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Longitudinal Effects of Working Memory on Internalizing and Externalizing Behavior Problems

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Longitudinal Effects of Working Memory on Internalizing and Externalizing Behavior Problems

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Dedication

I dedicate this project to my wife Tara for supporting me throughout graduate school. She has been more than patient with my inattentiveness and obliviousness.

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Longitudinal Effects of Working Memory on Internalizing and Externalizing Behavior Problems

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Several research studies have examined the link between working memory ability and behavior problems in youth. Research suggests that children with working memory deficits demonstrate lower levels of attention and higher levels of hyperactivity, physical aggression, and other behavior problems. The purpose of this research was to determine the effects of developmental trajectories of working memory on the developmental trajectories of behavior problems.

Results suggested that developmental increases in working memory did not lead to developmental decreases in behavior problems. Results from this study suggested that internalizing and externalizing behavior problems increase over the course of childhood. Several variables did lead to developmental change in behavior problems in children. Children who had lower initial levels of working memory increased in internalizing behaviors less than children with higher initial working memory ability. Also, high socioeconomic status led to smaller increases in internalizing and externalizing behavior,

high Peabody Picture Vocabulary Test (PPVT) scores led to larger increases in internalizing and externalizing behavior, and high PPVT scores led to larger decreases in inattentive and hyperactive behavior. Results are discussed in reference to current theories about working memory and behavior problems.

Table of Contents

List of Tables

List of Figures

CHAPTER 1: INTRODUCTION

Behavior problems in children predict negative outcomes later in life. Disruptive behaviors in elementary school predict personal academic outcomes, such as suspension from school and academic failure (Reinke, Herman, Petras, & Ialongo, 2008), and classroom problems, such as reduced instruction time (Arnold, 1997). Additionally, disruptive behavior is predictive of delinquency, affiliation with deviant peers, and substance abuse. It can also lead to interpersonal problems such as peer rejection (Reinke et al., 2008). Internalizing behaviors in children can lead to academic and social problems in childhood and substance use and abuse in adolescents and adults (Compton, Burns, Egger, & Robertson, 2002; Horn & Packard, 1985), and mental health problems in adults (Colman, Wadsworth, Croudace, & Jones, 2007). Providing interventions for children with behavior problems has the potential to help those children avoid problems in later childhood, adolescence, and adulthood.

Interventions for behavior problems may include many techniques and features that contribute to their success (Garland, Hawley, Brookman-Frazee, & Hurlburt, 2008). One common feature of interventions is psychoeducation, a technique through which children and their parents learn about the nature, causes, and development of behavior problems. Interventions also commonly teach children to identify their emotions and identify the cognitive, physical, and environmental sources of their emotions. For such intervention techniques to be effective, therapists must understand the contributors to a behavior problem.

Given that therapists benefit from research explicating the causes of a given behavior problem, continued research is necessary to inform therapists of variables that influence the course of behavior problems in children. Working memory is one possible influence on behavior problems in childhood. Children with various types of behavior problems perform worse than controls on measures of working memory, and the more severe the working memory deficit the more severe the behavior problem (Brunnekreef et al., 2007). The magnitude of the link between behavior problems and working memory is demonstrated by a research study examining mediators of the effect of premature birth on behavior problems (Nadeau, Boivin, Tessier, Lefebvre, Robaey, 2001). Results showed that working memory was the most important mediator of the effect of premature birth on inattentive behavior. Accordingly, therapists designing interventions should consider the possible contribution of working memory to their clients' behavior problems.

Working memory is a variable that will develop during childhood (Gathercole, Adams, & Hitch, 1994); however, many of the variables that influence behavior problems will not change or will change very little over the course of childhood. An individual's sex and socioeconomic status are among the more stable influences on behavior and growing up in a low socioeconomic environment can result in increased behavior problems over time (Ferrell & Sullivan, 2004). When variables that contribute to behavior problems are consistently present in a child's life, that child may develop maladaptive patterns of interacting with others (Dodge, 1993). Additionally, the patterns of behavior that develop early in a child's life may continue into adolescence and adulthood. Thus, consistent exposure to negative factors leads to patterns of behavior

problems; however, some factors that contribute to behavior problems will be present early in a child's life, but may not be present later in a child's life.

Although consistent exposure to harmful environments and events will affect the potential development of behavior problems, questions remain regarding the lasting effect of less stable influences, such as working memory, on behavior problems. Specifically, will developmental gains in working memory lead to decreases in behavior problems? Alternatively, will children with initial deficits in working memory develop behavioral patterns that continue in their youth despite later development in working memory skills? Finally, what has a stronger effect on the developmental trajectories of behavior problems: change in a variable that affects behavior problems or the constant impact of an unchanging variable? The development of working memory over the course of childhood may lead to changes in behavior problems; however, the effect of growth in working memory on behavior problems may be non-significant as children develop stable behavior patterns before their working memory increases significantly.

This research will contribute to the literature by providing further research on the influences on behavior problems. Specifically, it will answer whether or not change in working memory skills leads to change in behavior problems. To answer this question, the study will use a large sample and longitudinal design. Additionally, it will assess the impact of socioeconomic status, sex, and general intellectual development on behavior problems, and thus support or disconfirm the effect of these variables on behavior problems found in previous studies. Thus, this study will contribute to existing literature by providing information on the developmental influences of behavior problems using longitudinal data.

CHAPTER 2: REVIEW OF LITERATURE

Chapter Overview

This chapter begins with a discussion of working memory, theories regarding working memory, and the measurement of working memory. Next, the influences on working memory are discussed. A discussion of the influences on working memory is important as the proposed study is non-experimental, and as such, common causes of the independent and dependent variables must be identified to infer causation. Following the discussion of working memory is a discussion of behavior problems. Included in this section is an outline of the measure of behavior problems used in this study. This outline is provided to introduce the dependent variables, which will be reviewed as they relate to working memory. Also included in the section on behavior problems is a review of the influences on working memory which are also influences on behavior problems. This chapter concludes with a statement of the problem.

Working Memory

The term working memory is used to define multiple concepts in various fields of study. The term has been used to describe the ability to purposefully hold and rehearse information (Vasic, Lohr, Steinbrink, Martin, & Wolf, 2008), the ability to hold information in awareness and manipulate that information (Jenkins, Myerson, Hale, & Fry, 1999), and the ability to divide attention (Sebastian, Menor, & Elosua, 2006). Similarly, measures of working memory are designed to assess the ability to visually and verbally rehearse and transform information (Leffard et al., 2006). However, definitions and measures of working memory generally account for the ability to hold information in

immediate awareness and manipulate that information. For the purposes of this study, working memory involves the manipulation of information in immediate awareness.

Theories of Working Memory

Baddeley and Hitch (1974) developed one of the most well known theories of working memory. In their model, working memory is divided into the phonological and visuospatial subsystems which are governed by a central executive system. The phonological subsystem, or phonological loop, temporarily holds verbal and acoustic information using a phonological store. The phonological store is limited, and information held therein decays after a few seconds. However, verbal and acoustic information can be revived through subvocal rehearsal. Subvocal rehearsal cannot increase the capacity of the phonological loop; it can only keep information in one's immediate awareness. Accordingly, as higher demands, or larger amounts of information, are placed on the phonological loop, the first piece of information in a series may be lost before it can be rehearsed (Baddeley, 2003). Thus, people with larger phonological stores are able to rehearse more information and make that information available to the central executive.

The visuospatial sketchpad is similar to the phonological loop but is geared towards visual information. Like the phonological loop, it performs two functions. The visual component, or visual cache, stores static visual information but does not perform any functions on the information. Similar to the phonological loop, the visual cache is of limited capacity and information stored therein must be revived if it is to remain in one's immediate awareness. Accordingly, the spatial component, or inner scribe, rehearses visual information relating to movement (Logie, 1995). Despite similarities, the

visuospatial and phonological subsystems are distinct from each other. However, visual information may be recoded into verbal information. When presented with a task requiring visual working memory, adults often assign names to visual objects and rehearse the information subvocally in the phonological loop (Baddeley, 2003). Finally, like the phonological loop, the information stored and rehearsed therein is available to the central executive.

An addition to Baddeley and Hitch's original model includes a third subsystem of the central executive called the episodic buffer which is a temporary store wherein information from long-term memory is retrieved to be used by the central executive (Baddeley, 2000). And, like the phonological loop and visuospatial sketchpad, the episodic buffer is limited in its capacity.

Finally, the central executive component of working memory serves as a means to control attention and has at least three major functions. First, it focuses attention and prevents the phonological and visuospatial subsystems from performing unnecessary work by inhibiting irrelevant information from entering into awareness. Second, it divides attention and is able to work on two or more tasks at once. Third, the central executive system has the capacity to switch attention between tasks (Baddeley, 2001). The central executive can then draw information from the episodic buffer, phonological loop, and visuospatial sketchpad, hold the information in immediate awareness, and transform and manipulate that information.

The Cattell-Horn-Carroll (CHC) theory, a combination of the factor analytic-based theories of those for whom the theory is named, provides a taxonomy of human cognitive abilities. Moreover, CHC theory provides insight into how cognitive abilities,

including working memory abilities, are hierarchically organized and relate to each other. In CHC theory, cognitive abilities are organized into three strata or levels. All abilities are subsumed by a general intelligence factor, which composes stratum III. Stratum II is comprised of broad abilities including short-term memory, the limited-capacity ability to consciously apprehend and maintain information (McGrew, 2005). According to CHC theory, working memory is a stratum I, or narrow, ability subsumed by short-term memory. Working memory is defined as the ability to store and operate on information, divide attention, and manage limited-capacity resources (McGrew, 2005). The short-term memory broad ability factor also subsumes memory span, the ability to attend to and recall ordered elements and reproduce those elements in the correct order (McGrew, 2005). Thus, according to CHC theory, memory span, or the ability to rehearse information, and working memory are distinct but related concepts.

Parts of Baddeley's model of working memory have been incorporated into the CHC theory's definition of working memory. Specifically, the CHC definition of working memory recognizes the four subcomponents of Baddeley's model (McGrew, 2005). However, there is not an additional stratum to account for the subcomponents of working memory. Instead, working memory is different from the other narrow abilities in that it may be the driving force behind higher order cognitive abilities (McGrew, 2005). Thus, despite the position of working memory being ultimately subsumed by general intelligence in CHC theory, working memory influences higher-order abilities because such abilities are complex and require that large amounts of information be maintained and manipulated in one's immediate awareness.

The Embedded Processes model (Cowan, 2005) of working memory has received less attention that the CHC model and Baddeley's model of working memory. In the embedded processes model, working memory is a component of long-term memory and is divided into two components. One component is activated, or short-term, memory which is long-term memory that has been activated for processing. The other component is focus of attention which is the activated memory that is brought into awareness. The focus of attention construct is similar to other theories of working memory in that it is limited in its capacity.

Other researchers have focused on chunking, the ability to group pieces of information together. Without chunking information, adults can typically retain approximately seven items in their working memory. However, adults can group pieces of information together into chunks and manipulate chunks of information instead of individual pieces of information. Chunks can in turn be chunked to create a hierarchy of information making it possible to manipulate large amounts of data (Chase & Simon, 1973). However, chunking may be more a memory strategy or an indication of metacognition (Derry, Hawkes, & Tsai, 1987) and less a basis of memory theory. Importantly, the ability to purposefully chunk information may represent a developmental milestone in working memory abilities (Ottem, Lian, & Karlsen, 2007).

Notable differences exist in the theories of working memory. First, Baddeley model of working memory includes the rehearsal of information. That is, the function of the phonological loop, to hold information, is considered to be a function of working memory. Conversely, the CHC model of working memory maintains that the rehearsal of information is a function of memory span. For a cognitive process to be considered a

product of working memory according to CHC theory, information must be manipulated and not just held in immediate awareness. Another difference between the models is the relationship of working memory and long-term memory. The CHC model holds that long-term memory and working memory are different broad abilities while the Embedded Processes model holds that working memory is a function of long-term memory. Baddeley's model explains the relationship between long-term and working memory with the episodic buffer, a subsystem that serves as an interface between long and short-term memory. Thus, because working memory is defined differently in different models, a measure of working memory in one study may not measure what another researcher considers to be working memory.

Measures of Working Memory

There are several different methods of measuring working memory, many of which are based on the theories of working memory. Baddeley's model of working memory and the CHC theory serve as the basis for many measures of working memory, and some measures of working memory are based on both models such as the nonverbal working memory subtest of the Stanford Binet 5 (Roid, 2000). Individually administered intelligence tests, such as the Stanford Binet 5, often contain subtests which measure working memory. Researchers have employed computers in the assessment of working memory, and one self-administered questionnaire purports to measure working memory by instructing respondents to rate certain observed behaviors associated with working memory (Behavior Rating Inventory of Executive Function; Gioia, Isquith, Guy, & Kenworthy, 2000). Some of the most common types of working memory measures are discussed below.

The Wechsler Intelligence Scales for Children, Fourth Edition (WISC-IV) purports to include three measures of working memory: Digit Span, Letter-Number Sequencing, and Arithmetic; however, independent research does not support the use of Arithmetic as a measure of working memory (Keith, Fine, Taub, Reynolds, & Kranzler, 2006). Digit Span is not a unitary measure of working memory but is divided into two parts: Digits Forward and Digits Backward. The Digits Forward section of the Digit Span subtest involves an examiner stating a series of digits. The examinee is required to repeat the list back to the examiner. If the examinee restates the list correctly, then the examiner reads a longer list of digits and the examinee again repeats the list back to the examiner. The process is repeated until the examinee is no longer able to correctly repeat the list. The Digits Backward section of the Digit Span subtest is similar but requires the examinee to repeat the list of digits to the examiner backwards. The difference between these two tasks is not trivial. Most children show differences in their ability to perform these tasks and research suggests that they measure two distinct constructs (Reynolds, 1997). Digits Forward is a simpler and more sequential task while Digits Backwards is more complex and requires mental manipulation.

Other measures of working memory require test participants to sort and order elements of a list simultaneously. Letter-Number Sequencing is a measure of working memory on the WISC-IV in which an examinee is presented with a sequence of random letters and numbers. The examinee must then repeat the numbers in order and then the letters in alphabetical order back to the examiner. Similarly, the Auditory Working Memory subtest of the Woodcock Johnson-III (WJ-III) requires participants to sort digits and words, repeat the words in sequential order, and then the digits in numerical order.

Both of these tests require the ability to hold information in one's awareness, divide the information, and attend to the new groups of information to sort them. Such tasks are consistent with the definition of working memory that requires the storage and manipulation of information.

Measures of working memory are also designed to tap into the visuospatial sketchpad. The Stanford Binet 5 includes a nonverbal measure of working memory in which the examinee is prompted to tap blocks in the same order as the examiner. Such tasks are measures of visual memory span. As the test progresses, more complex tasks are required. The blocks are colored and the examinee is required to tap one color of block first and then the other color. Thus, the examinee is required to divide and sort the information visually. This task might be considered a visual counterpart to Letter-Number Sequencing.

Several other working memory tasks require the examinee to split attention resources between two tasks. These dual-task measures may have participants remember the last word in a sentence while also requiring participants to remember the message of the sentence (Bunge, Klingberg, Jacobsen, & Gabrieli, 1999). While such tasks primarily tap into the ability to divide phonological resources, other dual-task designs require participants to attend to both auditory and visual stimuli (Adcock, Constable, Gore, & Goldman-Rakic, 2000). In general, dual-task modalities are different from other working memory tasks in that they are used to measure the ability to divide attention as opposed to the ability to sort information.

Another common working memory task is the n-back task. In this task, the participant is presented with a series of stimuli. The participant is told to respond upon

encountering a stimulus that is the same as the stimulus presented n stimuli previously, where n is an integer and does not usually exceed three. Essentially, the participant is required to monitor the stimuli and update the information contained in immediate awareness. Thus, the test then measures the ability of the central executive to focus on information, divide attention, and shift between two tasks. This task can be manipulated to measure phonological or visuospatial memory systems (Owen, McMillan, Laird, & Bullmore, 2005).

Because working memory is a general construct which involves multiple processes, different measures of working memory may measure different abilities. The aforementioned measures of working memory included in intelligence tests require the manipulation of information in immediate awareness. However, many other measures are designed to assess working memory and do not require mental manipulation. According to Baddeley's model, measures of working memory likely measure memory span to a certain degree and measures of memory span likely measure working memory to a degree. Although the latter statement seems counterintuitive, memory span likely depends on the central executive as the central executive controls the focus of attention. The ability to focus attention is necessary for even basic memory span tasks (Engle, Tuholski, Laughlin, & Conway,1999). Measures such as the Digits Forward task on the WISC-IV require focused attention, a function of the central executive according to Baddeley's model of working memory, but do not require the manipulation of information. Such measures would be considered measures of memory span, not working memory, according to CHC theory. Likewise, measures of memory span on the WJ-III, a test constructed according to CHC theory, are considered by proponents of Baddeley's

model to measure the phonological loop and thus working memory (Leffard et al., 2006). The two theories are congruent in that tasks that require divided attention and the manipulation of data are considered to be measures of working memory according to both theories.

Influences on Working Memory

Research examining sex differences in working memory abilities have resulted in mixed results. One study using the Bannatyne Visuospatial Memory Test found no differences between males and females in preschool aged children (Aliotti, & Rajabiun, 1991). A comparison of males and females on the Continuous Visual Memory Test did not find group differences in children in grades one through five (Ullman et al., 1997). Additionally, a comparison of males and females on the WJ-III in CHC abilities did not find sex differences in a short-term memory broad ability factor but did find that females varied more than males in short-term memory ability between ages 12 and 14 (Reynolds et al. 2008). Several research studies have resulted in significant sex differences in working memory tests. Several research studies suggest that females score higher on auditory working memory tests while males score higher on visuospatial working memory tests (Huang, 1993; Lowe, Mayfield, & Reynolds, 2003; Robinson et al., 1996). Additionally, in children and adolescents, females show a small advantage over males in the Digit Span subtest of the various Wechsler intelligence tests (Lynn & Irwing, 2008). Contradictory results regarding sex differences in working memory may be a function of the nature of working memory tasks as many of the aforementioned studies used different assessment instruments.

Few research studies have examined the link between socioeconomic status (SES) and working memory. Researchers examining the effect of poverty on neurocognitive development found that poverty is associated with lower working memory abilities (Farah et al. 2006). Additionally, a sample of children from low SES backgrounds performed lower than did a sample of children from high SES background on the Digit Span subtest of the Wechsler Intelligence Scales for Children – Revised (Bowey, 1995). And, in a sample including individuals across the lifespan, individuals from low SES backgrounds performed lower on measures of short-term memory (Primerano, 2006). SES and working memory are correlated, but the preceding research studies are unclear as to the nature of causation. Nevertheless, SES is a plausible influence of working memory.

Cognitive factors such as memory span also affect working memory abilities. An analysis of the CHC abilities measured by the WJ-III suggests that memory span has a large effect on working memory and that cognitive processing speed affects both memory span and working memory abilities (McGrew & Woodcock, 2001). Research based on Baddeley's model suggests that the ability to perform well on working memory tasks reflects the combined abilities of short-term memory and the central executive (Engle et al., 1999). The central executive manipulates the information while the phonological loop or visuospatial sketchpad keeps the information available to the central executive. Thus, according to CHC theory, memory span influences working memory, and according to Baddeley's theory, memory span is a component of working memory. However, regardless of theory, memory span is an important influence on the ability to manipulate information.

The discussion of the influences on working memory leads to the question: can working memory be trained or manipulated? Several research studies have shown that teaching memory strategies can increase working memory capacity. In one study, participants increased their memory span when they were taught rehearsal strategies (Dunlosky & Kane, 2007; Turley-Ames & Whitfield, 2003). Gains were particularly noticeable in participants who initially had low working memory spans. Other strategies have been examined as well. Participants who were taught to chain items in a list together by generating a sentence with all the items in the list also showed gains in short-term memory abilities (McNamara & Scott, 2001). Moreover, participants trained with short-term memory strategies scored higher than controls on measures of working memory. Thus, strategies designed to enhance working memory can be effective, suggesting that working memory capacity can be purposefully increased.

