In terms of memory performance, children were better able to remember contextual details and resist falsely recognizing new items with age (Baker-Ward et al., 1993; Drummey & Newcombe, 2002; Lindsay et al., 1991; Lloyd et al., 2009; Picard et al., 2012; Pillemer et al., 1994; Riggins et al., 2009; Sluzenski et al., 2006). An age-related difference in children's recognition of previously viewed items was not present in the current study. Although some studies report linear increases in children's memory for individual items and/or actions (Drummey & Newcombe, 2002), the findings are mixed (Lloyd et al., 2009; Riggins et al., 2009). Whether or not age-related increases are found for item recognition may be dependent on the type of information assessed. For example, Drummey and Newcombe (2002) asked children to recall answers to facts learned during the experiment. This may be a more difficult task than asking children which actions were performed with objects (Riggins et al., 2009) or to acknowledge (via recognition) whether stimuli were previously encountered (Lloyd et al., 2009) , as was done in the current study. These results cannot be compared to studies that utilize measures of d′ (i.e., difference scores created by subtracting false alarms from accurately recognized items) as it is impossible to discern whether age-related changes are in recognition and/or false alarm rates (Marshall et al., 2002; Sluzenski et al., 2006).

The current study did not find that the relations between executive functioning and memory constructs were influenced by age. This question had not been addressed in the current literature. It seemed possible that, since 3-year-olds in particular perform worse than older children on executive function tasks overall (Diamond, 2006; Zelazo et al., 2008), the relation may have differed as a function of age. However, executive functions continue to develop across childhood and into early adulthood (Luciana & Nelson, 2002). Thus, executive functioning may continue to influence memory for contextual details until the mature state is reached. Although concerns about the design used by Manning and colleagues (2007) were addressed above, it is possible that executive functioning specifically influences memory during childhood as these abilities are developing and in aging populations as memory and executive functioning skills begin to decline.

We also found no relation between performance on the Narrative Memory task, a standardized assessment of memory, and our experimental paradigm when controlling for age group and general intellectual ability. This effect may have emerged due to different demands of the Narrative Memory task and our experimental memory paradigm. On the Narrative Memory task children were required to retrieve information from short story. Optimal performance required memory, processing efficiency, and verbal skills. In contrast, our paradigm was developed to be as child-friendly as possible. Children encoded each item in a play-like setting to increase experience salience and at retrieval children were given a self-paced forced-choice assessment to determine their memory for items and their details.

Study Limitations

One potential limitation of the current study involves the use of forced-choice assessments during our experimental memory paradigm. This measure was adapted from the infant memory literature to limit verbal skills necessary to perform our task. However, the use of forced-choice assessments did increase noise associated with the current paradigm. Correct action or location judgments included both items for which the children remembered that contextual detail as well as items for which the children correctly guessed. Despite this potential limitation, we believe that accurate indices of children's memory performance are present using our paradigm, and the strengths of the current design (i.e., including two contextual details and limiting verbal requirements) outweigh the limitations.

Another important caveat is that neither performance on the current memory paradigm nor the neuropsychological tasks is process pure. As previously discussed, many association paradigms have been developed to assess children's memory for contextual information. The process of recollection has been argued to subserve accurate performance on all of these various paradigms. However, familiarity can contribute to accurate source performance (Diana, Van den Boom, Yonelinas, & Ranganath, 2011; Diana et al. 2007), and may have done so on our paradigm. For example, children may have placed items in the location that overall seemed more familiar to them than the location that seemed less familiar. In regards to the executive function tasks, cognitive abilities required for accurate performance of various tasks often overlapped. For example, on the day/night task children had maintain the task rules in working memory and recruit inhibitory skills in order to perform satisfactorily. Further, these tasks are not specific for prefrontal functioning. In adults regions outside of the prefrontal cortex are also active, and performance on executive function does not reliably distinguish patients with frontal and temporal lesions (see Morgan & Lilienfeld, 2000 for additional discussion).

