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Working Memory Functioning In Children With Predominantly Inattentive Attention Deficit/Hyperactivity Disorder (ADHD) Versus Children With Predominantly Hyperactive ADHD

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A Research Report submitted to the Faculty of Humanities, University of the Witwatersrand, Johannesburg, in partial fulfillment of the requirements for the degree of Masters of Education in Educational Psychology by Coursework and Research Report.

Johannesburg, April, 2008

Declaration

I hereby declare that this research report is my own, unaided work, and has not been presented for any other degree at any other academic institution, or published in any form.

It is submitted in partial fulfillment of the requirement for the degree of Masters of Education in Educational Psychology by Coursework and Research Report at the University of the Witwatersrand, Johannesburg.

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Karen Allsopp April 2008
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Abstract

Working memory has been identified as an area in which children diagnosed with ADHD experience difficulty (Carnoldi, Marzocchi, Belotti, Caroli, De Meo & Braga, 2001). However, there are conflicting findings regarding the nature of working memory deficits in children diagnosed with ADHD and some researchers believe that working memory deficits may differ between the two ADHD subtypes (Diamond, 2005; Douglas, 2005; Knouse 2007; Milich , Balentine & Lynam, 2001). In addition, it is also thought that working memory may be one of the main contributing factors of this disorder (Rapport, Chung, Shore & Isaacs, 2001). Thus, there is clearly a need for additional and more detailed investigation into the way individuals with ADHD test with regard to their working memory functioning. This study attempted to examine the working memory functioning in children diagnosed with ADHD, in particular, the Predominantly Inattentive subtype and Predominantly Hyperactive/impulsive subtype in comparison to a control group.

A sample of seventy-two participants was tested using the Ravens Progressive Coloured Matrices (RPCM) and the Automated Working Memory Assessment (AMWA) to assess their nonverbal intelligence and working memory. The primary motivating factor for the choice of participants was that they had to have been diagnosed by a professional as having ADHD (either subtype) and they had to be in Grades one or two. None of the children in the control group met the DSM-IV-TR (APA, 2000) criteria for ADHD.

Repeated measures of Mann-Whitney and post-hoc analysis revealed that there were significant differences in the verbal short term memory, verbal working memory and visuospatial working memory between the three groups. Test results revealed no significant differences between the test scores of the Inattentive group and the control group in these areas. However, scores obtained by the Hyperactive/impulsive group differed significantly from those of the control and Inattentive groups. Score differences related specifically to verbal short term memory, verbal working memory and visuospatial working memory. This implies that children diagnosed with ADHD, (the Hyperactive/impulsive subtype) may need specific strategies in the classroom to enable them to encode, access and retrieve information

to ensure optimal performance. The implications of these findings are discussed further in the thesis.

"Ode on Working Memory

There once was a box called short term store
Whose function was storage and nothing more.
But along came Alan Baddeley
Whose subjects dual-tasked madly
And working memory replaced short term store forevermore.

For those who've been living in caves
Working memory is a system with slaves.
They are independent buffers
So that neither one suffers
When doing verbal memory with visual maze.

While storage is the job of each little slave
The central executive says how we behave.
From up in the prefrontal lobes
It activates and controls all nodes
Through a dopamine system acting as gates.

The unanswered questions on working memory abound
Despite numerous studies whose findings are sound.
What's needed right now
Is for us to see how
We can put all these data on common ground (Janice Keenan, quoted in Models of Working Memory Mechanisms of Active Maintenance and Executive Control, 2007, p. xviii)."

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Chapter 1

Introduction and Literature Review

1.1 Introduction

The present study is positioned within the Baddeley and Hitch (1974) multi-component model of working memory. Since Baddeley and Hitch (1974) first published their seminal paper on working memory, many theories regarding this construct have been proposed and researched (Colflesh & Conway, 2007). This multi-component approach to working memory aims to understand ways in which knowledge is provisionally stored and maintained in the performance of complex cognitive tasks. Working memory has been identified as one of the areas in which children with Attention Deficit/Hyperactivity Disorder (ADHD) may experience difficulty (Henry, 2001; Rapport, Chung, Shore & Isaacs, 2001). Consequently, a wealth of literature has been published in this regard and this study sought to contribute to the understanding of the nature of working memory with regard to ADHD. The following provides an overview of the empirical research in both of these fields. First, it is necessary to briefly describe memory and its functioning.

1.2 The theoretical and empirical underpinnings of this study

Memory can be defined as the ability to store and retrieve information (Cockcroft, 2002).

> "If any one faculty of our nature may be called more wonderful than the rest, I do think it is memory. There seems something more speakingly incomprehensible in the powers, the failures, the inequalities of memory, than in any other of our intelligences. The memory is sometimes so retentive, so serviceable, so obedient – and at others so bewildered and so weak – and at others again, so tyrannical, so beyond control!" (Austen, 1992 p.xvi)

Throughout history the intricate process of memory has been under speculation and investigation. This "wonderful faculty of nature" is the key to successful development and growth. Memory is a "faculty" that is continually in use, an indispensable and vital part of development and learning (Levin, 2002). Over the years there has been important progress in cognitive neuropsychology in terms of the understanding of the neurology and functioning of memory systems (Vallar, Di Betta & Silveri, 2006), resulting in the reconceptualisation of memory as being a system that comprised of at least two main components as opposed to one single unitary system, namely short term memory and long term memory. This was first proposed by Hebb in 1949 based on temporary electrical activation and neuronal growth, and by the late 1960s, many new models of memory had emerged around the concept of short term memory (Baddeley, 2003).