Development-Related Influences on Working Memory

Working memory ability varies by age (Jenkins et al., 1999), and several research studies have shown that memory span peaks during young adulthood (Hale, Bronik, & Fry, 1997; Dempster, 1981). Additionally, working memory is a construct that represents multiple subsystems that work together and develop at different rates. Research suggests that the three components of Baddeley's model develop early in childhood, are distinct by age six, and continue to develop into adolescence (Gathercole, Pickering, Ambridge, & Wearing, 2004). The phonological loop and the visuospatial sketchpad appear to be distinct constructs through all stages of childhood development (Gathercole et al., 2004). However, childhood developmental milestones associated with visual working memory are not necessarily synchronous with auditory working memory milestones (Gathercole

& Hitch, 1993). Accordingly, childhood is an important period in the development of working memory and its subsystems.

Several variables influence the development of working memory. The development and use of the phonological loop plays a major role in the development of auditory working memory. Not all children rehearse information in the phonological loop, and the younger the child, the less likely the child is to rehearse information in the phonological loop (Gathercole et al., 1994). Accordingly, children often rely solely on the phonological store without rehearsing it. Thus, information is quickly lost as the phonological store decays in a matter of seconds. As children use the phonological loop to rehearse information, their short-term memory develops and greater amounts of information are available to the central executive. Consequently the ability to manipulate information increases.

Development of the visuospatial sketchpad may depend on multiple variables. Young children depend on the visuospatial scratchpad to remember visual information. Certain visual information can be coded into the phonological system, and children begin to make use of this ability at about age seven. Children are then able to rehearse visual information in the phonological loop. As children develop this ability, they may score higher on measures of visual working memory. The ability to recode visual information into verbal information may be facilitated by development of reading ability because reading is the process of recoding visual information into phonological information. Alternatively, advances in visual working memory may be due to increases in general knowledge and, thus, greater ability to chunk information together. Additionally, visual

spatial working memory may be aided by deliberate processing strategies gained through maturation (Pickering, 2001).

Another explanation for age related variation in working memory is that increases in working memory are due to changes in processing speed (Hale & Fry, 1996). That is, given that the phonological store is limited by time and needs to be revived by rehearsal, individuals who can rehearse information faster are able to keep more information in immediate awareness. When more information can be rehearsed, more information is available to be manipulated. As children get older, their cognitive speed increases until young adulthood, and, thus, developmental trends in working memory are in part related to the development of cognitive speed (Kail & Park, 1994).

Another explanation of developmental variance in working memory ability relates to the functions of the central executive. Research suggests that adults and children are not as able to inhibit non-relevant information as compared to adolescents and young adults (Cornoldi & Vecchi, 2003). One of the functions of the central executive is to focus on relevant information. Given that short-term memory is of limited capacity, when operating at full capacity, if new information is introduced into short-term memory, then another item of information is lost. Accordingly, if non-relevant information is introduced into immediate awareness, then relevant information will be lost. And, if one loses the ability to focus on relevant information and block irrelevant information, then one's working memory will be impaired. Thus, age-related variability in working memory may be due to the loss of ability to focus on relevant information (Hasher & Zacks, 1988).

Consistent with Baddeley's theory of working memory, many researchers have pointed to the central executive as the source of age-related variability in working memory abilities (Pelosi & Blumhardt, 1999). Short-term memory appears to be less affected by age than memory that requires the manipulation of information. Accordingly, the central executive may be the source of age-related working memory variability. This idea appears to be consistent with theories citing relevant information inhibition as the determinant of change in working memory, as the central executive is responsible for focus of attention. Similarly, it would seem plausible that differences in the ability of the other two functions of the central executive, the ability to divide attention and switch the focus of attention, would cause variability in working memory abilities.

Summary of Working Memory

Several cognitive factors contribute to the developmental variation in working memory abilities. The development of the functions of the central executive plays an important role in the development of working memory, specifically the ability to inhibit irrelevant information. Cognitive developmental milestones such as the ability to recode visual information into verbal information and the ability to rehearse information subvocally also contribute to the development of working memory. Such developmental milestones occur early in childhood. Other factors such as increased knowledge and processing strategies also undergo development between ages seven and fifteen. Consequently, childhood and adolescence appear to be periods of importance in the development of working memory systems.

Some variables contribute to working memory ability but do not necessarily lead to different developmental trajectories. Poverty has an effect on working memory

abilities. Additionally, the sex of a child may play an important role in working memory. Because poverty and sex are also present throughout a child's development, childhood appears to be a time when all of the factors that influence working memory are at play.

Behavior Problems

Like the term "working memory," the term "behavior problem" is broad and is used to define different constructs. It defines behavior ranging from depression to hyperactivity; accordingly, behavior problems are often classified as internalizing or externalizing. Internalizing behaviors refer to internal distress caused by environmental factors, whereas externalizing behaviors, or disruptive behaviors, refer to acting out and interpersonal conflict (Brunnekreef et al., 2007). Common internalizing behaviors include anxiety and depression, and common externalizing behaviors include aggression and hyperactivity.

Measurement of Behavior Problems

One of the most common methods of behavior problem measurement is the use of rating scales. Such scales measure behavior problems on a continuum of frequency or severity and yield comparable information to other forms of behavior problem measurement (i.e., categorical measures; Moreland & Dumas, 2008; Pelletier, Collett, Gimpel, & Crowley, 2006; Sprafkin, Volpe, Gadow, Nolan, & Kelly, 2002). Research suggests that behavior rating scales demonstrate adequate reliability, can be accurately measured in children as young as two years old, and can reliably distinguish behavior problems from normal childhood behavior at early ages (Moreland & Dumas, 2008).

The Child Behavior Checklist (CBCL; Achenback, 1991) is a three point rating scale designed to measure specific behavioral and emotional problems. The parent rating

form includes a list of statements that describe behaviors of youth. Parents are asked to determine whether the statements are not true, sometimes/somewhat true, or always/often true as the statements relate to their child's behavior over the previous six months. Confirmatory factor analysis studies support the structure of the CBCL (Greenbaum & Dedrick, 1998); however results also have been used to make revisions to the CBCL and create more efficient measures for research. In a study on marriage, parent-child interactions, and child behavior problems, Peterson and Zill (1986) conducted a factor analysis on the CBCL. They constructed a new scale composed of the items that were the most reliable and loaded highest onto one of the subscales from their analysis. Their research resulted in four subscales: depressed/withdrawn behavior, antisocial behavior, impulsive/hyperactive behavior, and General Behavior Problems.

The four-factor version of the CBCL constructed by Peterson and Zill became the basis of the Behavior Problems Index (BPI), a measure used to assess behavior problems as part of the National Longitudinal Survey of Youth (1979) Children and Young Adults (NLSY79 Children and Young Adults). Other items were added from other child behavior rating scales to create a six subscale behavior measure (Center for Human Resource Research, 2006). The scales measure anxiety, sadness, feelings of inferiority (Anxious/Depressed); the need for attention and clinginess (Dependent); stubbornness, general disobedience, and argumentativeness (Headstrong); hyperactivity and impulsivity (Hyperactive); the degree to which the child interacts and gets along with other children (Peer Problems); and behaviors such as lying, lack of remorse, and deliberate disobedience (Antisocial). These six behavior problems will be the focus of the literature review on behavior problems.

The measure also yields two general scores, internalizing and externalizing. The internalizing and externalizing dimensions are not composed of summed subscale scores. Instead, individual items, regardless of their subscales, are allocated onto the internalizing and externalizing scales. In general, the internalizing score reflects the degree to which children display anxious/depressed behaviors, dependent behaviors, and, to a lesser degree, hyperactive behaviors and peer problems. The externalizing score generally reflects the degree to which children display antisocial behaviors, hyperactive behaviors, headstrong behaviors, have peer problems, and, to a lesser degree, anxious/depressed behaviors (Center for Human Resource Research, 2006).

Theories Regarding Behavior Problems

Several theories help explain both externalizing and internalizing behavior problems in children. According to social cognitive theories, externalizing behavior problems in children, such as aggression, disobedience, or stealing, stem from cognitive deficiencies that make it difficult for certain children to find alternative solutions to interpersonal conflict (Dodge, 1993). Children with externalizing behavior problems often lack problem solving skills and lack a repertoire of solutions to difficult problems (Lochman, Powell, Whidby, & Fitzgerald, 2006). Children with externalizing behavior problems tend to be overly sensitive and attribute hostile intentions to others. As a result, they struggle to generate solutions to interpersonal problems and act aggressively (Dodge, 1991). Additionally, they tend to over-identify their emotions as anger (Lochman et al., 2006). One of the important aspects of this model, as it relates to this literature review, is that children with certain externalizing behaviors are thought to have cognitive deficiencies which lead to poor problem solving skills.

According to cognitive theories, children who display internalizing behavior problems such as depression also misinterpret information. Such children are likely to internalize negative information and ignore positive information about themselves (Dodge, 1991). Because they are more likely to attend to negative information they develop negative self-schemas. Accordingly, when they retrieve information about the self from long-term memory, they remember negative information about themselves (Hammen & Rudolph, 2003). Alternatively, children with high levels of anxiety may develop schemas about aspects of their environment which cause fear (Kendall & Suveg, 2006). They then tend to interpret stimuli to be dangerous or harmful. Regardless of the disorder, according to cognitive theories, the schemas which one forms early in life affect later behavior patterns. Thus, the formation of schemas, based on early factors, helps explain behavior problem development.

Influences of Behavior Problems

The presence of behavior problems in children can begin early. Several studies have established the ability to distinguish between externalizing and internalizing behavior problems at early ages (Breitenstein, Hill, & Gross, In Press; Moreland & Dumas, 2008; Sterba, Prinstein, & Cox, 2007). One study suggests that in the general population, problem behavior generally decreases between ages 2 to 5 and increases during adolescent years (Keenan & Shaw, 1997). However, the stability of behavior problems at early ages is unclear. Disruptive preschoolers, as rated by parents and teachers, were rated as displaying similar behaviors at an eight month follow up, suggesting that children who demonstrate behavior problems early continue to demonstrate behavior problems (Gadow, Sprafkin, & Nolan, 2001). In another study,

67% of preschoolers identified as having behavior problems at age three were also identified as having behavior problems at age nine (Pierce, Ewing, & Campbell, 1999). However, other research suggests that behavior problems are not stable over time and that children who demonstrate behavior problems early will not necessarily demonstrate the same problems later (Bub, McCartney, & Willett, 2007). The difference in results may be due to methodology as the study suggesting a lack of stability in behavior problems over time used latent growth curve analysis.

Several other studies have examined the development of behavior problems over the course of childhood using latent growth modeling. One such study showed not only that children's levels of internalizing and externalizing behavior problems change over time, but also that children do not necessarily retain the same rank order over time. The study further showed that externalizing behaviors are more stable over time than internalizing behaviors (Bub et al., 2007). Another study showed that internalizing problems increase in a curvilinear fashion over time and that withdrawn behavior increases in adolescence (Bongers, Koot, Ende, & Verhulst, 2003). Another study highlighted the development of problem behavior between ages 11 and 18. Problem behavior was measured by alcohol and marijuana use, deviancy, and academic failure. Results suggested that all indicators of the behavior problem variable increase throughout adolescence (Duncan, Duncan, & Strycker, 2001). Although children and adolescents generally follow certain trends, several variables affect both initial levels of behavior problems and the development of behavior problems.

Socioeconomic Status

One influence on behavior problems is SES. Children from low SES backgrounds tend to exhibit more behavior problems than children from high SES backgrounds. The effects of living in disadvantaged neighborhoods are evident in children by the time they enter elementary school (Winslow & Shaw, 2007). One of the major reasons for this phenomenon is that children from low SES backgrounds are more likely to be exposed to crime and poverty (Beyers et al., 2003). Additionally, low SES children do not receive as much parental supervision as those from high SES backgrounds (Schonberg & Shaw, 2007). Those children who do not receive parental supervision are more likely to spend time in the community, and, due to the higher levels of crime in low SES communities, children from low SES backgrounds are more likely to exhibit externalizing behavior (Beyers et al., 2003). Accordingly, children from low SES backgrounds are at risk for exhibiting behavior problems.

Socioeconomic status also plays a role in the development of behavior problems. One study showed that those who witness violence early show more positive attitudes towards violence and less favorable attitudes towards nonviolence. Witnessing violence was also related to increases in drug use, increases in favorable attitudes towards violence, and decreases in attitudes supporting achievement (Farrell & Sullivan, 2004). SES is also predictive of initial levels of eternalizing behaviors and change in externalizing behaviors as reported by children's mothers; children from low SES backgrounds display higher levels of externalizing behaviors, and children from high SES backgrounds display greater decreases in externalizing behaviors. In the same study, initial levels of internalizing behaviors were higher for children from low SES backgrounds as reported by teachers (Kraatz Keiley, Bates, Dodge, & Petit, 2000). Long

term exposure to poverty results in higher levels of initial levels of childhood antisocial behavior and leads to increases in antisocial behavior over time. Conversely, children whose mothers were able to escape impoverished circumstances showed similar developmental trends in antisocial behavior as children whose mothers were never poor (Macmillan, McMorris, & Kruttschnitt, 2004). Thus, SES not only plays a role in initial influences on behavior problems, but also influences change in behavior problems over time.

Sex Differences

Behavior problems are also linked to sex differences. Boys often demonstrate higher levels of externalizing behavior problems than females while females demonstrate higher levels of relational aggression. Further, females and males demonstrate similar levels of lying and stealing (Tiet et al., 2001). Some of these differences may be due to environmental and social factors. One explanation is that direct aggression is discouraged in females, (Lagerspetz & Bjorkqvist, 1994) and, as such, females resort to indirect forms of aggression. Additionally, such differences may be due to different biological mechanisms. That is, males with externalizing behavior demonstrate reduced functioning of the autonomic nervous system while psychophysiological response patterns were greater for females (Beauchaine, Hong, & Marsh, 2008). Additionally, sex differences in alcohol-related problems may in part be due to genetic influences (McGue, Pickens, Svikis, 1992). Thus, significant sex differences are observable across multiple behavior problems.

Although sex influences behavior problems, it may not play a role in the development of behavior problems in childhood. One study found that although boys

demonstrated higher levels of aggressive behavior, both boys and girls demonstrated similar growth patterns in aggressive behavior (Prinzie, Onghena, & Hellinckx, 2006). Another study showed similar results for both externalizing and internalizing problem behaviors. Boys demonstrated higher initial levels of externalizing problems while girls demonstrated higher initial levels of internalizing problems. Sex did not predict change in externalizing or internalizing behavior over time (Dekovic, Buist, Reitz, 2003). Other research has also found differing levels of initial behavior problems and similar levels of growth, and found that girls and boys who began drinking at a young age showed similar levels of growth in behavior problems (Johnson, Arria, Borges, Ialongo, & Anthony, 1995). However, other research shows that during adolescence, developmental patterns shift as girls begin to mature faster than boys and, during this time, girls develop more internalizing behaviors relative to boys (Keenan & Shaw, 1997). Accordingly, the absence or presence of significant sex differences in behavior problem research may be related to the age range in the study and the rate of maturation during that age range.

Cognitive Ability

Cognitive ability is also a possible influence on behavior problems. In one study, the effect of intelligence scores on the persistence of conduct disorder was examined, and results showed that the persistence of conduct disorder was more likely in children with low verbal intelligence scores (Lahey et al., 1995). Additionally, scores at age five on measures of cognitive ability were found to be predictive of income, worklessness, depression, criminality in men, and teen motherhood (Feinstein & Bynner, 2004). In another study, scores from the Wechsler Intelligence Scales for Children – Third Edition (WISC-III) were predictive of later criminality, substance abuse, sexual adjustment, and

occupational outcomes; however, many of these relations disappeared after controlling for background factors. The effect of WISC-III scores gathered at ages eight and nine were examined at ages 15 to 25. Results showed that childhood WISC-III scores were related to childhood conduct problems, attention problems, anxiety/withdrawal, low SES, family stability, and parent adjustment problems. After controlling for background factors, WISC-III scores were still predictive of later depression (Fergusson, Horwood, & Ridder, 2005). Thus, while background factors such as SES account for more variability in behavior problems than intelligence scores, intelligence scores still account for some variance in behavior problems above and beyond those background factors.

Working Memory

Working Memory and Inattention/Hyperactivity. Several studies have examined the link between inattention and working memory. In one study, attention problems were regressed on Digits Forward and Digits Backwards from the WISC-III. While Digits Forward did not predict attention problems, Digits Backwards did predict attention problems as measured by the teacher report form from the CBCL (Hale, Hoeppner, & Fiorello, 2002). Similarly, other research shows that participants with Attention-Deficit Hyperactive Disorder (ADHD) did not differ from controls on a memory span subtest, but ADHD participants scored lower than controls on a digits-backward type test (McInnes, Humphries, Hogg-Johnson, & Tannock, 2003). In this study, nonverbal working memory tasks were also associated with ADHD but not nonverbal memory span tasks. Thus, measures of memory span are not predictive of inattention, but measures that require participants to manipulate information (working memory) are predictive of inattention.

Deficits in working memory are also associated with hyperactivity. In one study, researchers found that a measure of nonverbal working memory predicted hyperactive behavior after controlling for other executive functions (Seguin, Nagin, Assaad, & Tremblay, 2004). Similarly, research shows that hyperactive behavior is associated with nonverbal working memory and difficulties in sustained attention (Murphy, Barkley, Bush, 2001). In a nonclinical sample, spatial working memory deficits were associated with teacher rated impulsive and hyperactive behavior (Aronen, Vuontela, Steenari, Salmi, & Carlson, 2005). However, other research has found significant associations between hyperactive behavior and verbal working memory (McInnes et al. 2003). Specifically, children with ADHD did not differ from controls in verbal Memory Span, but did differ from controls in verbal working memory. In another study, children with ADHD performed worse on measures of verbal working memory than controls and children with ADHD who receive medication (Semrud-Clikeman, Pliszka, & Liotti, 2008). Thus, differences in both verbal and nonverbal measures of working memory are found when comparing children with ADHD to controls and are predictive of hyperactive behavior.

Not all studies have confirmed the link between working memory and hyperactive and inattentive behaviors. One study found no differences on measures of working memory between ADHD participants and controls aged 12 to 19. However, the lack of significant findings was explained by low task difficulty and the possible effect of cognitive development (Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001). Because executive function is related to age, the researchers reasoned that differences in working memory in children with behavior problems may disappear over time. Another study

examined the effect of working memory on attention problems across age groups. Results showed that verbal working memory did not predict inattention in 6 to 9.7 year olds but did predict inattention in 9.8 to 13 year olds (Brocki & Bohlin, 2006). Both of these studies suggest an age effect in working memory for children with inattentive and hyperactive behaviors. Accordingly, working memory abilities may explain developmental trends in inattentive and hyperactive behavior, specifically in late childhood and early adolescence.

Barkley's (1997) model of ADHD explains the link between working memory and hyperactive, impulsive, and inattentive behaviors. Key to the link between verbal working memory and behavior problems in this model is the internalization of speech. Children initially use speech to communicate with others, but over time speech becomes internalized. Other activities, such as play and emotion, may be internalized as well. The model suggests that children with ADHD experience a delay in the internalization of such activities. The delay in internalization results in less private and more public speech, and thus less reflecting on thoughts before acting thoughts out. Private speech is dependent on verbal working memory, the phonological, loop and the revival of auditory information in phonological loop. Accordingly, children with working memory deficits are less likely to revive information in the phonological loop and think about their actions resulting in impulsive behavior.