A final consideration surrounds the distinctiveness of executive functioning constructs. Many researchers agree that executive functioning in adults is separated into multiple constructs. However, these skills may not be distinct in early childhood. Using confirmatory factor analysis, executive functioning in young adults is best characterized by three factors that load onto inhibition, shifting, and updating (Miyake, Friedman, Emerson, Witzki, Howerter, & Wagner, 2000). In children 2-6-years-old, executive functioning is best explained by one factor (Wiebe, Espy, & Charak, 2008). This result may explain why in the current study executive functioning generally predicted memory for contextual details and false recognition in the whole sample with performance on no one executive function task being a significant individual predictor. Further, the brain regions that support performance of marker tasks in childhood may differ from those regions necessary for adults to perform the same task. This notion is supported by the increased neural specificity (i.e., increased activation of neural regions that correlate with behavioral performance and decreased activation of non-relevant regions) that has been documented on many cognitive tasks with age (Casey, Tottenham, Liston, & Durston, 2005).

Chapter 5: Future Directions

Many research areas should be investigated to extend the current study in the future. Future studies should determine whether the association between executive functioning and memory for contextual details is dependent on the type of contextual detail recalled. Children’s memory for location and action was assessed in the current study. As discussed above, each of these details has potential problems that may have influenced the presence of a relation between executive functioning and memory for contextual information. Studies with adults have shown that memory for item-feature and item-context relations differ and may recruit partially dissociable neural regions (Diana et al., 2007; Eichenbaum et al., 2007). Future studies should employ paradigms that include each of these types of contextual information in a single paradigm to discern whether item-feature or item-context information specifically is influenced by the development of executive functioning.

The influence of executive functioning on either item-feature or item-context information should be examined in the future both through the continued use of marker tasks as well as with neuroimaging techniques that allow for the assessment of connections between brain regions. While performance on executive functioning tasks largely recruits the prefrontal cortex and memory tasks, such as the Narrative Memory task, differentially recruits the medial temporal lobes, memory for contextual information may be dependent on the strength of the connections between these brain regions. Resting-state functional connectivity and diffusion tensor imaging methods could be used as indices of PFC-MTL connections. Future studies could use these methods and determine the relation between PFC-MTL connectivity to performance on paradigms that assess memory for contextual information across development.

Lastly, the relation between memory and executive function may be further elucidated through the assessment of children between the ages of 3- and 6-years old. The proposed study only assessed 3- and 6-year-old children during the first 6 months of their respective age ranges. Future studies conducted with children between 3- and 6-years-old would be able to assess developmental changes in the relations between memory for contextual details, false recognition, and executive function with greater specificity.

Appendix A

Institutional Review Board Approval Letter

October 21, 2010

To: Investigator: Tracy Riggins

Co-Investigator(s): Not Applicable

Student Investigator: Not Applicable

Department: BSOS - Psychology

From: Joseph M. Smith, MA, CIM

Manager

University of Maryland, College Park

Re: IRB Application Number: 08-0612 (PAS# 2270.6)

Project Title: "Neurobehavioral investigation of memory development"

Approval Date: 10-20-2010

Expiration Date: 10-20-2011

Type of Application: Renewal

Type of Research: Non-Exempt

Type of Review: Expedited

The University of Maryland, College Park Institutional Review Board (IRB)

approved your IRB

application. The research was approved in accordance with the University's IRB policies and procedures and 45 CFR 46, the Federal Policy for the Protection of Human Subjects. Please reference the above-cited IRB application number in any future communications with our office regarding this research.

Recruitment/Consent: For research requiring written informed consent, the IRB-approved and stamped informed consent document is enclosed. The IRB approval expiration date has been stamped on the informed consent document. Please keep copies of the consent forms used for this research for three years after the completion of the research.

Continuing Review: If you want to continue to collect data from human subjects or analyze data from human subjects after the expiration date for this approval, you must submit a renewal application to the IRB Office at least 30 days before the approval expiration date.

Modifications: Any changes to the approved protocol must be approved by the IRB before the change is implemented except when a change is necessary to eliminate apparent immediate hazards to the subjects. If you want to modify the approved protocol, please submit an IRB addendum application to the IRB Office.

Unanticipated Problems Involving Risks: You must promptly report any unanticipated problems involving risks to subjects or others to the IRB Manager at 301-405-0678 or jsmith@umresearch.umd.edu.

Student Researchers: Unless otherwise requested, this IRB approval document was sent to the Principal Investigator (PI). The PI should pass on the approval document or a copy to the student researchers. This IRB approval document may be a requirement for student researchers applying for graduation. The IRB may not be able to provide copies of the approval documents if several years have passed since the date of the original approval.

Additional Information: Please contact the IRB Office at 301-405-4212 if you have any IRB related questions or concerns.

