12-1-2013

An Examination of Memory in Children with Inattention, Hyperactivity, and Depressive Symptoms

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by

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B.S., Truman State University, 2011

A Thesis
Submitted in Partial Fulfillment of the Requirements for the
Master of Arts Degree

Department of Psychology
in the Graduate School
Southern Illinois University Carbondale
December 2013

THESIS APPROVAL

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A Thesis Submitted in Partial

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For the Degree of

Master of Arts

in the field of Psychology

Approved by:

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November 7, 2013

AN ABSTRACT OF THE THESIS OF

JORDAN CONSTANCE, for the Master of Arts degree in PSYCHOLOGY, presented on 31 OCTOBER 2013, at Southern Illinois University Carbondale.

TITLE: AN EXAMINATION OF MEMORY IN CHILDREN WITH INATTENTION, HYPERACTIVITY, AND DEPRESSIVE SYMPTOMS

MAJOR PROFESSOR: Dr. Michelle Kibby

The purpose of the current study was to explore the relationships between Attention-Deficit/Hyperactivity Disorder, depression, and memory impairment in children. It was hypothesized that level of inattention would negatively correlated with performance on measures of visual-spatial short-term memory and verbal memory. Children with greater levels of depressive symptoms were predicted to perform more poorly than less depressed peers on effortful measures of verbal and visual short-term memory, measures of verbal working memory, and measures of verbal long-term memory recall. Results indicated that impaired performance on one measure of visual-spatial short-term memory was related to increased levels of inattention and depression. Impairments were found on measures of verbal long-term memory recall and recognition related to greater attention problems, hyperactivity, and depressive symptoms. These deficits remained significantly related to inattention and hyperactivity beyond a deficit in encoding verbal material.

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CHAPTER 1

INTRODUCTION

Attention-Deficit/Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder that develops in childhood and is characterized by inattention, hyperactivity, and/or impulsivity (American Psychological Association, 2000). Thus, children with ADHD exhibit behaviors that affect their ability to function appropriately in daily life and can impair academic, social, and emotional functioning. They also commonly have problems with memory, planning, problem solving, and other executive and cognitive functions.

In children, depression and ADHD have been found to co-occur in 12-50% of cases (Angold, et al., 1999). Children with depression often present with problems related to irritability and sadness. They also frequently present with inattention. The long-term prognosis for children who are diagnosed with a depressive disorder is poor (Kessler, Avenevoli, & Merikangas, 2001). Even children who exhibit mild or subclinical depressive symptoms have been shown to have functional impairments (Lewinsohn, et al., 1998). Limited research has examined cognitive impairments in children with depression, but research in adults has found deficits in attention, processing speed, and memory.

Although individuals with ADHD and individuals with depression often exhibit deficits in some aspects of memory, no published research has examined memory deficits in the comorbid condition in children or adults. Moreover, limited research has examined depression's relation to memory on a continuum in general and depression's relation to memory in children in particular. Thus, this thesis examined multiple aspects of memory functioning in children with varying levels of inattention, hyperactivity, and depression. Instead of only focusing on children who meet full criteria for a depressive disorder, the present study examined depressive symptoms on a continuum, to determine if there is a more general relation between level of depression and level of memory impairment as prior research typically only has compared those with and without clinical depression. Likewise, instead of examining attention problems and hyperactivity dichotomously through a diagnosis of ADHD, the present study analyzed symptoms as continuous variables in order to account for subclinical levels of inattention and hyperactivity.

The current study examined four domains of memory: verbal short-term memory, visual short-term memory, verbal working memory, and verbal long-term memory. For verbal short-term memory, children's levels of inattention and hyperactivity symptoms were not expected to be related to performance, such that there was no impairment expected based on ADHD symptom levels. In contrast, level of depressive symptoms was hypothesized to be related to verbal short-term memory tasks requiring the greatest effort, while performance on less effortful tasks would not be related to depression symptoms. In terms of visual short-term memory, children with greater inattention symptoms were expected to be more impaired on measures of visual-spatial short-term memory, but not visual/non-spatial measures, than their less inattentive and hyperactive peers. For children with greater levels of depressive symptoms, performance was expected to decline on the most effortful task only, similar to verbal short-term memory.

Performance on tasks measuring verbal working memory was expected to be worse in children with higher levels of ADHD or depressive symptoms. For verbal long-term memory, levels of inattention or hyperactivity were not expected to be related to performance once encoding was controlled. In contrast, level of depressive symptoms was hypothesized to be negatively correlated with measures of recall, but not recognition, corresponding to the greater effort involved in recall tasks.

Children were recruited from the greater southern Illinois and Washington state areas as part of larger, NIH/NIMH grant-funded projects. A total of 148 children between the ages of 8 and 12 were included in the current study. The children were screened for study enrollment prior to beginning testing and after testing was completed. Children who completed testing were excluded if they had a history of medical or neurological disorders, significant pre- or post-natal complications, severe environmental problems, low IQ, or if they met criteria for reading disability.

The Behavior Assessment System for Children – Second Edition was used to assess parents' ratings of attention problems, hyperactivity, depressive symptoms, and withdrawal. The Children's Memory Scale and the Test of Visual-Perceptual Abilities were used to assess memory abilities. The Wechsler Intelligence Scale for Children – Third and Fourth Editions was used to assess intellectual abilities.

Results indicated partial support of the hypotheses. Verbal short-term memory was intact, regardless of level of ADHD or depressive symptoms. Likewise, verbal working memory performance was not related to the level of ADHD or depressive symptoms. These findings went against hypotheses. In contrast, one measure of visual-spatial short-term memory (Dot Locations) was negatively related to both attention problems and depressive symptoms. This is consistent with hypotheses as Dot Locations is a spatial measure, and spatial short-term memory was expected to be affected in those with greater attention problems as opposed to visual/non-spatial short-term memory. Moreover, Dot Locations was more effortful than the other visual short-term memory measures used, so it was expected to be affected in depression. Also partially consistent with hypotheses, delayed recall but not recognition for lists learned via selective reminding (Word Lists) was significantly related to level of depressive symptoms. This appeared to be due to poor encoding, however, as the relationship was no longer significant once encoding was controlled. Nonetheless, ADHD symptom levels also were correlated with delayed recall and recognition, even when encoding was controlled, which went against the hypothesis. Performance on a measure of semantic long-term memory (Stories) was not related to level of ADHD or depressive symptoms, consistent with hypotheses.

Clinically, these results suggest that children with greater levels of ADHD symptoms may learn best with visual material without a spatial component, or with verbal/auditory material, particularly when it is semantically organized for them. Children with ADHD also may have difficulty remembering effortful material, even if they were able to learn and encode it correctly. Children with greater depressive symptoms may have difficulty encoding and learning effortful material, but are able to recall and recognize it if it is encoded correctly.

In conclusion, these results support some of the previous research indicating intact verbal short-term memory, visual-non/spatial short-term memory, and verbal working memory in children with ADHD and/or depression, regardless of level of psychological impairment. Moreover, children with greater levels of depression were affected on more effortful tasks of verbal delayed recall but not recognition, consistent with the prior literature. This appeared to be due to poor encoding. Findings regarding intact semantic memory add to the literature given the limited research available on this topic. Additionally, ADHD symptoms associated with impairment for verbal long-term memory on a selective reminding task beyond encoding is a new finding and worthy of further research.

CHAPTER 2

LITERATURE REVIEW

The present study examined memory functioning in children with varying levels of depressive and ADHD symptoms. As such, this literature review will report existing research pertaining to working memory, ADHD, and depression in children. Memory impairments in children with ADHD and depression were examined in depth, and general impairments in individuals with comorbid ADHD and depression condition also were considered. Finally, memory impairments in children with ADHD and depression were reviewed.

Memory

Working Memory (WM) has been defined as the ability to maintain information in consciousness while processing or manipulating the same or other information (Tillman, Eninger, Forssman, & Bohlin, 2011). WM is crucial to the acquisition of cognitive and motor skills (Logan, 1988). It predicts intellectual functioning, academic achievement, and other higher order functions (Daneman & Merikle, 1996; Fry & Hale, 1996; Gathercole & Pickering, 2000). It is used in activities such as reading comprehension, mathematics, following instructions, and planning behavior in relation to a goal (Tillmann, et al., 2011).

There are multiple models of working memory in the cognitive literature (Miyake & Shaw, 1999). However, the present study used Baddeley's model, as it is commonly used in the neuropsychological literature in general and in studies on ADHD in particular. Baddeley's model of WM (1986) is composed of verbal and visual-spatial short-term storage systems, as well as a central executive (CE) that regulates and controls the two storage systems. The Phonological Loop is the verbal storage system. It stores linguistic information, and the information stored here decays rapidly unless rehearsed. Weaknesses in the phonological loop are associated with problems learning new vocabulary (Baddeley, Gathercole, & Papagno, 1998) and phonologically decoding words (Kibby, 2009; Kibby, et al., 2004). The phonological loop has two subcomponents: the phonological store, which retains information for a short period of time, and an articulatory rehearsal mechanism, also known as the subvocal rehearsal mechanism. The Visual-Spatial Sketchpad is the visual-spatial storage system. It stores visual material and spatial location information for a short period of time unless rehearsed. Weaknesses in the visual-spatial sketchpad are associated with low academic achievement in literacy and arithmetic (Gathercole & Pickering, 2000). The Central Executive controls and manipulates the information being held in short-term memory. It also acts on information retrieved from long-term memory (Baddeley, 1996). It supports complex cognitive processes, such as mental calculation, language, reading comprehension, and writing (Martinussen, et al., 2005). Although the CE was originally proposed as a domain-general mechanism (Baddeley 1986, 2000), recent research suggests that it might be best conceptualized as at least partially domain-specific, with dissociable verbal and visual-spatial components (Kibby, 2012; Martinussen, et al., 2005).

The Episodic Buffer is a component added more recently by Baddeley. It is responsible for integrating multi-modal representations (Baddeley, 2000; Holmes, et al., 2010). It is theorized to be analogous to the screen of a computer, holding multiple – but a limited number – of pieces of information, which are available to conscious awareness (Baddeley, Allen, & Hitch, 2010). It is essentially passive, but can receive information from long-term memory, working memory, and perception, and provides a link between the central executive and information needed for working memory (Baddeley, Allen, & Hitch, 2010). It also plays a role in connecting the storage components and central executive to the long-term memory system (Baddeley, 2000;

Rose & Craik, 2012). This component is a new addition to the model, and, hence, has limited research on it in the neuropsychological literature and in the ADHD literature in particular. It also is of dispute in the cognitive literature in terms of its validity (Baddeley, Allen, & Hitch, 2010). Thus, it will not be included it in this thesis project.

Verbal and visual-spatial storage capacity has been found to contribute to working memory performance (Magimairaj & Montgomery, 2012). Additionally, age, processing speed, and attentional capacity are important factors in a child's working memory ability. Multiple studies have found that general processing speed and storage capacity uniquely contribute to a child's working memory (Bayliss, et al., 2003, 2005; Majimairaj, Montgomery, Marinellie, & McCarthy, 2009). Many abilities that increase with development, such as perception, language, other executive functions and attentional capacity, also contribute to greater working memory performance (Magimairfaj & Montgomery, 2012). Thus, this literature review will address these in relation to depression and ADHD as well.

For the purposes of the current study, the term working memory (WM), which includes the central executive, is used when memory tasks require both storage of information and mental manipulation. The term short-term memory (STM) is used when tasks require brief storage but minimal mental manipulation, such as on a list learning, passage learning or digit span forward task. The term long-term memory (LTM) is used to refer to tasks requiring storage over a delay of 20 minutes or more (Kibby & Cohen, 2008).

ADHD

ADHD is characterized by severe and pervasive deficits in inattention and/or hyperactivity/impulsivity (American Psychological Association, 2000). To be diagnosed with ADHD, a child must exhibit six inattentive or hyperactive/impulsive behaviors for at least six months before the age of seven according to the *Diagnostic and Statistical Manual – Fourth Edition* (DSM-IV; APA, 2000). These behaviors must be present in two or more settings, and must impair the child's daily functioning. Children with ADHD often have difficulty taking turns, tend to interrupt or talk excessively, and often appear not to be listening (APA, 2000). Their performance is often worse on tasks that occur later in the day, tasks that are complex or tedious, when inhibition is necessary, with long reinforcement delays, and in the absence of adult supervision (Antrop, Roeyers, Van Oost, & Boysse, 2000; Carlson & Mann, 2002; Dane, Schachar, & Tannock, 2000; Luk, 1985; Solanto, et al., 2001).

ADHD is a disorder that affects approximately 5% of children worldwide (Polanczyk, et al., 2007). By adolescence, approximately 30% of children with ADHD have failed a grade, compared with 10% of children without ADHD. Over half of children and adolescents with ADHD have received some form of academic tutoring or support (Barkley, Anastopoulos, Guevremont, & Fletcher, 1991). Children with ADHD also have a higher high-school dropout rate (approximately 30%), and have lower occupational and socioeconomic statuses than their non-ADHD counterparts as adults (Barkley, 2002; Mannuzza & Klein, 2000).

The ADHD spectrum includes two distinct but correlated symptom domains: inattention-disorganization and hyperactivity-impulsivity. Three subtypes exist in the DSM-IV based on these domains: predominantly hyperactive-impulsive type (ADHD-HI), predominantly inattentive type (ADHD-PI), and combined type (ADHD-C) (Miller, Nigg, & Miller, 2009). Problems with hyperactivity and inhibition often begin around the ages of 3-4 years, although it can be as late as 5-7 in more mild cases (Mash and Barkley, 2003), with inattention problems presenting later, as early as age 5 or as late as age 10 (Hart, et al., 1995; Loeber, Green, Lahey, Christ, & Frick, 1992; Milich, Ballentine, & Lynam, 2001). ADHD-HI is most often diagnosed in preschoolers as older children either: (1) "grow out of it" and fail to meet threshold later in childhood for ADHD; or (2) develop problems with inattention and meet criteria for ADHD-C (Barkley, 2003). As such, this diagnosis is rare after preschool/early elementary school and will not be included in this thesis. Thus, this project will include ADHD-PI and ADHD-C.

A review by Barkley (2003) found that male children were between 2.5-5.6 times more likely to be diagnosed with ADHD as females. This is particularly true in clinic samples. Although boys are more likely to be diagnosed with ADHD, studies have found that girls who are diagnosed may be just as, if not more, impaired in terms of social skills, comorbidities, intelligence, academic achievement (Gaub & Carlson, 1997; Gershon, 2001; Rucklidge & Tannock, 2001). Nonetheless, studies assessing executive functioning have not found significant gender differences (Castellanos, et al., 2000; Murphy, et al., 2001)

Research suggests that inattention might stem from two separate sources: deficient selective attention and sluggish cognitive processing, or poor persistence, inhibition and resistance to distraction (Barkley, 2003). Children who have a sluggish cognitive processing, called ‘sluggish cognitive tempo’, may have more memory retrieval weaknesses. They also may have more internalizing problems, such as anxiety, depression and withdrawal, as well as greater social dysfunction, but less comorbidity with conduct problems (Barkley, 2003, Carlson & Mann, 2002). Calhoun and Dickerson Mayes (2005) have reported poorer performance on the Processing Speed Index (PSI) of the WISC-III in some children with ADHD-PI than other children with ADHD, which they suggested may be related to a distinction between children with a sluggish cognitive tempo and children with just inattention symptoms. A study by Carlson and Mann (2002) found that ADHD-PI was uniquely associated with a sluggish cognitive tempo when compared to children with ADHD-C, and that a sluggish cognitive tempo can distinguish between two potential subtypes of ADHD-PI: one including the typical inattentive symptoms used to diagnose ADHD and one including symptoms of slow processing and a sluggish or drowsy affect (Wåhlstedt & Bohlin, 2010). However, these subtypes did not predict the presence of more severe attention or learning problems in one group versus another. There also is research which goes against the notion of subtypes within ADHD-PI, finding those with ADHD-PI and C are high on the inattention dimension in general and have cognitive executive functioning deficits associated with it (Houghton, et al., 1999; Nigg, Blaskey, Huang-Pollock, & Rappley, 2002). Moreover, the presence of ADHD in general has been associated with slower processing speed (Shanahan, et al., 2006). Thus, this issue is far from resolved.