Barkley's model also explains the link between nonverbal working memory and behaviors associated with ADHD. Within nonverbal working memory, mental images and sequences of events can be analyzed in order to anticipate future actions and sequences of events. To maximize the potential to sequence events, one must maximize

the ability to focus on, and pay attention to, the information in one's mind. This ability, like the ability to use the phonological loop, develops over time. Developmental deficits in the ability to focus on and manipulate information lead to a reduction in the ability to sequence events, find recurring patterns, and anticipate rewards. Children with low visual working memory abilities are then more likely to act impulsively without considering consequences.

Working Memory and Antisocial Behavior. Working memory is also related to antisocial behaviors. One study examined cognitive differences between boys who had and had not been expelled from school due to physical aggression, failure to follow rules, and possession of weapons (among other behavior problems). Results showed that children expelled from elementary school scored lower on measures of verbal working memory than non-expelled children; however, no difference in verbal working memory were found for high school age adolescents (Ripley & Yuill, 2005). Another study examined the role of working memory in the link between aggression and response perseveration, controlling for general memory. Researchers engaged participants in the Card-Playing Task and defined perseveration as continued play "past the point where the rate of punishment outweighs the rate of reward, which results in losses of the maximum possible earnings." Results showed that physically aggressive boys with lower working memory scores were more likely to perseverate (Seguin, Arseneault, Boulerice, Harden, & Tremblay, 2002). Other research has found that working memory mediates the relationship between social deviance and alcoholism. Results showed that participants who scored high on a measure of social deviance and low in working memory reported more alcohol use than participants who scored high on both measures (Finn & Hall,

2004). Accordingly, working memory is predictive of antisocial behaviors and has an effect on the actions of people who display antisocial behaviors. Additionally, age may play a role in the link between working memory and antisocial behaviors.

The link between antisocial behavior and working memory may be explained in part by the role working memory plays in problem solving. As previously mentioned, children with externalizing behaviors tend to lack problem solving skills, and according to Seguin et al. (2004):

> Working memory allows an individual to shift perspectives on a problem, define goals while considering several parameters of a problem simultaneously, plan a strategy while anticipating consequences, execute steps of a plan held in memory, monitor progress, detect and correct errors, and accommodate new data while filtering out interference.

When such processes fail and children are exposed to negative environmental factors, children are more likely to resort to aggressive forms of conflict dispute (Aguilar, Sroufe, Egeland, & Carlson, 2000). Additionally, results from the study employing the Card-Playing Task suggest that adolescents with lower working memory abilities are less able to attend to and monitor relevant information, reevaluate their behavior, and change their actions based on relevant information (Seguin et al., 2004). Accordingly, low working memory ability may not only contribute to antisocial behavior, but may contribute to the perseveration of antisocial behavior.

Working Memory and Headstrong Behavior. The link between working memory and headstrong behavior is not as well established as the link between working memory and other externalizing behaviors. One study examined the link between hard-to-manage

preschoolers and cognitive functions. Results showed that children in the hard-to-manage group scored significantly lower than children in the control group on a task designed to measure working memory and planning abilities. The hard-to-manage group also showed deficits in inhibitory control and flexibility of attention (Hughes, Dunn, & White, 1998). Accordingly, group differences in hard-to-manage preschoolers and controls may reflect comorbidity between headstrong behavior and ADHD.

Research examining cognitive profiles of children and adolescents with Oppositional Defiant Disorder (ODD), a disorder that is marked by symptoms consistent with headstrong behavior as defined by the BPI, does not show that children and adolescents with ODD show deficits in working memory when compared to controls (van Goozen et al., 2004; Thorell & Wahlstedt, 2006). Comparisons of ADHD/ODD, ODD, and ADHD groups did not reveal a relationship between ODD symptoms and working memory deficits, but ADHD symptoms were associated with working memory deficits (Oosterlaan, Scheres, & Sergeant, 2005). Such research further suggests that any relationship between headstrong behavior and working memory deficits may be due to the comorbidity of ADHD and ODD.

Working Memory and Peer Problems. Little research exists related to both working memory and peer problems. One study found that social competence was related to working memory but not memory span tasks. The explanation for this phenomenon was that multitasking and the central executive are necessary processes for social competence (Lieberman & Rosenthal, 2001). Other research has suggested that social skills, theory of mind (the ability to understand other people's thoughts, beliefs, and intentions, etc.), and working memory development may all be related. One study showed

a significant negative correlation between working memory and social problems and a significant positive correlation between working memory and theory of mind. Similar to other research examining the link between working memory and behavior problems, tasks requiring the manipulation of information were significantly correlated with theory of mind while memory span tasks were not (Fahie & Symons, 2003). Accordingly, working memory and higher order thought processes, such as other executive functions, are associated with theory of mind and thus perspective taking and empathy (Call & Tomasello, 1999). Thus, if working memory influences social skills, then the development of the ability to attribute mental states to others is a likely mediator.

Working Memory and Anxiety/Depression. Working memory and anxiety have been examined in multiple research studies; however unlike working memory and other behavior problems, anxiety is thought to affect working memory abilities (rather than the reverse). Some research has found that threat-induced anxiety affects visuospatial working memory but not verbal working memory (Shackman et al., 2006). Other studies have found both working memory and visuospatial working memory deficits caused by anxiety. In one study, spatial and digit span tasks were not related to self-reported worry, but spatial and digit reversed tasks were related to self-reported worry (Crowe, Matthews, & Walkenhorst, 2007). Another study compared working memory abilities in high and low anxiety students according to Baddeley's model of working memory. Results showed that anxiety did not affect tasks designed to measure the abilities of the phonological loop or visuospatial sketchpad; however, anxiety did affect the central executive, or the scores on tasks requiring the manipulation of information (Eysenck, Payne, & Derakshan,

2005). Thus, anxiety appears to affect working memory as opposed to memory span, and it may affect visuospatial more than verbal working memory.

Multiple theories explain the link between anxiety and working memory deficits. Neurobiological theorists have identified the infralimbic medial prefrontal cortex as a brain structure that is responsible for the regulation of both anxiety and working memory (Wall & Messier, 2000). Lee (1995) hypothesized that an individual's stores of knowledge contain a network of emotion schemas. When an individual encounters a stressful situation, the anxiety network is cued and working memory capacity is diminished as the individual attends to irrelevant information. Likewise, according to processing-efficiency theory, individuals who become anxious engage in task-irrelevant worry and allocate working memory resources, which are finite, to irrelevant information. Thus, task-relevant working memory capacity is diminished. This theory also accounts for positive effects of anxiety on working memory by acknowledging that moderate amounts of anxiety can result in the allocation of more resources to a task. Thus, anxiety is most likely to negatively affect working memory when anxiety is high or the task is complex (Eysenk & Calvo, 1992).

Multiple research studies have found differences in depressed and non-depressed participants on measures of working memory. In one study using the CBCL, children high on the anxious/depressed scale as rated by teachers scored lower than peers on measures of visual working memory (Aronen et al., 2005). While such differences may have been due to the anxiety component of the scale, other studies have found differences in working memory in depressed and control groups. In one study, researchers examined event-related potentials (ERPs) in depressed participants and controls. Results showed

that ERPs differed significantly between depressed and non-depressed participants (Pelosi, Slade, Blumhardt, & Sharma, 2000). Another study showed significant differences between depressed and control participants on an n-back test of working memory (Harvey et al. 2004). Thus, a significant relation appears to exist between depression and working memory independently of anxiety.

Although a consistent link between working memory and depression is evident, research studies show conflicting results regarding the effect of depression on the various components of working memory. The results of a comparison between depressed individuals and controls showed that depression affects all components of working memory: the phonological loop, visuospatial sketchpad, and the central executive (Christopher & MacDonald, 2005). However, not all studies have found differences between depressed participants and controls in the phonological and visuospatial components of working memory. A comparison of individuals with Major Depressive Disorder and controls revealed deficits in the central executive but not the phonological loop or visuospatial sketchpad for depressed individuals (Rose & Ebmeier, 2006). A consistent finding of both studies is the reduced ability to manipulate information while held in immediate awareness in depressed individuals.

Some theories explaining the link between working memory and depression are similar to theories explaining the link between working memory and anxiety. Specifically, individuals with depression use working memory resources to ruminate on task-irrelevant information, especially emotional information. Thus, less working memory capacity is devoted to task relevant information and individuals with depression score lower than controls on measures of working memory (Joormann, 2006). However,

individuals with depression may also have difficulties expunging irrelevant information from working memory. Difficulties with inhibiting irrelevant information could lead to uncontrollable negative thoughts and thus increased depression (Joorman & Gotlib, 2008). Accordingly, deficits in working memory, especially as they relate to the ability to focus on and inhibit information, could influence depressive symptoms.

Working Memory and Dependent Behavior. Working memory abilities and the degree to which a child is dependent on a parental figure may be independent of each other. Several literature searches were unsuccessful in trying to find research articles linking dependent behavior with working memory. The dependent behavior scale of the BPI measures behaviors such as the tendency to cling to adults, high levels of crying, demanding attention, and general dependency. Because such behaviors are not likely to place high demands on the ability to manipulate information in immediate awareness, a relation between working memory and dependency is unlikely.

Summary

Theories explicating the causes of behavior problems often specify cognitive deficits as contributors to behavior problems. One cognitive deficit that has received attention is working memory. Research shows that working memory is related to both internalizing and externalizing behavior problems, and multiple research studies have found group differences in working memory abilities between controls and children with depression, anxiety, hyperactive behavior, inattentive behavior, antisocial behavior, and peer problems. The relation between working memory and some of these abilities has been explained by theory. Specifically, deficits in working memory directly affect hyperactive and inattentive behavior, as hyperactive behavior is a product of reduced

internalization of speech and other processes and inattentive behavior is a product of reduced ability to focus. Antisocial behavior is also affected by working memory as working memory plays a major role in problem solving and the ability to generate solutions to a problem. Conversely, theory suggests that anxiety and depression reduce working memory abilities as emotional material occupies immediate awareness and reduces the amount of information that can be processed by working memory structures. However, other research suggests that the ability to inhibit irrelevant information from entering immediate awareness is a function of working memory. Thus, deficits in the ability to inhibit information may contribute to internalizing behaviors. Accordingly, working memory may contribute to both externalizing and internalizing behaviors.

Common Cause

The number of factors that influence behavior problems far exceed the scope of this review. Accordingly, the only influences on behavior problems discussed here are those that potentially influence working memory as well. Among these factors are SES, sex, and cognitive ability. Although the link between SES and working memory has not been examined at great length, several studies show that children from low SES backgrounds perform worse than children from high SES backgrounds on measures of working memory. Additionally, SES affects behavior problems. Children from low SES backgrounds are more likely to demonstrate externalizing behaviors and SES is likely to contribute to the development of externalizing behaviors in children. Thus, SES is possible common cause of both working memory ability and behavior problems.

Sex is also a common cause of variation in working memory and behavior problems. Research shows that females score higher on measures of auditory working

memory while males tend to score higher on measures of visuospatial working memory. Additionally, males and females show different levels of internalizing and externalizing behavior problems with males demonstrating more externalizing and females demonstrating more internalizing behavior problems. However, sex may not play a role in the development of behavior problems in children. Nevertheless, sex does appear to affect both working memory ability and behavior problems.

Finally, cognitive abilities, such as memory span, may be a common cause of working memory and behavior problems. Cognitive factors such as processing speed and memory span influence working memory as memory span stores the information made available to working memory and processing speed increases the rate at which information can be rehearsed. Measures of general intelligence are predictive of certain behavior problems; however, the effect of specific cognitive abilities, other than working memory, on behavior problems is not known. And, while much of the effect of intelligence scores on behavior problems may be explained by SES, intelligence scores are independently predictive of behavior problems. At the very least, memory span is a likely common cause of behavior problems and working memory and other cognitive abilities may be common causes as well.

Statement of the Problem

This study will add to the literature on the link between working memory and behavior problems by answering the question: Do developmental changes in working memory affect the development of behavior problems in children? Sufficient evidence exists to hypothesize that changes in working memory abilities will lead to changes in certain behavior problems. First, working memory develops at different rates in children,

which is in part due to individual progress through certain milestones. Milestones in the development of working memory include the development of the phonological loop, subvocal speech, and the ability to recode visuospatial information into phonological information. Second, children who demonstrate behavior problems during their youth will not necessarily demonstrate behavior problems in adolescence. Thus, behavior problems develop differently in children. Third, working memory affects certain behavior problems; however, no research has examined the relationship between growth in working memory and growth in behavior problems with longitudinal data.

The hyperactive and inattentive behaviors are the most likely behaviors to be affected by changes in working memory. Working memory is hypothesized to be one of the key cognitive factors that influences hyperactive and inattentive behavior, and the development of such behaviors are hypothesized to be dependent on the development of working memory. Specifically, hyperactive behavior is thought to be caused by delays in subvocal speech and subvocal speech is a product of working memory. Accordingly, as children develop subvocal speech, they may show decreases in hyperactive behavior. Additionally, deficits in the ability to inhibit irrelevant information from entering immediate awareness contributes to inattentive behavior and changes in the ability to inhibit information may lead to changes in inattentive behavior. Thus, both inattentive and hyperactive behaviors should be inversely related to working memory.

Development in working memory abilities may also influence the development of other externalizing behavior problems. Externalizing behaviors are influenced by cognitive deficits such as planning and problem solving. As working memory is required for higher order thought such as planning and problem solving, changes in working

memory may lead to an increased ability to plan, problem solve, and generate solutions to problems. As such abilities increase, externalizing behaviors may decrease.

Changes in working memory should correlate with changes in symptoms of anxiousness and depression. However, the nature of causality is unclear. Some theories suggest that depression and anxiety cause decreases in working memory as individuals occupy working memory capacity with irrelevant information. Other theories suggest that the central executive, a component of working memory, is responsible for filtering irrelevant information; thus, individuals with diminished working memory abilities are more likely to suffer from problems with depression and anxiety. If such theories are correct, changes in working memory scores should predict changes in depression and anxiety.

Finally, changes in both externalizing and internalizing problems may not be affected by changes in working memory. That is, behavior problems across childhood and adolescence may primarily be affected by early experiences. According to cognitive theories, repeated experiences help form schemas, and as experiences accumulate and children develop patterns of interacting with their environments, they are less likely to explore new ways of interacting with their environments (Crick & Dodge, 1994). Thus, the effect of working memory on behavior problems may be strongest during early childhood, and the effect of deficits in working memory early in life may be a stronger predictor of later behavior problems than changes in working memory. Such results would indicate that young children who show low scores on measures of working memory would be candidates for early behavior interventions.

CHAPTER 3: METHOD

Data Set

This study used the NLSY79 – Children and Young Adults data set. This data set includes over 11,000 participants who are the children of women of the National Longitudinal Survey of Youth (1979; NLSY79). The NLSY79 is a nationally representative survey of young men and women aged 14 to 22 in 1979. Accordingly, the NLSY79 Children and Young Adult survey is representative of children born to women born between 1957 and 1964. The NLSY79 Children and Young Adult survey began in 1986 and is administered biennially. The most current round of data available for analysis was administered in 2006.

The NLSY79 – Children and Young Adults data set includes data from child assessments, self-reports from children ages 10 to 14, and relevant information from the main NLSY79 interviews with the children's mothers. Assessments were conducted primarily through personal interviews and include information about the child's family background, prenatal and postnatal health history, home environment, cognitive development, motor development, social development, emotional development, educational experiences, and preteen and teen behaviors. Relevant to this study are measures of cognitive ability, behavior problems, and family background characteristics. Additionally, because participants' mothers were assessed in the NLSY79 survey, the two data sets can be linked using the mothers' identification number to obtain further background information. Accordingly, a wealth of longitudinal data is available through the linked data sets.

Participants

The sample for the current investigation included 3,927 children from the NLSY79 – Children and Young Adult survey. Participants were selected from the data set if they met two criteria. First, only one child per household could be in the study. This data set contains all of the children of the women who participated in the NLSY79 and thus many of the participants in the data set have brothers and sisters in the data set. In order to not violate the assumption of structural equation modeling that each observation is drawn independently from the sample, only one participant per household was randomly selected to participate in this study. Second, each participant had to have the opportunity to have participated in at least two assessments. As participants were first interviewed in 1986 and some participants were 13 years old or older in 1986, those participants only had the opportunity to be assessed once. Additionally, participants who were 7 or 8 in 2006, the most recent survey year, only have had the opportunity to be assessed once. Such participants were excluded from this research study to get a better estimate of the developmental trajectories of working memory and behavior problems in children.

The method of analysis that was used in this study is latent growth modeling which requires that each participant is measured on the same variable at least three times. As participants are included in this study having had only two assessments and the data set contains missing data for participants who have had the opportunity to be assessed three times, full information maximum likelihood estimation was used to estimate missing data. Full information maximum likelihood estimation is one of the best ways to

handle missing data and can be used to handle missing data in longitudinal data analyses (Graham, 2009).

Demographic information for the sample is provided in Table 1. Children included in the sample were between the ages of 7 and 14. The sample includes approximately equal numbers of males and females, and the average highest grade completed by participants' mothers was 12th grade.

Table 1

Demographic Characteristics of Study Sample

Variable	N
Total Sample	3,927
Sex	
Female	1,894
Male	2,033
Year of Birth	
Low	1973
High	1998
Median	1985
Race/Ethnicity	
African American	1135
Hispanic	741
Non-African-American, Non-Hispanic	2051
Maternal Education	
≤11th Grade	715
High School Graduate/GED	1274
1-3 Years College	749
≥ 4-Year Degree	526

Measures

Working Memory

The Digit Span Backwards task was used to measure working memory. This task requires the ability to hold information in immediate awareness and manipulate that information, and thus, meets the criteria of working memory tasks. The Digit Span Backwards test represents half of the Digit Span subtest of the WISC-III (as well as previous and subsequent versions of the Wechsler intelligence tests). The task requires that individuals listen to a series of numbers and repeat the numbers to the examiner backwards. The task increases in difficulty and ends when the examinee fails two consecutive trials. The participant's raw score, which was used in this investigation, is the sum of the number of correct trials.

The psychometric properties of the Digit Span subtest of the WISC-III appear sound. In a cross-battery confirmatory factor analysis of the WJ-III and WISC-III, the Digit Span subtest of the WISC-III and the numbers reversed subtest of the WJ-III (a subtest similar to Digit Span Backwards) appeared to be strong indicators of working memory (Phelps, McGrew, Knopik, & Ford, 2005). Also, the median internal consistency coefficient for the Digit Span Subtest of the WISC-III is .79 (Kamphaus, 2001). Finally, the Digit Span Backwards task does not appear to show cultural bias (Mott, Baker, Ball, Keck, & Lenhart, 1995). Thus, scores on the Digit Span tasks appear reliable and valid.

Behavior Problems

As previously mentioned, the BPI measures several behavior problems, and the NLSY79 – Children and Young Adult study offers externalizing and internalizing composite scores. The questionnaire is completed by the child's mother, and responses to

the questions are in the same three-point format as the CBCL. A table including the questions included in the BPI, the corresponding behavior problems measured by these questions, and whether the questions measure internalizing or externalizing behaviors, is provided in the Appendix.

Scores on the BPI demonstrates adequate reliability and validity. Internal consistency coefficients for the externalizing scale ranged from .868 to .890 from 1990 to 1994. Internal consistency coefficients for the internalizing scale ranged from .744 to .781 from 1990 to 1994 (Guttmannova, Szanyi, & Cali, 2008). An examination of the validity of the BPI published by the Center for Human Resource Research reported that the BPI is a robust predictor of attitudes and behavior problems in children (Mott et al., 1995). Additionally, the researchers concluded that there is little evidence for systematic non-completion for those of African-American or Hispanics descent, or other respondents. Generally, African-American students score higher on the BPI (as do older children), a phenomenon the researchers attributed to the effects of SES. Finally, results showed that the BPI correlates as expected with measures of maternal education, family income, and sex.