Appendix B

Receptive Vocabulary Protocol

Materials

Materials included the WPPSI-III Administration and Scoring Manual and WPPSI-III Stimulus Booklet 1.

Start

2-3-year-olds began with Item 1, and 4-7-year-olds began with Item 6. If 4-7-year-olds answered Item 6 incorrectly, the previous question was asked. This continued until they answered correctly and then task proceeded. If they answered Item 6 correctly, they automatically received 1 point per question for the first 5 items.

Task

The child was shown 4 pictures on a single page and asked to identify a particular item. For example, the child was shown the stimulus page for Item 1 and told to *"Show me the foot."* The task continued to be administered in the same manner until the child consecutively answered 5 questions incorrectly or completed all 38 items.

Scoring

Scoring occurred during task administration. The child received 1 point for each item correctly identified.

Dependent Measures

The Receptive Vocabulary dependent measure was the sum of the child's correct responses. Scores scaled by age were obtained from the WPPSI-III Administration and Scoring Manual.

Appendix C

Block Design Protocol

Materials

Materials included the WPPSI-III Administration and Scoring Manual, WPPSI-III Stimulus Booklet 1, WPPSI-III blocks, and a stopwatch.

Start

2-3-year-olds began with Item 1, and 4-7-year-olds began with Item 6.

Task

For Items 1-12, the experimenter modeled a block design for the child. For Item 13, the child was shown a model and the pictorial representation. For Items 13-20 the child had to create the block design based solely on the picture. For Items 1-10 the child created block designs using four red and white solid blocks. For Items 11-20 the child created block designs using four blocks that have 1 solid white side, 1 solid red side, and 4 diagonally separated sides that are half red and half white. Each item was timed. The child had 30 seconds to complete Items 1-7, 60 seconds for Items 8-13, and 90 seconds for Items 14-20.

To begin the experimenter said, *"Let's play with blocks. Watch me."*

For each item the experimenter assembled the model while describing the construction aloud. For example, *"I put a red block here and another red one here."*

Then, the experimenter prompted the child to create the model by saying, *"Now you make it. Work as fast as you can and tell me when you are done. Go ahead."*

For Items 1-6 the child was given a maximum of 2 trials to correctly complete the task.

After Item 10, the child was instructed about the new blocks.

At Item 13 the experimenter showed how to make the design using the picture. For subsequent items the experimenter did not model the design for the child.

Scoring

Scoring occurred during task administration. For Items 1-6 the child received 2 points if the design was correctly constructed on Trial 1 and 1 point if the design was correctly constructed on Trial 2. For subsequent trials the child received 2 points if the design was correctly constructed and 0 points if the design was incorrectly constructed.

Dependent Measures

The Block Design dependent measure was the sum of the child's correct responses. Scores scaled by age were obtained from the WPPSI-III Administration and Scoring Manual.

Appendix D

Narrative Memory Protocol

Materials

The NEPSY-II Stimulus Book was used for task administration.

Start

3-4-year-olds and 5-10-year-olds completed different versions of the Narrative Memory task that were standardized for their respective ages.

Task

3-4-year-old task.

"I am going to tell you a story about this picture [point to the picture]. *Listen very carefully then tell the story to me. Ready?"*

"One Saturday, Daddy helped Suzie and Tony make cookies. Tony is Susie's little brother. Tony made sugar cookies. Susie made chocolate chip cookies. Tony took the cookies to preschool for snack time. The boys and girls all said, "Thank you."

Free recall.

"Now tell me everything you can remember from the story and start from the beginning."

If child had difficulty getting started, the experimenter asked, *"How did the story start?"* or say, *"Let's try. Once upon a time…"*

If the child did not respond, the experimenter said, *"Just tell me anything you can remember from the story about the cookies."*

If the child still did not respond, the experimenter said, *"Tell me what happened on Saturday in the story."*

If the child stopped before the end of the story, the experimenter said, *"Tell me more"* or ask *"What happened next?"*

Cued recall.

For each story detail the child did not provide during Free Recall, the experimenter asked the Cued Recall question provided on the Record form.

For example, if the child did not say the boy's name then the experimenter asked *"What was the boy's name?"*

Recognition.

The experimenter read each Recognition question to the child from the Record Form, even if the child gave the correct responses to the Cued Recall questions.

5-10-year-old task.

"I am going to read a story to you about a boy and his sister."