The majority of research concerning human memory has been conducted within the information processing framework. This framework conceptualizes memory as a series of intricate, interrelated processes that encode, store and retrieve information. In this framework, sensory information is assimilated and changed into memory, via encoding. This information is then symbolized or stored in the brain, and subsequently retrieved and made available to the individual. A deficit during encoding, storage or retrieval may result in a failure to remember (Cockcroft, 2002). According to the early information processing framework, for example Atkinson and Shiffrin (1968), information is assimilated through a series of temporary sensory registers into a restricted capacity short-term store and subsequently fed into and out of long term memory. However, this early understanding of memory was incompatible with well established theories regarding learning. Furthermore, early information processing theory was largely incompatible with data concerning the impact of neuropsychological damage to the short term store. According to this framework, patients with short term store impairments should have shown a limited capacity for long term learning or every day cognitive activities (Baddely, 2003). However, these patients showed very few cognitive problems aside from severely impaired short term memory. In order to understand this phenomenon, Baddeley and Hitch (1974) used secondary tasks to deplete the availability of short term memory in participants performing reasoning or learning tasks, on the assumption that the latter were reliant on working memory. Baddeley

and Hitch (1974) found clear, but not severe, impairment in the patients' short term memory and based on these findings, they proposed a three component model of working memory, a model that comprised of separable, interacting components to replace the unitary system (Baddeley, 2003).

1.3 The structure and functioning of working memory

1.3.1 Working memory, a distinct memory system

Baddeley and Hitch (1974) propose that, while working memory shares commonalities with short term memory structures and processes, the two are nevertheless distinct memory systems. Whilst there are short term memory components to working memory models, the concept of short term memory is separate from these hypothetical concepts. Short term memory refers to information that is maintained at a surface level that does not depend on permanent knowledge structures in order to operate (Engle, Cantor & Carullo, 1992; Isak & Plante, 1997). Gathercole and Alloway (2006) consider short term memory to be a component of working memory, concerned with straightforward storage, whereas other researchers (e.g. Engle, Cantor & Carullo, 1992) argue that short term memory and working memory are separate from one another (Gathercole & Alloway, 2006). Both sets of theorists agree that important theoretical distinctions should be made between the passive short term memory system and a more dynamic working memory system. The short term memory system specializes in the temporary storage of material within particular information domains i.e., visual spatial or verbal (Gathercole & Alloway, 2006). Short term capacity is determined by practiced skills and strategies, such as rehearsal and chunking, which have traditionally been measured by digit span and word recall tasks (Daneman & Carpenter, 1980).

It is worth noting that the capacity of short term memory is linked to the speed of speech (Cockcroft, 2002). Thus, the faster an individual speaks, the more information s/he is able to rehearse. By the age of 8 years, it can be expected that many children will use articulatory rehearsal to support at least some memory tasks (Hutton & Towse, 2001). Visuospatial short term memory tasks and verbal short term memory tasks capture less underlying

cognitive skills than verbal working memory tasks and visuospatial working memory tasks (Kane, Hambrick, Tuholski, Wilhelm, Payne & Engle, 2004). Thus, studies reveal that when short term memory and working memory tests are conducted on children and adults, there are several differences between the data from short term memory and working memory tests. Working memory scores are often lower than their short term memory equivalent (generally half the value) and importantly, working memory tasks are often better predictors of complex cognitive skills, such as reading comprehension (Hutton & Towse, 2001; Savage, Cornish, Manly & Hollis, 2006).

As is clear from the description above, the relationship between short term memory and working memory is differently described by various theorists, however, it appears that most theorists agree that working memory and short term memory share a close relationship in that they both refer to temporary memory and both play an important role in learning during childhood (Gathercole & Alloway, 2006).

1.3.2 Characteristics and structure of working memory

There are numerous questions regarding working memory that remain unresolved and are the subject of continual ongoing research. These include the mechanisms for information coding and retrieval, as well as the representation format for different types of information (e.g. verbal or visuospatial) and the control, regulation, function and structure of working memory (Miyake & Shah, 2007). Fortunately, the characteristics of working memory are not completely unknown. It is recognized that this component of memory is utilized to momentarily hold in mind the different aspects of what individuals do daily. Humans utilize working memory to understand and represent their immediate environment and hold on to information about their immediate past experiences (Baddeley & Logie, 2007). It is also recognized that working memory has limited capacity, and is capable of only partial retention of past experience, with the degree of retention being dependent on the demands of the task and length of the task being performed (Logie, 1995). Working memory plays a vital role in the acquisition of original knowledge and problem solving. It is also vital for creating, linking and acting on current goals (Baddeley, 1986). In addition, research has consistently

demonstrated significant relationships between working memory and a wide range of cognitive abilities such as language comprehension, mental arithmetic, reasoning and general intelligence (Abu-Rabia, 2003;Hutton & Towse, 2001; Savage et al., 2006). All cognitive activities require the moment-to-moment monitoring, processing and maintenance of task-relevant information which are supported by different components of working memory (Baddeley & Logie, 2007). Working memory capacity therefore has important consequences for higher cognitive functioning (Alloway, Gathercole & Pickering, 2006).

In an attempt to elaborate on the working memory process, recent neurological research revealed that the posterior cortex may be more important than the frontal cortex for the storage of information in working memory. This implies that the information entering working memory from the external visual world is processed by structures in the parietal and temporal lobes which are specialized for perceptual processing. These neuro-anatomical structures remain active when the stimulus is removed for a brief time. In the same way, information entering working memory from long term memory is also stored via the structures that mediate its perception (Jonides, Lacey & Nee, 2005). The activation in these structures will fade with time and interference unless there is repeated rehearsal of them and this is controlled by the circuitry that also controls modulation or rehearsal of incoming information. i.e. the selective attention mechanism. The circuitry that controls rehearsal makes use of perceptual-motor processes in the parietal and frontal cortex, including the same mechanism that controls external speech. However, this hypothesis still needs to be tested thoroughly (Jonides et al., 2005).

Various theoretical frameworks have been proposed to account for the structure of working memory. Some researchers conceptualise working memory as a single controlled capacity system which competes for a limited resource pool, whilst others conceptualize working memory as a multi-component system comprising specialized subsystems that together emphasise combined processing and storage used in activities of daily living (Logie & Pearson, 1997), i.e. domain specific storage, domain general storage or specific executive functioning (Engle, Cantor & Carullo,1992; Kyllonen & Christal, 1990; Miyake & Shah, 2007). The Baddley and Hitch (1974) multi-component model, which is the most extensively

researched and most frequently used model of working memory (Miyake & Shah, 2007), forms the theoretical basis for this study. According to this model, working memory is comprised of several specialized components, including the central executive and two slave systems. Neuropsychological and neuroimaging studies support this model of working memory, which has subsequently been modified to include an episodic buffer (Baddeley, 2000). Evidence supporting the separability of the three-sub components of working memory is abundant, ranging from the selective interference effects found in normal adults in dual-task paradigms, through to the pattern of selective sparing and impairments in brain-damaged patients, to the differential rates of developmental changes observed in children (Baddeley, 1996; Baddeley & Hitch, 2007; Bayliss, Jarrold, Baddeley, Gunn & Leigh, 2005; Smith & Jonides, 1999).