Children who present with hyperactive, impulsive behavior (i.e.; disinhibition) often have problems involving voluntary or executive inhibition of behavioral responses (Nigg, 2001). A study by Nigg and colleagues (2002) found impairment in motor inhibition in both ADHD-C and ADHD-PI subtypes, but boys with ADHD-C were more impaired than boys with ADHD-PI. This is most likely due to the fact that behavioral and motor regulation difficulties are associated with the hyperactive/impulsive domain, which is associated with ADHD-C but not ADHD-PI. However, some children with ADHD-PI may have subclinical levels of hyperactive or impulsive symptoms (not meeting full criteria for ADHD-C), which would explain Nigg and colleagues' findings in girls. Problems associated with the inattention dimension are seen in both the ADHD-PI and ADHD-C subtypes, and some researchers believe that it is the PI dimension that is associated with the cognitive executive dysfunction often seen in ADHD (Mash and Barkley, 2003). Barkley (1997) suggests that the inattention dimension reflects problems with the executive function of working memory, specifically.

Visual Processing in ADHD

Based upon a literature review, deficits in visual perception typically are not found in the ADHD literature when tasks have low spatial demands. However, impaired right parietal lobe functioning has been implicated in ADHD, including deficits in spatial processing (Aman, Roberts, & Pennington, 1998; Johnson, et al., 2010). More specifically, Aman and colleagues (1998) found impairments in boys with ADHD (all subtypes) on a mental rotation task. This finding was supported by the research of Silk and colleagues (2005). Although frontal lobe neural circuitry deficits have been long-researched in ADHD, parietal lobe deficits are relatively new findings. This is important as deficits in spatial short-term memory have been found in ADHD (Kibby & Cohen, 2008), which will be discussed in the ADHD working memory section.

Language Functioning in ADHD

Although language impairments are not required for a diagnosis of ADHD, many researchers have found higher levels of language impairment in children with ADHD than typically developing controls at the group level (Helland, et al., 2012).

Language functioning encompasses phonological processing, semantic processing, and syntax knowledge/use, both receptively and expressively. It also includes pragmatics. Many believe there are three main aspects of phonological processing: phonological awareness, rapid naming, and phonological short-term memory. Phonological awareness typically is considered to be intact in children with ADHD when they do not have comorbid language impairment (Gooch, Snowling, & Hulme, 2011; Purvis & Tannock, 2000). For example, a study by Purvis and Tannock (2000) compared the performance of children with ADHD, reading disability, the comorbid condition, and typically developing controls on measures of phoneme pronunciation, segmentation, deletion, and blending, and found that the ADHD group performed comparably to controls. However, 30-60% of children with ADHD have comorbid specific language impairment (D'Incau, 2000), and some studies do not exclude language impairment, which may influence findings on phonological processing in ADHD.

Regarding rapid naming, most researchers agree on the presence of a deficit in ADHD (Hynd, et al., 1991; Raberger & Wimmer, 2003; Semrud-Clikeman, Pliszka, & Liotti, 2008; Shanahan, et al., 2006; Tannock, Martinussen, & Frijters, 2000). Shanahan and colleagues (2006) found deficits in children with ADHD (subtype unspecified) on rapid color, number, letter, and picture naming. An additional study by Semrud-Clikeman, Guy, Griffin, and Hynd (2000) found impairment in children with ADHD (subtype unspecified) on rapid color and object naming, but not naming of letters or numbers. Likewise, Semrud-Clikeman, Pliska, and Liotti (2008) found impairment in children with ADHD (subtype unspecified) on rapid color naming. However, a study by Raberger and Wimmer (2003) did not find impairment in rapid digit or color naming in children with ADHD (subtype unspecified). Thus, the presence of a rapid-naming deficit is partially supported in the literature, although the specific etiology of this deficit has yet to be determined. One possible explanation is slow processing speed in this population (Shanahan, et al., 2006). Phonological short-term memory will be discussed in the ADHD working memory section.

Deficits in basic receptive and expressive language typically are not found in the ADHD literature when comorbid language impairment is excluded; however, many children with ADHD have trouble with pragmatics, which includes many conversational aspects of language (Purvis & Tannock, 1997). For example, children with ADHD exhibit difficulties following conversation flow and taking turns speaking during a conversation (Humphries, Koltun, Malone, & Roberts, 1994; Purvis & Tannock, 1997). Because language deficits typically are not found if higher-level demands, such as pragmatics, are kept to a minimum, they likely are not a source of verbal memory impairment in ADHD if language impairment is excluded.

Processing Speed in ADHD

Several studies have examined processing speed in ADHD, with most researchers finding it to be impaired in ADHD compared to controls (Calhoun & Mayes, 2005; Kibby & Cohen, 2008; Nigg, et al., 2002; Shallice et al., 2002; Shanahan, et al., 2006; Willcutt, et al., 2005). For example, Purvis and Tannock (2000) found that children with ADHD (subtype unspecified) have significantly slower response times on tasks of continuous performance, such as the go/no-go task and the Connors Continuous Performance Test (CPT; Conners & Staff, 2000). Shanahan and colleagues (2006) also found significant impairment on measures of both verbal and motor processing speed in children with ADHD (all subtypes) when compared to controls. No differences were found between ADHD-C and ADHD-PI (ADHD-HI was not included in the subtype comparison). Moreover, a meta-analysis by Willcutt and colleagues (2005) found significant impairment on stop-signal reaction time (SSRT) and the CPT in ADHD.

A study by Calhoun and Mayes (2005) found that children with neurological disorders, such as ADHD, autism, bipolar disorder, and learning disability were more impaired on the Processing Speed Index and Freedom from Distractibility Index of the WISC-III as compared to the Verbal Comprehension Index and Perceptual Organizational Index than were children with anxiety, depression, and oppositional defiant disorder. The authors suggested that processing speed, attention, and writing weaknesses often co-occur in children with neurological disorders, such as ADHD. This is important because individuals with slow processing speed often have problems with learning rate, comprehending new information, performance speed, and mental fatigue (Prifitera, Weiss, & Saklofske, 1998). They also tend to have problems with working memory (Jacobson, et al., 2011). Of note, processing speed is related to working memory performance (Fry & Hale, 2000).

Executive Functioning in ADHD

Children with ADHD often have executive functioning deficits (EF; Barkley, 1997; Barkley, 1998; Chelune, Ferguson, Koon, & Dickey, 1986; Heilman, Voeller, & Nadeau, 1991; Pennington & Ozonoff, 1996; Quay, 1988). EF has been defined as cognitive functions that aid appropriate problem-solving behavior in order to attain a future goal and meet environmental demands (Willcutt, et al., 2001). Key EF components include set-shifting, interference control, response inhibition, planning, and working memory (Martel, Nikolas, & Nigg, 2007). Some believe EF deficits are a major factor in the poor academic performance of ADHD (Daley & Birchwood, 2009).

A meta-analysis (Willcutt, et al., 2005) found significant deficits in planning, spatial and verbal working memory, reaction time, and omission errors, even after controlling for intelligence, reading achievement and symptoms of comorbid disorders. This suggests that the relationship between EF deficits and ADHD is not better explained by group differences on these variables. Moreover, studies suggest that sex differences in EF are not present in ADHD (Seidman et al., 2005).

Barkley (1997) and others found deficits in response inhibition in individuals with ADHD-C. Willcutt and colleagues (2001) discovered that individuals with ADHD displayed significantly worse scores on measures of inhibition, even when controlling for reading disability, intelligence, and other disruptive behavioral disorders. Likewise, a meta-analysis of studies using the Stop Task found consistent deficits in inhibition in ADHD (Oosterlaan & Sergeant, 1998) that were not explainable by IQ, comorbid disorders, or reading disability. Some authors have suggested that performance on measures of response inhibition, such as the SSRT or CPT, may be disparate between subtypes of ADHD (Barkley, 1997; Chhabildas, et al., 2001; Nigg, 2001). This will be elaborated upon subsequently.

Multiple studies have found no differences in cognitive EF performance between ADHD-PI and ADHD-C subtypes, as noted above (Hinshaw, et al., 2002; Martel, Nikolas, & Nigg, 2007; Riccio, et al., 2006). Cognitive weaknesses in EF may be primarily related to the inattention-disorganization domain of ADHD (Sonuga-Barke, 2005), thus affecting both ADHD-PI and ADHD-C. Since diagnoses of both ADHD-C and ADHD-PI require impairment in attention, these subtypes may be similarly impaired in cognitive EF (Martel, Nikolas, & Nigg, 2007). ADHD-C is more likely to have deficits in behavioral EF (inhibition, impulsivity, or overactivity) given diagnostic criteria, and more severe deficits in EF in general as both dimensions are affected in ADHD-C (Martel, Nikolas, & Nigg, 2007). For example, ADHD subtypes differ on the Stop task, with children with ADHD-C performing worse than controls in a study by Nigg (2002). Interestingly, boys with ADHD-PI were not impaired on this task, but girls with ADHD-PI were when compared to controls. This is consistent with the notion that there may be subclinical behavioral regulation deficits in some children with ADHD-PI.

A great deal of research has shown deficits in behavioral regulation in ADHD-C, as noted above. It also has demonstrated working memory deficits in both subtypes of ADHD, as noted in the subsequent section. Nonetheless, the literature is disparate about the presence of deficits in other aspects of EF. For example, Klorman and colleagues (1999) found that children with ADHD-C and ADHD-HI were more impaired than children with ADHD-PI on the Tower of London, a task requiring the participant to plan a series of moves to get colored discs or balls into a predetermined arrangement. These impairments in planning skills were supported by a study by Nigg (2002), but the subtype differences were not as clear. Nigg found significant deficits in planning for children with ADHD-C, not ADHD-PI, compared to controls, but the two subtypes did not differ significantly from each other. Nonetheless, other studies have not found differences in planning deficits by ADHD subtype (Houghton et al., 1999).

When examining problem solving, the findings in the ADHD literature are disparate. In terms of the Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948), which measures planning and set-shifting, some researchers report deficits on the WCST (Romine, et al., 2004) while others find it to be intact in ADHD (Willcutt et al., 2005). Nigg (2002) found impairments on the Trailmaking task (Reitan, 1986), a timed measure of set-shifting, in ADHD-PI but not ADHD-C. Correspondingly, a meta-analysis by Pennington and Ozonoff (1996) suggests that inhibitory control and planning are impaired in ADHD-C but not set-shifting. Nonetheless, more recent research has found deficits in set shifting in ADHD-C (Willcutt et al., 2005). Thus, when examining the literature presented in this section, it is clear that deficits in planning, problem-solving, and set-shifting are inconsistently found in ADHD. This is likely due to the heterogeneity of the disorder, as noted by Nigg (2010).

Nigg (2010) found that EF deficits in ADHD are heterogeneous, with some youth showing problems and others not. A review by Nigg and collegues (2005) found that approximately 20% of children with ADHD-C were not impaired on any measure of EF, and that children with EF weaknesses did not display homogenous deficits (the EF measures affected varied across individuals with ADHD). No more than 51% of the children with ADHD-C in the studies examined were impaired on any one measure of EF (as determined by performance falling below the 10^{th} percentile of control subjects' performance), with performance on timed measures most likely to be impaired. Thus, although ADHD is typically characterized by an array of EF deficits, many children with ADHD display differing impairments and levels of impairment.

Summary

Children with ADHD typically have more academic and behavioral problems than their normally developing counterparts. Although they do not usually present with deficits in simple visual perception and phonological processing, they often exhibit problems with pragmatic language functioning, and ADHD does co-occur with language impairment in semantic/syntactic aspects of language. Children with ADHD also often have slower processing speed and worse spatial processing than their non-ADHD peers. Many researchers find that individuals with ADHD exhibit weaknesses in executive functions, such as planning, inhibition, working memory, reaction time, and set-shifting, but executive weakness findings are disparate in the literature and inconsistent across individuals with ADHD. Cognitive functioning in ADHD was reviewed as visual perception, language, processing speed, and executive functioning are all related to working memory functioning. Working memory functioning in ADHD will be discussed next.

ADHD and Memory

Phonological Loop

In general, the findings on verbal STM and the phonological loop in ADHD are disparate, with some researchers finding deficits and others finding the phonological loop to be intact. It has been suggested that the discrepant findings regarding verbal STM deficits in ADHD may be more related to the comorbid language problems experienced by many individuals with ADHD (Kibby, 2012), as many studies do not report the prevalence rates of comorbid language impairment in their sample. However, a meta-analysis, which controlled for comorbid reading and language problems, found moderate impairments in verbal storage in ADHD (Cohen's *d*

= .47; Martinussen, et al., 2005). However, they did not specify which tasks were used, or how verbal storage deficits varied with type of task used.

Research by individuals who specified tasks suggests that individuals with ADHD may perform comparably to controls on forward digit span, but they are impaired compared to controls on backward digit span (Karatekin, 2004). Forward digit span primarily uses the verbal buffer and subvocal rehearsal mechanism (phonological loop), whereas backward digit span also uses the central executive. This supports the idea that the phonological loop is intact in ADHD, but the central executive may be impaired (see below, Karatekin, 2004). However, in a study by Kibby and Cohen (2008), children with ADHD performed better on Numbers Backward than on Numbers Forward, suggesting that they are able to complete a verbal STM task that is perceived to be sufficiently challenging better than the easier measure, Numbers Forward, which is perhaps perceived to be less challenging and, thus, less interesting or engaging. Thus, the verbal STM deficit when present may be a result of inattention, especially for rote phonetic material that is presented once briefly and requires verbatim repetition (e.g., forward digit span). Their performance on other verbal STM subtests that do not require verbatim repetition and are longer/more forgiving of momentary attention lapses may be intact.

Kibby and Cohen (2008) found verbal short-term memory to be spared on most verbal STM measures in ADHD (using Stories, Word Lists, and Word Pairs from the Children's Memory Scale (CMS); Cohen, 1997). The Stories subtest requires individuals to remember semantically organized material presented orally in story format, and brief lapses in attention can be overcome by encoding the rest of the material, as verbatim recall is not required. Likewise, Word Lists consists of one list of words presented multiple times, and the words do not need to be remembered in serial order. Thus, by the end of the repetitions, many children are able to attend to, and remember, a sufficient number of the words. Additionally, Korkman and Pesonen (1994) found that children with ADHD did not differ from typically developing controls on simple phonological STM tasks. A study by Roodenrys and colleagues (2001) comparing children with dyslexia, comorbid ADHD and dyslexia, and typically developing controls found significant differences between the clinical and control groups on digit and word span tasks, but not between the ADHD/dyslexia and dyslexia groups. This suggests that deficits in the phonological loop were related to the dyslexia, with no unique impairments contributed by the ADHD group. Likewise, others found no differences between children with ADHD and controls in serial recall of words (Benezra and Douglas, 1988) or forward or backward digit span (Shue and Douglas, 1992).

Few studies have examined short-term memory abilities in ADHD subtypes. One such study by O'Donnell (2004) found no significant differences between controls, ADHD-C, or ADHD-PI on WISC-III Digit Span Forward or the California Verbal Learning Test – Children's Version (CVLT-C) List A – Trial 1 (Pearson, 1994). Additionally, a study by Pasini and colleagues (2007) found no differences between controls, ADHD-C, or ADHD-PI boys on the WISC-R Digit Span Forward. A study by Cockcroft (2011) did find a significant difference in verbal STM performance on tasks of digit recall, word recall, and non-word recall between children with ADHD and typically developing controls, but not between ADHD subtypes (ADHD-PI and ADHD-HI). Thus, the limited literature that has examined subtypes individually found no significant differences in performance on verbal STM measures.