"Jim had a big, black dog named Pepper. By Jim's house was a tall tree with branches that he couldn't reach. One day Jim got a ladder and climbed up. Pepper watched Jim as he sat on a branch and looked out over his neighborhood. When he started to get down, his foot slipped, his shoe fell off, and the ladder fell down. Jim didn't fall, because he held onto a branch, but he couldn't get down. Suddenly Pepper ran away with Jim's shoe in his mouth. Jim was sad because Pepper didn't stay with him. Pepper took the shoe to Anna, Jim's sister. He barked and

barked. Then Anna understood that Jim was in trouble. She followed Pepper to the tree and rescued Jim."

Free recall.

"Now tell me everything you can remember from the story and start from the beginning."

If child had difficulty getting started, the experimenter asked, *"How did the story start?"*

If the child did not respond, the experimenter said, *"Just tell me anything you can remember from the story."*

If the child stopped before the end of the story, the experimenter said, *"Tell me more"* or ask *"What happened next?"*

Cued recall.

For each story detail the child did not provide during Free Recall, the experimenter asked the Cued Recall question provided on the Record form.

For example, if the child did not say the boy's name the experimenter asked *"What was the boy's name?"*

Recognition.

The experimenter read each Recognition question to the child from the Record Form, even if the child gave the correct responses to the Cued Recall questions.

Scoring

Scoring occurred during task administration. The child received 2 points for each detail correctly recalled during Free Recall. The child received 1 point for each detail for recalled during Free Recall. Free and Cued Recall was combined score on the Free and Cued Recall sections. The child receives 1 point for each detail remembered during Recognition.

Dependent Measures

Free Recall, Free and Cued Recall, and Recognition percentages were calculated.

Appendix E

Day/Night Task Protocol

Procedure References

Gerstadt, C. L., Hong.Y. J., & Diamond, A. (1994). The relationship between cognition and action: performance of children 3.5-7 years old on Stroop-like day-night test. *Cognition*. *53*, 129-153. doi:10.1016/0010-0277(94)90068-X

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Materials

Two 8.5” x 11” stimuli were used for task administration. One stimulus showed a white moon and stars on a dark blue background and the other showed a yellow sun on a white background (see Figure 1).

Task Preparation

A spreadsheet was used to counterbalance what side each card was located across participants.

Task

Verification.

The experimenter verified that the child understood the picture representation. By asking *"Which one is day?" and "Which one is night?"*

Task instructions.

"Now we are going to do something different. When I say 'day' point to this one [point to the night card]. *When I say 'night' point to this one* [point to the day card]."

Practice.

"Now you try."

"Day"

If child answers incorrectly, the experimenter repeated the instructions and redid this trial.

If child answers correctly, the experimenter said *"Good job!"* and continued to next trial.

"Night"

If child answered incorrectly, the experimenter repeated the instructions

If child answers correctly, the experimenter said "*Good job!"* and continue to test trials.

Test.

1. “*Night*”

2. “*Day*”

3. “*Day*”

4. “*Night*”

5. “*Day*”

6. “*Night*”

7. “*Night*”

8. “*Day*”

9. “*Day*”

10. “*Night*”

11. “*Day*”

12. “*Night*”

13. “*Night*”

14. “*Day*”

15. “*Night*”

16. “*Day*”

Scoring

Scoring occurred after task administration from video by undergraduate research assistants. Accuracy was assessed by summing correct responses. Mean response latency was assessed from the time the experimenter provides the *“Day”* or “*Night”* prompts to when the child points to the chosen stimulus.

Dependent Measures

Only original response accuracy was examined for the present report.

Appendix F

Delay of Gratification Task

Materials

Materials included a stopwatch, dessert plates, mini marshmallows, goldfish crackers, and M&M's.

Task

Instructions.

The experimenter brought the child into the testing suite.

"Would you rather have marshmallows, goldfish, or M&M's?"

The experimenter placed 2 of the chosen item on one plate and 10 of the chosen item on another plate.

"*Would you rather have this many* [the experimenter pointed to plate of with 2 snacks] *or this many* [the experimenter pointed to plate of 10 snacks]?"

"I have to go out of the room for a little while. If you wait until I come back you can eat these [point to preferred reward]. *Or you can eat these* [point to unpreferred reward] *and I will come right back. But if you eat* these [point to unpreferred reward] *then you can't have these* [point to preferred reward]."

Comprehension check.

"*What will happen if you wait for me to come back*?"

"*Remember, stay in your chair*."

Task.