The structure of Baddeley and Hitch's (1974, revised 1986) multi-component model is described in detail in Figure 1 (p.17). This figure shows the most recent multi-component model of working memory.

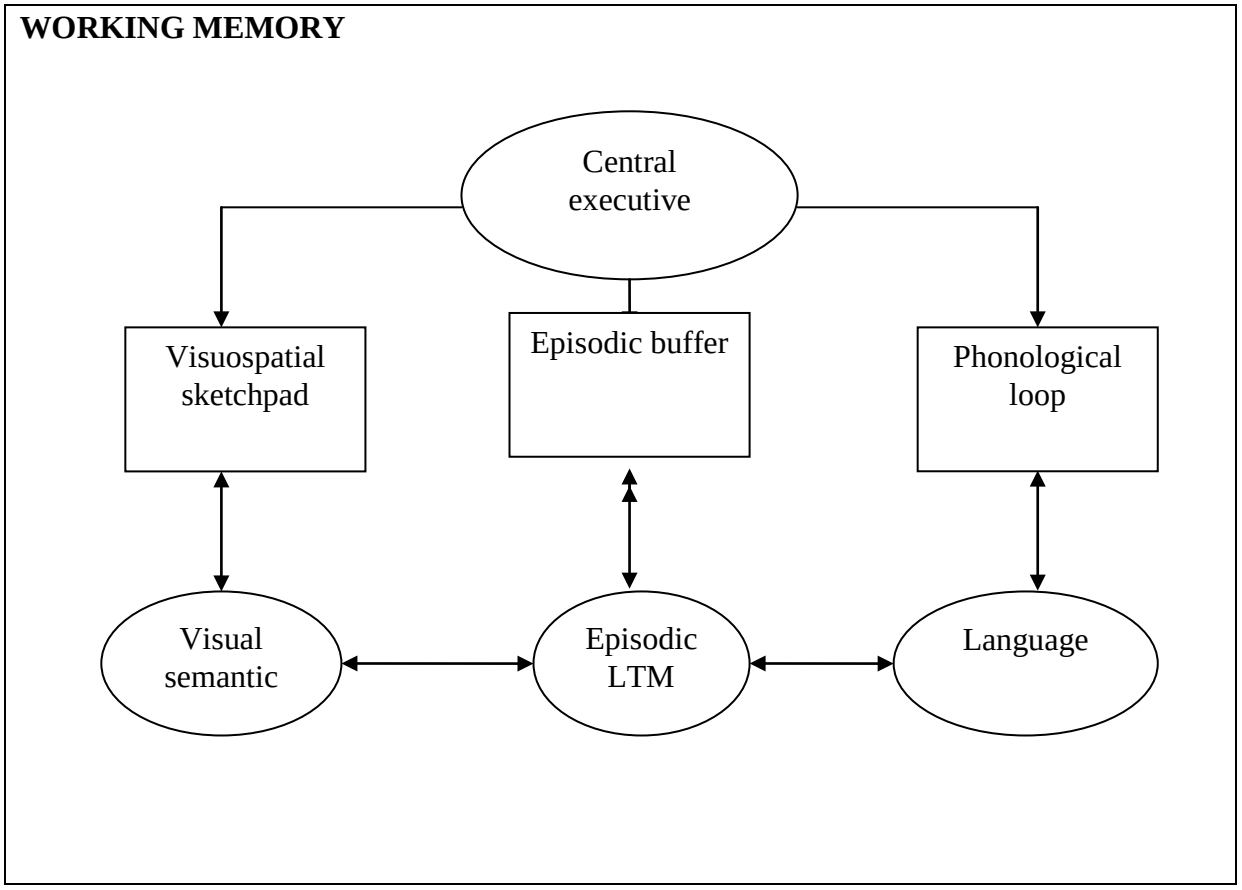


Figure 1: Baddeley's Multi-Component Model of Working Memory adapted from The multi-component model of working memory: Explorations in experimental cognitive psychology (p. 4), by G. RepovŠ and A. Baddeley, 2006, *Neuroscience*, *139* (1) 5-21.

As Figure 1 shows, this model of working memory comprises a limited capacity attentional controller, the central executive aided by two subsystems, one concerned with acoustic and verbal information, namely the phonological loop and the other performing a similar function for visual and spatial information, namely the visuospatial sketchpad. This working memory model is better able to explain performance in concurrent immediate memory tasks than theories that assume a single processing and storage system or a limited capacity attentional system coupled with activated memory traces (Cocchini, Logie, Sala, MacPherson & Baddeley, 2002). Each of the subsystems making up Baddeley and Hitch's (1986) model of working memory is described below.

1.3.3 The phonological loop

The phonological loop is speech-based and responsible for the temporary storage of all information that is able to be verbalized, such as spoken words, printed words, and identifiable objects (Gathercole & Alloway, 2006). It is comprised of two parts, namely the phonological store, and an articulatory rehearsal mechanism (Baddeley, 1996). The articulatory rehearsal mechanism acts as an inner ear by maintaining information in its auditory form for 1-2 seconds, where it is circulated in a similar manner to a tape loop. In this way, an individual is able to remember a telephone number just heard, provided that s/he keeps rehearsing it (Baddeley, 1996). Spoken words enter the phonological store directly, whereas written words or visual material needs to be converted into an articulatory code by the articulatory rehearsal mechanism befor being able to enter the phonological store (Baddeley, 1996). Baddeley and Hitch (1996) assume that individual differences in the phonological loop reflect the amount of memory activation obtainable. For example, patients with impaired verbal short term memory appear to be able to encode verbal material normally, in so far as perceiving words and sentences, but the trace of such perceptual processing does not continue, demonstrating a lack of either adequate activation or maintenance (Miyake & Shah, 2007). Tasks that make use of the phonological loop are learning to read, language comprehension and vocabulary acquisition, and it is thought that a deficit in the phonological loops system may result in a difficulty in learning to read. However, this hypothesis is still under investigation (Baddeley, 1986).