In summary, many studies have found the phonological loop to be spared in ADHD, although some studies have found deficits in verbal STM. However, it is unknown how much of the deficits found in this area are due to inattention and/or comorbid language impairment rather than verbal STM per se. The limited research that has been conducted suggests that subtypes of ADHD do not differ in functioning on measures of the phonological loop.

Visual-spatial Sketchpad

Various meta-analytic and empirical studies have shown the visual domain of working memory to be impaired in ADHD more than the verbal domain (d = 0.85; Alloway, 2011; Martinussen, et al., 2005; Rhodes, Park, Seth, & Coghill, 2012; Tillman, et al., 2011). However, one must distinguish between visual-spatial and visual/non-spatial short-term memory given these may be dissociable aspects of the visual-spatial sketchpad (Gathercole, 1994). Kibby and Cohen (2008) found that children with ADHD have intact STM for visual/non-spatial material (CMS Faces Immediate Memory) but impaired visual-spatial STM (CMS Dot Locations, Picture Locations). Likewise, other studies have found deficits in spatial span tasks in children with ADHD (Kempton, et al., 1999; Barnett, et al., 2001). Visual-spatial short-term memory was assessed by Karatekin (2004) using a task where a small dot was presented on a sheet of paper, and the participant was asked to mark the location of the dot on a blank sheet of paper after a delay (zero to 30 seconds). A verbal distracter task was performed during the delay to prevent verbal rehearsal. The ADHD group had significantly greater distance errors than the control group. Nonetheless, a study by Tripp, Ryan, and Peace (2002) did not find significant differences in performance on spatial span tasks between ADHD and control groups, even after controlling for IQ. However, the sample was atypical, in that there was a 20-point IQ difference between the ADHD and control groups, and the mean IQ in the ADHD group was in the Low Average range.

In terms of ADHD subtypes, Pasini and colleagues (2007) found that performance on the Rey-Osterrieth Complex Figure Test (Osterrieth, 1944) and Corsi Block Tapping Test (Corsi, 1972; both measures of visual-spatial STM) was not significantly different between controls, ADHD-C, or ADHD-PI when studying boys and using age and PIQ as covariates. However, Cockcroft (2011) found significant differences between children with ADHD and typically developing controls on dot recall, maze memory, and block recall tasks, but they did not find significant differences in performance between ADHD subtypes (ADHD-PI and ADHD-HI). Nonetheless, Martinussen and Tannock (2006) found greater impairment for ADHD-C than ADHD-PI on spatial storage (tasks unspecified).

Overall, the current evidence suggests that the ADHD subtypes may be commensurate in visual STM performance. In terms of the visual-spatial sketchpad, the visual/non-spatial aspect appears to be intact in ADHD based on the one study found, whereas the visual-spatial aspect appears to be impaired in many. Clearly more research is needed on the visual/non-spatial aspect of the visual-spatial sketchpad in ADHD.

Central Executive

Although there is debate in the literature about the centrality of a working memory deficit to ADHD, recent studies have elaborated on these inconsistencies. Studies by Karatekin (2004) and Martinussen and Tannock (2006) suggest that deficits in ADHD are more pronounced in working memory tasks than in short-term memory tasks, resulting from an insufficiency of the central executive. Thus, studies which do not tap CE functioning are less likely to find WM deficits in ADHD.

In terms of visual-spatial WM, a meta-analysis detected significant effects when spatial working memory was differentiated from simple storage, suggesting that the manipulation of spatial material (the visual-spatial CE) is implicated in ADHD, beyond the deficit of the visual-spatial store (d = 1.14; Martinussen, et al., 2005). Martinussen and colleagues (2005) also found that the visual-spatial CE was more impaired than the verbal CE (tasks unspecified; *d* = 0.43). Another meta-analysis found significant impairments in six out of eight studies on children with ADHD using visual-spatial CE measures (self-ordered pointing and CANAB spatial working memory; d = 0.63; Willcutt, et al., 2005). When contrasting types of visual material, impairment was found on a visual-object (non-spatial) N-back task, but not on a visual-spatial N-back task, in boys with ADHD-C compared to typically developing controls (Pasini, et al., 2007).

As with the phonological loop, findings on the verbal CE are inconsistent in the literature (see Kibby, 2012 for a review), perhaps due to inadequate measurement or because the verbal CE deficit is found primarily in individuals with a comorbid language weakness. With regard to measurement, Roodenrys (2006) found the verbal CE to be impaired, but only on specific tasks. In particular, tasks that required planning/strategizing, attention shifting, and generating random or novel sequences were the most impaired in their sample as opposed to simpler tasks (e.g., list learning, span tasks). Another study by Roodenrys and colleagues (2001) found that children with comorbid ADHD/dyslexia performed more poorly on measures of the verbal central executive that were challenging (e.g., memory updating, random generation tasks) than children with only dyslexia or typically developing controls. This will be elaborated upon subsequently.

A meta-analysis by Willcutt and colleagues (2005) found significant impairments in six out of 11 studies of children with ADHD on verbal CE measures (Working Memory Sentence Span and Digit Span Backward; *d* =.55). Pasini and colleagues (2007) found impairment in a phonological N-back task in boys with ADHD-C when compared to typically developing controls. Moreover, Roodenrys and colleagues (2001) found that children with ADHD and comorbid reading disability performed significantly worse than children with reading disability only and typically developing controls on the Children's Paced Auditory Serial Addition Task

(CHIPASAT), as well as on mentally demanding memory updating and random generation tasks. These results were replicated in a study where children with ADHD were compared to typically developing controls on the CHIPASAT (Siklos & Kerns, 2004). The CHIPASAT aurally presents children with a series of digits, and the children must add each digit to the preceding digit throughout the task. Neither of these studies, however, controlled for mathematical ability.

In terms of subtypes, Martinussen and Tannock (2006) found that inattention symptoms, but not hyperactivity or impulsivity, contributed unique variance in predicting central executive performance on working memory measures. They described impairments of both subtypes (ADHD-PI and ADHD-C) on spatial central executive functioning, but greater impairment for ADHD-C on the verbal central executive. Additionally, a study by Walkowiak (2008) found impairment in both ADHD-C and ADHD-PI compared to controls on the Numbers Reversed and the Auditory Working Memory subtests of the Woodcock-Johnson Test of Cognitive Ability (WJ-Cognitive; Woodcock & Johnson, 1989). Interestingly, she found that the ADHD-C group was more impaired on the Numbers Reversed subtest, and the ADHD-PI group was more impaired on the Auditory Working Memory subtest. The author concluded that the presence of a WM deficit is evident, but the impairments do not seem to be more specific or severe in either subtype. Taken together, these studies support previous research suggesting that both ADHD-PI and ADHD-C subtypes exhibit similar neuropsychological profiles (Chhabildas, Pennington, & Willcutt, 2001; Nigg, Blaskey, Huang-Pollock, & Rappley, 2002), but children with ADHD-C may have more severe neuropsychological impairments than ADHD-PI on some measures (Gadow et al., 2004; Nigg et al., 2002). This may be due to the fact that children with ADHD-C have symptoms of both inattention and hyperactivity/impulsivity dimensions, which may lead to more severe impairment.

Engelhardt, Nigg, Carr, and Ferriera (2008) found that impairments in working memory in ADHD are related to an inability to distribute controlled attention under interference conditions, rather than a limitation in the number of items that can be held in working memory. Other studies suggest that impairments in working memory are related to poor strategy use: when individuals with ADHD were taught to use a strategy, they performed comparably to controls (Cornoldi, Barbieri, Gaiani, & Zocchi, 1999). Roodenrys and colleagues (2001) theorized that children with ADHD may have difficulties modifying and accommodating new input, and they have trouble changing from a simple rehearsal strategy that can be used when no updating is required to a more complex process when they need to update the stored information. It is possible that more than one of these hypotheses is the case (e.g., poor strategy usage along with problems with the CE in allocating attention properly during tasks requiring divided attention).

Long-Term Memory

Few studies have examined long-term memory functioning in children with ADHD. Of those examining long-term memory (LTM), most studies have found LTM to be intact in ADHD, as long as deficits in encoding abilities were controlled (Kaplan, Dewey, Crawford, & Fisher, 1998; Muir-Broaddus, Rosenstein, Medina, & Soderberg, 2002; Plomin & Foch, 1981). No significant differences have been reported in recall compared to recognition of information. Kibby and Cohen (2008) found LTM to be intact in ADHD, regardless of the modality, when they controlled for initial encoding of the material. This was true for both free recall and recognition tasks.

Summary

Research on verbal short-term memory in children with ADHD is inconclusive, but many researchers find it to be intact in ADHD when assessed using measures of simple span, list learning, and semantic short-term memory. Differences in verbal short-term memory between subtypes have not been found consistently. In contrast to verbal short-term memory, visual-spatial short-term memory impairment has been demonstrated in ADHD using measures of spatial span and visual-spatial figure recall. Individuals with ADHD typically are not impaired on measures of visual/non-spatial short-term memory, but the literature on this is sparse. In terms of working memory, or the central executive, most researchers agree on a deficit in both verbal and visual-spatial working memory, with visual-spatial working memory being affected to a greater extent than verbal working memory. Children with ADHD-C and ADHD-PI exhibit similar memory impairments, although some researchers find greater neuropsychological impairment in children with ADHD-C than ADHD-PI. Long-term memory is typically found to be intact in children with ADHD once encoding ability is controlled. Subtypes have not been analyzed in this aspect.

Depression

Depression is a common psychiatric disorder that affects millions of individuals throughout the world (Baune, et al., 2010). Prevalence rates of depression range from 0.4 - 2.5% in children and between 0.4-8.3% in adolescents (Anderson and McGee, 1994; Fleming and Offord, 1990; Kashani et al., 1987; Lewinsohn et al., 1993, 1994). The lifetime prevalence in adolescents ranges from 15-20%, which is comparable to the rate in adult populations (Birmaher, et al., 1996). Mood disorders with an early onset, like those appearing in childhood, may be the most severe form of a mood disorder (Kessler, Avenevoli, & Merikangas, 2001). For children and adolescents who have had a major depressive episode, the probability of recurrence is 40% by two years post-episode and 70% by five years post-episode (Rao et al., 1995).

Diagnosis of Unipolar Depression

Major Depressive Disorder (MDD) is characterized by symptoms of depressed mood (or irritable mood in children), diminished interest in activities that used to be pleasurable (more common in adolescents), significant weight loss or gain (or in children, a failure to make expected weight gains), sleep disturbances, psychomotor agitation or retardation (more common in adolescents), fatigue, feeling worthless or excessively guilty, difficulties in concentration, and/or recurrent thoughts of death or suicidal ideation (APA, 2000). For a diagnosis of MDD, five or more symptoms must be present during the same two-week period, and this must represent a change from previous functioning. Likewise, at least one of the symptoms must be depressed mood, loss of interest or pleasure in things that were formally pleasurable, or, in children, irritability.

Although the diagnostic criteria for MDD in children are the same as those for adults, there is a greater occurrence of irritability rather than depressed mood. This can present as uncooperativeness, apathy, and disinterest (Kashani, Holcomb, & Orvaschel, 1986). In children with MDD, symptoms of separation anxiety, phobias, somatic complaints, and behavioral symptoms may occur more frequently than in adults, (Birmaher, et al., 1996). Additionally, younger children (pre-adolescence) are less likely to report dysphoria or feelings of hopelessness, and are more likely to display depressed affect or appearance than adolescents or adults (Carlson & Kashani, 1988). In contrast, adolescents are more likely to present with symptoms of melancholia, vegetative signs, anhedonia, psychosis, suicide attempts, and increased lethality of the suicide attempt than children. Impairment in functioning also tends to increase in adolescence (Birmaher, et al., 1996).

For dysthymia, irritable or depressed mood must be present for at least one year in children and adolescents (but for two years in adults, APA, 2000). Symptoms may include changes in eating habits, changes in sleep patterns, low energy or fatigue, low self-esteem, poor concentration or difficulty making decisions, and feelings of hopelessness (APA, 2000). According to one study, dysthymic disorder in children differs from MDD in its primary presentation, with it being gloomy thoughts and negative affect (Kovacs, Akiskal, Gatsonis, & Parrone, 1994). Other symptoms, such as feeling unloved, anger, self-deprecation, somatic complaints, anxiety, and disobedience may be present in early onset dysthymia (Kovacs, et al., 1994). Additionally, children with dysthymia often have fewer symptoms of anhedonia, social withdrawal, fatigue, reduced sleep, or poor appetite than children with MDD, although they may still be present (Kovacs, et al., 1994). The prevalence of dysthymia is estimated to range from 0.6 - 1.7% in children and 1.6-8.0% in adolescents (Kashani et al., 1987; Lewinsohn et al., 1993, 1994).

Dysthymia tends to have an earlier age of onset than MDD. It is estimated that 70% of children with dysthymia eventually meet criteria for "double depression," or a diagnosis of both major depression and dysthymia, (Birmaher, et al., 1996). Children who develop double depression typically have their first major depressive episode within two years after the onset of dysthymia (Kovaks et al., 1994). It has been shown that children with this profile are significantly more impaired than children with a single mood disorder diagnosis (Goodman, et al., 2000).

Childhood-onset depression is considered rare; for those that do experience depression in childhood, onset is typically around age 11 for dysthymia and age 14 for MDD (Lewinsohn, et al., 1993). However, some symptoms may manifest earlier but not sufficiently enough to meet diagnostic criteria. MDD occurs at approximately the same rate in male and female children, but in adolescence the rate increases to 2:1 females to males. This adolescent gender ratio is similar to the ratio in adults (Birmaher, et al., 1996). While the reasons for these sex differences are still unclear, they likely can be attributed to genetics, biological changes associated with puberty, an increased prevalence of anxiety disorders in females, a cognitive predisposition, and sociocultural factors (Breslau et al., 1995; Reinherz et al., 1989). For the purposes of this study, the prevalence rates were expected to be similar in boys and girls because the sample is pre-adolescence in age.

Recently, studies also have examined the existence of “subsyndromal” or “subthreshold” depression. In adolescents, it has been shown that individuals who fail to meet complete criteria for a diagnosis of MDD, but still exhibit subclinical depressive symptoms, manifest almost as much psychosocial dysfunction as those who meet criteria for the diagnosis, and that the level of psychosocial impairment correlates positively with the number of depressive symptoms (Lewinsohn, Rhode, & Seeley, 1998). Individuals who fully meet criteria for MDD only differ significantly from those who fail to meet complete criteria by having higher levels of suicidal ideation. This is consistent with adult literature indicating that individuals with subthreshold depression still experience more difficulties in psychosocial functioning than their less-depressed peers (Lewinsohn, et al., 1998). Although some studies have not found executive functioning impairments in children with mild depressive symptoms (Favre, et al., 2009), no studies have examined memory deficits in children with mild or sub-clinical depressive symptoms. Thus, this thesis will focus on depressive symptoms on a continuum as to better represent the spectrum of depressive symptom severity, rather than focusing only on children who meet full DSM-IV criteria for MDD or dysthymia.

Taken together, the research suggests that the severity of an individual's depressive symptoms impacts their performance on neuropsychological measures. Thus, this provides support for measuring depressive symptoms on a continuum in the present study, rather than dichotomously.

Cognitive Deficits in Depression

As the literature on cognitive deficits in depression is limited in children, much of this section will address the adult literature on the topic. Murrough and colleagues (2011) identified two types of cognitive dysfunction in MDD: cognitive biases and cognitive deficits. Cognitive biases are defined as distorted information processing and biased attentional allocation toward negative instead of positive stimuli. These may play a strong contributing role in the development of unipolar depression. In adults with unipolar depression, significant cognitive deficits are found in selective attention and set shifting (Landro, Stiles, & Sletvold, 2001; Purcell et al., 1997), processing speed (Austin, et al., 1999; Emerson, Mollet, & Harrison, 2005), planning and problem solving (Levin, et al., 2007), while many more automatic functions are found to be spared. This will be addressed in more detail next.