Then, the experimenter left the room and watched the child on the video. The experimenter waited 5 minutes. If the child ate the reward, the experimenter entered the room and the task was over.

"*Did I tell you I would give you another one?"*

Scoring

Scoring occurred during task administration. The experimenter began the timer when the testing suite door was closed. The task was scored for whether or not the child ate the snack, and, if the child ate the snack, how the length of time the child waited.

Dependent Measures

Only the dichotomous variable for delaying gratification or failing to do so was used in the present analyses.

Appendix G

Digit Span

Materials

Numbered lists were obtained from the Woodcock-Johnson III Numbers Reversed Task. The first three exemplars for each digit length were chosen to form four lists each ranging from 2-7 digits.

Task

Instructions.

"*I am going to say some numbers. Then, I want you to say the same numbers. For example, if I say 3…4, you would say 3…4*."

"*This time you tell me the numbers: 6…8* (spoken at one digit per second)."

If necessary, the experimenter additional pairs of digits from the following list until the child understood the task: *"2…8," "6…1," "3…6"*

Test items.

If children correctly recalled the digits for 3 out of 4 lists, they advanced to the next level. If this criterion was not reached, the task ended.

"Ready? Remember to tell me the numbers."

Two digits:

L1: *"2…5"*

L2: *"9…3"*

L3: *"4…7"*

L4: *"1…6"*

"I am going to say three numbers. Ready? Remember to tell me the numbers."

Three digits:

L1: *"7…3…6"*

L2: *"3…9…4"*

L3: *"8…1…6"*

L4: *"5…9…2"*

"I am going to say four numbers. Ready? Remember to tell me the numbers."

L1: *"9…3…6…1"*

L2: *"8…5…2…6"*

L3: *"4…7…3…1"*

L4: *"3…6…2…9"*

"I am going to say five numbers. Ready? Remember to tell me the numbers."

L1: *"5…9…2…4…7"*

L2*: "1…6…4…8…5"*

L3: *"5…2…8…3…7"*

L4: *"8…4…1…6…9"*

"I am going to say six numbers. Ready? Remember to tell me the numbers."

L1: *"2…5…9…3…7…4"*

L2: *“7…3…6…1…5…2”*

L3: *“2…6…8…5…9…4”*

L4: *“3…9…4…2…7…1”*

“I am going to say seven numbers. Ready? Remember to tell me the numbers.”

L1: *“8…1…6…3…7…8…5”*

L2*: “9…3…6…1…7…5…8”*

L3: *“6…3…1…8…4…7…2”*

L4: *“1…8…3...6…9…2…5”*

Scoring

Scoring occurred during task administration.

Dependent Measure

The dependent measure was the total number of digit sequences the child recalled.

Appendix H

Dimensional Change Card Sort (DCCS) Task Protocol

Procedure Reference

Zelazo, P. (2006). The DCCS: A method of assessing executive function in children. *Nature Protocols*, *1* (1), 297-302

Materials

Materials included 2 4" x 2.75" targets cards (i.e., blue rabbit and red boat), 21 4" x 2.75 test cards (i.e., 7 red rabbit cards, 7 blue boat cards, 4 bordered red rabbit cards, 3 bordered blue boat cards), and two wooden sorting apparatuses (see Figure X).

Task Preparation

A spreadsheet was used to counterbalance sheet which dimension was relevant during the pre-switch phase across participants. The experimenter placed the blue rabbit and the red boat target cards above the left and right card sorting trays, respectively.

Task

The experimenter labeled the target cards by both dimensions. **"*Here's a blue rabbit and here's a red boat.*"**

Beginning with color game.

Instructions.

"*We are going to play a card game. This is the color game. In the color game, all the blue ones go here* [pointing to the tray on the left], *and all the red ones go there* [pointing to the tray on the right]."

The experimenter sorted one type of test card (e.g. a blue boat) by color, and then said, "*See, here's a blue one. So it goes here* [place it face down in the tray on the left]." Then, the experimenter repeated the pre-switch rules, "*If it's blue it goes here, but if it's red it goes there*."

The experimenter showed the child the other type of test card (e.g., a red rabbit), and say, "*Now here's a red one. Where does this one go?*"

If the child sorted it **correctly** or indicated the correct tray by pointing the experimenter said, "*Very good. You know how to play the color game.*"

If the child **pointed**, the experimenter said, "*Can you help me put this one down?*" The experimenter ensured the card was face down in the appropriate tray, turning the card if necessary.