1.3.4 The visuospatial sketchpad

The visuospatial sketchpad is a specialized, temporary memory system responsible for the storage of visuospatial information over a short period of time (Gathercole & Pickering, 2000). Evidence for the visuospatial working memory has been obtained from research on memory for spatial movement and for visual patterns. In order to prove that there were separate subcomponents within the visuospatial sketchpad, Logie and Pearson (1997) conducted a study investigating visuospatial working memory in children aged 5, 8 and 11. These children’s memory spans for recognition and recall of square matrix patterns and

movements to a series of targets (the Corsi block test) were tested. Test results showed that, within each age group, the span measures for patterns correlated poorly with span for movements. Performance on both types of tasks improved with age, and span for patterns improved much faster across age than span for movement sequences (Logie & Pearson, 1997). This developmental fractionation indicated that the capacity of these subsystems developed at different rates, providing support for the existence of separate components within the visuospatial sketchpad (Logie & Pearson, 1997). These components were named the visual cache and the inner scribe (Logie, 1995). The visual cache holds information about the spatial location of objects, and represents a record of visual processing that includes the object as well as spatial information in an integrated manner (Logie, 1995). The inner scribe maintains sequences of movement that are not solely dependant on visual perceptual input. The relative physical location of objects can be determined by hearing, by touch, or by arm movement as well as vision. In this way the blind have been found to also store spatial representation in the inner scribe (Logie, 1995). "Pure" measures of visuospatial working memory are difficult to develop, since many types of visuospatial images, such as pictures of familiar objects, can be coded in working memory using phonological or semantic representations (Pickering, 2001).

1.3.5 The central executive

The central executive is the component of working memory responsible for controlling resources and monitoring information processing across informational domains (Alloway et al., 2006). Although the central executive is not yet fully understood, it is a vital component according to the Baddeley and Hitch (1974) model of working memory. Recent theories regarding the central executive conceptualise this structure as a supervisory or attentional control system (Roodenrys, Koloski & Grainger, 2001). Baddeley (2000) understood the central executive‘s role to be that of coordinating the subsidiary memory systems (i.e. the phonological loop and visuospatial sketchpad). The central executive is hypothesized to work together with, and regulate, the two storage systems used for the temporary storage of different types of information, that is the verbal or auditory, and the visual and spatial (Henry, 2001). It is suggested that the central executive is responsible for attention and

inhibition of irrelevant information from entering the working memory (Pickering, 2001). Thus, its function is to control encoding and retrieval strategies, switch attention, and mentally direct material held in the slave systems (Baddeley, 2000). The central executive can be measured by a random generation task. The ability to generate numbers is a 'basic' function of the human mind, even if those numbers are not mathematically 'random'. Relevant literature suggests that humans consciously generate random numbers as well as distractions that reduce that effort, such as concurrent tasks that take up memory or powers of concentration reduce the randomness of the numbers (Baddeley, 1986). When participants are asked to produce random sequences at speed they tend to produce series according to the conventional sequence – 1234, 7654 etc., as if the mind has exhausted its ability to screen the numbers fast enough, relying on simpler default orders to deliver a number in time. Baddeley (1986) suggests that during random generation, the central executive acts as a filtering device, screening out automatically generated (and therefore nonrandom) responses. Several studies have suggested that random generation can be used to load the central executive selectively within the working memory system (Swanson, Howard & Saez, 2006).

It is thought that the efficiency of the central executive may be related to the process of updating. Updating requires the initial monitoring and coding of incoming information for relevance to the task at hand, and then appropriately revising the items held in working memory by replacing old, no longer relevant information for newer, more relevant information (Swanson et al., 2006). It is assumed that the updating function goes further than the simple maintenance of task-relevant information given that updating requires an active manipulation of relevant information in working memory. Inadequate updating may impair the efficiency of the central executive system. Another possible source of difficulty that may impair the efficient operation of the central executive is speed of processing. Several researchers have argued that processing speed accounts for the relationship between working memory and cognitive performance on a variety of tasks. Processing speed is assumed to determine capacity given that processing (i.e. encoding, transforming, retrieving) is time related. A faster rate of processing allows for more information to be processed, thus enabling a more functional working memory capacity (Swanson, et al., 2006).

1.3.6 The episodic buffer

The latest addition to the multi-component model, the episodic buffer, is responsible for the assimilation of information from different components of working memory and long term memory into multi-dimensional representation. Individuals' verbal working memory and visuospatial working memory vary greatly, and act separately from one another, but their functioning may be integrated by the episodic buffer (Baddeley, 2000). One possibility is that developments in the episodic buffer facilitate the recoding of visual material into a verbal form.

The theoretical framework discussed above, together with relevant research, has outlined the multi-component approach to working memory, which is able to provide a understanding of the way in which information is temporarily stored and maintained in the performance of complex cognitive processing and provides a useful basis for the systematic accumulation of knowledge about important cognitive activities (Baddeley & Hitch, 2007). However, even though psychologists understand a great deal about the basic features and structure of working memory, there is currently little agreement about the way in which information is processed (Jonides et al., 2005). This highlights the need for future focused research investigating the processing of information in the working memory system.

1.4 The development of working memory

Given that this study focuses on children, it is necessary to take into account the development of working memory across childhood. In a completely developed working memory system, visual and phonological coding exist together on a continuum, under the control of attentional and inhibitory mechanisms (Pickering, 2001). Changes in knowledge, processing strategies, processing speed, attentional, processing capacity, passive memory loss and storage capacity, are to be expected to influence performance on working memory tasks (Pickering, 2001). Many studies have researched age-related growth in children's working memory. This research has indicated that their working memory spans increase progressively between 3 and 15 years of age (Cowan, 1997; Gathercole & Baddeley,1993).