In terms of more automatic functions, one early review reported visual perceptual deficits in individuals with depression (Miller, 1975), but the measures used appear to more accurately reflect other constructs. For example, the author reported deficits in recognition of emotional words or common household objects, but the studies cited measured response time for these stimuli, and processing speed is affected in depression (see below). Likewise, the author cites findings of impaired figure rotation, but he suggests that this may be better accounted for by difficulties with set-shifting. After a thorough search of the literature, no studies could be found that examined pure visual perception, perhaps because no one has found a deficit in this area.

Likewise, no studies were found that indicate the presence of a language impairment in depression on untimed tasks or tasks without a working memory or executive demand. However, verbal fluency has been found to be impaired. In a study of depressed adults, Naismith and colleagues (2003) found impairment on a semantic fluency task when compared to non-depressed controls. Similarly, a review by Rogers and colleagues (2004) found consistent impairments in verbal fluency. This may be a result of impaired processing speed or executive functioning, however, and not of deficient language functioning as these tasks are timed and require mental search.

Processing speed is often affected in unipolar depression. For example, Austin and colleagues (1999) found impaired reaction time in hospitalized, depressed adults when compared to controls. A study by Landro, Stiles, and Sletvold (2001) found significant deficits in depressed adults compared to non-depressed controls on a choice reaction time test. A study by Emerson, Mollet, and Harrison (2005) found that boys (age 9-11) with elevated scores on the Child Depression Inventory (CDI) exhibited longer completion time on the Trail Making Test (Form A). However, a study using the Motor Speed subtest of the Delis Kaplan Executive Function System (D-KEFS) found no differences between depressed children and non-depressed controls in a clinical sample on motor speed (Magnis, 2009). As this finding is seemingly inconsistent with diagnostic criteria from the DSM-IV-TR for depression, which include psychomotor agitation or retardation, it should be noted that the comparative population for this study was also from a clinical setting, with most children having a psychological diagnosis other than depression. It may be the case that these other diagnoses are also characterized by psychomotor slowing or that childhood depression has less slowing associated with it than depression of adulthood (Mash & Barkley, 2003).

In terms of executive functioning, set-shifting often is impaired in depressed individuals, although some researchers have found conflicting results (Rogers, et al., 2004). Austin and colleagues (1999) found impairment in hospitalized, depressed adults age 20 and older on the WCST and Trailmaking Test B when compared to controls. Likewise, Merriam, Thase, Haas, Keshavan, and Sweeney (1999) reported significant impairment on the WCST in adults diagnosed with MDD compared to non-depressed controls, and Purcell and colleagues (1997) found impairments in depressed adults on a task of attentional set shifting. These results also have been replicated in children, with one study finding impairment in set-shifting in pre-adolescent boys (Emerson, Mollet, & Harrison, 2005). However, in a study of depressed adults, Landro, Stiles, and Sletvold (2001) did not find significant impairments on Trailmaking Test B when depressed individuals were compared to non-depressed controls.

A review by Rogers and colleagues (2004) found multiple studies showing impairments in planning, as measured by the Tower of London test, in depressed adult populations. However, a study by Naismith and colleagues (2003) did not find significantly impaired performance on the Tower of London in depressed adults when compared to non-depressed controls. The review by Rogers and colleagues also found impairments in depressed adults on timed measures of inhibition, such as the Stroop Color-Word test. Nonetheless, a study of adolescents with MDD found no differences between depressed individuals and controls in behavioral inhibition using the CANTAB battery (Kyte, Goodyer, & Sahakian, 2005).

When analyzing problem-solving, a review by Levin and colleagues (2007) found impaired performance in depressed adults on measures asking participants to generate novel responses and manipulate information. Levin and colleagues found that the depressed individuals were less able to come up with effective strategies or develop alternative solutions to a problem. Naismith and colleagues (2003) found impaired performance in depressed adults compared to non-depressed controls on Raven's Colored Progressive Matrices, a measure of nonverbal problem solving and reasoning. Similarly, Emerson and colleagues (2005) found impaired categorical problem solving in a sample of boys ages 9-11 with elevated depression scores when compared to non-depressed controls.

Thus, taken together, the bulk of the literature suggests that executive functioning is affected in depression, similar to ADHD. Nonetheless, the reason for executive dysfunction in depression may differ from that of ADHD. In depression, executive dysfunction may be due to an overall deficit in effortful processing. While automatic processing tends to be spared in unipolar depression, effortful processing tends to be affected (Cohen, et al., 1982). Porter and colleagues (2007) suggest that impairments are most likely to be found on tasks of attentional control or executive function, corresponding to the great amount effort required for these tasks.

Summary

When depressive symptoms manifest in childhood, these individuals typically present with greater irritability, rather than the depressed mood and anhedonia typically seen in depressed adults. Although childhood-onset depression is rare, many symptoms may present at sub-clinical levels in childhood before full diagnostic criteria are met. Few researchers have examined cognitive deficits in children with unipolar depression. Adults with depressive disorders tend to exhibit the largest deficits on tasks requiring greater amounts of effort, such as those requiring selective attention, set shifting, processing, planning, and problem solving. They also tend to have slower processing speed. More automatic functions, such as visual processing or language functioning, are not found to be impaired when measures are untimed.

Depression and Memory

The research on memory deficits in children with depression is sparse and lacking. Thus, the following articles focus primarily on adults with depression. Any studies that include children will be noted. A limitation of the depression literature is that they do not use a theoretical model of memory similar to Baddeley's, but instead tend to look at the level of effort required for encoding (Bartfai, et al., 1991). Additionally, researchers tend to focus on affective or emotional stimuli rather than using neutral stimuli when studying cognition (Burt, Zembar, & Niederehe, 1995). Hence, it is unknown whether they would have a deficit if neutral stimuli were used. Although used of affective stimuli has special implications in depression research, it is not the focus of this thesis, and, thus, will not be covered.

Phonological Loop

A study by Bartfai and colleagues (1991) reported that depressed individuals have greater difficulty with memory tasks that require sustained effort, such as free recall and list learning, when compared to tasks carried out more automatically, such as simple span tasks. In support of this hypothesis, Landro, Stiles, and Sletvold (2001) did not find significant deficits compared to non-depressed controls on a digit span forward task. However, Gohier and colleagues (2009) did find impaired performance on a digit span forward task, providing evidence of the mixed nature of findings on this subject.

On tasks of list learning, multiple researchers have found deficits, corresponding with the increased difficulty of (long) list encoding and recall as compared to digit span. Wolfe and colleagues (1987) found impairment in unmedicated depressed adults on list recall from the Rey Auditory Verbal Learning Test (RAVLT; Schmidt, 1996), in which individuals are presented with 15 common words five times orally and asked to recall them after each presentation. On recognition trials from the RAVLT, depressed individuals were more likely than controls to incorrectly answer “yes” to items that were not on the original list, suggesting a susceptibility to distracter items. Coughlan and Hollows (1984) also found impairment on a task for which subjects were required to learn a list of 15 words over the course of five trials. Moreover, Kelley and colleagues (2013) found impairment in depressed individuals compared to healthy controls on encoding and recognition of nouns presented in a list format. One study found impaired word list learning on the CVLT in patients with MDD but not sub-clinical depression when compared to controls (Mesholam-Gately, et al., 2012). Thus, when lists are long, several researchers have found deficits in STM in depressed individuals.

Few studies were found that examined STM for semantically-coded material. A meta-analysis by McDermott and colleagues (2009) reported no significant impairment in semantic memory, which they measured using the Semantic Fluency Test (d = -0.11). Coughlan and Hollows (1984) also reported intact performance on a story recall measure. This may correspond to a lesser amount of effort required to encode material that is semantically organized already as opposed to rote lists.

Visual-Spatial Sketchpad

Similar to verbal STM, studies have found impairment in effortful visual-spatial STM tasks. A meta-analysis found greater impairments on the Rey-Osterrieth Complex Figure Test immediate reproduction (d=-1.02) than on the Wechsler Memory Scale – Revised Visual Reproduction I (d=-0.71) or the Benton Visual Retention Test (0.39), perhaps corresponding to the level of complexity/effort required to learn and reproduce each measure as the Rey uses a more complex figure (Zakzanis, Leach, & Kaplan, 1998), or to the Rey having greater spatial demands. Another study found a significant impairment in a design-learning task, in which subjects were shown a design for ten seconds during four trials and then had to reproduce it on a grid after each exposure (Coughlan & Hollows, 1984).

In contrast, a study by Tavares and colleagues (2007) failed to find impairment in depressed adults compared to controls on tasks of spatial span or spatial recognition where reproduction demands were less than the tasks described above. A meta-analysis by McDermott and colleagues (2009) did not find significant impairment on tasks of spatial recognition or pattern recognition (r = -0.17). Other studies found no impairment on measures of spatial span or pattern recognition from the CANTAB (Weiland-Fiedler, et al., 2004) or on a figure recall task (Coughlan & Hollows, 1984).

Coughlan and Hollows (1984) found recognition memory for faces to be unimpaired, suggesting intact visual-nonspatial memory. This may be influenced by the format of the stimuli (recognition instead of recall), however, which is more likely to be intact since it requires less effortful processing. No other studies examining visual-nonspatial memory in depressed individuals were found, other than those cited in the preceding paragraphs. Thus, it appears that visual-spatial and visual/non-spatial STM may be intact when recognition testing or span testing is used. However, when greater reproduction is required, their performance appears to deteriorate.

Central Executive

Although relatively few studies have found impairment in the phonological loop or visual-spatial sketchpad in depressed individuals when using simple span tasks, many researchers have found deficits in WM when effortful processing is required (Zakzanis, Leach, & Kaplan, 1998; Gualtieri, Johnson, & Benedict, 2006; Channon, Baker, & Robertson, 1993). A meta-analysis by Zakzanis and colleagues (1998) suggested that tasks requiring more effortful processing were more impaired in adults with depression than less effortful tasks. For example, significant impairments were found on the Arithmetic subtest of the WAIS-R (-0.89). Landro and colleagues (2001) and Andersson and colleagues (2010) found impairment compared to non-depressed controls on the Paced Auditory Serial Addition Test (PASAT), in which subjects were required to add pairs of successive numbers, with digits being presented in two- or four-second intervals. Studies also have found deficits in depressed participants compared to non-depressed controls on backward digit span (Channon, et al., 1993) and a letter-number sequencing task (Andersson, et al., 2010). Moreover, Weiland-Fiedler and colleagues (2004) found impairment on a spatial working memory task from the CANTAB, in which subjects were required to search for hidden "tokens" within a spatial array and were penalized for returning to squares under which they had already looked. A study found impairments on a visual recall (n-back) task, in which the subject was required to press a button corresponding to the location of a dot they had seen one, two, or three trials previously (Rose & Ebmeier, 2006). In contrast, the meta-analysis by Zakzanis and colleagues (1998) found minimal effect sizes on the Digit Span (both Forward and Backward) subtest of the WAIS-R and on the PASAT. Thus, although there is some discrepancy, most recent research concluded that depressed individuals have greater difficulty on tasks of requiring more demanding encoding and retrieval.

Gotlib and Joormann (2010) theorized that there is a finite amount of resources available for cognitive operations, and that a depressed state either consumes or reduces these resources. They suggest that resources are used by task-irrelevant emotional processing, leading to greater impairment on effortful tasks. Furthermore, they suggested that impairments in working memory were due to a deficit in the removal of irrelevant negative material from working memory. Other studies have found that depressed individuals have difficulty inhibiting the processing of irrelevant information (Hertel, 2004) or with paying attention to, or concentrating on, the task at hand (Mathews & MacLeod, 2005).

Hasher and colleagues (1999) suggested that, for working memory to be most efficient, an individual must be able to both: (1) limit the amount of information that goes into working memory; and (2) update the contents of working memory by removing information that is no longer pertinent. When this process doesn't function properly, the individual links important information with irrelevant details, and this connection is stored. This makes retrieval slower and less accurate, and makes an individual more likely to retrieve irrelevant information. These individuals are more likely to keep unimportant information in working memory longer, which can disrupt a coherent thought process (Hasher, et al., 1999). Regardless of which of these proposed etiologies is correct, individuals with depression appear to have deficits in the central executive.

Long-Term Memory

In terms of verbal long-term memory, deficits have been found in both retrieval and recall. For example, Landro and colleagues (2001) found significant impairment in long-term recall compared to non-depressed controls on the Randt Memory Test, which consists of subtests measuring list learning, associative learning, and story memorization, all of which the subject is asked to recall 24 hours after stimulus presentation. In contrast, a study by Mesholam-Gately and colleagues (2012) found that individuals with MDD showed significantly better performance on a delayed recall trial of the CVLT when provided with recognition prompts than they did without the prompts. The authors suggest that this supports evidence of a retrieval deficit in MDD, and that when the task is made less effortful via recognition testing, depressed individuals are able to perform more comparably to controls.

When studying visual long-term memory, a study using the Kimura Recurring Recognition Figures Test, a measure in which individuals are asked to discriminate between figures they have and have not seen before, failed to find significant differences between depressed and control groups (Landro, Styles, & Sletvold, 2001). This task has no reproduction demands. In contrast, a meta-analysis found moderate impairment on the Wechsler Memory Scale – Revised Visual Reproduction II (*d*=-0.67) and the Rey-Osterrieth Complex Figure delayed reproduction (*d*=-0.63; Zakzanis & colleagues, 1998) tests. As these tasks are both measures of free recall/retrieval, these findings are consistent with those for verbal long-term memory, showing greater deficits for retrieval than recognition. Both have tasks reproduction demands as well, consistent with the findings on STM discussed above.

Summary

Individuals with depression typically present with short-term memory deficits on tasks that are considered effortful. This includes measures of central executive functioning and measures of short-term memory that are rote and lengthy. Researchers typically do not find deficits on tasks measuring simple span or recognition, but they are more likely to find impairment on tasks of recall, both verbal and visual, particularly when the material is complex. This is true for both short-term memory and long-term memory.

Depression and ADHD

Depression and ADHD have been estimated to co-occur in 12-50% of cases of ADHD, a rate over five times higher than in children and adolescents without ADHD, based on a review of studies with community samples (Angold et al., 1999). Rates are even higher in clinical samples (Pliska, 1998). Compared to children and adolescents with MDD alone, youth with MDD and ADHD have earlier onsets and longer durations of depressive episodes (Biederman, et al., 2008), greater episode recurrence (Biederman, et al., 2008), higher rates of suicidality and hospitalization (Biederman, et al., 2008), and higher overall health care costs (Fishman, et al., 2007).

Longitudinal research is consistent with these findings. For example, a 13-year follow-up study found that children ages 4-12 with ADHD were more likely to qualify for a diagnosis of MDD during adolescence or young adulthood (17%) than were controls (4%; Fischer, Barkley, Smallish, & Fletcher, 2002). Moreover, children diagnosed with ADHD by ages 4-6 were more likely than controls to develop MDD or dysthymia or to attempt suicide by the age of 18 (Chronis-Tuscano, et al., 2010). All subtypes of ADHD in the young children significantly predicted depression and/or suicide attempts 5 to 13 years later in adolescence. Females were at a greater risk for depression and suicide attempts than males (Chronis-Tuscano, et al., 2010). A review by Biederman, Newcorn, and Sprich (1991) reported that attention deficit disorder (ADD) and MDD shared common familial risk factors: the risk of MDD among relatives of an individual with ADD was significantly higher than the risk for relatives of control children.