This study used subscales from the BPI, but altered some of the subscales so that subscales were unitary measures of internalizing and externalizing behaviors. The Anxious/Depressed subscale was divided into an Anxious and a Depressed subscale. The Anxious subscale consisted of the items “Is too fearful or anxious” and “Worries too much.” The Depressed subscale consisted of the remaining items that measure internalizing behaviors from the Anxious/Depressed subscale and the item “Is withdrawn, does not get involved with others.” Adding the final item to the depressed subscale is

warranted as withdrawal is an indication of depression (American Psychiatric Association, 1994, p. 349). Two items from the Hyperactive scale were used for a Inattentive scale: “Has difficulty concentrating/paying attention” and “Is easily confused, seems in a fog.” Thus, the Anxious, Depressed, and Inattentive scales were measures of internalizing behaviors.

Externalizing behaviors were measured by the Hyperactive, Antisocial, and Headstrong scales. The new Hyperactive scale consisted of the items from the original Hyperactive scale not included in the Inattentive scale. The Antisocial scale did not retain the item “Does not seem to feel sorry after misbehaving.” All other items on the Antisocial scale remained. The Headstrong scale also remained the same.

To form the new scales items were parceled to create variables. Again, this technique was used as the various behavior problem scales contain both internalizing and externalizing items and unitary measures of internalizing and externalizing behaviors were required for this study. For example, the Hyperactive scale on the BPI contains internalizing and externalizing items and was split into externalizing items which composed the new Hyperactive scale and internalizing items which composed the new Inattentive scale. New scales were made by adding the scores of individual items together. The Anxious scale, which consisted of the variables, “Is too fearful or anxious” and “Worries too much”, was created by adding the scores together for each participant. As the possible responses for each variable range from 0 (Not True) to 2 (Often True) the Anxiety scale had a range of 0 to 4. Parceling, by adding the raw scores for each question together to make a scale, was used for all behavior problem scales except the headstrong scale which was not altered.

Socioeconomic Status

This study used maternal education, the educational level of the mother's spouse or partner living in the home, and total family income as measures of SES (Acevedo-Polakovich, 2006). Maternal education is measured by the highest grade completed by the participant's mother, and the education level of the mother's spouse or partner is also measured by the highest grade completed by the mother's spouse or partner. Both the education variables and the total family income variables are reported by participants' mothers; however, the total family income variable was obtained through the NLSY79 data set while the maternal education variable is obtained through the NLSY79 – Children and Young Adult data set. Finally, to account for possible fluctuations in income, income data from all time points were included in the analyses.

Other Cognitive Measures

The Digit Span Forward task was used as a measure of memory span. Tasks such as Digit Span Forwards, in which the respondent repeats a series of items to an examiner, have been identified as measures of memory span in numerous studies (e.g., Chincotta, Underwood, Ghani, Papadopoulou, & Wresinski, 1999; Ottem, Lian, & Karlson, 2007). The Digit Span Forwards task is consistent with the Digit Span Backwards in validity and reliability (Mott et al., 1995); however, the backwards and forwards tasks represent distinct abilities (Reynolds, 1997).

The Peabody Picture Vocabulary Test (PPVT) was used to account for cognitive abilities outside the domain of short-term memory. To administer the PPVT, an examiner shows an examinee a page with multiple pictures and names one of the items on the page. The examinee is asked to point to the picture mentioned by the examiner. Thus, the

PPVT is a measure of receptive language skills. According to CHC theory, the PPVT measures crystallized intelligence, the narrow ability of lexical knowledge, and, to a lesser degree, the narrow abilities general information and language development (Flanagan & Ortiz, 2001). The PPVT is an ideal variable to control for non-short-term memory abilities as measures of crystallized intelligence are among the best predictors of general intelligence (Gignac, 2006). Additionally, the PPVT is predictive of scholastic aptitude (Mott et al., 1995). Finally, the reliability and validity of the PPVT in the NLSY79 – Children and Young Adult sample are evidenced by predicted associations with social and economic variables (Mott et al., 1995).

Data Reorganization

The format in which the data is available was reorganized for data analysis. The data set is formatted such that each measure is provided for each year in which they were collected. Accordingly, children of multiple ages all have data in the same variable. To best answer this study's research questions the data was reorganized so that data is organized by the age of the participant and not the year in which it was collected. Because data were collected every other year data were organized into four groups. The first group included measures collected for each participant at ages 7 to 8. The second group, which was referred to as Wave 2 data, consisted of data measured two years after the first assessment. Similarly, Wave 3 and Wave 4 data consisted of data measured four and six years after the first assessment.

Research Questions

Research Question 1: Do the developmental trajectories of children's working memory vary?

Before other analyses could be completed it was determined whether or not children's working memory ability develops at different rates. Previous research suggests that working memory is an ability that develops throughout childhood and into adulthood (Dempster, 1981; Hale et al., 1997). Additionally, working memory theories suggest that working memory develops at different rates in different individuals (Barkley, 1997). Accordingly, it was hypothesized that the developmental trajectories of children's working memory would vary significantly.

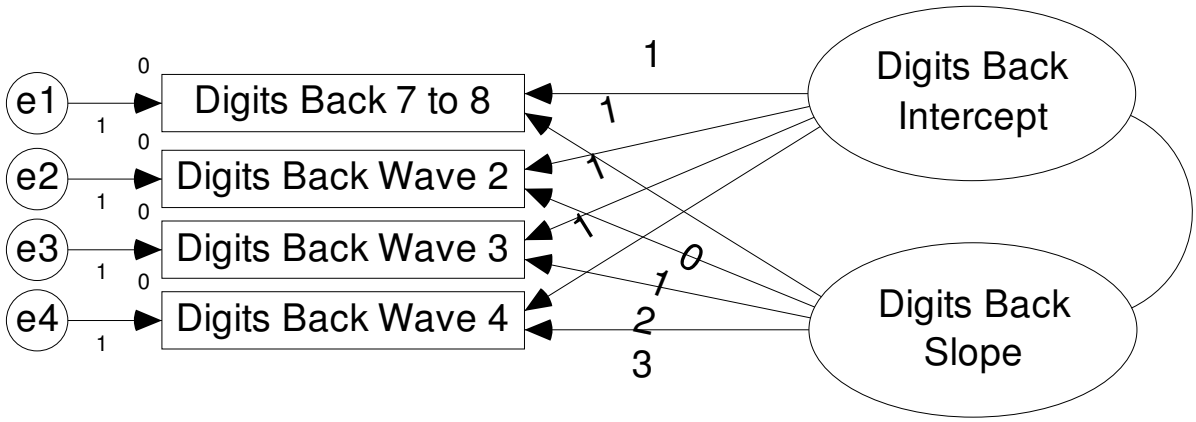
Latent growth modeling (LGM) was used to test if developmental trajectories of children's working memory vary significantly. LGM uses structural equation modeling to model latent slope and intercept factors. To model developmental trajectories using LGM a variable needs to be measured for each participant at least three times. An intercept factor is created, and paths from the latent intercept factor to each variable are constrained to a value of one. The mean of the intercept factor represents the initial status of the variable, and as such, a significant mean indicates that the initial status of the variables in the model is significantly different than zero. Thus, the latent intercept factor is similar in concept to the intercept of a regression equation (Duncan, Duncan, Strycker, Li, & Alpert, 1999). The variance of the intercept factor indicates the degree to which participants vary in their initial status of the variables in the model.

A slope factor is also created. The paths from the slope factor to the variable measured at time one is constrained to zero, the paths from the slope factor to the variable measured at time two is constrained to one, and so forth. The mean of the slope factor represents the average growth rate in the variable over time (Duncan et al., 1999). A significant positive mean for the slope factor indicates that the variable increases over

time, and a significant negative mean for the slope factor indicates that the variable decreases over time. The variance of the slope factor indicates the degree to which the developmental trajectories of participants vary on the variable. A LGM is shown in Figure 1.

Figure 1

Latent Growth Model



Structural equation models are either retained or rejected based on the consistency between a proposed model and the data. To assess the fit of a single model the Comparative Fit Index (CFI) was used in conjunction with the Tucker-Lewis Index (TLI) and the Root Mean-Square Error of Approximation (RMSEA). Values exceeding .96 for the CFI and TLI and below .06 for the RMSEA indicate that a model fits the data well (Hu & Bentler, 1998, 1999). Change in chi-squared will be used to compare nested models (Keith, 2006; Loehlin, 2004). Finally, the Akaike Information Criteria (AIC) will be used to compare non-nested models where smaller values suggest better fit (Loehlin, 2004).

The first and second research questions were tested using the same model. This model consisted of a growth curve for working memory, a growth curve for internalizing behavior problems, and a growth curve for externalizing behavior problems. The slope and intercept factors for each growth curve were allowed to covary as shown in Figure 2. A significant variance of the slope factor for the working memory growth curve would indicate that the developmental trajectories of children's working memory vary significantly.

Research Question 2: Do the developmental trajectories of children's internalizing and externalizing behavior problems vary significantly?

As with working memory, before other analyses could be completed it was determined whether or not children's behavior problems develop at different rates. Several research studies show that children vary in the development of behavior problems (Bongers et al., 2003; Bub et al., 2007; Duncan et al., 2001). Accordingly, it was hypothesized that in the current sample children would vary in the development of behavior problems.

As previous stated, this research question was answered using the same model as was used to answer the first research question. Likewise, significant variances of the slope factors for the internalizing and externalizing growth curves indicated that the developmental trajectories of children's internalizing and externalizing behavior problems vary significantly. However, as shown in Figure 2, the growth curves for internalizing and externalizing behavior problems are different than the growth curve for working memory. Curve-of-factors LGMs were used to estimate developmental trajectories for internalizing and externalizing behavior problems because multiple

measured variables were available for internalizing and externalizing behavior problems. In a curve-of-factors LGM, latent variables are used instead of measured variables for each time point. Also, paths from first-order factors to similar measured variable are constrained to be equal across time points. Error variances for similar measured variables are allowed to covary. For each first-order factor, the intercept of one measured variable is constrained to 0 (the same measured variable is chosen for each factor; Duncan et al., 1999). Thus, for the internalizing behavior problems growth curve, a latent internalizing behavior problem variable is composed of measured Anxious, Depressed, and Inattentive variables for each time point and the latent variables are used to form the growth curve (see Figure 3).

Figure 2

Working Memory, Internalizing, Externalizing LGM

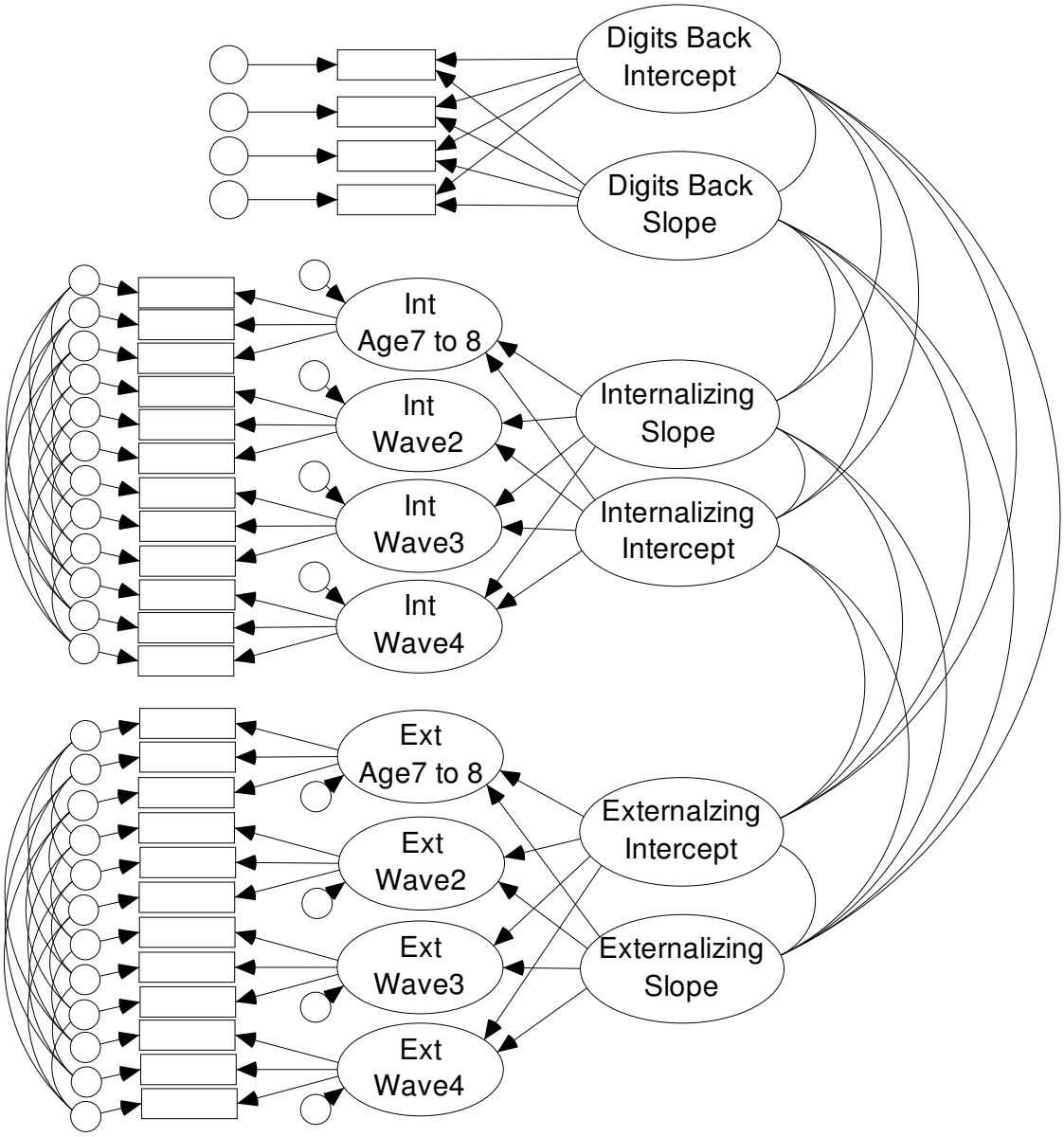
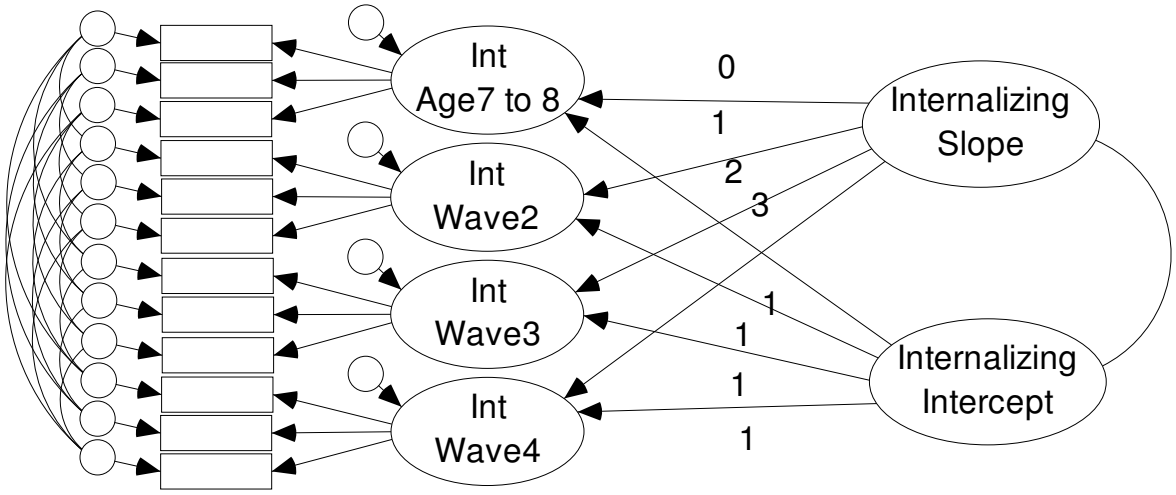


Figure 3

Curve-of-factors LGM



Research Question 3: Do differences in the developmental trajectories of working memory explain differences in the developmental trajectories of behavior problems?

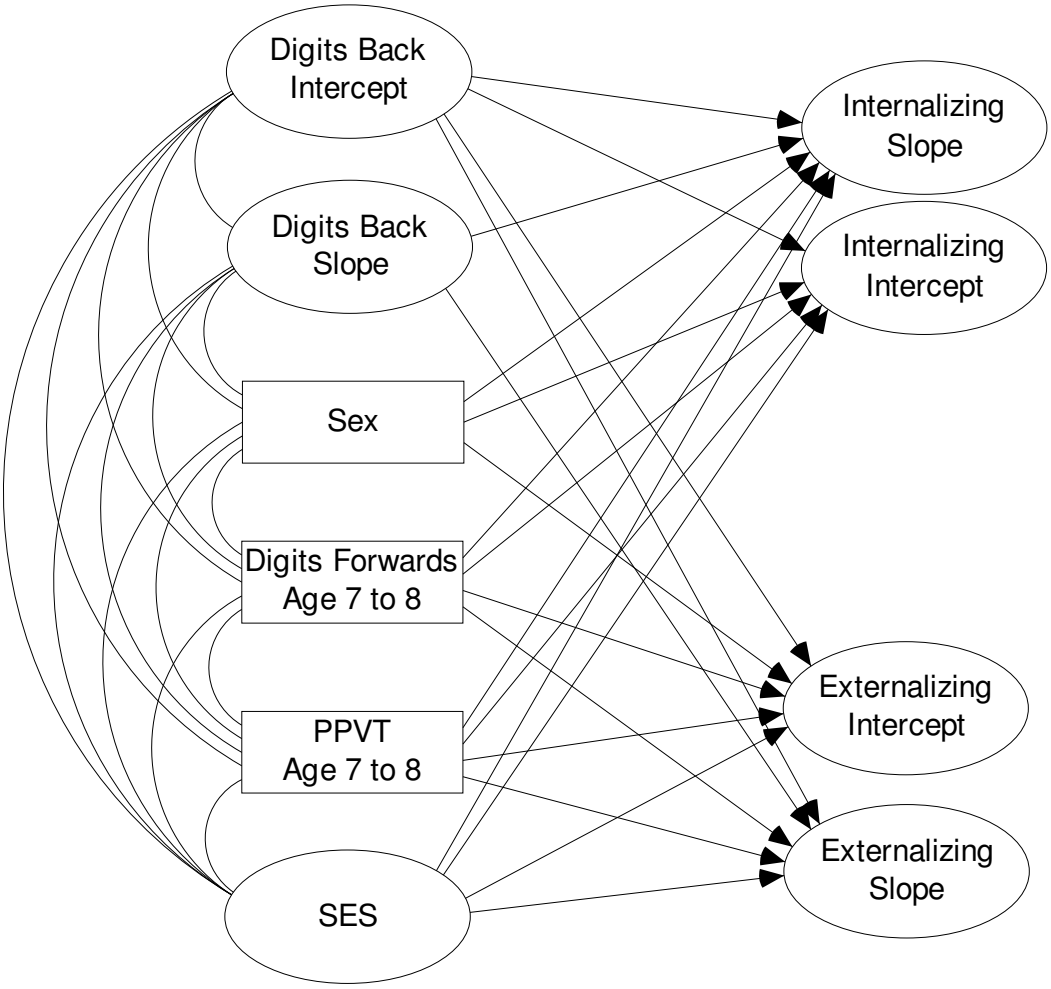
Previous research shows that working memory affects behavior problems such as hyperactivity (Seguin et al., 2004), inattention (Hale et al., 2002), antisocial behavior (Ripley & Yuil, 2005), and depression (Joorman & Gotlib, 2008). Additionally, Barkley's (1997) theory of ADHD identifies developmental delays in working memory as a major influence in the development of ADHD. Accordingly, it was hypothesized that developmental trajectories of working memory are inversely related to developmental trajectories of internalizing and externalizing behavior problems.