Studies indicate that children's verbal working memory improves across the course of childhood, (Cowan, 1997, 2000; Gathercole & Baddeley, 1993) and studies involving digit span measures indicate a positive correlation with age (Ferguson, Bowey & Tilley, 2002) with span increasing from approximately two digits for 2-year-old to five digits for 7-year-olds and seven digits for adolescence (Dempster, 1981). The results obtained from research using tasks that require both storage and processing, such as backward digit span or operations span, support the proposal of fixed growth; however, spans are typically poorer than studies involving purely digit span measures by roughly two units (Pascual-Leone, 2000). The processes and mechanisms that bring about these improvements are still being investigated. This is also true for age-related changes in processes such as sub-vocal rehearsal and articulation rate, which have been investigated in children and show a steady improvement in the speed of verbal rehearsal, thus allowing more items to be stored. As articulation rate increases and children are able to rehearse faster (vocally or sub-vocally), span increases and word length effects become more prominent. The word length effect has been found in children as young as 4 years old suggesting that articulation rate is important at a young age (Gathercole & Baddeley, 1993). Over the course of development, children increasingly rely more on more sophisticated forms of rehearsal instead of faster repetition. Overall empirical studies support claims that verbal working memory improves during childhood and suggest that increases are due to more sophisticated and efficient processing of verbal information. There appears to be an increase in the capacity of the visual working memory which parallels improvements in the phonological loop (Pickering, 2001).

Visual working memory increases between the ages of 5 and 11 years (Pickering, 2001). By the age of 4 or 5, children can remember two to three item sequences of pictures (Gathercole & Baddeley, 1993). However, younger children find it more difficult when the pictures of items on a list bear a resemblance to one another than when they are visually distinct. This is found as early as preschool age, whereas, older children have more trouble with recall when the verbal labels for the images have similar sounding names. Thus, visual similarity effects decrease with age, whereas phonological similarity effects increase with age. This may be attributed to the fact that young children use their visual system for rehearsal of visual

information, but some time between 6 and 8 years of age, children begin using their verbal system for rehearsal.

During the early stages of development, the basic perceptual and sensory motor functions of working memory are enhanced, in the later stages the neurological networks develop in order to integrate complex processes associated with working memory function (Pickering, 2001). This may explain why children are better able to assemble information in a working memory task in a meaningful way as they get older, due to the increased content and development of their long term memory. This process is often referred to as "chunking" or grouping the information in a meaningful way. Research has proven that chunking increases the performance on phonological working memory tasks, because memory items are grouped on the basis of information held in long term memory, which results in a reduced quantity of information being held in working memory (Pickering, 2001). It appears that older children and adults' working memory operation is conditional on the efficient allocation of phonological and visuospatial slave system resources by the central executive (Pickering, 2001). Visuospatial working memory tasks rely heavily on executive functioning which does not fully develop until adolescence. Consequently, the contribution of attention processes to visuospatial working memory tasks is unlikely to be at its most powerful until this stage of development (Pickering 2001). Much has been written about the differences between verbal and visuospatially based memories. This is particularly relevant in a developmental context as children's reliance on these codes appears to be different (Hutton & Towse, 2001). This needs to be taken into consideration in any study on working memory in children and will be discussed along with the findings in the final chapter of this report.

Relatively little is known about the development of the central executive over childhood. However, it has been suggested that this component of working memory is particularly important to visuospatial memory tasks, due to the significant attentional requirements of these tasks (Pickering, 2001). It is probable that younger children draw more on executive resources to perform short term memory tasks, due to the fact that the brain areas related to higher level cognition are still developing. Therefore, older children have greater cognitive

resources and younger children do not have the benefit of these additional support systems (Alloway et al., 2006).

It is thought that changes in integrative ability within the episodic buffer take place over the course of childhood. Mounoud (1996) considered that a general change in cognition is driven by neurological maturation and supported by the environment. However, no studies have directly examined development within the episodic buffer, though research on the development of the phonological loop and development of the visuospatial sketchpad supply evidence about changes that may be expected. Research indicates that visual-verbal integration may go through significant changes during middle childhood and elementary school years. Pickering (2001) particularly suggests that the change from visual to verbal processing occurs around 8 years of age. Gathercole, Pickering, Ambridge and Wearing (2004) propose that the change in processing occurs around 7 years of age.

1.5 Deficits in working memory and attention

Although the model of working memory outlined above conceptualizes working memory as a distinct memory system, the model does not imply that working memory functions as a discrete separate entity. In fact, it appears that at times, the terms working memory and attention are so intertwined that these constructs are sometimes used interchangeably and Baddeley (1993) once remarked that working memory may be better construed as working attention. The inter-connectedness between attention and working memory has been empirically established. For example, researchers have suggested that working memory capacity is limited by controlled attention, which is the ability to allocate attentional resources despite distraction or interference (Alloway et al., 2006). Children with high working memory capacity have also demonstrated greater available attentional resources available to them than individuals with low capacity (Baddeley, 1993). Further studies support the view that many children who have been diagnosed with attention difficulties, particularly ADHD, have cognitive deficits with regard to working memory, that is, they have difficulty holding information that directs behaviour (Sinha, 2005). An inter-connection between attention and working memory has also been demonstrated with adults. In a series of

three experiments conducted on adults (mean age 28), increased working memory load was demonstrated to reduce the executive control of attention measures via task-switching and inhibitory management paradigms (Alloway et al., 2006). The task was a serial stream of single colour words in congruent fonts, with the word presented for 900 ms followed by a 600 ms inter-stimulus interval. Participants were trained to respond to each of the words with a single 'Go trial' button press and to withhold this response when either of two different circumstances arose. The first was if the same word was presented on two consecutive trials (Repeat No-go), and the second was if the word and font of the word did not match (Stroop No-go). By having competing types of response inhibition rules, they aimed to vary the strength of stimulus–response relationships, whereby representations of rules competitively suppress one another such that the more prominent rule would suppress the weaker rule and so produce a significant number of errors, a small proportion of which may go unnoticed due to focusing mainly on the dominant rule.