In terms of ADHD subtypes, one study found that the inattention dimension (children with ADHD-C or ADHD-PI) predicted depression compared to controls, but the hyperactive/impulsive dimension (children with ADHD-C or ADHD-HI) predicted suicide attempts compared to controls. This may reflect the impact of impulsivity on suicidal behavior (McGirr, Renaud, Bureau, Seguin, Lesage, & Turecki, 2008). A study by Power and colleagues (2004) found no significant differences in levels of depression between ADHD subtypes, but this could be related to the inattention present across subtypes. Nonetheless, some research suggests that there are differences within the ADHD-PI group: individuals with inattention with a high sluggish cognitive tempo may have elevated levels of anxiety, depression, and withdrawal compared to inattention without sluggish cognitive tempo (Carlson & Mann, 2002). This may explain the heterogeneity in findings related to ADHD and internalizing disorders.

In their examination of cognitive functioning, Günther and colleagues (2011) did not find a significant difference on neuropsychological measures between children with ADHD and children with ADHD and comorbid depression. Tasks used measured sustained attention, inhibition, and set-shifting, but they did not measure memory. Günther and colleagues (2011)'s study included children with mild to moderate depression. Likewise, Mayes and colleagues (2009) found that performance on measures of IQ (WISC or WASI), academic achievement (WIAT or WIAT-II), attention (Gordon Diagnostic System), graphomotor ability (Beery-VMI), and processing speed (Symbol Search from the WISC-III or WISC-IV) was not significantly different between groups of children with ADHD alone or ADHD and anxiety/depression. However, their study only included an "anxious/depressed" group and did not analyze the performance of children with ADHD and only anxiety or depression. In contrast, Favre and colleagues (2009) found that a group of participants diagnosed with both ADHD and comorbid MDD performed significantly worse on the WCST and Trail Making Test – Part B than did subjects with MDD without ADHD. Studies comparing ADHD, depression and both disorders on visual perception and language measures were not found.

Summary

Depression and ADHD co-occur to a much higher extent than one would expect based on the prevalence rates of either disorder alone. Few researchers have examined cognitive impairments in children with comorbid ADHD and depression. The existing research is inconclusive regarding additive deficits in the comorbid condition, but the scarcity of the literature suggests that further research needs to be conducted before drawing definitive conclusions.

Depression, ADHD, and Memory

The literature is sparse on memory deficits in children with comorbid depression and ADHD. A study by Gardner (2012) found no significant differences in performance on measures of verbal or visual working memory, using the Wide Range Assessment of Memory and Learning – Second Edition (WRAML-2), between children with ADHD and children with ADHD and depression. However, this study did not include a non-ADHD control group, and, thus, it was difficult to determine the level of impairment found in either group. Two studies examined working memory performance in children with ADHD compared to children with ADHD and anxiety or depression (Mayes, et al., 2009; Piper, 2006). Significant differences between groups were not found in either study; however, it is impossible to determine whether or not these findings would have been different had the authors differentiated between internalizing diagnoses.

Purpose of the Current Study

In order to address this limitation in the literature, the current study analyzed children's memory abilities in relation to symptom levels of depression, inattention, and hyperactivity. The current study examined available aspects of memory functioning, as a pre-existing data source was used (Dr. Kibby's Child-Clinical Neuropsychology Lab database, which will be described more in the Methods section). These memory modalities included verbal short-term memory, visual short-term memory, verbal working memory, and verbal long-term memory. Because the database did not have a measure of visual-spatial working memory on a sufficient number of subjects (less than half of the database), it was not included in this study. The sample consisted of 148 children recruited from southern Illinois and eastern Washington state between the ages of 8 and 12 years.

This study contributed to the existing literature in multiple ways. First, it added to the limited research on depression in relation to memory functioning in childhood. Second, it analyzed both depression and ADHD from a continuum perspective, which enhanced the literature on both topics. The literature on ADHD and the literature on depression tend to focus on the disorders at the group level, and by focusing on the symptoms on a continuum, the present study was able to characterize the entire dimension of symptoms.

Hypotheses

Hypothesis 1

For measures of verbal short-term memory (CMS Numbers Forward, CMS Stories Immediate Recall, CMS Word Lists Learning), small, non-significant correlations were expected between memory functioning and levels of inattention and hyperactivity. In contrast, level of depressive symptoms was expected to be significantly negatively correlated with performance on a task that requires more effortful encoding (Word Lists Learning) in contrast to less effortful ones (Stories, Numbers Forward).

Hypothesis 2

For measures of visual-spatial short-term memory (CMS Picture Locations, CMS Dot Locations Learning), level of inattention was predicted to be negatively correlated with the spatial memory measures (Picture Locations, Dot Locations Learning). This was not anticipated on a measure of visual/non-spatial short-term memory (TVPS Visual Memory). Level of depression symptoms was predicted to be significantly negatively correlated with a measure requiring greater reproduction, Dot Locations, which was believed to be more effortful than the other visual short-term memory measures. However, this was not expected on a measure of visual/non-spatial short-term memory (TVPS Visual Memory), which uses a recognition format, and on a measure of simple span (Picture Locations), as these are believed to be less effortful.

Hypothesis 3

In terms of verbal working memory, inattention and hyperactivity symptoms were predicted to be negatively correlated with both measures of verbal working memory (CMS Numbers Backward, CMS Sequences). Likewise, level of depressive symptoms was expected to be negatively correlated with working memory measures because of the level of effort required.

Hypothesis 4

In terms of long-term memory (CMS Word Lists Delayed Recall and Delayed Recognition, CMS Stories Delayed Recall and Delayed Recognition), no relations were expected between these measures and levels of inattention and hyperactivity symptoms, once ability to encode the information was controlled. In contrast, level of depression was hypothesized to be negatively correlated with measures of recall but not recognition, as recognition is less effortful.

CHAPTER 3

METHODS

Participants

Participants for the current study were recruited via larger, NIH-funded projects (R03 HD048752, R15 HD065627), which examined neuropsychological characteristics of children with Attention-Deficit/Hyperactivity Disorder (ADHD), children with reading disability (RD), children with comorbid ADHD and RD, and typically developing controls. All children were between 8 and 12 years of age. Children were recruited from local schools, through referrals from physicians and psychologists, and through flyers and media advertisements. As compensation for participating in the larger study, families received a comprehensive neuropsychological evaluation with a diagnosis, if warranted, thorough descriptions of their child's cognitive/academic strengths and weaknesses, and recommendations to help the child better succeed at home and at school. A total of 269 children from Southern Illinois, Eastern Washington, and the surrounding communities had participated in the larger study at the time of the current study. The sample for the present study is comprised of 148 children (see exclusion criteria below), and is 90% Caucasian and 53% male. See Table 1 for demographic statistics.

For the purposes of the larger study, children were screened twice: once at intake and again after the neuropsychological battery was administered. Children who completed testing were excluded from the present study if they had a history of medical or neurological disorders (e.g., traumatic brain injury, tics, immune disorders), any significant pre- or post-natal complications (e.g., prematurity, low birth weight, or birth trauma), or severe environmental problems (e.g., suspected abuse) (N=18). Children who achieved a best estimate of intelligence below 80 also were excluded from the present study (N=3). A child's best estimate of intelligence was defined as the Full Scale Intelligence Quotient (FSIQ) when no significant discrepancies between factors existed; the General Ability Index (GAI) when the Verbal Comprehension Index (VCI) and Perceptual Reasoning Index (PRI) were commensurate and either the Processing Speed Index (PSI) or Working Memory Index (WMI) was significantly worse than the VCI or PRI; or as the VCI or PRI/POI when a significant discrepancy existed between the VCI and PRI or VCI and POI. Furthermore, children with RD (N=54) or comorbid ADHD/RD (N=34) were excluded, as children with RD often present with a separate set of memory deficits. Children with any form of language disorder also were excluded from the present study, as their difficulty comprehending and encoding verbal material would interfere with the verbal memory measures (N=25). It should be noted that multiple children met more than one exclusionary criterion.

Measures

Behavior Assessment System for Children – Second Edition (BASC-2, Reynolds & Kamphaus, 2004)

The BASC-2 is a set of questionnaires that assess a child's internalizing and externalizing behaviors, as well as their adaptive functioning, in multiple settings. In the larger study, the Parent Report Scale (PRS) and the Teacher Report Scale (TRS) were used to assess functioning at home and at school, respectively. For the purposes of this study, only the PRS report of symptoms was used, as parents see their children in multiple settings and are generally considered to be better reporters of internalizing symptoms than teachers (Youngstrom, Loeber, & Stouthamer-Loeber, 2000). Moreover, the TRS was missing on several children who were tested over the summer. The questionnaires are divided by age group: preschool (2-5), school-age (6-11), and adolescence (12-21). Only the school-age and adolescence forms were used for the larger study. Gender-appropriate norms were used for this study. For the PRS, reliability was obtained on a combined gender sample of children ages 8-11 (child form) and ages 12-14 (adolescent form). BASC-2 subscale scores are reported as T-scores, with a mean of 50 and a standard deviation of 10. For the purposes of this study, only the Attention Problems, Hyperactivity, Depression, and Withdrawal scales were used. Percentages of children who fell into the Normal, At-Risk, and Clinically Significant ranges are reported in Table 4.

The Attention Problems and Hyperactivity subscales of the BASC-2 were used to assess ADHD symptoms on a continuum. The Attention Problems subscale measures common symptoms of the inattention dimension of ADHD (e.g., the tendency to be easily distracted and unable to concentrate for long periods of time). The Attention Problems subscale has alpha reliability coefficients of .87 for children and .88 for adolescents on the PRS. Concurrent validity with the Child Behavior Checklist (CBCL; Achenbach, 1991) Attention Problems subscale is .62 (Vaughn, Riccio, Hynd, & Hall, 1997). The Hyperactivity subscale measures symptoms common to the hyperactive/impulsive dimension of ADHD (e.g., the tendency to be overly active, to rush through work or activities, and to act without thinking). This subscale has alpha reliability coefficients of .86 for children and .82 for adolescents on the PRS. Concurrent validity with the CBCL Attention Problems subscale is .71 (Vaughn, et al., 1997).

The Depression and Withdrawal scales of the BASC-2 will be used to assess depression severity. The Depression subscale measures symptoms commonly seen in depressed children and adolescents, including feelings of unhappiness, sadness, or stress, which may result in an inability to carry out everyday activities. The Withdrawal subscale measures the tendency to avoid others and social situations, which are common symptoms in depression (Mash & Barkley, 2003). On the PRS, the Depression subscale has alpha reliability coefficients of .88 for children and .86 for adolescents. Concurrent Validity with the CBCL Anxiety/Depression subscale is .70 (Vaughn, et al., 1997). The Withdrawal subscale has alpha reliability coefficients of .81 for children and .82 for adolescents. Concurrent validity with the CBCL Withdrawal subscale is .55 (Vaughn, et al., 1997). An average of the Depression and Withdrawal scales was used to represent depressive symptoms, in order to more widely capture the spectrum of childhood depressive symptoms.

Wechsler Intelligence Scale for Children – Third Edition (WISC-III; Wechsler, 1991)

The WISC-III was administered to a subset of children at the onset of the study as a measure of their intelligence, and was used in the current study to determine the best estimate of intelligence for exclusion criteria. The Full-Scale Intelligence Quotient (FSIQ) is calculated from four index scores measuring unique aspects of intelligence: Verbal Comprehension Index (VCI), Perceptual Organization Index (POI), Freedom from Distractibility Index (FDI), and Processing Speed Index (PSI). All Index scores have a mean of 100 and a standard deviation of 15. Individual subtest scores have a mean of 10 and a standard deviation of 3. Forty-six children from the current study were evaluated using the WISC-III.

The FSIQ of the WISC-III has a concurrent validity correlation of .96 with the previous version, the WISC-R (Wechsler, 1991; Wechsler, 1994). The test-retest reliability coefficient for the FSIQ in a sample of children ages 10-11 is .95. The VCI measures verbal reasoning and acquired knowledge, and is comprised of the following subtests: Information, Similarities, Vocabulary, and Comprehension. The VCI has a split-half reliability for children and adolescents ages 6-16 of .94, and a test-retest reliability for children ages 10-11 of .93. The POI, which measures nonverbal reasoning and visual-spatial processing, is comprised of the following subtests: Picture Completion, Picture Arrangement, Block Design, and Object Assembly. The POI has a split-half reliability for children and adolescents ages 6-16 of .90 and a test-retest reliability for children ages 10-11 of .87. The FDI, which measures verbal working memory and focused auditory attention, is comprised of the Arithmetic and Digit Span subtests. The split-half reliability of the FDI for children ages 6-16 is .87, and the test-retest reliability for children ages 10-11 is .86. The PSI, which measures information processing speed, is comprised of the Coding and Symbol Search subtests. The split-half reliability of the PSI for children ages 6-16 is .85, and the test-retest reliability for children ages 10-11 is .85.

Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV; Wechsler, 2004)

The WISC-IV was administered from 2006 to 2013 as a measure of cognitive ability (Wechsler, 2004), and was used in the current study to determine the best estimate of intelligence for exclusion criteria. Similar to the WISC-III, a Full-Scale Intelligence Quotient (FSIQ) is derived from scores on the Verbal Comprehension Index (VCI), the Perceptual Reasoning Index (PRI), the Working Memory Index (WMI), and the Processing Speed Index (PSI). The FSIQ of the WISC-IV has a concurrent validity correlation of .89 with the preceding edition, the WISC-III. The WISC-IV FSIQ has a test-retest reliability of .93. The VCI measures verbal reasoning and acquired knowledge, and is composed of the following subtests: Similarities, Vocabulary, and Comprehension. The internal consistency coefficient of the VCI is .94, and its concurrent validity with the WISC-III VCI is .88 (Flanagan & Kaufman, 2004). The PRI measures nonverbal reasoning and visual-spatial processing, and is comprised of the following subtests: Block Design, Matrix Reasoning, and Picture Concepts. The PRI has an internal consistency coefficient of .92, and a concurrent validity with the WISC-III POI of .72 (Flanagan & Kaufman, 2004). The WMI measures verbal working memory and focused auditory attention, and is comprised of the Digit Span and Letter-Number Sequencing subtests. The WMI has an internal consistency coefficient of .92, and a concurrent validity with the WISC-III FDI of .72 (Williams, Weiss, & Rolfhus, 2003). The PSI measures information processing speed, and is comprised of the Coding and Symbol Search subtests. The PSI has an internal consistency coefficient of .86, and a concurrent validity with the WISC-III PSI of .81 (Williams, Weiss, & Rolfhus, 2003). As noted previously, the WISC was used to exclude children who had mental retardation or borderline intellectual deficiency because they are associated with memory deficits, as well as deficits in multiple other areas of cognition.

Test of Visual-Perceptual Skills – Revised (TVPS-R, Gardner, 1996)

The TVPS-R was used to measure a child's visual-perceptual and visual STM skills. One subtest of the TVPS-R was used for this study, Visual Memory. The Visual Memory subtest assesses a child's ability to learn complex, novel geometric forms during a five-second presentation and then select the correct form out of an array of similar choices. The split-half reliability of the Visual Memory subtest is between .30-.58 for children ages 8-12, with a total group reliability coefficient of .80. Visual Memory has a concurrent validity with the WISC-III VIQ of .28, and .35 with the WISC-III PIQ. It was used as a visual/non-spatial measure of the visual-spatial sketchpad.

Children's Memory Scale (CMS; Cohen, 1997)

The CMS was used to assess learning and memory functioning (Cohen, 1997). It consists of multiple subtests, and the following were used for the purposes of this study: Stories, Word Lists, Numbers, Sequences, Dot Locations, and Picture Locations. Stories assesses the child's ability to learn and recall semantically organized verbal material (contains two different stories). It consists of an immediate recall, delayed recall, and delayed recognition portions. The immediate recall portion was used as a measure of the phonological loop. Split-half reliability for children ages 8-12 years is between .71-.78 for Stories Immediate Recall, .71-.80 for Stories Delayed Recall, and .74-.77 for Stories Delayed Recognition.