To test the effect of the developmental trajectories of working memory on the developmental trajectories of behavior problems the growth curves model with all growth curves and background variables was estimated. Background variables includeed sex, the Digit Span Forwards raw score as measured at ages 7 to 8, the PPVT standard score as

measured at ages 7 to 8, and a latent SES variable composed of income and parental education variables. Background variables were free to covary with the Digit Span Backwards slope and intercept variables. Dependent variables consisted of slope and intercept latent variables for internalizing and externalizing behaviors. Paths from all background variables and the Digit Span Backwards intercept factor pointed to all of the dependent variables. Paths from the Digit Span Backwards slope factor pointed to all of the dependent slope variables but not the dependent intercept variables as seen in Figure 4. Paths from the Digit Span Backwards slope factor did not point to the dependent intercept variables because the intercept factors of the behavior problems variables represent initial ability at ages 7 to 8 and the Digit Span Backwards slope factor represents change over the ages of 7 to 14. It seems illogical based on time precedence that a variable that accounts for change over time could affect a variable that accounts for initial status.

Figure 4

Proposed Baseline Structural Model



With all variables in the model, several modifications to the model were evaluated. First, the error variances of each growth curve were constrained to be equal. Testing for the equality of error variances was done one growth curve at a time and a non-significant increase in $\chi 2$ indicated that the modification improves model fit. Second, the error variances of each growth curve were allowed to covary. Testing the correlated error variances was done one growth curve at a time and a significant decrease in $\chi 2$

indicated that the modification improves model fit. Finally, paths from the slope variables to the age variables were released to test for linearity. Testing for linearity in the growth curves was done one growth curve at a time and a significant decrease in $\chi 2$ indicated that the modification improves model fit.

To provide evidence of the reliability of the model modifications, a calibration/validation approach to data analysis was used. This process is accomplished by randomly splitting the data base into two groups and using one group for the calibration group and one half for the validation group. Initial analyses, including the testing of hypotheses, were performed on the calibration group. Then all modifications from the calibration group were tested simultaneously on the calibration and validation groups. A model that demonstrates invariance using the calibration and validation samples suggests that results from the study are reliable.

Once invariance was established, the effects on the developmental trajectories of internalizing and externalizing behavior problems were evaluated. A significant negative path from the working memory slope variable to the internalizing slope variable indicated that developmental trajectories of working memory are inversely related to developmental trajectories of internalizing behavior problems. Likewise, a significant negative path from the working memory slope variable to the externalizing slope variable indicated that developmental trajectories of working memory are inversely related to developmental trajectories of externalizing behavior problems.

Research Question 4: Do SES, other cognitive factors, and sex contribute to differences or growth in behavior problems?

Previous research shows that children from low SES backgrounds show different trajectories in behavior problems than children from high SES backgrounds (Macmillan et al., 2004). Additionally, children with low scores on intelligence tests are more likely to have behavior problems than children with high scores on intelligence tests (Mathijssen, Koot, & Verhulst, 1999), and sex is predictive of externalizing and internalizing behavior problems (Prinzie et al., 2006). Accordingly, it was hypothesized that SES would be inversely related to the developmental trajectories of internalizing and externalizing behavior problems, but it was hypothesized that other cognitive factors and sex would not affect the developmental trajectories of internalizing and externalizing behavior problems.

The same model that was used to test the previous research question was used to test this research question. A significant negative path from the SES slope variable to the internalizing slope variable indicated that developmental trajectories of working memory are inversely related to developmental trajectories of internalizing behavior problems. Likewise, a significant negative path from the SES slope variable to the externalizing slope variable indicated that developmental trajectories of working memory are inversely related to developmental trajectories of externalizing behavior problems. Non-significant paths from the PPVT, Digit Span Forwards, and sex variables to the internalizing and externalizing slope variables indicated that the other cognitive factors and sex do not affect the developmental trajectories of internalizing and externalizing behavior problems.

CHAPTER 4: RESULTS

Overview

The following sections contain the statistical analyses of the proposed methods outlined in the previous chapter. First, descriptive statistics of the variables are presented followed by a description of the main analyses. The proposed analyses were attempted as described in the previous chapter; however, the proposed models did not fit the data well. Consequently, instead of using only the slope and intercept factors of internalizing and externalizing growth curves as dependent variables, a third growth curve was created for Inattentive/Hyperactive behaviors. And, the slope and intercept factors of the Inattentive/Hyperactive growth curve were also used as dependent variables.

Descriptive Statistics

Sample sizes, minimum and maximum values, means, and standard deviations for internalizing behavior problems are reported in Table 2. Internalizing behaviors are reported as raw scores where a score of zero means that none of the behaviors that compose a scale were observed by the child's mother. Because individual items from the BPI use a scale ranging from Never True (0) to Often True (2), and the Inattentive and Anxiety scales are composed of two items the maximum possible score was four. Because the Depression scale was composed of four items the maximum score was eight.

Table 2

Internalizing Behavior Problems Descriptive Statistics for Calibration/Validation Samples

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Inattentive 7 to 8	1627/1574	0/0	4/4	.76/.76	.98/1.00
Inattentive Wave 2	1614/1580	0/0	4/4	.77/.76	1.00/1.03
Inattentive Wave 3	1459/1419	0/0	4/4	.76/.75	1.03/1.02
Inattentive Wave 4	1092/1095	0/0	4/4	.67/.74	1.01/1.07
Depressed 7 to 8	1619/1562	0/0	8/8	.83/.83	1.24/1.19
Depressed Wave 2	1607/1561	0/0	8/8	.88/.90	1.31/1.24
Depressed Wave 3	1448/1405	0/0	8/8	.93/.95	1.36/1.38
Depressed Wave 4	1091/1088	0/0	8/8	.93/1.01	1.41/1.44
Anxious 7 to 8	1480/1434	0/0	4/4	.80/.82	.96/.94
Anxious Wave 2	1539/1477	0/0	4/4	.86/.84	.96/.95
Anxious Wave 3	1418/1377	0/0	4/4	.83/.81	.96/.96
Anxious Wave 4	1083/1086	0/0	4/4	.74/.72	.96/.92

Sample sizes, minimum and maximum values, means, and standard deviations for externalizing behavior problems are reported in Table 3. Externalizing behaviors are reported as raw scores where a score of zero means that none of the behaviors that compose a scale were observed by the child's mother. Because the Hyperactive scale is

composed of three items, the Headstrong scale is composed of five items, and the Antisocial scale is composed of six items, the respective maximum possible scores were six, ten, and twelve.

Table 3

Externalizing Behavior Problems Descriptive Statistics for Calibration/Validation Samples

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Hyperactive 7 to 8	1623/1568	0/0	6/6	1.52/1.46	1.35/1.35
Hyperactive Wave 2	1610/1577	0/0	6/6	1.40/1.40	1.39/1.36
Hyperactive Wave 3	1451/1407	0/0	6/6	1.35/1.29	1.37/1.34
Hyperactive Wave 4	1088/1087	0/0	6/6	1.22/1.27	1.35/1.37
Headstrong 7 to 8	1616/1562	0/0	10/10	2.75/2.64	2.18/2.15
Headstrong Wave 2	1604/1568	0/0	10/10	2.71/2.60	2.29/2.16
Headstrong Wave 3	1450/1409	0/0	10/10	2.76/2.67	2.32/2.23
Headstrong Wave 4	1090/1085	0/0	10/10	2.78/2.71	2.34/2.31
Antisocial 7 to 8	1603/1550	0/0	10/11	1.28/1.19	1.63/1.57
Antisocial Wave 2	1597/1554	0/0	11/12	1.30/1.17	1.79/1.69
Antisocial Wave 3	1434/1382	0/0	10/10	1.27/1.31	1.75/1.72
Antisocial Wave 4	1081/1074	0/0	10/10	1.32/1.37	1.78/1.86

Sample sizes, minimum and maximum values, means, and standard deviations for the Digit Span variables and the PPVT are reported in Table 4. The Digit Span variables are reported as raw scores and the PPVT variable is a standardized score.

Table 4

Digit Span and PPVT Descriptive Statistics for Calibration/Validation Samples

Variable	N	Minimum	Maximum	Mean	Std. Dev.
Digits Span Back 7 to 8	1515/1440	0/0	12/11	3.68/3.73	1.55/1.53
Digits Span Back Wave 2	1314/1264	0/0	12/13	4.69/4.74	1.71/1.77
Digits Span Back Wave 3	828/808	0/0	12/13	5.21/5.17	1.95/1.97
Digits Span Back Wave 4	142/139	2/2	13/13	5.87/5.79	2.27/2.06
Digits Span Forward 7 to 8	1515/1443	0/0	13/14	5.35/5.50	1.92/2.02
PPVT 7 to 8	488/466	20/20	137/136	91.91/91.58	18.40/17.73

Sample sizes, minimum and maximum values, means, and standard deviations for the household income and parental education variables are reported in Table 5. The household income variables are dollar amounts which have been divided by 1,000. The Highest Grade Completed by Child's Mother (HGC Mother) and Highest Grade Completed by the Spouse/Partner of the Child's Mother (HGC Spouse/Partner) are reported as number of grades completed.

Table 5

Socioeconomic Status Descriptive Statistics for Calibration/Validation Samples

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Income 7 to 8	1411/1348	.00/.00	974.10/974.10	42.84/47.32	62.55/78.57
Income Wave 2	1518/1491	.00/.00	974.10/974.10	46.61/45.61	76.67/63.88
Income Wave 3	1405/1354	.00/.00	974.10/974.10	46.52/48.33	65.26/72.62
Income Wave 4	1282/1223	.00/.00	974.10/839.08	49.50/47.74	68.21/58.00
HGC Mother	1662/1602	3/0	20/20	12.55/12.72	2.43/2.51
HGC Spouse/Part	1118/1114	0/0	20/20	12.97/13.03	2.76/2.75

Main Analyses

Research Question 1: Do the developmental trajectories of children's working memory vary?

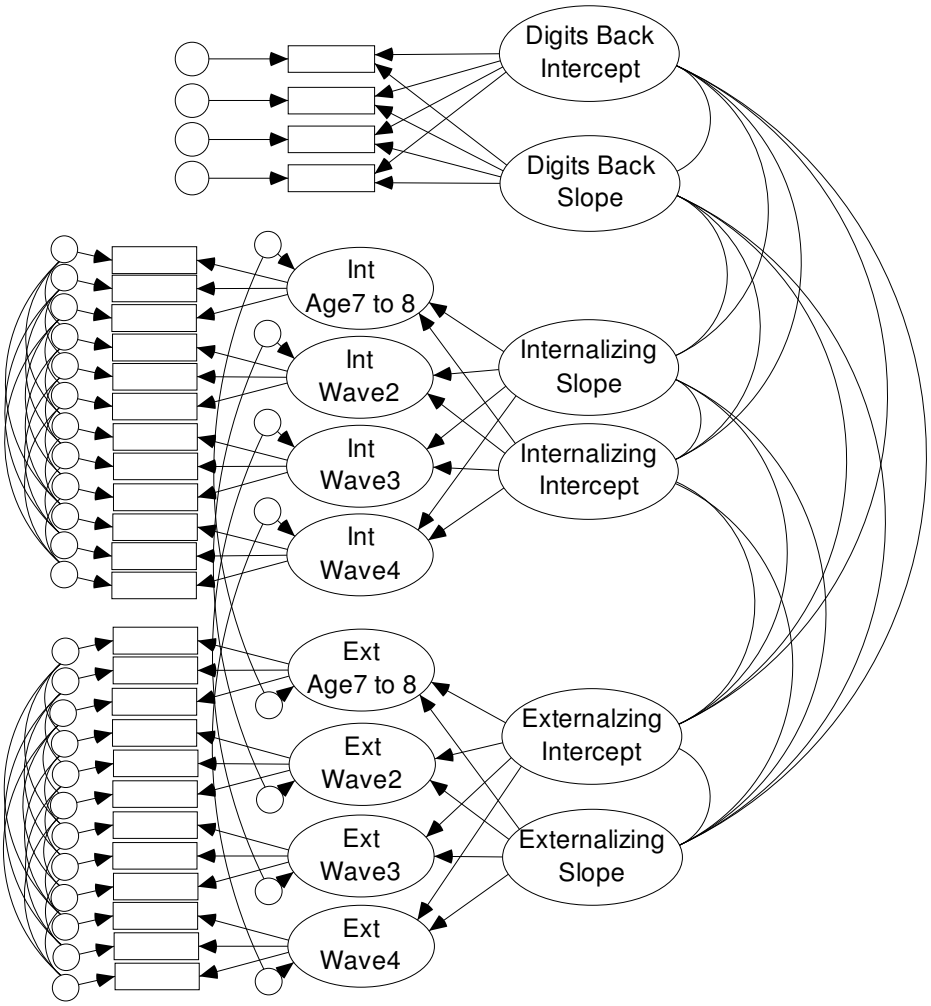
To answer this question, a model with working memory, internalizing, and externalizing growth curves was estimated. Slope and intercept latent factors were allowed to covary with each other. This model fit the data poorly (CFI = .912, TLI = .887, RMSEA = .050). Additionally, this model resulted in correlations between factors that exceeded 1.00. Correlations between internalizing slope and externalizing slope and between internalizing intercept and externalizing intercept factors were both above 1.00.

To address the impossible parameters, a new model, shown in Figure 5, was estimated wherein error variances of internalizing age/wave factors were allowed to

covary with error variances of externalizing factors of equal ages/waves. This modification was made because it was thought that internalizing and externalizing behaviors would be closely related at each age group, not due to modification indices. This model resulted in a significant decrease in χ^2 ($\Delta\chi^2 = 1546.016$, $\Delta df = 4$, $p < .001$). However, the TLI indicated that the model only fit the data moderately well (CFI = .956, TLI = .942, RMSEA = .036). All parameters in this model had reasonable values; however, correlations between error variance were high with three of four correlations between .93 and .95. Additionally, correlations between externalizing slope and internalizing slope and between externalizing intercept and internalizing intercept were both .96 and .92 respectively, suggesting that the factors are very closely related.

Figure 5

Measurement Model of Growth Curves



Because correlations between externalizing and internalizing factors were high, a model in which all behavior problems were included in a single growth curve was estimated. This model also only fit the data moderately well (CFI = .952, TLI = .941, RMSEA = .036). Accordingly, this model was not investigated further.

Because the original hyperactive scale from the BPI was split into an inattentive and hyperactive scale, a model was estimated wherein the Inattentive scale was removed

from the internalizing growth curve and the Hyperactive scale was removed from the externalizing growth curve. The Inattentive and Hyperactive scales were combined into an Inattentive/Hyperactive growth curve. Accordingly, the internalizing growth curve consisted of the Anxious and Depressed scales and externalizing growth curve consisted of the Headstrong and Antisocial scales. Again, this modification was based on the fact that items on the BPI measuring inattentive and hyperactive behaviors were originally grouped into one scale. Thus, it was thought that the model might fit the data better if the newly formed inattentive and hyperactive scales were grouped into their own growth curve model. This model fit the data poorly (CFI = .910, TLI = .878, RMSEA = .052). Additionally, this model resulted in correlations that exceeded 1.00.

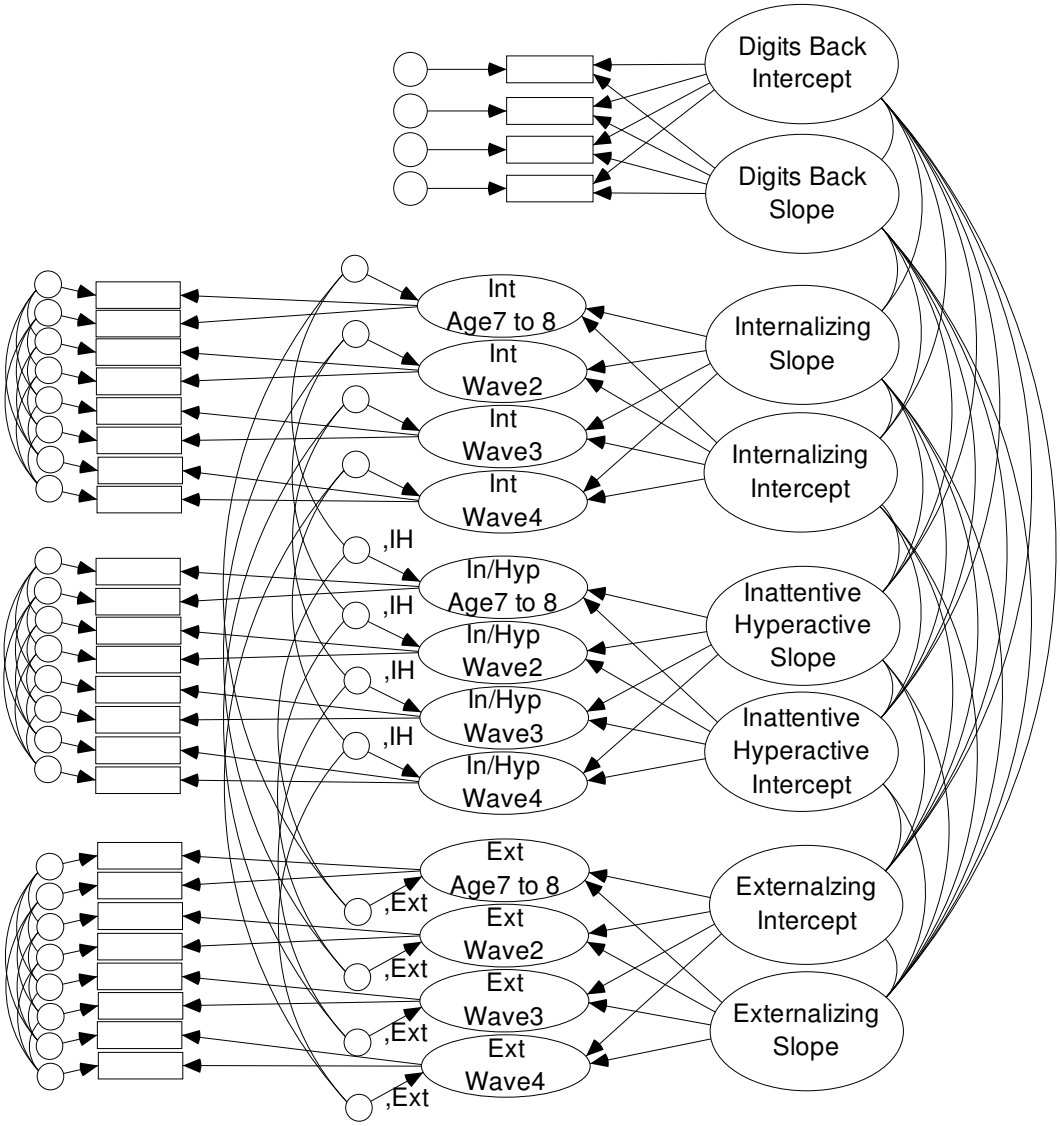
To address the implausible parameters, a new model was estimated wherein error variances of internalizing age/wave factors were allowed to covary with error variances of externalizing and Inattentive/Hyperactive factors of equal ages/waves. Again, this model suggests that internalizing, externalizing, inattentive, and hyperactive behaviors are closely related at each age group. This model resulted in a statistically significant decrease in χ^2 ($\Delta\chi^2 = 2381.547$, $\Delta df = 12$, $p < .001$). Additionally, the model fit the data well (CFI = .977, TLI = .967, RMSEA = .027). However, the correlation between error variances of the externalizing and the Inattentive/Hyperactive age 7 to 8 factors exceeded 1.00.

To further address the parameters, error variances of the externalizing age/wave factors were constrained to be equal and the error variances of the Inattentive/Hyperactive age/wave factors were constrained to be equal as shown in Figure 6. This model resulted in a significant increase in χ^2 ($\Delta\chi^2 = 17.113$, $\Delta df = 6$, $p = .009$)

indicated that this model did not fit the data as well as the previous model. However, all parameters were reasonable, and the model fit the data well (CFI = .977, TLI = .968, RMSEA = .027). This model was used to answer the first research question because it was the only model tested in which all parameters were reasonable and which fit the data well.