In particular, they aimed to benefit from the over learned human behaviour of reading the word rather than the colour of the letters (the Stroop effect) and in so doing predispose participants to monitor for the repeat rather than the Stroop No-gos. Participants were trained to press a different 'error awareness' button on the trial following any commission errors and were not required to make the standard Go response. This research supported the attentional control theory that active maintenance of competing task goals is vital for executive functioning and working memory capacity (Hester & Garavan, 2005). In addition, the findings of this research also suggest that, when information currently maintained in working memory is re-encountered, it is harder to exert executive control over it (Hester & Garavan, 2005). Based on these and similar findings, there is a growing emphasis on the closer examination of tasks and processes that can be used to tap the central executive as a means of clarifying the nature of deficits in this system (Miyake & Shah, 2007; Roodenrys et al. 2001).

In practical terms, current research suggests that working memory deficits may manifest as inattention and contribute to poor academic performance. As working memory is primarily located in the prefrontal cortex of the brain, deficits in working memory occur in several disorders where the prefrontal cortex is affected, such as ADHD (Klingberg, Fernell, Olesen, Johnson, Gustafsson, Dahlstrom, Gilberg, Forssberg & Weterberg, 2005). Children

diagnosed with ADHD and children who have working memory deficits share many of the same characteristics in the classroom, such as forgetting instructions, place-keeping errors in complex tasks and failure to meet simultaneous processing and storage demands (Gathercole & Alloway, 2006). Children diagnosed with ADHD also need to be "managed" in classroom situations. Deficits in working memory are often experienced by educators as inattention problems, like difficulty focusing on reading a text, or memory problems, such as forgetting what to do while walking from one room to another. In children the problem is often remembering what to do next and this affects their planning ability (Douglas, 2005). Thus, it is not surprising that impairment in executive functioning such as response inhibition, vigilance, working memory and planning have been identified as an area of deficit in children with ADHD and neuropsychological studies have supported these findings (Carnoldi, Marzocchi, Belotti, Caroli, De Meo & Braga, 2001).

Most studies investigating the relationship between working memory and ADHD have focused on the ADHD Combined type or a mixed group of ADHD participants (Milich et al., 2001). Results from these studies have indicated that children with ADHD have visuospatial working memory and verbal working memory impairment in comparison to a normal control group of children (Roodenrys et al., 2001). Due to the high reliance on verbal instruction in the classroom, and reliance on visuospatial working memory and verbal working memory to perform basic skills such as reading, writing and mental arithmetic, deficits in this area may directly influence all classroom based activities and learning (Henry, 2001).

In sum, the literature outlined thus far suggests that working memory and attention are closely linked. There appear to be working memory deficits in children diagnosed with ADHD, however it is uncertain where these differences lie as children's reliance on verbal and visuospatial based memories appear to differ. Most probable is that there may be a deficit in the functioning of the central executive, whose main function is attention and monitoring. The following section will provide a broad overview of relevant literature focusing on the history of ADHD, from its earlier classification to the current, multi-dimensional conceptualization of ADHD. This section will also outline central points of the current debate concerning the general characteristics of ADHD and its different subtypes.

Additional literature concerning the link between working memory, attention and ADHD will be explored.

1.6 Attention Deficit/Hyperactivity Disorder

The history of the classification of ADHD is fraught with controversy. The identification of the most significant symptoms of ADHD is a debate that still continues. Some researchers propose an inadequate inhibitory process and others adhere to the earlier emphasis of attention problems as the core difficulty. Recently, it has been proposed that working memory may be the core deficit of this disorder (Rapport et al., 2001). Over the years these classification controversies have undergone continual research (Milich et al., 2001).

The concept of ADHD has evolved over the last 30 years. This recurrently encountered neurobiological disorder in childhood has been the focus of significant research (Brown & Perrin, 2007). In order for a child to be diagnosed with this disorder they have to meet the DSM-IV-TR criteria for ADHD (Sprafkin & Gadow, 2007). At first, ADHD was classified as a hyperkinetic reaction of childhood. It first appeared as a diagnostic category in the DSM-II (American Psychiatric Association [APA], 1968), at which time it was conceptualised as having a core dysfunction of excess motor activity. In the DSM-III (APA, 1980), it was later labeled as Attention Deficit Disorder (ADD). Virginia Douglas's research on ADHD was an influential motivation for the above reconceptualisation (Flory, Milich, Lorch, Hayden, Stronge & Welsh, 2006). Her research incorporated a number of components, including disinhibition and dysregulation difficulties, thus, moving the focus away from hyperactivity towards the problems in sustaining attention in tasks, hence the label of Attention Deficit Disorder (ADD) (Martinussen, 2005). At this time, ADHD was subdivided into sub-types, distinguishing between individuals with and those without hyperactivity. Thus, the role of hyperactivity in ADHD shifted from being a core component of the disorder to being an unessential concomitant symptom.

Following the publication of the DSM-III-R (APA, 1987), evidence supporting the validity of a multi-dimensional approach to ADHD began accumulating. Various factor analysis

studies found that symptoms of ADHD could be grouped into two factors, these being inattention and hyperactivity/impulsivity. This resulted in ADHD being reconceptualised as a disorder having two distinct areas of dysfunction (Milich, Balentine & Lynam, 2001). The criterion for ADHD presented in the DSM-IV (APA, 1994) reflects a multi-dimensional conceptualization of the disorder. This is supported by Barkley's (1997) model of ADHD, which specifies problems in disinhibition as the core component. (Barkley, 1997). Currently, as reflected in the DSM-IV-TR, ADHD is subdivided into three categories (Milich et al., 2001). The DSM-IV-TR criteria are shown in Table 1 (p. 29).

Table 1: DSM-IV-TR Diagnostic Criteria for Attention-Deficit/Hyperactivity Disorder adapted from *Kaplan & Sadock's Synopsis of Psychiatry Behavioral Sciences/Clinical Psychiatry. (9th ed.)*(p. 1225),by B. J. Sadock & V.A. Sadock, 2002, New York: Lippincott Williams & Wilkins.