Word Lists measures a child's ability to learn and recall a list of unrelated words over four learning trials. A selective reminding procedure is used, in which the child is told the words that they missed on each trial, but the words that they recalled correctly are not repeated for them, and any incorrect words are not corrected. Hence, they need to update their short-term memory of the list with the new words provided, along with retaining the words they already recited on the previous trial. This test measures the phonological loop as well as the central executive to some extent due to the mild updating demands of the task. It also consists of an immediate recall, delayed recall, and delayed recognition portions. The split-half reliability of Word Lists for children ages 8-12 is between .81-.89. Both Stories Immediate and Word Lists Learning go into the CMS Verbal Immediate Index, which has a concurrent validity with the WISC-IV FSIQ of .56. Stories Delayed Recognition and Word Lists Delayed Recognition load onto the CMS Verbal Delayed Index, which has a concurrent validity with the WISC-IV FSIQ of .63. Stories Delayed Recognition and Word Lists Delayed Recognition load onto the Delayed Recognition Index of the CMS, which has a concurrent validity with the WISC-IV FSIQ of .48 (Drozdick, Holdnack, Rolfhus, & Weiss, 2008). These correlations are where expected when one considers the tests measure overlapping but dissociable constructs.

The Numbers subtest assesses a child's ability to repeat digit sequences of increasing length. In the Forward portion, the child must repeat the digits in the same sequence in which they were presented. This was used as a measure of the phonological loop. In the Backward portion, the child must repeat the digits in the reverse order in which they were presented. This was used as a measure of the central executive. The split-half reliability of Numbers Forward for children ages 8-12 is between .71-.80, and is between .66-.80 for Numbers Backward.

The Sequences subtest measures a child's ability to mentally manipulate and sequence auditory information as quickly as possible (e.g., saying the days of the week backward, the months of the year backward). This was used as a measure of the central executive. The split-half reliability of Sequences for children ages 8-12 is between .81-.85. Numbers and Sequences both go into the Attention/Concentration Index of the CMS, which has a concurrent validity with the WISC-IV FSIQ of .72 (Drozdick, et al., 2008).

Dot Locations measures a child's ability to learn the spatial locations of an array of dots over three learning trials presented for 5 seconds each. The current study used the learning score, which is an immediate recall score based on the three trials, and the long delay recall score. There is no recognition measure for this subtest. The learning score is a visual-spatial measure of the visual-spatial sketchpad. The split-half reliability for children ages 8-12 is between .61-.76 for Dot Locations Learning.

Picture Locations assesses a child's immediate visual-spatial short-term memory span for objects presented once for 2 seconds. The number of objects presented gradually increases over trials, similar to Numbers Forward. Thus, it was used as a visual-spatial measure of the visual-spatial sketchpad. The split-half reliability for children ages 8-12 for the Picture Locations subtest is between .67-.81. Picture Locations and Dot Locations go into the Visual Immediate Index of the CMS, which has a concurrent validity with the WISC-IV FSIQ of .34 (Drozdick, et al., 2008). This lower correlation is expected when one considers that there is no measure similar to Picture Locations on the WISC core battery.

Procedure

All procedures were approved by the Institutional Review Board of Southern Illinois University – Carbondale before the study commenced, as well as throughout data collection. Parents or legal guardians provided informed consent for all children who participated in the study. In addition, each child provided informed assent. All children participated in a full day of neuropsychological testing using a fixed battery. Any individuals who were regularly on psychostimulant medication for ADHD were off medication on the day of testing. Prior to the testing day, parents and teachers of each child completed several questionnaires, including the BASC-2 PRS. At the completion of testing, each child received a t-shirt, and parents later received a comprehensive neuropsychological evaluation, including recommendations for accommodations and a diagnosis if one was warranted. Assessments were administered by student examiners, who were trained by upper-level graduate students and verified by Dr. Michelle Kibby. All measures were double checked for scoring accuracy.

CHAPTER 4

RESULTS

Preliminary Results

All variables were tested for skewness and kurtosis and were transformed if the skewness or kurtosis z-scores were greater than an absolute value of 3, using logarithmic, inverse, and quadratic transformations. Square root transformations were initially attempted to correct positive skew, but when these were not sufficient, logarithmic and inverse transformations were performed. A quadratic transformation was used on one variable to correct negative skew. See Table 2 for skewness and kurtosis values. After variables were transformed, all variables were transformed to z-scores to compare performance across measures.

Independent variables included the BASC-PRS Attention Problems score (z-score), the BASC-PRS Hyperactivity score (natural log, z-score), and the average of the BASC-PRS Depression and Withdrawal z-scores. The average of the parent ratings of depression and withdrawal was chosen as the measure of depressive symptoms based upon comparison of Pearson correlations between Depression, Withdrawal and the average of the two with memory functioning, because the literature is not set on the best definition of depression from a dimensional perspective. Although some literature indicates that self-report is the best estimate of internalizing symptoms in children and adolescents (Youngstrom, Loeber, & Stouthamer-Loeber, 2000), a valid self-report measure was not available, and thus parent ratings were used. Nonetheless, clinical depression often includes symptoms of social withdrawal along with dysphoria/irritability in children (Mash & Barkley, 2003). Dependent measures included subtests from the CMS and TVPS that varied by analysis based upon the hypothesis tested. See

Table 3 for means and standard deviations of independent and dependent variables (prior to transformations). See Table 4 for percentages of children that fell into the Normal, At-Risk, and Clinically Significant ranges for each independent variable (prior to transformations).

Results

A canonical correlation analysis was run in SPSS 20 to assess psychological symptoms' correlations with memory performance. This method was used as it allowed for the inclusion of multiple independent and dependent continuous variables, which was not possible using MANOVA or multiple regression. By using canonical correlation, the current study was able to determine if correlations between sets of variables were significant while taking into account correlations within sets. Using canonical correlation also served as a test to ensure correlations between sets were significant before reviewing several multiple regression results. For all analyses, Attention Problems, Hyperactivity, and the depression measure were used as independent variables, as noted above.

For each canonical correlation, the output was examined as follows. The significance of Wilks' Lambda was used to determine the significance of the correlation between the sets of memory and depression variables. If the value of Wilks' Lambda was determined to be significantly different from zero, the remainder of the output was examined. The canonical correlation statistic and eigenvalue (squared canonical correlation statistic) were examined for each root, and the significance of the roots was determined. For all analyses performed, only the first root (if any) revealed a significant canonical relationship, and thus the other roots were not examined. If the first root depicted a significant correlation between sets, the standardized canonical coefficients for the first variate for each set were examined. The standardized canonical coefficients are similar to factor loadings in a factor analysis, and indicate the strength of the relationship each individual variable has with its variate set. The canonical loadings for the first root were also examined. The canonical loadings indicate the simple linear correlation between each variable and its respective canonical variate.

Next, the percentage of variance explained by each set was examined. The output reports the variance for each set of variables (independent and dependent, or psychological and memory) accounted for by their own set and by the opposite set. The percentage of variance of the variables explained by their own canonical variate indicates the shared variance, and the percentage of variance of the variables explained by the opposite canonical variate indicates redundancy.

The canonical output also gives separate multiple regressions for each dependent variable. These were examined for each analysis as a follow-up to the canonical correlation for significant analyses and in an exploratory fashion for nonsignificant canonical analyses. These multiple regressions are similar to standard multiple regressions, but the degrees of freedom are restricted by the number of subjects used in the canonical correlation analysis: if a subject was missing data for any variable, it was excluded from the entire analysis. Therefore, in some instances, a follow-up multiple regression was performed with dependent variables that had independent variables approaching significance as predictors. This was done to maximize power and to include as many subjects as possible in the analysis.

Hypothesis 1: Verbal short-term memory

The dependent variables included z-scores for Numbers Forward, Stories Immediate Recall, and Word Lists Learning from the CMS (Table 5). The canonical correlation was not significant, Wilks' lambda = 0.92, $F(9, 338.44) = 1.25$, $p = .262$ (Table 6).

Given low power, the multiple regressions included in the canonical output were examined in an exploratory fashion for each dependent variable (Table 7). This analysis revealed that Attention Problems had a trend towards significance with Numbers Forward. Thus, an exploratory multiple regression was performed to see if Numbers Forward was significantly predicted by psychological symptoms when used alone as the dependent variable in an analysis (Table 8). The findings remained nonsignificant ($F(3, 141) = 1.31$, $p = .274$). The individual coefficients were also insignificant, although attention problems had a trend toward significance ($B = -0.23$, $p = .056$).

Hypothesis 2: Visual short-term memory

The dependent variables for Hypothesis 2 included z-scores for CMS Dot Locations, CMS Picture Locations, and TVPS Visual Memory (squared; Table 9). The canonical correlation was significant, indicating a relationship between visual short-term memory skills and psychological symptoms, Wilks' lambda = .88, $F(9, 318.97) = 1.92$, $p = .049$ (Table 10).

The canonical correlation analysis yielded three functions, each composed of two sets of variates. Function 1 accounted for 74.71% of the total shared variance across sets, with 9% total variance explained (Canonical R^2; Table 10). The first function, which was comprised of variate 1 from both sets, was likely driving the significant relationship between sets as functions 2-3 were not significant (*p*s > .10; Table 10). Function 1 typically explains the most variance within set in canonical correlation.

For variate 1 of the memory variables, the standardized canonical coefficients were as follows: TVPS Visual Memory, $R = -0.32$, Dot Locations, $R = 0.97$, Picture Locations, $R = 0.20$ (Table 12). The standardized canonical coefficients can be interpreted similarly to factor loadings in a factor analysis, with greater magnitudes indicating stronger loadings onto the variate. This indicates that the first root for the memory variables was driven primarily by Dot Locations. Moreover, the first root for the memory variables accounted for 36.33% of within set variance and 3.29% of the variance in the psychological variables (Table 11).

Additionally, depressive symptoms (inverse) had the greatest contribution to the first root for the psychological variables (R = -0.80), followed closely by attention problems (R = -0.73). In contrast, hyperactivity (natural log) had a smaller contribution (R = -0.42; Table 12). The first root for the psychological variables explained 30.64% of within-set variance and 2.77% of the variance in the memory set (Table 11).

When the multiple regressions from the canonical correlation output were examined next in the SPSS printout, scores for Dot Locations were significantly predicted by a combination of attention problems, hyperactivity, and depressive symptoms, $F(3, 134) = 3.97$, $p = .009$ (Table 13). Scores for TVPS Visual Memory and Picture Locations were not significantly predicted by the psychological variables, as noted subsequently. The scores for Dot Locations were significantly predicted by attention problems (B = -0.24, $p = .049$) and the inverse of depressive symptoms (B = -0.21, $p = .025$) but not hyperactivity (B = -0.09, $p = .451$). Additionally, scores for Picture Locations were significantly predicted by levels of attention problems (B = -0.25, $p = .042$) but this finding was not supported by the overall regression model, ($F(3, 134) = 1.52$, $p = .212$), due to the non-significance of hyperactivity and depression (ps > .10), and thus this finding should be interpreted cautiously. TVPS Visual Memory was not significantly predicted by any of the psychological variables, which is consistent with the overall regression model ($F(3, 134) = 1.08$, $p = .360$).

A follow-up exploratory multiple regression was performed to see if Picture Locations was significantly predicted by the psychological variables when it was the only dependent variable in the model (Table 14). This was done to maximize power by including more subjects in the analysis, since the canonical correlation excludes subjects who are missing data for any variable included in the analysis. The multiple regression was not significant ($F(3, 134) = 1.54$, $p = .207$), although the coefficient for attention problems was significant ($B = -0.25$, $p = 0.041$). The coefficients for hyperactivity ($B = 0.115$, $p = .362$) and depressive symptoms ($B = -0.07$, $p = .470$) were not significant.

Hypothesis 3: Verbal working memory

The dependent variables for Hypothesis 3 were CMS Numbers Backward and Sequences (Table 15). The canonical correlation for this analysis was not significant, Wilks' lambda = 0.95, $F(6, 280.00) = 1.18$ $p = .316$ (Table 16). The multiple regressions also were examined in an exploratory fashion and were non-significant (*p*s > .10; Table 17).

Hypothesis 4: Verbal long-term memory

The dependent variables for Hypothesis 4 included CMS Word Lists Delayed Recall, Word Lists Delayed Recognition, Stories Delayed Recall, and Stories Delayed Recognition (Table 18). The canonical correlation was significant, Wilks' Lambda = .83, $F(12, 352.18) = 2.14$, $p = .014$, indicating a significant relationship between verbal long-term memory variables and psychological predictors, taking into account correlations within sets (Table 19).

When examining the canonical correlation more closely, the first function accounted for 51.83% of the total shared variance across sets, with 9% of the total variance explained (Function 1 Eigenvalue = 0.10; Table 19). The first function was likely driving the significant relationship between sets as functions 2-3 were not significant (*p*s > .05; Table 19).

The first root of the memory variables was primarily driven by Word Lists Delayed Recall ($R = -0.94$). The remaining standardized canonical coefficients were as follows: Stories

Delayed Recall, *R* = 0.36, Stories Delayed Recognition, *R* = -0.52, Word Lists Delayed Recognition, *R* = 0.11 (Table 21). The first memory root accounted for 28.23% of the variance in the memory variables (within-set variance) but only 2.57% of the variance in the psychological variables (Table 20).

The first psychological variable root was being driven by hyperactivity (natural log; *R* = -1.03) and the inverse of depressive symptoms (*R* = -0.90; Table 21). Attention problems loaded less strongly onto the first root (*R* = 0.65). The first root of the psychological variables accounted for 20.13% of the within-set variance but only 1.83% of the variance in the memory variables (Table 20).

The multiple regressions from the canonical output were analyzed next (Table 22). Word Lists Delayed Recall ($F(3, 136) = 3.70$, $p = .013$) and Word Lists Delayed Recognition ($F(3, 136) = 2.80$, $p = .042$) were significantly predicted by the combination of psychological variables. Stories Delayed Recall and Stories Delayed Recognition were not (*p*s > .10). Examining the predictors individually, Word Lists Delayed Recall was significantly predicted by attention problems (*B* = -0.24, *p* = .043), the natural log of hyperactivity (*B* = 0.29, *p* = .018), and the inverse of depressive symptoms (*B* = 0.21, *p* = .022). Word Lists Delayed Recognition was significantly predicted by attention problems (*B* = -0.34, *p* = .004), and hyperactivity approached significance as a predictor (*B* = 0.24, *p* = .052). Depressive symptoms were not a significant predictor (*B* = -0.043, *p* = .648).

Follow-up hierarchical regressions were performed to determine the effect of encoding on long-term memory performance, by including Word Lists Learning as a predictor in the first block of the regression, psychological variables in the second block, and long-term memory as the dependent variable (Tables 23 and 24). These analyses indicate that the significant effects of the psychological variables on Word Lists Delayed Recall and Word Lists Delayed Recognition are still present even after controlling for encoding. More specifically, for Word Lists Delayed Recall, hyperactivity (natural log) was still a significant predictor of performance ($B = 0.22$, $p = .012$; Table 23). Attention problems ($B = -0.13$, $p = .151$) and depressive symptoms ($B = 0.12$, $p = .092$) were no longer significant predictors. On Word Lists Delayed Recognition, Attention Problems remained a significant predictor of performance ($B = -0.24$, $p = .015$) after controlling for encoding (Table 24). As in the original analysis, hyperactivity ($B = 0.18$, $p = .067$) and depressive symptoms ($B = -0.13$, $p = .104$) were not significant predictors of Word Lists Delayed Recognition performance.

CHAPTER 5

DISCUSSION

The purpose of the present study was to examine the effects of ADHD symptoms and depressive symptoms on memory performance. Inattention, hyperactivity, and depressive symptoms were examined on a continuum to analyze the effects of a range of symptoms on memory performance.