Figure 6

Modified Measurement Model with Growth Curves



The variance for the latent intercept variable for Digits Backwards was significant (1.148, $p < .001$) and suggests that children between the ages of 7 and 14 vary in their initial ability to recite a series of digits backwards from memory. Accordingly, results indicate that children's initial working memory ability varies significantly. The mean for

the latent slope variable for Digit Span Backwards was significant (.849, p < .001) and suggests that children between the ages of 7 and 14 increase in their ability to recite a series of digits backwards from memory. The variance for the latent slope variable for Digit Span Backwards was significant (.141, p = .005) and suggests that the developmental trajectories of children's ability to recite a series of digits backwards from memory varies significantly between the ages of 7 and 14. Accordingly, results indicated that children vary in their initial working memory ability, that children's working memory ability grows during the ages of 7 to 14 and that the developmental trajectories of children's working memory vary significantly.

Research Question 2: Do the developmental trajectories of children's behavior problems vary?

The variance for the latent externalizing intercept variable was statistically significant (.714, p $p < .001$) and suggests that children between the ages of 7 and 14 vary in their initial levels of externalizing behavior problems. The mean for the externalizing latent slope variable was statistically significant (.029, $p = .015$) and indicates that children between the ages of 7 and 14 increase in externalizing behavior problems. The variance for the latent slope variable for externalizing was statistically significant (.041, $p < .001$) and suggests that children have different developmental trajectories between the ages of 7 and 14 for externalizing behavior problems. In sum, these results indicated that children vary in their initial levels of externalizing behavior problems, children's externalizing behaviors increase during the ages of 7 to 14, and children vary significantly in their externalizing developmental trajectories.

The variance for the latent intercept variable for internalizing was statistically significant (.636, $p < .001$) and provides evidence that children between the ages of 7 and 14 vary in their initial internalizing behavior problems. The mean for the latent slope variable for internalizing was statistically significant (.047, $p < .001$) and suggests that children between the ages of 7 and 14 increase in internalizing behavior problems. The variance for the latent slope variable for internalizing was statistically significant (.043, $p < .001$) and indicates that children have different developmental trajectories between the ages of 7 and 14 for internalizing behavior problems. Accordingly, results suggested that children vary in their initial levels of internalizing behaviors, children's internalizing behavior problems increase during the ages of 7 to 14, and that children vary significantly in internalizing developmental trajectories.

The variance for the latent intercept variable for Inattentive/Hyperactive behavior was statistically significant (.345, $p < .001$) and suggests that children between the ages of 7 and 14 vary in their initial inattentive and hyperactive behaviors. The mean for the latent slope variable for Inattentive/Hyperactive was statistically significant (-.023, $p = .001$) and suggests that children decrease in inattentive and hyperactive behaviors between the ages of 7 and 14. The variance for the latent slope variable for Inattentive/Hyperactive behavior was statistically significant (.013, $p < .001$) and suggests that children's inattentive and hyperactive developmental trajectories vary significantly between the ages of 7 and 14. In sum, results suggested that children vary in their initial levels of inattentive and hyperactive behavior problems, children's inattentive and hyperactive behaviors decrease during the ages of 7 to 14, and children vary significantly in inattentive and hyperactive developmental trajectories.

Research Question 3: Do differences in the developmental trajectories of working memory explain differences in the developmental trajectories of behavior problems?

To examine the effect of working memory on behavior problems the data set was split into calibration and validation subsamples. Each case was randomly assigned to either the calibration or validation sample. The calibration sample was used to establish a baseline model and test modifications of that model. After modifications to the baseline model were evaluated, a model including all modifications was tested for invariance using the calibration and validation samples.

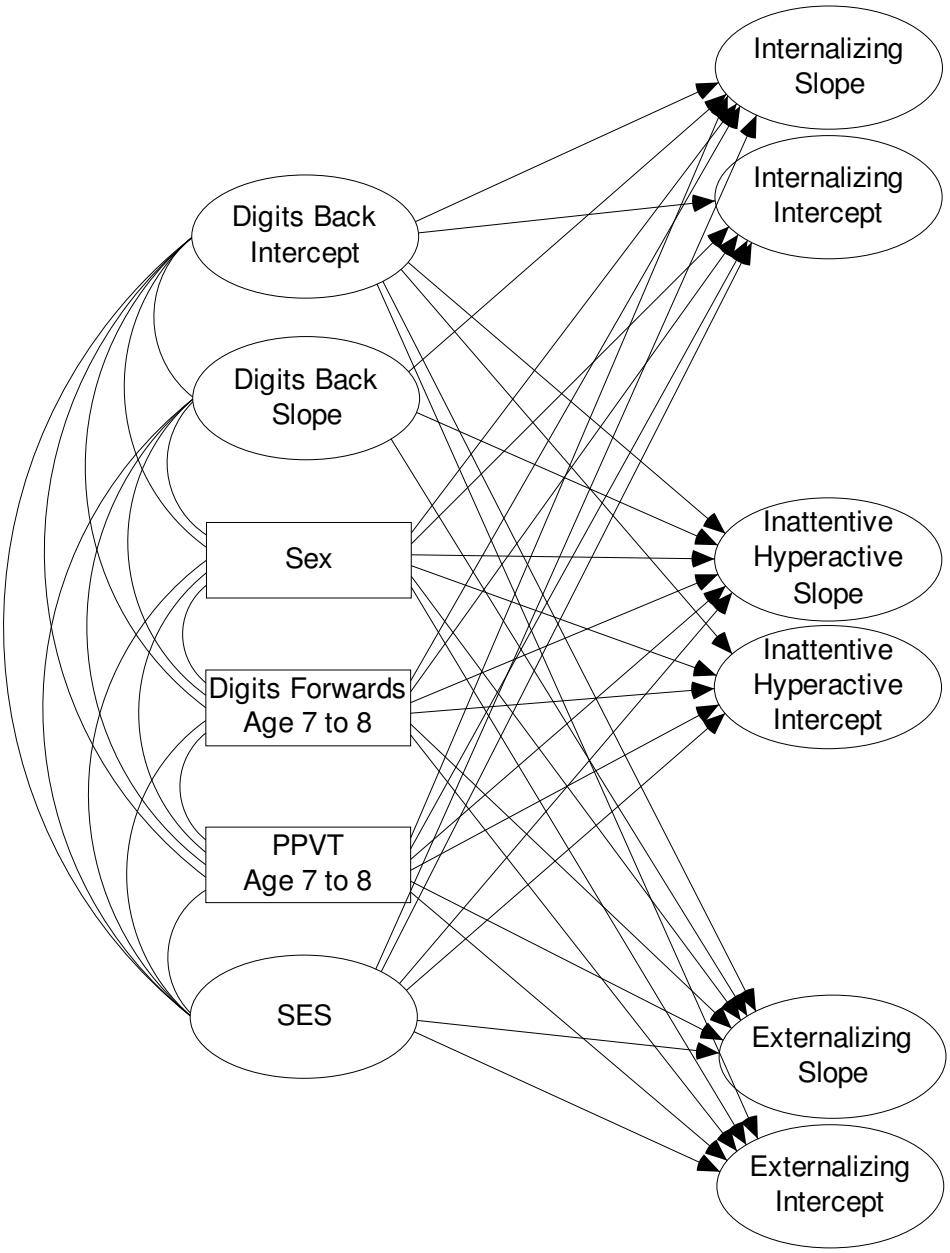
Baseline Model

First, a model with all growth curves and background variables was estimated. Error variances for the latent externalizing age/wave variables were constrained to be equal and error variances for the latent inattentive/hyperactive age/wave variables were constrained to be equal in keeping with the modifications made to the models of the previous research questions. Background variables included sex, the Digit Span Forwards raw score measured at ages 7 to 8, the PPVT standard score from ages 7 to 8, and a latent SES variable composed of income and parental education variables. Background variables were free to covary with the Digit Span Backwards slope and intercept variables. Dependent variables consisted of slope and intercept latent variables for internalizing, Inattentive/Hyperactive, and externalizing behaviors. Paths were included from all background variables and the Digit Span Backwards intercept factor to each of the dependent variables. Effects from the Digit Span Backwards slope factor were assumed to affect all of the dependent slope variables but not the dependent intercept variables as seen in Figure 7. That is, change in working memory was not assumed to

affect initial levels of the behavioral outcomes. This model fit the data well (CFI = .967, TLI = .969, RMSEA = .022). Therefore the model was retained as a baseline model.

Figure 7

Baseline Structural Model



Model Modifications

Next, error variances were tested for equality. Error variances from the Inattentive/Hyperactive and externalizing factors were already constrained to be equal leaving the error variances from the internalizing age factors and the Digit Span Backwards measured variables to be tested for equality. Constraining the internalizing age error variances to be equal led to an increase in χ^2 that was not statistically significant, accordingly this modification was retained. Constraining the Digit Span Backwards age error variances to be equal led to a significant increase in χ^2; accordingly, this modification was not retained (Table 6).

Table 6

Equal Error Variances

Model	χ^2	df	$\Delta\chi^2$	Δdf	p
Baseline Model	1050.271	534			
Internalizing	1052.150	537	1.88	3	0.598
Digit Span Backwards	1065.402	537	15.131	3	0.002

In the following step, error variances were allowed to covary. Allowing error variances to covary is an assumption often tested in latent growth models (Kline, 2005). As the error variances for each age/wave group were already allowed to covary with each other across behavior problems, only the error variances for the Digit Span Backwards were tested to determine if they covaried. Allowing the error variances from the Digit Span Backwards to covary did not lead to a statistically significant decrease in χ^2 ($\Delta\chi^2$ = .854, Δdf = 3, p = .837). As such, this modification was not retained.

Finally, paths from the slope variables to the age variables were released to test for linearity in growth. Because each growth curve has four age groups, only two parameters could be released. Accordingly, the paths from the slope variables to wave 2 and wave 3 variables were released for each of the four growth curves. Start values based on the original constraints were used instead of the original constraints. For example, instead of constraining the path from the Digit Span Backwards slope variable to the Digit Span Backwards Wave 2 and Wave 3 variables to be two and three, the numbers two and three were used as a start value for those paths. Results are shown in Table 7. Releasing regression paths from slope factors for internalizing, externalizing, and Inattentive/Hyperactive to age/wave factors did not result in statistically significant decreases in χ^2. However, releasing the paths for the Digit Span Backwards slope variable to the Digit Span Backwards Wave 2 and Wave 3 variables did result in a statistically significant decrease in χ^2 suggesting nonlinear growth in working memory for children aged 7 to 14. Unstandardized regression weights for the Digit Span Backwards slope variable to measured variables for ages 7 to 8, Wave 2, Wave 3, and Wave 4 were 0, 1.195, 2.008, and 3. Thus, although statistically significant, departures of linearity in the Digit Span Backwards growth curve model were small.

Table 7

Tests of Linearity

	χ^2	df	$\Delta\chi^2$	Δdf	p
Original Model	1050.271	534			
DSB	1043.347	532	6.924	2	0.031
Internalizing	1048.470	532	1.801	2	0.406
Externalizing	1050.197	532	0.074	2	0.964
Inattentive/Hyperactive	1049.549	532	0.722	2	0.697

In sum, the two modifications were retained. The variances for the internalizing age factors were constrained to be equal and the two paths from the Digit Span Backwards slope factors to the Digit Span Backwards Wave 2 and Wave 3 variables were released.

Calibration/Validation Invariance

The new model was then tested for invariance (see Table 8). Calibration and validation samples were estimated using the same model where no parameters were constrained to be equal across groups to establish configural invariance. In sequential steps constraints were made to test increasing levels of invariance. Accordingly, in the next step, measurement weights were constrained to be equal across groups. Measurement weights were invariant so the constraint of equal measurement weights across groups was retained. Next, measurement intercepts, structural weights, structural means, structural covariances, structural residuals, and measurement residuals were tested for invariance. Measurement intercepts, structural weights, structural means, and

structural covariances were found to be invariant. Structural and measurement residuals were not invariant. Requiring structural and measurement residuals to be equal across groups is a strict level of invariance (Meredith & Teresi, 2006). Thus, for the purposes of this research study, the calibration and validation samples are considered to demonstrate acceptable levels of invariance.

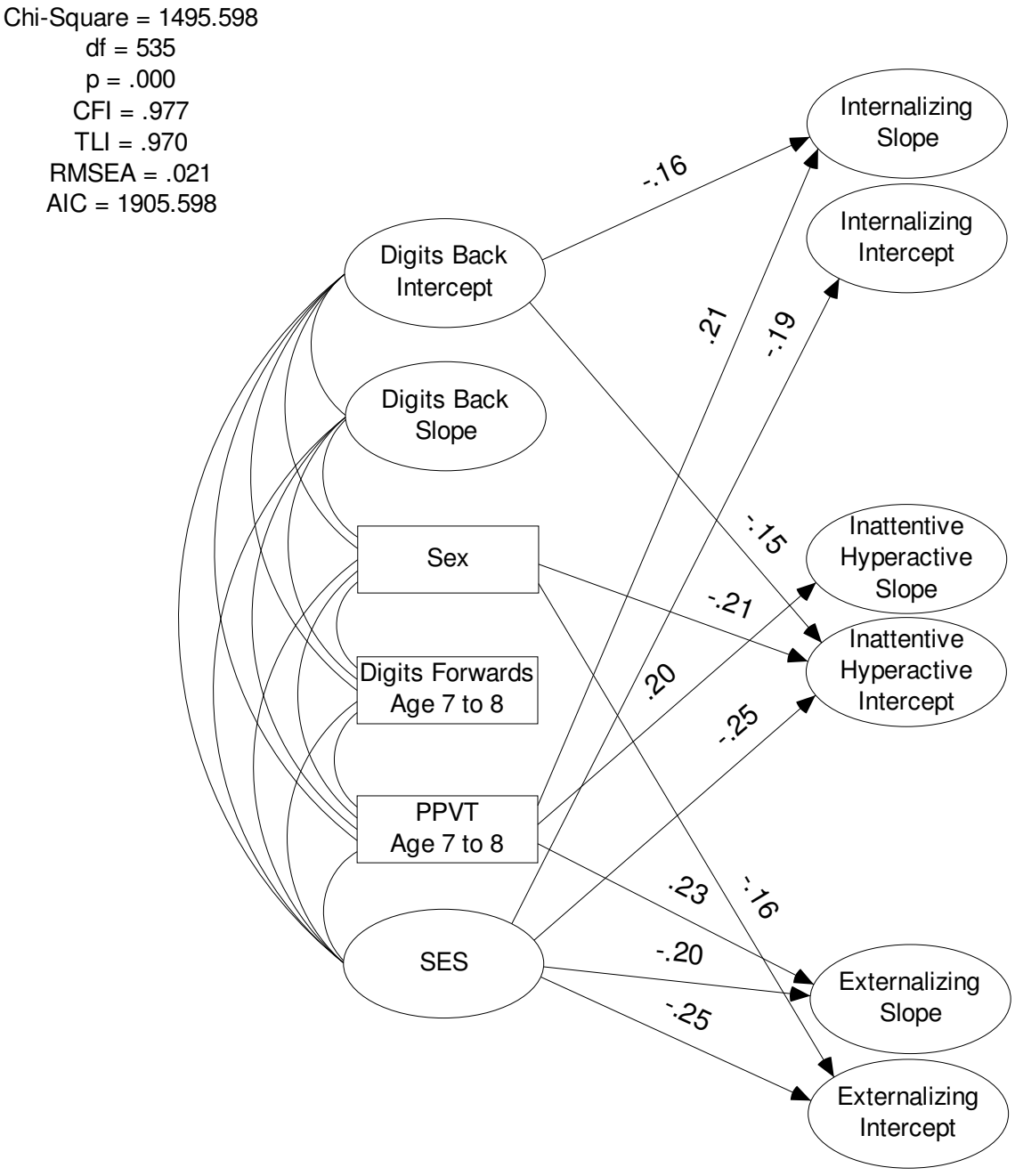
Table 8

Calibration/Validation Invariance

	χ^2	df	$\Delta\chi^2$	Δdf	p	CFI	TLI	RMSEA
Configural	2122.119	1076				0.975	0.967	0.016
Meas. weights	2133.158	1081	11.038	5	0.051	0.975	0.967	0.016
Meas. intercepts	2155.979	1099	22.821	18	0.198	0.975	0.968	0.016
Structural weights	2181.380	1132	25.401	33	0.825	0.975	0.969	0.015
Structural means	2185.405	1135	4.025	3	0.259	0.975	0.969	0.015
Structural cov.	2202.148	1156	16.743	21	0.727	0.975	0.969	0.015
Structural residuals	2261.611	1189	59.464	33	0.003	0.974	0.97	0.015
Meas. residuals	2645.423	1265	383.811	76	<.001	0.967	0.963	0.017

Figure 8

Modified Final Structural Model with Significant Paths and Standardized Coefficients

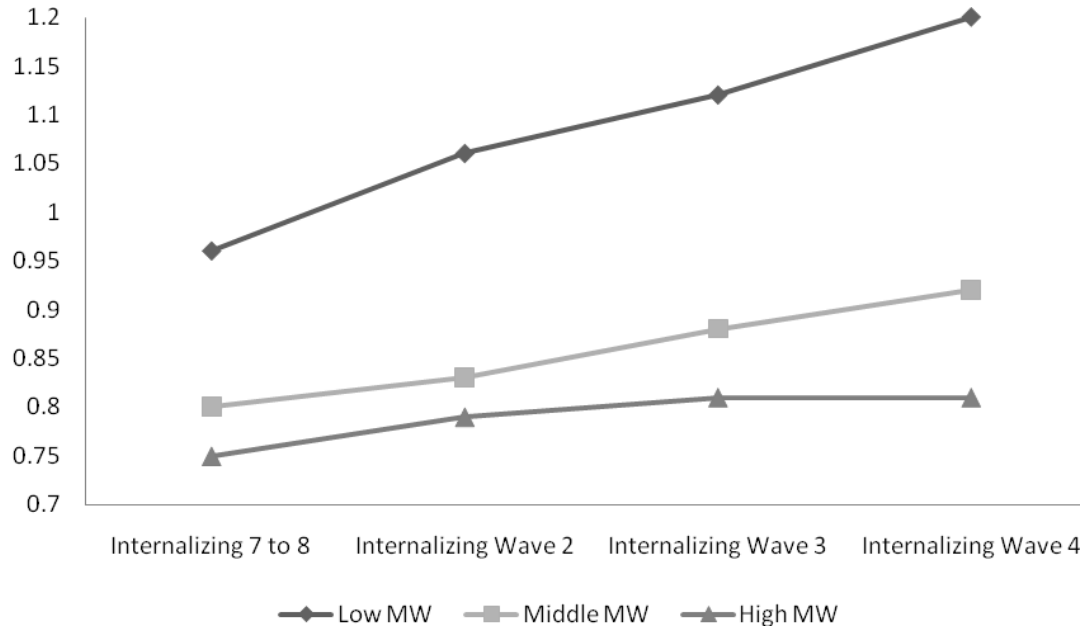


Model Interpretation

With invariance established, the model can be interpreted to understand the effects of independent variables on dependent variables. The effect of the intercept of Digit Span Backwards on the intercept of internalizing behavior problems was not significant ($\beta = .014$, $p = .740$) suggesting that initial levels of working memory do not affect initial levels of internalizing behaviors. The effect of the intercept of Digit Span Backwards on the slope of internalizing behavior problems was statistically significant and negative ($\beta = -.157$, $p = .036$) providing evidence that initial levels of working memory affect developmental trajectories of internalizing behaviors. For every standard deviation increase in initial working memory ability, the slope of internalizing behaviors decreased by .157 standard deviations as shown in Figure 9. The effects of the slope of Digit Span Backwards on the slope of internalizing behavior problems was not statistically significant ($\beta = .069$, $p = .483$) indicating that developmental trajectories in working memory do not affect the developmental trajectories of internalizing behavior problems.