If **incorrect**, the experimenter said "*No, this one's red, so it has to go over here in the color game. Can you help me put this red one down?*"

Pre-switch phase.

"*Now it's your turn. So remember, if it's blue it goes here, but if it's red it goes there*."

The experimenter randomly selected a test card, showed it to the child, and labeled it by the relevant dimension only.

"*Here's a red/blue one. Where does it go?*"

If the child pointed, the experimenter could sort it for him/her.

"*Let's do another one*." or "*Let's do it again*." or "*How about another one?*"

The experimenter was neutral, non-evaluative, and non-corrective (e.g. do not say, "Okay").

The experimenter ensured that the same type of test card was not selected on more than 2 consecutive trials.

The experimenter repeaed the pre-switch rules. "*Play the color game: If it's blue it goes here, but if it's red it goes there. Here's a red/blue one. Where does it go?"* or *"Here's a red/blue one, where does this one go?*"

Post-switch shape game.

"N*ow we're going to play a new game. We're not going to play the color game anymore. We're going to play the shape game. In the shape game, all the rabbits go here* [pointing to the tray on the left], *and all the boats go there* [pointing to the tray on the right]. *Remember, if it's a rabbit, put it here, but if it's a boat, put it there. Okay?"*

The experimenter randomly selected a test card, showed it to the child, and labeled it by the relevant dimension only.

"Here's a rabbit/boat one. Where does it go?"

If the child pointed, the experimenter sorted it for them.

"Let's do another one." or *"Let's do it again."* or *"How about another one?"*

The experimenter was neutral, non-evaluative, and non-corrective (e.g. do not say, "Okay").

The experimenter ensured that the same type of test card was not selected on more than 2 consecutive trials.

The experimenter repeated the post-switch rules. *"Play the shape game: If it's a rabbit it goes here, but if it's a boat it goes there. Here's a rabbit/boat one. Where does it go"?* or "*Here's a rabbit/boat one, where does this one go?"*

The same instructions were used when children performed the shape game first.

Criteria for border version.

If the child accurately sorted at least 5 cards correctly, they continued to the border version.

Border version.

Task preparation.

The experimenter collected all the cards from the trays. The experimenter selected 4 red rabbits and 3 blue boats, and combined these with the border cards (four red rabbits and three blue boats).

"*Okay, you played really well. Now I have a more difficult game for you to play. In this game, you sometimes get cards that have a black border around it like this one [show a red rabbit with a border]. If you see cards with a black border, you have to play the color game. In the color game, red ones go here and blue ones go there [pointing to the appropriate trays]. This card's red, so I'm going to put it right there* [placing it face down in the appropriate tray].

But if the cards have no black border, like this one [show them a red rabbit without a border], *you have to play the shape game. In the shape game, if it's a red rabbit we put it here, but if it's a boat, we put it there* [pointing to the appropriate trays]. *This one's a rabbit, so I'm going to put it right here* [placing it face down in the appropriate tray]. *Okay? Now it's your turn."*

This procedure continued for 12 trials.

"Remember, if there's a black border, you have to play the color game. But if there's no black border, you have to play the shape game."

The experimenter selected a test card.

"Here's one with/without a black border. Where does it go?"

"Let's do another one." or *"Let's do it again."* or *"How about another one?"*

The experimenter was neutral, non-evaluative, and non-corrective (e.g. do not say, "Okay").

Troubleshooting.

Hesitation.

The experimenter propmpted the child again (e.g. *"Here's a _______, where does it go?*"

If the child was still hesitant, the experimenter said "*Let's do another one*" and come back to the card later.

Refusal.

"*You can point to the box*"

If the child still refused, the task was terminated.

Response change.

The child was allowed to change responses, but only the final response was recorded. Then, the experimenter said "*Are you sure?*" then went to next trial.

Desire feedback.

The child was never given feedback.

"Sort the card" or "Let's do another one"

Pick up cards in tray.

"*Those cards have to stay there, but let's do another one*"

Want a break.

Breaks were discouraged by saying "*We're almost done.*"

If child had to have a break, the interrupted step was repeated and the task completed.

Scoring

Scoring occurred after task administration from video by undergraduate research assistants. Accuracy was assessed by summing correct responses and by assessing the length of time between when the child was handed the card and when the child sorted it to the final response bin.

Dependent Measure

Accuracy summed across the standard and bordered versions was the only dependent measure used for the current study.

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