Hypothesis 1 predicted that levels of inattention and hyperactivity would not be related to performance on verbal short-term memory measures, but that level of depressive symptoms would be negatively correlated with performance on the most effortful verbal short-term memory task. It was found that psychological variables were not significant predictors of verbal short-term memory performance. This supports previous literature suggesting the absence of verbal short-term memory deficits in ADHD when children do not have comorbid language impairment (Karatekin, 2004; Kibby & Cohen, 2008; Korkman & Pesonen, 1994; Roodenrys, et al., 2001). Indeed, a study using two of the same measures from the CMS (Word Lists and Stories) found that children with ADHD performed comparably to controls (Kibby & Cohen, 2008). Stories, a measure of short-term memory for passages, presents information in a story format, and because material doesn't need to be remembered verbatim, brief lapses in attention are not exceedingly detrimental. Word Lists is a selective reminding task, and because information is presented over multiple trials, children have multiple opportunities to encode the words versus verbatim span measures. In contrast, forward digit span places greater demands on focused attention than the other two measures because information is presented once and has to be recalled verbatim, and it had a trend towards significance, consistent with the Kibby and Cohen study.

The current study predicted that depressive symptoms would be negatively correlated with performance on the task that was most effortful (Word Lists). This was not found, perhaps for a few reasons. The tasks might not have been sufficiently effortful to be impaired in children with depressive symptoms. Bartfai and colleagues (1991) found that tasks requiring sustained attention were the most impaired. Thus, perhaps the tasks were short enough to be encoded adequately. Secondly, since the present sample had primarily not depressed or sub-clinically depressed subjects, the level of depressive symptoms might not have been great enough to impair verbal short-term memory performance. Mesholam-Gately and colleagues (2012) found impaired list-learning in patients with MDD but not sub-clinical depression when compared to controls. As expected, forward digit span and immediate passage recall were not significantly related to depressive symptoms. These tasks are less effortful and so can be readily performed by individuals with depressive symptoms.

Hypothesis 2 predicted that level of inattention would be negatively correlated with performance on visual-spatial short-term memory measures but not the visual/non-spatial measure and that level of depressive symptoms would be negatively related to performance on the most effortful visual short-term memory task. The present study found that impairment on Dot Locations was correlated with level of attention problems and level of depressive symptoms, which supports the hypothesis. This is commensurate with previous literature finding impairment on visual STM tasks in ADHD (Barnett, et al., 2001; Karatekin, 2004; Kibby & Cohen, 2008; Kempton, et al., 1999) and on more effortful tasks in depressed individuals (Bartfai, et al., 1991; Zakzanis, Leach, & Kaplan, 1998). It is worth noting that hyperactivity was less associated with impairment on Dot Locations, which supports previous research finding no significant differences between subtypes on measures of visual short-term memory (Cockcroft, 2011; Pasini, et al., 2007), as inattentive symptoms are characteristic of all children with ADHD, regardless of subtype (PI versus C).

Interestingly, no significant impairments were found on Picture Locations, even though this is another visual-spatial STM task. However, it should be noted that attention problems was negatively correlated with performance on Picture Locations. The lack of significance in the regression may reflect a lack of power or very small effect size of the other two variables in the equation. While the overall regression model was not significant, it is worth exploring further whether attention problems may be related to impaired performance on Picture Locations, a finding that would be consistent with prior research (Kibby & Cohen, 2008). Combined with Dot Locations being impaired and visual/non-spatial STM being unaffected with increasing attention problems, findings suggest that visual-spatial STM may be affected in children with ADHD but visual/non-spatial STM may be spared. This may be related to deficits in spatial processing related to decreased right parietal lobe functioning (Aman, Roberts, & Pennington, 1998; Johnson, et al., 2010).

Picture Locations is a measure of simple span, with difficulty increasing with more stimuli as the task progresses. Thus, it may be perceived as less effortful than Dot Locations, where all of the stimuli are presented at once. There also may be a difference in the level of interest generated by the task: Picture Locations' stimuli include pictures of trains, cars, and animals that vary across trials, which may make the task more interesting to children. It also has shorter time limits. The short stimuli presentation time may make it easier for children with higher levels of depressive symptoms to pay attention, as they typically have difficulties on sustained, effortful tasks (Bartfai, et al., 1991).

Commensurate with previous research, greater ADHD symptomology was not related to greater impairment on the TVPS Visual Memory. Although few researchers have examined visual/non-spatial short-term memory, Kibby and Cohen (2008) found intact performance in children with ADHD on a measure of visual/non-spatial short-term memory from the CMS (face recognition). Researchers have typically found visual processing to be intact when spatial demands are low, but impaired performance on tasks requiring greater spatial processing or mental rotation (Aman, et al., 1998; Johnson, et al., 2010), as noted above. Thus, the finding of intact visual/non-spatial performance is in accordance with the ADHD literature. Performance on the TVPS Visual Memory was also unrelated to level of depressive symptoms. Although depression research hasn't explicitly examined visual/non-spatial short-term memory, the intact performance on this task may be related to the minimal amount of effort required to complete the measure. The TVPS utilizes recognition format, thus requiring less effort than the free recall measures.

In terms of verbal working memory, no deficits were found, contrary to prediction. This supports findings by several researchers who suggest that verbal working memory is intact in ADHD, or at least that verbal working memory is only mildly affected (Alloway, 2011; Martinussen, et al., 2005; Rhodes, Park, Seth, & Coghill, 2012; Tillman, et al., 2011). The studies that have found the most impairment in verbal working memory in ADHD have used fairly difficult working memory tasks, such as an n-back task, the CHIPASAT, and tasks that required planning and strategizing (Pasini, et al., 2007; Roodenrys, 2006; Roodenrys, et al., 2001; Siklos & Kerns, 2004). Although some studies found impairment in children with ADHD on Digit Span Backward, a verbal working memory measure used in the current study, others did not (see meta-analysis by Willcutt, et al., 2001). Additionally, Nigg (2010) suggest that executive functioning deficits are not a central impairment in ADHD, which would suggest that working memory abilities may only be impaired in some individuals with ADHD. This finding is also supportive of a meta-analysis by Willcutt and colleagues (2005) that found verbal working memory impairment in children with ADHD in only six out of 11 studies. Therefore, it may be the case that our sample of children with greater ADHD symptomotology had fewer verbal working memory deficits, or that our tasks were not sufficiently difficult to find impairments.

Regarding depressive symptoms, the null findings on verbal working memory may indicate that: (1) our working memory measures weren't effortful enough to cause impairment; (2) impairment on working memory measures is not found in a nondepressed to sub-clinically depressed samples; or (3) both. This conclusion is supported by research by Favre and colleagues (2009) who did not find executive functioning impairments in children with mild depressive symptoms. Although Favre and colleagues (2009) did not specifically examine memory impairments, working memory is considered to be an executive function, and, thus, similar findings for working memory tasks might be expected.

Hypothesis 4 predicted that verbal long-term memory would not be associated with level of ADHD symptoms after controlling for encoding, and that level of depression would be negatively correlated with recall abilities, but recognition would not. This hypothesis was partially supported. The canonical correlation demontrated that memory impairments were predicted by a combination of ADHD and depressive symptoms, with hyperactivity and depressive symptoms the strongest predictors of memory impairment. Word Lists Delayed Recall appeared to be making the strongest contribution of the variables in the memory set. Therefore, the combination of ADHD and depressive symptoms is associated with impairment on the most difficult long-term memory task – a measure of free recall of a list of unrelated words.

The multiple regression analysis indicated that levels of impairment in attention problems, hyperactivity, and depressive symptoms were correlated with performance on Word Lists Delayed Recall. Additionally, level of inattention was negatively correlated with performance on Word Lists Delayed Recognition. Stories Delayed Recall and Stories Delayed Recognition were not significantly predicted by any of the psychological variables. For Stories, the lack of significant findings fills a gap in the literature regarding memory for semantically organized material for both ADHD and depression. For ADHD, only one previously examined memory for semantically organized material (Kibby & Cohen, 2008), and the authors found intact short-term and long-term memory functioning (. A few researchers have studied memory for semantically-organized material in individuals with depression, and all found it to be intact (Coughlan & Hollows, 1984; McDermott, et al., 2009). They suggested that this was related to the lesser amount of effort required to encode the semantically organized material as opposed to rote material.

In terms of Word Lists, deficits on recall and recognition remained even after controlling for encoding, which was unexpected. Although few studies have examined long-term memory in ADHD, those that have typically reported intact long-term memory once encoding was controlled (Kaplan, Dewey, Crawford, & Fisher, 1998; Muir-Broaddus, Rosenstein, Medina, & Soderberg, 2002; Plomin & Foch, 1981). Kibby and Cohen (2008) found intact long-term memory for both recall and recognition measures, once encoding was controlled. For Word Lists Delayed Recall, hyperactivity remained a significant predictor, and for Word Lists Delayed Recognition, attention problems were a significant predictor after controlling for encoding.

Depressive symptoms no longer significantly predicted either variable. This pattern of findings may suggest that for more difficult measures of recall, the effects of depressive symptoms and attention problems may be accounted for by insufficient encoding strategies. The fact that hyperactivity remained a significant predictor is a novel finding, since hyperactivity is typically not associated with cognitive impairment (Sonuga-Barke, 2005). As the hyperactivity dimension of ADHD is often associated with impulsivity, hastiness in answering may account for some of the difficulties in long-term memory recall. For Word Lists Recognition, attention problems remained as a significant predictor, indicating that children with inattention problems may have difficulties recognizing difficult material even if it is encoded properly. This may suggest that children with attention problems are more likely to make careless errors on the recognition task. Depressive symptoms was not a significant predictor of recognition, which supports other prior research suggesting that individuals with depression have difficulties with more difficult or effortful tasks (such as recall) but not less effortful ones (e.g., recognition; Bartfai, et al., 1991). Mesholam-Gately and colleagues (2012) found that issues with retrieval were present in individuals with MDD, but the impairment was not present when recognition prompts were given. They suggested that this was because the recognition prompts made the task less effortful.

Overall, this pattern of results suggests that a long-term memory deficit for effortful material exists beyond encoding for individuals with inattention and hyperactivity symptoms. This is a novel finding. The lack of significant findings in previous studies may be a result of the measures used or subject pool. The fact that impairment was found in both recall and recognition suggests that the difficulty of remembering the measure may impact long-term performance, beyond just encoding deficits.

Limitations and Future Directions

Subjects in the present study were primarily nondepressed or only sub-clinically depressed. Future research should focus on differences between sub-clinical depression, clinical depression and controls in children, in order to tease apart deficits across the depressive symptoms continuum. Additionally, the current study had no non-verbal working memory measures because the CMS does not include them. A measure of visual long-term memory (Dot Locations Delayed Recall) was not included because no corresponding recognition measure was available, nor were delayed measures available for the TVPS, and because the literature doesn't indicate a deficit in visual long-term memory associated with high levels of depression or ADHD symptoms. Future studies should include these measures, particularly in light of the current verbal long-term memory findings.

Although studies have shown that youth are the best reporters of internalizing symptoms, this study did not have an appropriate self-report measure of depressive symptoms available, and thus parent report was used. Future research should include a self-report measure of internalizing symptoms to most accurately identify internalizing symptoms.

Additionally, the current study had a very small number of subjects that met clinical criteria for both ADHD and depression. Since our subjects were taken from a community sample, this may indicate that the overall comorbidity rates for the two disorders might not be as high as that suggested by studies which use clinical samples. Thus, further research on prevalence rates of comorbidity of ADHD and depression is warranted in community samples.

Future research should also examine the neural networks implicated in memory, ADHD, and depression. The prefrontal cortex has been implicated in working memory pathways, as well as in ADHD and depressive functioning (Dickstein, Bannon, Castellanos, & Milham, 2006;

Drevets, et al., 1992; Hampson, Driesen, Skudlarski, Gore, & Constable, 2006; Koenigs & Grafman, 2009; Wager & Smith, 2003). In adults, researchers found that the pulvinar of the thalamus has higher baseline activity in depressed individuals than healthy controls (Hamilton, et al., 2012), and the amygdala is also implicated (Drevets, et al., 1992). Working memory and ADHD symptoms also have fronto-parietal connections (Dickstein, et al., 2006; Rottschy, et al., 2012). Additionally, brain regions implicated in speech and verbal processing are active during verbal working memory tasks (Rottschy, et al., 2012), and systems for visual orienting and visual processing are active in visual working memory tasks (Corbetta, Kincade, & Shulman, 2002).

Theoretical and Clinical Implications

The present study supports and adds to the previous literature by demonstrating that deficits in verbal short-term memory, visual/non-spatial short-term memory, and verbal working memory performance were not associated with any level of psychological symptoms. No impairment related to semantically organized material was found for any level of ADHD or depressive symptoms, suggesting that this memory modality is intact in these populations. This finding adds to the minimal research previously conducted with semantically organized material in these populations. Additionally, greater impairment for verbal long-term memory beyond encoding was associated with higher levels of ADHD symptoms, which is contradictory to previous literature. This suggests some difficulty with both free recall and aided recognition for children with inattention and hyperactivity symptoms. Although long-term memory recall impairments were related to depressive symptoms, this deficit did not persist once encoding was controlled, which may suggest that generation/use of encoding strategies may be the most effortful part of memory tasks for this population, and is, thus, the most difficult.

Clinically, these findings suggest that individuals with ADHD symptoms may learn best with semantically organized verbal or auditory material, or with visual material without a spatial component. Children with ADHD symptoms also may have difficulty recalling and recognizing effortful material, even if they were able to encode it correctly. Thus, hastiness and inattention during memory tasks may impact performance, and therefore should be carefully observed. Additionally, children with depressive symptoms may have difficulty encoding effortful material, but when the material is encoded, they are able to recall and recognize it. Therefore, frequent repetitions for learning material may be crucial, along with training in encoding strategies.

Conclusion

The current study examined the effect of inattention, hyperactivity, and depression on memory abilities. Performance on visual-spatial short-term memory tasks was negatively correlated with depressive and ADHD symptoms. Verbal long-term memory performance on measures of recall and recognition was negatively correlated with ADHD symptoms even after controlling for encoding abilities, which is a novel finding. This research informs work with children with ADHD and depression, such that they remember material best when it is presented in a visual/non-spatial format, or when it is verbal but semantically organized. In sum, there are effects of inattention, hyperactivity, and depression on memory abilities, and the contribution of these symptoms to performance should be studied further.