Figure 9

Mean Internalizing Scores Grouped by Working Memory Ability



The effect of the intercept of Digit Span Backwards on the intercept (β = -.059, *p* = .137) and slope (β = -.107, *p* = .168) of externalizing behavior problems was not statistically significant suggesting that initial levels of working memory do not affect initial levels or the developmental trajectories of externalizing behaviors. The effect of the slope of Digit Span Backwards on the slope of externalizing behavior problems was also not statistically significant (β = .108, *p* = .323) indicating that developmental trajectories in working memory do not affect the developmental trajectories of externalizing behavior problems.

The effect of the intercept of Digit Span Backwards on the intercept of Inattentive/Hyperactive behavior problems was statistically significant, suggesting that initial levels of working memory affect initial levels of Inattentive/Hyperactive behaviors

(β = -.148, $p < .001$). For every standard deviation increase in working memory Inattentive/Hyperactive behavior problems decrease by .148 standard deviations, all things being equal. The effect of the intercept of Digit Span Backwards on the slope of Inattentive/Hyperactive behavior problems was not statistically significant (β = -.075, p = .364) suggesting that initial levels of working memory do not affect developmental trajectories of Inattentive/Hyperactive behaviors. The effect of the slope of Digit Span Backwards on the slope of Inattentive/Hyperactive behavior problems was also not statistically significant (β = .079, p = .493), indicating that developmental trajectories in working memory do not affect developmental trajectories in Inattentive/Hyperactive behaviors.

In sum, controlling for the effects of SES, sex, general cognitive ability, and memory span, the only variable that significantly affected the developmental trajectory a behavior problem was the initial status of working memory as it affected the change in internalizing behaviors. However, initial working memory ability also affected the initial status of Inattentive/Hyperactive behaviors. Developmental trajectories of working memory did not affect any of the developmental trajectories of internalizing, externalizing, or Inattentive/Hyperactive behavior problems. As such, the hypothesis that developmental increases in working memory would lead to developmental decreases in behavior problems was not supported.

Research Question 4: Do SES, other cognitive factors, and sex contribute to initial differences or growth in behavior problems?

Standardized regression weights and their corresponding levels of significance are shown in Table 9 for all background variables.

Table 9

Standardized Regression Weights and Levels of Significance

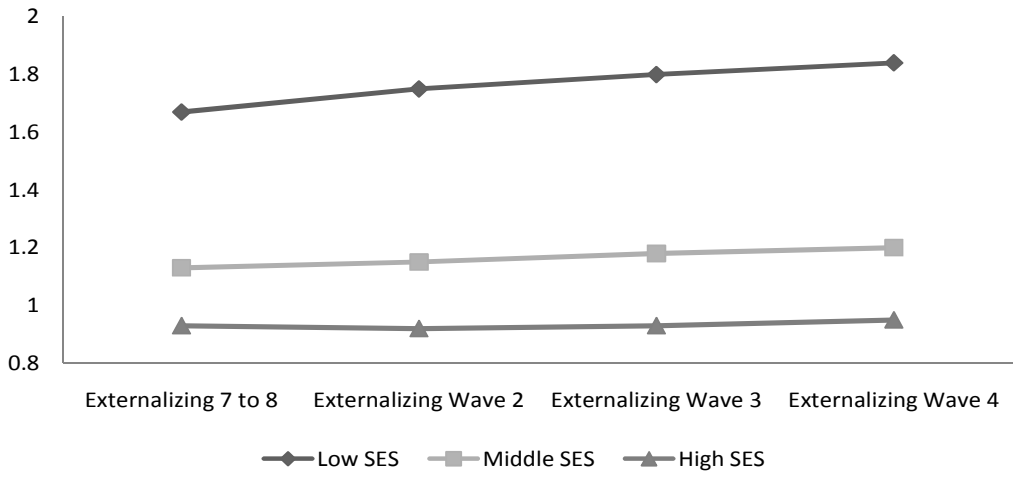
	SES		Sex		Digit Span Forwards		PPVT	
	β	*p*	β	*p*	β	*p*	β	*p*
Internalizing Intercept	-.190	< .001	-.025	.301	-.041	.199	-.033	.548
Internalizing Slope	-.108	.101	.035	.397	.013	.814	.211	.018
Externalizing Intercept	-.249	< .001	-.159	< .001	-.013	.663	-.049	.343
Externalizing Slope	-.200	.003	.053	.219	.043	.426	.230	.012
Inattent/Hyper Intercept	-.249	< .001	-.209	< .001	-.006	.843	-.072	.132
Inattent/Hyper Slope	.087	.241	.027	.569	.013	.825	.200	.045

The effect of SES on the intercept of internalizing behavior problems was statistically significant providing evidence that SES affects initial levels of internalizing behaviors (β = -.190, $p < .001$). Every standard deviation increase in SES resulted in .190 standard deviations decrease in internalizing behavior problems. The effect of SES on the slope of internalizing behavior problems was not significant, suggesting that SES did not affect developmental trajectories of internalizing behaviors (β = -.108, $p = .101$). The effect of SES on the intercept of externalizing behavior problems was statistically significant indicating that SES affects initial levels of externalizing behaviors (β = -.249, $p < .001$). Every standard deviation increase in SES resulted in a .249 standard deviation decrease in externalizing behavior problems. The effect of SES on the slope of externalizing behavior problems was also statistically significant suggesting that SES

affects developmental trajectories of externalizing behaviors (β = -.200, p = .003). Every standard deviation increase in SES results in .200 standard deviations decrease in the slope of externalizing behavior problems (see Figure 10).

Figure 10

Mean Externalizing Scores Grouped by SES



The effect of SES on the intercept of Inattentive/Hyperactive behavior problems was significant, providing evidence that SES affects initial levels of Inattentive/Hyperactive behaviors (β = -.249, p < .001). For every standard deviation increase in SES, Inattentive/Hyperactive behavior problems decrease .249 standard deviations. The effect of SES on the slope of Inattentive/Hyperactive behavior problems was not statistically significant suggesting that SES does not affect developmental trajectories of Inattentive/Hyperactive behaviors (β = .087, p = .241).

The effect of sex on the intercept (β = -.025, p = .301) and slope (β = .035, p = .397) of internalizing behavior problems was not statistically significant indicating that

sex does not affect initial levels or developmental trajectories in internalizing behaviors problems. The effect of sex on the intercept of externalizing behavior problems was statistically significant (β = -.159, $p < .001$) and indicates that boys are rated as demonstrating significantly more externalizing behavior problems than girls. The effect of sex on the slope of externalizing behavior problems was not statistically significant (β = .053, $p = .219$), however, suggesting that sex does not affect the developmental trajectories of externalizing behavior problems. The effect of sex on the intercept of Inattentive/Hyperactive behavior problems was statistically significant (β = -.209, $p < .001$) and indicates that boys are rated as demonstrating significantly more Inattentive/Hyperactive behavior problems than girls. The effect of sex on the slope of Inattentive/Hyperactive behavior problems was not statistically significant (β = .027, $p = .569$) suggesting that sex does not affect the developmental trajectories of Inattentive/Hyperactive behavior problems.

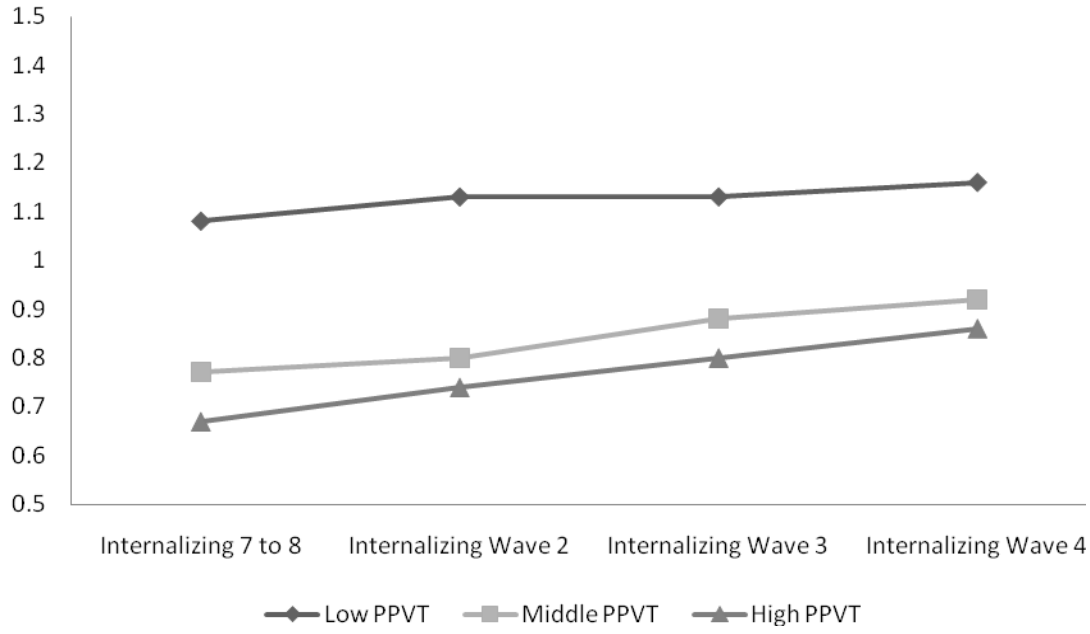
The digit span forwards variable did not have a statistically significant effect the intercepts of the internalizing (β = -.041, $p = .199$), externalizing (β = -.013, $p = .663$), or Inattentive/Hyperactive intercept variables (β = -.006, $p = .843$). Likewise the digit span forwards variable did not have a statistically significant effect the slopes of the internalizing (β = .013, $p = .814$), externalizing (β = .043, $p = .426$), or Inattentive/Hyperactive intercept variables (β = .013, $p = .825$). As such, simple memory span did not appear to have a statistically significant effect on initial differences in or developmental trajectories of behavior problems.

The PPVT scores measured at ages 7 to 8 did not have a statistically significant effect on the intercept of internalizing behavior problems (β = -.033, $p = .548$). However,

the PPVT did have a statistically significant effect on the slope of internalizing behaviors (β = .211, p = .018), suggesting that for every standard deviation increase in PPVT scores, internalizing slope increases by .211 standard deviations (see Figure 11). Brighter children showed more increases in internalizing behaviors than did children of lower cognitive ability

Figure 11

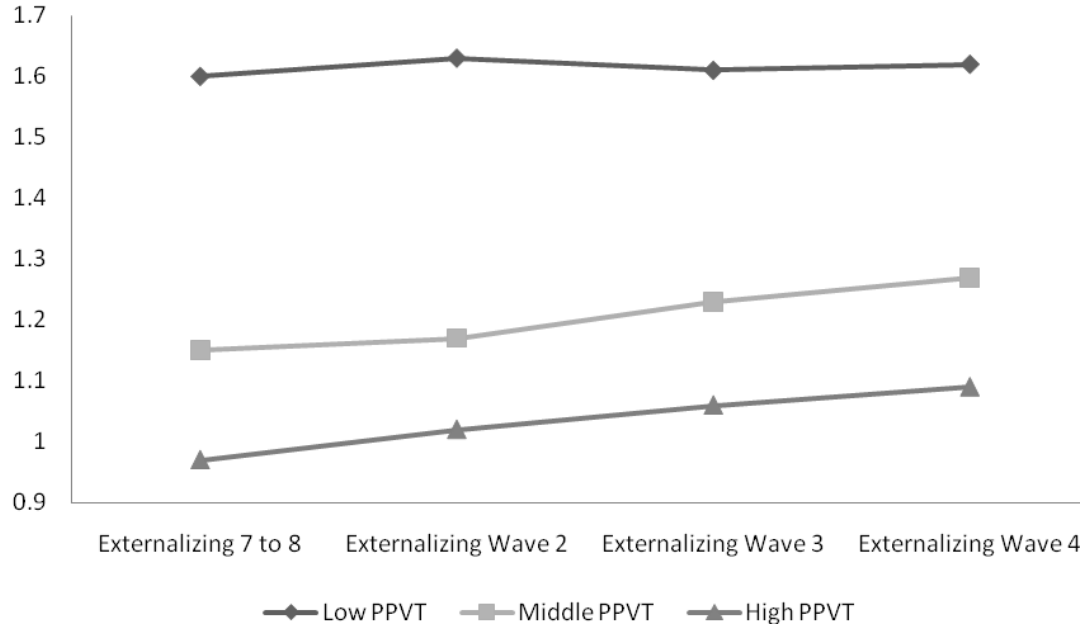
Mean Internalizing Scores Grouped by PPVT Scores



The PPVT scores measured at ages 7 to 8 did not have a statistically significant effect on the intercept of externalizing behavior problems (β = -.049, p = .343). However, the PPVT did have a statistically significant effect on the slope of externalizing behaviors (β = .230, p = .012) indicating that for every standard deviation increase in PPVT scores, externalizing slope increases by .230 standard deviations (see Figure 12).

Figure 12

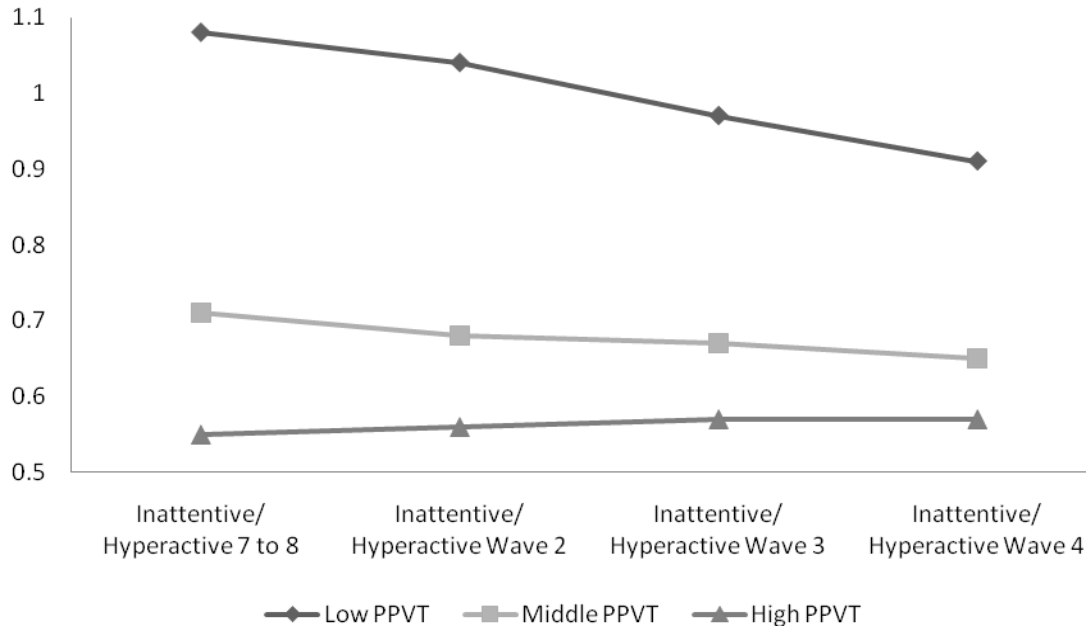
Mean Externalizing Scores Grouped by PPVT Scores



The PPVT scores measured at ages 7 to 8 did not have a statistically significant effect on the intercept of Inattentive/Hyperactive behavior problems (β = -.072, p = .132). However, the PPVT did have a statistically significant effect on the slope of Inattentive/Hyperactive behaviors (β = .200, p = .045) indicating that for every standard deviation increase in PPVT scores, Inattentive/Hyperactive slope increases by .200 standard deviations (see Figure 13).

Figure 13

Mean Inattentive/Hyperactive Scores Grouped by PPVT Scores



In sum, many of the background variables included in the model had statistically significant effects on the initial levels and developmental trajectories of internalizing, externalizing, and Inattentive/Hyperactive behavior problems. Initial levels of internalizing were affected by SES and the developmental trajectories of internalizing behavior problems are affected by initial ability in working memory, general cognitive ability, and SES. Initial levels of externalizing behavior problems were affected by sex and SES while developmental trajectories in externalizing behavior problems were affected by general cognitive ability and SES. Finally, initial levels of Inattentive/Hyperactive behaviors were affected by initial working memory ability, sex, and SES while developmental trajectories of Inattentive/Hyperactive behaviors were affected only by general cognitive abilities.

CHAPTER 5: DISCUSSION

Summary

Previous research has shown that children with working memory deficits demonstrate lower levels of attention and higher levels of hyperactivity, physical aggression, and other behavior problems. However, the relation between working memory behavior problems over the course childhood is unclear. The purpose of this study was to determine whether or not developmental trajectories in working memory affect developmental trajectories in internalizing and externalizing behavior problems.

Before such questions could be examined, it was necessary to determine whether the developmental trajectory of working memory in children varied significantly. Therefore, it was hypothesized that children would vary significantly in developmental trajectories of working memory ability. It was also necessary to determine if the developmental trajectories of internalizing and externalizing behavior problems varied significantly in children. Similarly, it was hypothesized that children would vary significantly in developmental trajectories of internalizing and externalizing behavior problems. Finally, it was hypothesized that developmental trajectories in working memory and behavior problems would be inversely related. Specifically, it was hypothesized that children who experience large developmental gains in their working memory ability would show comparable decreases in behavior problems, and children who experience small developmental gains in their working memory ability would show comparable small decreases or even increases in behavior problems.

Development of Working Memory

The results from this study suggest that working memory in children generally increases over the ages of seven to fourteen. Results also show that developmental trajectories in working memory vary significantly from child to child. Moreover, growth in working memory in children appears to be non-linear. On average, children experience larger increases in working memory between ages 7 to about 11 or 12 and a smaller increase in working memory between ages 11 or 12 to 14. Accordingly, the first research hypothesis that developmental trajectories of children's working memory would vary significantly was supported by the results.

Development of Behavior Problems

The second research hypothesis that children's developmental trajectories would vary in behavior problems was also supported by the results of this study. The results from this study suggest that internalizing and externalizing behaviors in children generally increase over the ages of 7 to 14. Results further suggest that the developmental trajectories of internalizing and externalizing behaviors vary significantly from child to child. However, the results from this study suggest that inattentive and hyperactive behaviors in children generally decrease over the ages of 7 to 14. Still, the developmental trajectories of inattentive and hyperactive behaviors vary significantly from child to child.

An unexpected finding of the study was the better fit of models where the inattentive behavior scale was removed from the internalizing factors, the hyperactive behavior scale was removed from the externalizing factors, and the two were combined into a new growth curve. Although no explicit hypothesis was formulated regarding the best way to group behavior problems, it was assumed that the best way to group behavior

problems would be into externalizing and internalizing behaviors. However, models with growth curves for internalizing and externalizing behavior problems did not fit the data well, whereas models with a separate Inattentive/Hyperactive growth curve did fit the data well. Increases in externalizing and internalizing and decreases in inattentive and hyperactive behaviors over the ages of 7 to 14 may explain why the models with an Inattentive/Hyperactive growth curve fit the data better than those which do not. That is, inattentive and hyperactive behaviors seem to follow different developmental trajectories than do other internalizing and externalizing behaviors. The finding that the model fit the data better with Inattentive/Hyperactive factors, while unexpected, was not surprising as the items that made up the Inattentive and Hyperactive scales were available in the original data set as a single Hyperactive scale.

Although models where the Inattentive and Hyperactive scales were removed from the internalizing and externalizing factors fit the data better than models with just internalizing and externalizing scales, the Inattentive/Hyperactive age/wave error variances correlated highly with the internalizing and externalizing error variances. Such results suggest that inattentive, hyperactive, internalizing, and externalizing behavior problems are all closely related. However, in the final model, which included background variables, the Inattentive/Hyperactive, internalizing, and externalizing intercept and slope factors were affected by different variables. Thus, the three groups of behavior problems examined in this study appear to be distinct from each other but closely related.