DSM-IV-TR Diagnostic Criteria For Attention-Deficit/Hyperactivity Disorder

Either (1) or (2)

(1) Inattention: Six (or more) of the following symptoms of ***inattention*** have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level:

Inattention

- Often fails to give close attention to details or makes careless mistakes in schoolwork, work or other activities
- Often has difficulty sustaining attention in tasks or play activities
- Often does not seem to listen when spoken to directly
- Often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace(not due to oppositional behaviour or failure to understand instructions)
- Often has difficulty organizing tasks and activities (e.g. toys, school assignments, pencils, books or tools)
- Is often distracted by extraneous stimuli
- Is often forgetful in daily activities

(2) Hyperactivity-Impulsivity: Six (or more) of the following symptoms of ***hyperactivity-impulsivity*** have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level.

Hyperactivity

- Often fidgets with hands and feet or squirms in seat
- Often leaves seat in classroom or in other situations in which remaining seated is expected
- Often runs about or climbs excessively in situations in which it is

inappropriate (in adolescents and adults, may be limited to subjective feelings of restlessness)

- Often has difficulty playing or engaging in leisure activities quietly
- Is often "on the go" or often acts as if "driven by a motor"
- Often talks excessively

Impulsivity

- Often blurts out answers to questions before the questions have been completed
- Often has difficulty awaiting turn
- Often interrupts or intrudes on others (e.g. butts into conversations or games)

A. Some hyperactive-impulsive or inattentive symptoms that caused impairment were present before 7 years

B. Some impairment from the symptoms is present in two or more settings (e.g., at school or work and at home).

Code based on type:

Attention-Deficit/Hyperactivity Disorder, Combined Type: If both Criteria A1 and A2 are met for the past 6 months.

Attention-Deficit/Hyperactivity Disorder, Predominantly Inattentive Type: If Criterion A1 is met but Criterion A2 is not met for the past 6 months

Attention-Deficit/Hyperactivity Disorder, Predominantly Hyperactive-Impulsive Type: If Criterion A2 is met but Criterion A1 is not met for the past 6 months

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As reflected in Table 1, ADHD is currently divided into three subtypes. The first subtype being Predominantly Inattentive subtype (Inattentive subtype), which, as the name implies, involves inattention and results in the impaired investment, organization and maintenance of attention in children. The Inattentive subtype is characterised by a sluggish cognitive tempo, drowsiness, lethargy and hypo-activity. Children diagnosed with the Inattentive subtype, rather than being distractible, may experience problems with under-arousal and motivation rather than inhibitory control (Diamond, 2005), as seen in Table 2 (p. 32). In addition, inattentive symptoms in early childhood tend be developmentally stable and are a predictor

of subsequent cognitive and academic impairments. This is in contrast to the disruptive hyperactive-impulsive symptoms which decrease with age and are associated with aggression and oppositional behaviour, but not necessarily cognitive dysfunction (Martinussen, 2005). The second ADHD subtype is the Predominantly Hyperactive-Impulsive subtype (Hyperactive/impulsive subtype), which, as the name implies, involves hyperactivity and impulsivity and results in the child fidgeting, squirming, being unable to sit still in a classroom, running about or climbing, experiencing difficulty in participating in leisure activities quietly, and excessive talking. The third subtype is the Combined subtype, which is a combination of both Inattentive and Hyperactive/impulsive subtype characteristics (Holz & Lessing, 2002).

The changing DSM classifications have emphasized different primary symptoms underlying ADHD, starting with hyperactivity in the DSM-II, followed by attention problems in the DSM-III, and at present emphasizing both attention problems and hyperactive/impulsive behaviour in the DSM-IV-TR. Some researchers adhere to the identification of the primary deficit of children diagnosed with ADHD as being inhibitory processes, such as Barkley (1997), others adhere to the earlier emphasis on attentional problems, such as Brown and Perrin (2007) and more recently, some proposing working memory as a core deficit of the disorder (Rapport et al., 2001). As this study examined the working memory functioning of the two subtypes of ADHD, it is necessary to explore the distinctions between each subtype in greater detail. The characteristics of the Hyperactive/impulsive subtype and Inattentive subtype are summarised in Table 2 (p. 32).

Table 2: A Comparison of the Characteristics of ADHD Hyperactive/impulsive and Inattentive Subtypes adapted from Attention-deficit disorder (attention-deficit/hyperactivity disorder without hyperactivity): A neurobiologically and behaviorally distinct disorder from attention-deficit/hyperactivity disorder (with hyperactivity). *Development and Psychopathology* 17 (p. 810), by A. Diamond.

Hyperactive/impulsive subtype	***Inattentive subtype***
Hyperactive, always on the go, impulsive.	Hypo-active and sluggish and have slow response speeds.
Primary deficit in response inhibition.	Primary deficit in working memory, especially prominent in auditory processing because of the demands it places on working memory.
Often insufficiently self-conscious.	Tends to be overly self-conscious.
Social problems due to impulsivity and over assertiveness, butts in, takes things belonging to others, fail to wait their turn, and act without first considering the feelings of other.	Social problems because to passive, shy, or withdrawn.
Tend to be extroverted.	More likely to be introverted.
Externalizing behaviours, such as conduct disorder, aggressivity, disruptive behaviour and even oppositional defiant disorder are more commonly comorbid with the Hyperactive/impulsive subtype.	Internalized disorders, such as anxiety or depression, are more common in children diagnosed with the Inattentive subtype. Tend to be socially isolated or withdrawn. Reading and language deficits and problems with mental mathematical calculations are

	more commonly comorbid with the Inattentive subtype.
Respond positively to methylphenidate.	Those who are helped with methylphenidate often do best at low doses.
Most respond positively to methylphenidate in moderate to high doses.	Many children diagnosed with the Inattentive subtype are helped by amphetamines rather than methylphenidate.
More likely to smoke than the Inattentive subtype as there are marked similarities in the neurobiological and psychological effects of nicotine and methylphenidate.	More easily bored than distracted. Problem lies more in motivation than in inhibition. Challenge or risk may be key to keeping their attention and eliciting optimum performance. May involve in risk-taking and thrill-seeking activities as ways to experience a level of engagement.