Table 1

Demographics and Independent Variables

	Mean	Standard Deviation	Minimum	Maximum
Age	10.15	1.36	8 year, 0 months	12 year, 11 months
FSIQ*	102.39	12.11	71	131
Attention Problems'	59.37	12.01	32	79
Hyperactivity'	53.99	14.02	30	96
Depression'	53.21	13.03	34	107
Withdrawal'	52.80	12.06	35	100

*units are in standard scores (mean=100, SD=15)

'units are in T-scores (mean=50, SD=10)

Table 2

Skewness and Kurtosis Transformations

Variable Name	Skewness Statistic	Skewness Standard Deviation	Skewness z-score	Kurtosis Statistic	Kurtosis Standard Deviation	Kurtosis z-score
CMS Numbers Forward	-0.053	0.199	-0.266	-0.693	0.396	-1.750
CMS Stories Immediate Recall	-0.003	0.200	-0.015	0.192	0.397	0.484
CMS Word Lists Learning	0.517	0.200	2.585	0.642	0.397	1.617
CMS Dots Learning	-0.289	0.200	-1.445	-0.837	0.397	-2.108
CMS Picture Locations	-0.068	0.205	-0.332	-0.260	0.407	-0.639
TVPS Visual Memory	-0.785	0.200	-3.925	0.467	0.397	1.176
CMS Numbers Backward	-0.092	0.199	-0.462	-0.862	0.396	-2.177
CMS Sequences	-0.013	0.200	-0.065	-0.552	0.397	-1.390
CMS Stories Delayed Recall	0.051	0.201	0.254	0.003	0.399	0.008
CMS Word Lists Delayed Recall	0.073	0.201	0.363	-0.337	0.399	-0.845
CMS Stories Delayed Recognition	0.152	0.201	0.756	0.460	0.399	1.153
CMS Word Lists Delayed Recognition	0.262	0.203	1.291	-1.196	0.404	-2.960
BASC-PRS Depression	1.388	0.201	6.905	2.874	0.400	7.185
BASC-PRS Withdrawal	0.857	0.201	4.264	0.963	0.400	2.408
BASC-PRS Attention Problems	-0.490	0.201	-2.438	-0.631	0.400	-1.578
BASC-PRS Hyperactivity	0.696	0.201	3.463	0.080	0.400	0.200

Corrected Variables:						
TVPS Visual Memory (squared)	-0.333	0.200	-1.665	-0.298	0.397	-0.751
BASC-PRS Depression (inverse)	-0.048	0.201	-0.239	-0.420	0.400	-1.050
BASC-PRS Withdrawal (natural log)	0.274	0.201	1.363	-0.335	0.400	-0.838
BASC-PRS Hyperactivity (natural log)	0.106	0.201	0.527	-0.375	0.400	-0.938

Table 3

Means and Standard Deviations of Dependent Variables

Variable Name	Mean	Standard Deviation	Minimum	Maximum
CMS Numbers Forward	96.62	16.66	60	135
CMS Stories Immediate Recall	106.60	14.37	65	145
CMS Word Lists Learning	88.88	14.79	55	140
CMS Dots Learning	101.16	15.13	65	130
CMS Picture Locations	98.93	15.95	60	135
TVPS Visual Memory	99.82	16.23	55	125
CMS Numbers Backward	93.82	16.17	60	130
CMS Sequences	98.98	14.18	65	130
CMS Stories Delayed Recall	105.48	15.89	65	145
CMS Word Lists Delayed Recall	94.52	14.45	60	130
CMS Stories Delayed Recognition	99.59	13.53	55	140
CMS Word Lists Delayed Recognition	87.61	17.59	60	120

Note: all units are in standard scores

Table 4

Subjects in Normal, At-Risk, and Clinically Significant Ranges from the BASC-PRS

Sample Size in Each Range

Variable	Normal	At-Risk	Clinically Significant
Attention Problems	59	59	27
Hyperactivity	101	22	22
Depression	108	24	13
Withdrawal	105	27	13

Percent in Each Range

Variable	Normal	At-Risk	Clinically Significant
Attention Problems	40.69	40.69	18.62
Hyperactivity	69.66	15.17	15.17
Depression	74.48	16.55	8.97
Withdrawal	72.41	18.62	8.97

Table 5

Canonical Correlation of Verbal Short-Term Memory Performance with Psychological Function – Hypothesis 1

Verbal short-term memory variables	Psychological variables
CMS Numbers Forward (z-score)	BASC-PRS Attention Problems (z-score)
CMS Stories Immediate (z-score)	BASC-PRS Hyperactivity (natural log; z-score)
CMS Word Lists Learning (z-score)	Average of BASC-PRS Depression and Withdrawal (inverse; z-score)

Table 6

Canonical Correlation Analysis Relating Verbal Short-Term Memory Performance to Psychological Function – Hypothesis 1

Measures of Overall Model Fit for Canonical Correlation Analysis

Canonical Function	Canonical Correlation	Canonical R^2	Percent Shared Variance	F Statistic	Probability
1	0.228	0.05	67.54	1.25	0.262
2	0.142	0.02	25.39	0.92	0.450
3	0.076	0.01	7.07	0.81	0.369

Multivariate Tests of Significance

Statistic	Value	Approximate F Statistic	Probability
Pillai's trace	0.08	1.26	0.258
Hotelling's trace	0.08	1.25	0.265
Wilks' lambda	0.92	1.25	0.262
Roy's gcr	0.05		

Table 7

Multiple Regression Results from Canonical Correlation Output – Hypothesis 1

Dependent Variable	Adjusted R^2	F Statistic	Probability
CMS Stories Immediate	.001	1.02	.383

Predictor	B	ß	Standard Error	Probability
Attention Problems	-.15	-.15	.12	.197
Hyperactivity (natural log)	-.004	-.004	.12	.972
Depressive Symptoms (inverse)	-.05	-.04	.11	.636

Dependent Variable	Adjusted R^2	F Statistic	Probability
CMS Numbers Forward	.006	1.31	.274

Predictor	B	ß	Standard Error	Probability
Attention Problems	-.23	-.23	.12	.056
Hyperactivity (natural log)	.15	.15	.12	.213
Depressive Symptoms (inverse)	.02	.02	.11	.875

Dependent Variable	Adjusted R^2	F Statistic	Probability
CMS Word Lists Learning	.04	2.15	.097

Predictor	B	ß	Standard Error	Probability
Attention Problems	-.16	-.16	.12	.172
Hyperactivity (natural log)	.10	.10	.12	.432
Depressive Symptoms (inverse)	.18	.15	.11	.102

Table 8

Exploratory Multiple Regression for CMS Numbers Forward – Hypothesis 1

	Adjusted R^2	F statistic	Probability	
Model	.006	1.54	.207	

Variable	B	SE B	ß	Probability
Attention Problems	-.25	.12	-.25	.041
Hyperactivity (natural log)	.11	.12	.12	.362
Depressive Symptoms (inverse)	-.08	.11	-.07	.470

Table 9

Canonical Correlation of Visual Short-Term Memory with Psychological Function – Hypothesis 2

Visual Short-Term Memory Variables	Psychological Variables
TVPS Visual Memory (squared; z-score)	BASC-PRS Attention Problems (z-score)
CMS Dot Locations Learning (z-score)	BASC-PRS Hyperactivity (natural log; z-score)
CMS Picture Locations (z-score)	Average of BASC-PRS Depression and Withdrawal (inverse; z-score)

Table 10

Canonical Correlation Analysis Relating Visual Short-Term Memory Performance to Psychological Function – Hypothesis 2

Measures of Overall Model Fit for Canonical Correlation Analysis

Canonical Function	Canonical Correlation	Canonical R^2	Percent Shared Variance	F Statistic	Probability
1	0.301	0.09	74.71	1.920	0.049
2	0.179	0.03	24.79	1.100	0.355
3	0.026	0.00	0.51	0.090	0.764

Multivariate Tests of Significance

Statistic	Value	Approximate F Statistic	Probability
Pillai's trace	0.12	1.90	0.051
Hotelling's trace	0.13	1.92	0.048
Wilks' lambda	0.88	1.92	0.049
Roy's gcr	0.09		

Table 11

Redundancy Analysis of Dependent and Independent Variates for Canonical Function 1 – Hypothesis 2

Standardized Variance Explained by:

Variate Set	Their Own Canonical Variate (percent shared variance)	The Opposite Canonical Variate (precent redundancy)
Dependent Variables	36.33	3.29
Independent Variables	30.64	2.78

Table 12

Canonical Weights and Structure for the First Canonical Function – Hypothesis 2

	Standardized Canonical Coefficients	Correlation Between Variable and Its Canonical Variate
Dependent Variables		
TVPS Visual Memory	-0.319	0.028
CMS Dot Locations	0.973	0.949
CMS Picture Locations	0.198	0.434
Independent Variables		
Attention Problems	-0.732	-0.699
Hyperactivity	-0.421	-0.582
Depressive Symptoms	-0.801	-0.304

Table 13

Multiple Regression Results from Canonical Correlation Output – Hypothesis 2

Dependent Variable	Adjusted R^2	F Statistic	Probability
TVPS Visual Memory	.002	1.08	.360

Predictor	B	ß	Standard Error	Probability
Attention Problems	-.19	-.19	.12	.121
Hyperactivity (natural log)	.19	.19	.13	.142
Depressive Symptoms (inverse)	.07	.06	.11	.539

Dependent Variable	Adjusted R^2	F Statistic	Probability
CMS Dot Locations Learning	**.06**	**3.97**	**.009**

Predictor	B	ß	Standard Error	Probability
Attention Problems	**-.23**	**-.24**	**.11**	**.049**
Hyperactivity (natural log)	-.09	-.09	.12	.451
Depressive Symptoms (inv)	**-.24**	**-.21**	**.10**	**.025**

Dependent Variable	Adjusted R^2	F Statistic	Probability
CMS Picture Locations	.01	1.52	0.212

Predictor	B	ß	Standard Error	Probability
Attention Problems	**-.25**	**-.25**	**.12**	**.042**
Hyperactivity (natural log)	.11	.12	.12	.358
Depressive Symptoms (inverse)	-.08	-.07	.11	.483

Table 14

Exploratory Multiple Regression for CMS Picture Locations – Hypothesis 2

	Adjusted R^2	F Statistic	Probability
Model	.01	1.54	.207

Variable	B	SE B	ß	Probability
Attention Problems	**-.25**	**.12**	**-.25**	**.041**
Hyperactivity (natural log)	.11	.12	.11	.362
Depressive Symptoms (inverse)	-.08	.11	-.07	.470

Table 15

Canonical Correlation of Verbal Working Memory Performance with Psychological Function – Hypothesis 3

Verbal Working Memory Variables	Psychological Variables
CMS Numbers Backward (z-score)	BASC-PRS Attention Problems (z-score)
CMS Sequences (z-score)	BASC-PRS Hyperactivity (natural log; z-score)
	Average of BASC-PRS Depression and Withdrawal (inverse; z-score)

Table 16

Canonical Correlation Analysis Relating Verbal Working Memory Performance to Psychological Function – Hypothesis 3

Measures of Overall Model Fit for Canonical Correlation Analysis

Canonical Function	Canonical Correlation	Canonical R^2	Percent Shared Variance	F Statistic	Probability
1	0.209	0.04	89.51	1.18	0.316
2	0.073	0.01	10.49	0.38	0.686

Multivariate Tests of Significance

Statistic	Value	Approximate F Statistic	Probability
Pillai's trace	0.05	1.18	0.316
Hotelling's trace	0.05	1.18	0.315
Wilks' lambda	0.95	1.18	0.316
Roy's gcr	0.04		

Table 17

Multiple Regression Results from Canonical Correlation Output – Hypothesis 3

Dependent Variable	Adjusted R^2	F Statistic	Probability
CMS Numbers Backward	.02	1.93	.127

Predictor	B	ß	Standard Error	Probability
Attention Problems	-.02	-.02	.12	.883
Hyperactivity (natural log)	-.13	-.13	.12	.273
Depressive Symptoms (inverse)	.10	.08	.11	.373

Dependent Variable	Adjusted R^2	F Statistic	Probability
CMS Sequences	<.001	0.75	.525

Predictor	B	ß	Standard Error	Probability
Attention Problems	-.11	-.11	.12	.344
Hyperactivity (natural log)	.02	.02	.12	.875
Depressive Symptoms (inverse)	.05	.05	.11	.632

Table 18

Canonical Correlation of Verbal Long-Term Memory Performance with Psychological Function – Hypothesis 4

Verbal Long-Term Memory Variables	Psychological Variables
CMS Stories Delayed Recall (z-score)	BASC-PRS Attention Problems (z-score)
CMS Word Lists Delayed Recall (z-score)	BASC-PRS Hyperactivity (natural log; z-score)
CMS Stories Delayed Recognition (z-score)	Average of BASC-PRS Depression and Withdrawal (inverse; z-score)
CMS Word Lists Delayed Recognition (z-score)	

Table 19

Canonical Correlation Analysis Relating Verbal Long-Term Memory Performance to Psychological Function – Hypothesis 4

Measures of Overall Model Fit for Canonical Correlation Analysis

Canonical Function	Canonical Correlation	Canonical R^2	Percent Shared Variance	F Statistic	Probability
1	0.301	0.09	51.83	2.14	0.014
2	0.258	0.07	36.97	2.07	0.057
3	0.146	0.02	11.20	1.46	0.235

Multivariate Tests of Significance

Statistic	Value	Approximate F Statistic	Probability
Pillai's trace	0.18	2.14	0.014
Hotelling's trace	0.19	2.12	0.015
Wilks' lambda	0.83	2.14	0.014
Roy's gcr	0.09		

Table 20

Redundancy Analysis of Dependent and Independent Variates for Canonical Function 1 – Hypothesis 4

Standardized Variance Explained by:		
Variate Set	Their Own Canonical Variate (percent shared variance)	The Opposite Canonical Variate (precent redundancy)
Dependent Variables	28.23	2.57
Independent Variables	20.13	1.83

Table 21

Canonical Weights and Structure for the First Canonical Function – Hypothesis 4

	Standardized Canonical Coefficients	Correlation Between Variable and Its Canonical Variate
Dependent Variables		
CMS Stories Delayed Recall	0.357	-0.091
CMS Word Lists Delayed Recall	-0.944	-0.893
CMS Stories Delayed Recognition	-0.523	-0.440
CMS Word Lists Delayed Recognition	0.111	-0.361
Independent Variables		
Attention Problems	0.652	0.280
Hyperactivity	-1.031	-0.184
Depressive Symptoms	-0.895	-0.701

Table 22

Multiple Regression Results from Canonical Correlation Output – Hypothesis 4

Dependent Variable	Adjusted R^2	F Statistic	Probability	
CMS Stories Delayed Recall	0.02	1.83	.144	
Predictor	B	ß	Standard Error	Probability
Attention Problems	-.18	-.18	.12	.131
Hyperactivity (natural log)	.03	-.03	.12	.781
Depressive Symptoms (inverse)	-.03	-.02	.11	.800

Dependent Variable	Adjusted R^2	F Statistic	Probability	
CMS Word Lists Delayed Recall	0.06	3.70	.013	
Predictor	B	ß	Standard Error	Probability
Attention Problems	-.24	-.24	.12	.043
Hyperactivity (natural log)	.29	.29	.12	.018
Depressive Symptoms (inverse)	.25	.21	.11	.022

Dependent Variable	Adjusted R^2	F Statistic	Probability	
CMS Stories Delayed Recognition	0.001	1.06	.365	
Predictor	B	ß	Standard Error	Probability
Attention Problems	-.14	-.14	.12	.240
Hyperactivity (natural log)	.11	.11	.12	.381
Depressive Symptoms (inverse)	.12	.11	.11	.272

Dependent Variable	Adjusted R^2	F Statistic	Probability	
CMS Word Lists Delayed Recognition	0.04	2.80	.042	
Predictor	B	ß	Standard Error	Probability
Attention Problems	-.35	-.34	.12	.004
Hyperactivity (natural log)	.24	.24	.12	.052
Depressive Symptoms (inverse)	-.05	-.04	.11	.648

Table 23

Follow-up Regression of Word Lists Delayed Recall Performance After Controlling for Encoding – Hypothesis 4

Variable	B	SE B	ß	Probability	ΔR^2	ΔF	Probability
Step 1					.48	130.18	<.001
CMS Word Lists Learning	.70	.06	.69	<.001			
Step 2					.03	2.54	.059
CMS Word Lists Learning	.68	.06	.67	<.001			
Attention Problems	-.13	.09	-.13	.151			
Hyperactivity (natural log)	**.22**	**.09**	**.22**	**.012**			
Depressive Symptoms (inverse)	.13	.08	.12	.092			

Table 24

Follow-up Regression of Word Lists Delayed Recognition Performance After Controlling for Encoding – Hypothesis 4

Variable	B	SE B	ß	Probability	ΔR^2	ΔF	Probability
Step 1					.32	65.42	<.001
CMS Word Lists Learning	0.57	.07	.57	<.001			
Step 2					.04	3.00	.033
CMS Word Lists Learning	0.57	.07	.57	<.001			
Attention Problems	**-0.25**	**.10**	**-.24**	**.015**			
Hyperactivity (natural log)	0.19	.10	.18	.067			
Depressive Symptoms (inverse)	-0.15	.09	-.13	.104			

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