Internalizing Behaviors

The only link between working memory and developmental trajectories in behavior problems was that initial working memory skills were inversely related to

increases in internalizing behaviors. On average, children showed increases in internalizing behaviors from the ages of 7 to 14; however, children who initially demonstrate high working memory ability showed smaller increases in internalizing behaviors than did children with average levels of working memory. Likewise, children who initially demonstrate low working memory ability show larger increases in internalizing behaviors than the average child. Accordingly, initial differences in working memory, not developmental trajectories of working memory, led to differential developmental increases in internalizing behaviors.

The other variable that affected the developmental trajectory of internalizing behavior problems was the children's PPVT scores. The PPVT was included in the model to estimate the effects of general cognitive ability because verbal ability, which the PPVT measures, is a good indicator of general cognitive ability. However, the PPVT is intended to be a measure of verbal ability, specifically, receptive language. Accordingly, the effect of the PPVT on the developmental trajectory of internalizing behavior may suggest that general cognitive ability, verbal ability, or receptive language skills affect the developmental trajectory of internalizing behaviors. Still, children who score higher on the PPVT increase in internalizing behavior problems more than other children. One possible explanation for this finding is that children with higher verbal skills are more likely to ruminate than children with lower verbal skills. Thus, children with low initial working memory ability, who may have difficulty expunging thoughts from their consciousness, and high verbal ability may be particularly at risk for developing internalizing behavior problems.

Socioeconomic status was the only variable that affected initial levels of internalizing behavior problems. Children from higher SES backgrounds were more likely to have lower initial levels of internalizing behavior problems. However, sex did not have an effect on initial levels of internalizing behavior problems suggesting that at ages 7 to 8 males and females display similar levels of internalizing behavior problems. The effect of sex on initial levels of internalizing behavior problems may have been non-significant because differences between males and females on measures of internalizing are not apparent until later in adolescence.

Externalizing Behaviors

Developmental trajectories in externalizing behavior problems were affected by PPVT performance and SES. Again, the PPVT score, although intended to approximate the effect of general cognitive ability, might represent verbal or receptive language skills. Interpreting the PPVT as a measure of general cognitive ability would suggest that general cognitive ability has a positive effect on the development of externalizing behavior problems. That is, children who have higher cognitive ability also increase in externalizing behaviors at a faster rate than other children. While this finding seems counterintuitive, a qualitative analysis of the data suggests that children with higher PPVT scores also had lower initial externalizing symptoms. Children who have higher PPVT scores at ages 7 to 8 then increase in externalizing behaviors, never reaching the levels of externalizing behavior as children with low PPVT scores, while children who have low PPVT scores show higher initial externalizing behaviors but do not increase in externalizing behavior. Socioeconomic status had the opposite effect on developmental trajectories in externalizing behavior problems. Children from higher SES backgrounds

showed smaller increases in externalizing behaviors than other children. Additionally, SES had a greater effect on the development of externalizing behaviors than did PPVT scores suggesting that family background has a greater influence on externalizing behaviors than does general cognitive ability.

Initial levels of externalizing behaviors were affected by sex and SES. Results suggested that boys have more initial externalizing behaviors than girls, and children from lower SES backgrounds are more likely to have higher initial externalizing behaviors than other children. Also, SES appears to have a stronger effect on initial externalizing behaviors than sex.

Inattentive and Hyperactive Behaviors

Initial working memory ability did have an effect on initial levels of inattentive and hyperactive behaviors. Children with above average working memory ability demonstrated less inattentive and hyperactive behavior than children with below average working memory ability. Additionally, sex and SES affected initial levels of inattentive and hyperactive behaviors. On average, boys tend to have higher levels of inattentive and hyperactive behavior than do girls ages 7 to 8. Also, children from low SES backgrounds tend to have higher levels of inattentive and hyperactive behavior than children from high SES backgrounds. And, SES had a larger effect on initial levels of inattentive and hyperactive behavior than sex or working memory.

The only variable that affected the developmental trajectories of inattentive and hyperactive behavior was the PPVT score measured at ages 7 and 8. Again, the effect of the PPVT score may represent constructs other than general cognitive ability. However, interpreting the PPVT score as a measure of general cognitive ability, general cognitive

ability appears to have a positive effect on the slope of inattentive and hyperactive behavior. Additionally, the average slope of inattentive and hyperactive behavior is negative suggesting that such behavior decreases in children between 7 and 14. Thus, children with higher general cognitive ability decrease in inattentive and hyperactive behavior at a slower rate than do other children. And, although the effect of general cognitive ability on initial levels of inattentive and hyperactive behavior was not significant, qualitatively, it appears that children with low cognitive ability have higher initial levels of inattentive and hyperactive behavior. Accordingly, over time the gap in inattentive and hyperactive behavior in children with low and high general cognitive ability becomes narrower such that children with low cognitive ability decrease in inattentive and hyperactive behavior at a faster rate than other children.

Non-Significant Effects

One of the major finding of this study was that the developmental trajectories of working memory in children do not have an effect on the developmental trajectories of behavior problems. This finding was consistent across behavior problems as growth in working memory did not predict change in internalizing, externalizing, or inattentive and hyperactive behavior problems. Although there was significant variance in the developmental trajectories of children's working memory ability and in the developmental trajectories of children's behavior problems, there was no relation between the developmental trajectories of working memory and behavior problems.

Initial working memory ability also does not affect the development of externalizing, inattentive, or hyperactive behaviors. That is, children whose working memory ability is above average and children whose working memory ability is below

average tend to increase in externalizing behaviors and decrease in inattentive and hyperactive behaviors at the same rate. Thus, neither developmental trajectories of working memory nor initial working memory ability appear to affect the developmental trajectories of externalizing, inattentive, or hyperactive behaviors.

Relation to previous research

Results from this study showed varying degrees of consistency with results from other research studies. The working memory growth curve in this study supported previous research suggesting that working memory develops throughout childhood (Gathercole et al., 2004). However, results from this study were less consistent with results from other studies in regards to the developmental trajectories of behavior problems. Previous research using the same measures and part of the same sample as this study found no developmental changes in children ages 7 to 14 (Kowaleski-Jones & Duncan, 1999). Another study found developmental decreases in externalizing and internalizing behavior problems (Mathijssen et al., 1999). However, research focusing on internalizing behaviors did find increases in internalizing behaviors (Bongers et al., 2003).

There are several possible reasons for the discrepancies in the results. First, the study that used the same survey (Kowaleski-Jones & Duncan, 1999) only looked at the Behavior Problems Index as whole and did not examine the subscales. Likewise, other studies have examined developmental trajectories in internalizing and externalizing behaviors, without separating hyperactivity/inattention. Here, when a model examining internalizing and externalizing behavior problems did not adequately fit the data in this study, the inattentive scale was removed from the internalizing scale and the hyperactive

scale was removed from the externalizing scale in order to achieve a better fitting model. Another reason for discrepancies between this study and other studies is that this study used a curve-of-factors latent growth model to allow internalizing, externalizing, inattentive, and hyperactive latent variables instead of measured variables. Thus, the latent variables that composed the growth curve accounted for error in the measurement of behavior problems. Finally, different informants may rate behavior problems in the same child differently. In one study, the results from mother questionnaires showed increasing levels of externalizing behaviors over time, but results from teacher questionnaires showed decreasing levels of externalizing behaviors over time in the same children (Kraatz Keiley et al., 2000).

The results from this study can also be compared to research about inattentive and hyperactive behavior. Theory regarding behaviors associated with ADHD suggests that as children are able to process more information in working memory stores, inattentive and hyperactive behaviors should decrease (Barkley, 1997). Several research studies have found that working memory deficits are associated with hyperactive behavior (Seguin et al., 2004; Murphy et al., 2001; Aronen et al., 2005). Results from this study similarly suggested that initial deficits in working memory led to higher initial levels of inattentive and hyperactive behavior. However, the results of this study suggest that increases in working memory do not have an effect on decreases in inattentive and hyperactive behaviors between the ages of 7 and 14. Thus, this study confirmed previous research suggesting that working memory affects hyperactive and inattentive behavior; however, results from this study did not support theory suggesting that increases in working memory would lead to decreases in hyperactive and inattentive behavior.

The same theory suggests that working memory has an effect on the internalization of speech and children who are not able to internalize their speech verbalize and act out thoughts instead of thinking them (Barkley, 1997). Such behavior is then interpreted as hyperactive. A measure of the internalization of speech should then predict developmental trajectories in hyperactive behavior. Although the PPVT was meant to estimate the effects of general cognitive ability in this study, the PPVT is designed to measure verbal ability, and thus, PPVT scores may share common variance with the ability to internalize speech. Additionally, the only variable that affected developmental trajectories in inattentive and hyperactive behavior was the PPVT. Thus, the effect of the PPVT on the slope of inattentive and hyperactive behaviors may be due to PPVT scores measuring, in part, the internalization of speech.

Other research suggests that children with ADHD score lower than controls on tasks that require following directions and remembering long sentences (Iwanaga, Ozawa, Kawasaki, & Tsuchida, 2006). The same research study also did not find differences in ADHD and control groups on a task similar to the digit span task. Similarly, this research study found that PPVT scores but not working memory affects inattentive and hyperactive developmental trajectories. Accordingly, differences in the ability to follow directions among participants with and without ADHD and ADHD-like symptoms may be more a function of verbal ability and less a function of working memory or memory span.

The effect of initial working memory ability on the developmental trajectory of internalizing behaviors also supports previous research. Multiple research studies have examined the relationship between internalizing behaviors such as depression and

anxiety. Such studies suggest that depression and anxiety reduce working memory ability by using stores of working memory to process task-irrelevant information (Aronen et al., 2005; Eysenk &Calvo, 1992; Lee, 1995). However, other research suggests that the ability to keep task-irrelevant material out of working memory is a function of working memory (Joorman & Gotlib, 2008). The current study found that children with lower initial levels of working memory increase in internalizing behaviors more than other children. Thus, working memory ability affects later internalizing. The possibility that depression and anxiety may in return affect working memory was not considered by this study but that children with lower working memory ability are more likely to develop internalizing symptoms was supported by this research.

One of the more curious findings of this study was that children who score higher on the PPVT increase in internalizing behavior problems at a faster rate than do other children. Previous research suggests that depression and anxiety are associated with low verbal test scores and that people who have depressive symptoms score lower than controls on measures of verbal ability (Fossati, Guillaume, Ergis, & Allialaire, 2003). However, this study suggests that high verbal ability leads to the development of internalizing symptoms. It is important then to distinguish between the natures of the research studies. While previous research has primarily investigated the effects of internalizing symptoms on verbal and cognitive ability, the purpose of the research study was to examine the effects of cognitive ability on the likelihood of developing internalizing symptoms later on in childhood. Thus, while depression may have a detrimental effect on verbal and general cognitive ability, high verbal or cognitive ability may lead to the development of internalizing symptoms.

The effects of sex on the various dependent variables supported previous research studies. Previous research suggests that boys demonstrate more externalizing behaviors than girls and boys also demonstrate more inattentive and hyperactive behaviors than do girls (Tiet et al., 2001; Hermens, Kohn, Clarke, Gordon, & Williams, 2005). Although girls typically demonstrate more internalizing behaviors than boys, differences between boys and girls in internalizing symptoms do not become apparent until early adolescence (Keenan & Shaw, 1997). As the initial measurement of internalizing symptoms occurred at ages 7 to 8, sex differences in internalizing behaviors would not be expected. And, while previous research suggests that boys and girls differ in internalizing symptoms over time, which would have been evident with a significant effect of sex on the internalizing slope factor, the maximum age of this study may have been too young to detect significant differences. Accordingly, the results from this study generally support previous research regarding sex differences in behavior problems.

The effect of SES on the dependent variables also supported previous research. Previous research suggests that children from low SES backgrounds are more likely to have more internalizing, externalizing, inattentive, and hyperactive symptoms than children from higher SES backgrounds (Beyers et al., 2003; Rapport et al., 2008). Additionally, previous research suggested that children from high SES backgrounds are more likely to show greater decreases in externalizing behaviors than other children (Kraatz Keiley et al., 2000), and this study showed that children from high SES backgrounds are more likely to show smaller increases in externalizing behaviors than other children. Although previous studies and this study differ in the average trend of

externalizing behavior problems throughout childhood, they both found that change in children from higher SES backgrounds tended towards less behavior problems.

Limitations

One of the limitations of this study was the use of only one informant, the mother, to measure behavior problems. Not only will different informants have different perspectives, but they also may see children in different environments, which in turn may elicit different behaviors. Previous research suggests that growth curves of behavior problems based off of mother questionnaires differ from growth curves based on teacher questionnaires (Kraatz Keiley et al., 2000). Accordingly, only using one informant to estimate behavior problems may lead to biased results. The use of multiple informants, such as teachers and self-reports, would have reduced bias in the measurement of behavior problems. This addition would be best accomplished by creating a latent variable where similar scales completed by different informants loaded onto that variable. For example, a latent anxiety variable would be composed of several anxiety scales completed by different informants. Then the latent anxiety variable would be combined with a latent depression variable to for the latent internalizing variable. Latent internalizing variables gathered across time would then form the internalizing growth curve.

A similar limitation of this study was the use of only one measure of working memory. Various measures have been developed to study working memory, each measuring a slightly different facet than the other. Specifically, some measures of working memory have been developed to measure visual working memory while others, such as the digit span backwards task used in the current study, have been developed to

measure auditory working memory. Accordingly, using multiple measures of working memory in a curve-of-factors LGM would have improved this study.

Another potential limitation of this study is that the children of original NLSY participants might not be willing to fully participate in the study. Despite a participant's willingness to participate and fill out behavior rating scales regarding their children, their children might not choose to complete their part of the assessment such as the digits backwards and PPVT assessments. Specifically, children with behavior problems might be particularly averse to completing assessments. Completing multiple assessments over the course of 8 years would then be especially improbable. Thus, children who are rated as having fewer behavior problems might be more willing to complete the child assessments leading to skewed results.

Finally, using the BPI to measure behavior problems may be another limitation of this study. Questions on the BPI and CBCL, from which the BPI was derived, were written to maximize test-retest reliability (Crawford & Lee, 1991; Peterson & Zill, 1986). Because test-retest reliability increases when scores across time are similar, using BPI scores may have minimized intra-individual changes in behavior problems across time. Using another measure, one that is sensitive to intra-individual change as opposed to inter-individual change, may be more appropriate for longitudinal research of behavior problems.

Advantages

The design of this study had several advantages over other types of longitudinal studies such as panel designs. First, this study made use of latent growth modeling which allows for the estimation of initial status and developmental trajectories for each of the

behavior problems and working memory using latent variables. Instead of estimating the effect of a variable at the beginning of the study on another variable at later time points in the study, this design allows for the estimation of the effect of a variable on the developmental trajectory of another variable. Thus, this study examines the effect of working memory on the development of behavior problems and not the effect of working memory on later behavior problems.

Additionally, within the context of latent growth modeling, this study used a curve-of-factors model. As such, the variables used to estimate the growth curves for behavior problems were also latent variables. Using latent variables as opposed to measured variables yields more accurate estimates of internalizing, externalizing, and inattentive and hyperactive behaviors.

A final advantage of this study was the large sample size and the use of calibration and validation samples. Model modifications were made to one group and then tested on another group to ensure that the modifications were not capitalizing on chance in a particular sample. By randomly splitting the data set into two groups, each comprised of nearly 2,000 participants, and testing for invariance, the likelihood that the results from this study can be generalized are greater than if only one group had been analyzed.

Future Directions

Some of the results from this study do not support previous research, and as such, warrant further exploration. One of the most surprising results from this study was the effect of PPVT scores on the developmental trajectories of internalizing and externalizing behavior problems. Specifically, research should confirm the results of this study which

suggest that children who score higher on the PPVT increase in internalizing and externalizing behavior problems at a faster rate than do other children. Such research might determine whether general cognition, verbal ability, or receptive language skills are the cause of increases in behavior problems. Moreover, given additional support for this study's findings, research should focus on factors that mediate the effect of PPVT scores on increases in internalizing and externalizing behavior problems.

Future research might also examine the relation between working memory and internalizing behavior problems. While this research suggested that initial levels of working memory affect developmental trajectories in internalizing behaviors, it is still possible that depression in turn affects working memory. Accordingly, future research should investigate the possibility that depression and working memory work in a cyclical fashion such that individuals with low working memory ability are more likely to develop depression and when depression is manifest, it in turn lowers working memory.

Finally, future research might also examine whether the effects of working memory, SES, general cognitive ability, and sex, on the development of behavior problems varies across different populations. Such research might specify groups based on categorical variables such as sex. Alternatively, latent class analyses may be used to examine how working memory affects behavior problems in different groups of children. Such analyses would reveal how children group together based on how their working memory ability affects their behavior problems.

Conclusions

The purpose of this research was to determine the effects of developmental trajectories of working memory on the developmental trajectories of behavior problems.

Previous research suggested that children who scored lower on measures of working memory were more likely to be rated as having more behavior problems. Previous research also suggested that, over the course of childhood, children were likely to increase in working memory ability and decrease in various behavior problems. Accordingly, it was hypothesized that increases in working memory over the course of childhood would lead to decreases in behavior problems.

Results suggested that developmental increases in working memory did not lead to developmental decreases in behavior problems. Moreover, results from this study suggested that internalizing and externalizing behavior problems increase, not decrease, over the course of childhood. However, several variables did lead to developmental change in behavior problems in children. Children who had lower initial levels of working memory increased in internalizing behaviors less than children with higher initial working memory ability. Also, high SES led to smaller increases in internalizing and externalizing behavior, high PPVT scores led to larger increases in internalizing and externalizing behavior, and high PPVT scores led to larger decreases in inattentive and hyperactive behavior.

Finally, longitudinal research using latent growth modeling is a promising methodology for the study of behavior problems. It not only allows researchers to examine trends in the developmental trajectories of behavior problems but also allows researchers to determine what variables influence those trajectories. Although variables that reduce behavior problems are important, variables that continue to reduce behavior problems over time may be of greater importance. Accordingly, this research provides

useful information regarding the variables that will reduce or slow the increase of behavior problems over time.

Appendix

BPI Item Description	Subscale	Externalizing/Internalizing
Sudden changes in mood or feeling	Anxious/Depressed	E
Feels/complains no one loves him/her	Anxious/Depressed	I
Is too fearful or anxious	Anxious/Depressed	E/I
Feels worthless or inferior	Anxious/Depressed	I
Is unhappy, sad, or depressed	Anxious/Depressed	E/I
Cheats or tells lies	Antisocial	E
Bullies or is cruel/mean to others	Antisocial	E
Does feel sorry after misbehaving	Antisocial	N/A
Breaks things deliberately	Antisocial	E
Is disobedient at school	Antisocial	E
Trouble getting along with teachers	Antisocial	E
Difficulty concentrating/attention	Hyperactive	I
Is easily confused, seems in a fog	Hyperactive	E/I
Is impulsive or acts without thinking	Hyperactive	E
Has trouble getting mind off thoughts	Hyperactive	E
Restless, overly active, cannot sit still	Hyperactive	E
Trouble getting along with children	Peer Problems	E
Is not liked by other children	Peer Problems	E
Withdrawn	Peer Problems	I
Is disobedient at home	Headstrong	E

BPI Item Description	Subscale	Externalizing/Internalizing
Is stubborn, sullen, or irritable	Headstrong	E
Has strong temper and loses it easily	Headstrong	E
High strung, tense, and nervous	Headstrong	E
Argues too much	Headstrong	E
Clings to adults	Dependent	I
Cries too much	Dependent	I
Demands a lot of attention	Dependent	I
Is too dependent on others	Dependent	I
Worries too much	N/A	N/A

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