One diagnostic debate that has persisted for the past 20 years, concerns the validity of the ADHD Inattentive subtype. Before the introduction of this disorder (DSM- III, 1980), it had not yet been conceptualised that children may have significant attentional problems, without the associated over activity and impulsivity. When the Inattentive subtype was first introduced, various studies investigated the validity of this subtype of ADHD. These studies attempted to identify commonalities and differences between the two major subtypes of ADHD, i.e., those with concomitant hyperactivity and impulsivity and those with attention problems alone. As the literature addressing this issue grew, a number of reviews have appeared disputing the validity of the Inattentive subtype (Carlson, 1986; Carlson, Booth, Shin & Carnu, 1999 ; Carlson & Mann, 2000; Goodyear & Hynd, 1992; Wheeler & Carlson, 1994) and currently, the subtypes of ADHD are often regarded as part of one combined group and are not differentiated within studies.

However, there is a great deal of empirical evidence suggesting distinct differences between the two subtypes, to the extent that some researchers, like Diamond (2005), argue that the Inattentive subtype and Hyperactive/impulsive subtype are not two different types of ADHD, but two different disorders with different cognitive and behavioral profiles. Others argue that is possible that the Inattentive subtype may be better conceptualised as a form of Learning Disorder (Milich et al., 2001). For example, Gathercole and Alloway (2006) recently found that there is no strong case for claiming that impairments of working memory are a general characteristic of children with attentional disorders as their study indicated that children diagnosed with the Hyperactive/impulsive subtype did not have an unexpectedly poor memory function. Gathercole and Alloway (2006) propose that the Hyperactive/impulsive subtype may have the ability to hold information in memory, but may not take the time to actively manipulate information in the mind and consequently may perform poorly on tasks requiring the use of working memory capacity.

An additional study by Nigg, Baskey, Huang-Pollock and Rappley (2002) also examined this issue. The authors compared children diagnosed with ADHD (the Combined subtype) to a normal control group on a stop signal task, an empirically validated measure of behaviour inhibition. Results of this study revealed deficits in behavioural inhibition for the Combined subtype, with no such deficit found for the control group. Furthermore, when subtype differences are investigated, children diagnosed with the Inattentive subtype have been found to perform more poorly on achievement measures than children diagnosed with ADHD Combined subtype, particularly with maths achievement.

These findings indicate that the processing deficits in the Combined and Inattentive subtype may be qualitatively different. There is also preliminary evidence to support the hypothesis that working memory deficits are more strongly associated with symptoms of inattention than with symptoms of hyperactivity-impulsivity in children (Martinussen, 2005).

Frank and Ben-Nun (1988) studied differences between boys diagnosed with the Hyperactive/impulsive subtype and boys diagnosed with the Inattentive subtype using a neuropsychological battery. Children with the Hyperactive/impulsive subtype were more

likely to have a history of perinatal or neonatal abnormality. In addition, they were likely to have abnormal results on neurological examinations of motor skills. The Hyperactive/impulsive group performed significantly below the Inattentive group on tests of visual perception, visual sequential memory and writing performance.

1.7 The role of impaired executive functioning in ADHD

For a number of years, ADHD has been associated with deficits in frontal lobe functioning (Barkley, Grodzinsky & DuPaul, 1992). Neuropsychological testing and advanced neuroimaging procedures have also directed theoretical attention towards conceptualizing ADHD as a deficit in executive functioning (Barkley, 1998; Nigg, 2001), with evidence emerging that children with ADHD consistently exhibit deficits in executive functioning (Flory et al., 2006; Oorsterlaan, Scheres & Sergeant, 2004). Researchers refer to executive functioning as a collection of cognitive control processes that operate on lower-level processes. Children with impaired executive functioning often exhibit many of the problems associated with ADHD, including inattention, disinhibition, poor planning and a deficient working memory (Barkley, 1997). Interest in executive functioning in children with ADHD developed from research demonstrating that prefrontal damage is associated with particular kinds of cognitive deficits, and from brain imaging studies demonstrating abnormalities in frontal-striatal-cerebellar networks in children diagnosed with ADHD. Prefrontal areas also play an important role in the cognitive and motor deficits of children diagnosed with ADHD (Douglas, 2005). Attempts to characterize the cognitive deficits of children diagnosed with ADHD have focused on several key processes, including attention, inhibition, state regulation, delay aversion and executive functioning (Douglas, 2005). The question of whether attention problems are differentially related to distinct executive functions remains unresolved.

Barkley's (1997) model places *behaviour inhibition* as the core executive function deficit in children diagnosed with ADHD, resulting in *secondary* deficits in other control processes, such as working memory and attention. According to this model of ADHD, hyperactivity, a "core" inhibitory deficit, impairs the development of several executive functions, including

working memory. Barkley (1997) views ADHD as a difficulty in sustaining effort over time, related to motivation, rather than to skill. The foundation of Barkley's (1997) model is behaviour inhibition, or the delay of motor response, a delay which allows for the development of executive functions. Barkley (1997) conceptualizes the four executive functions as working memory, self – regulation of affect/ motivation, internalized speech, and reconstitution (refer to Figure 2). Self–regulation of affect involves both the ability to moderate the expression of feelings so they do not get out of control, and the ability to increase motivation as needed (for example, when performing a monotonous task). Internal speech facilitates the use of rules as guides to socially acceptable behaviour and the use of strategies in problem solving. Reconstitution is the ability to reconstitute (change the form) of past events and anticipate future ones. This involves the analysis and synthesis of behaviour, verbal fluency, behavioural fluency, goal-directed behavioral creativity, behavioural simulations and syntax of behaviour and involves high-level thinking, particularly analysis, synthesis and creativity (Wenar & Kerig, 2000). The final outcome of these executive functions is motor control, along with goal-directed behaviour that becomes increasingly lengthy, complex and adaptive. Each of the four mechanisms has its own developmental course, for example, those that involve speech develop later than those that do not (Wenar & Kerig, 2000).

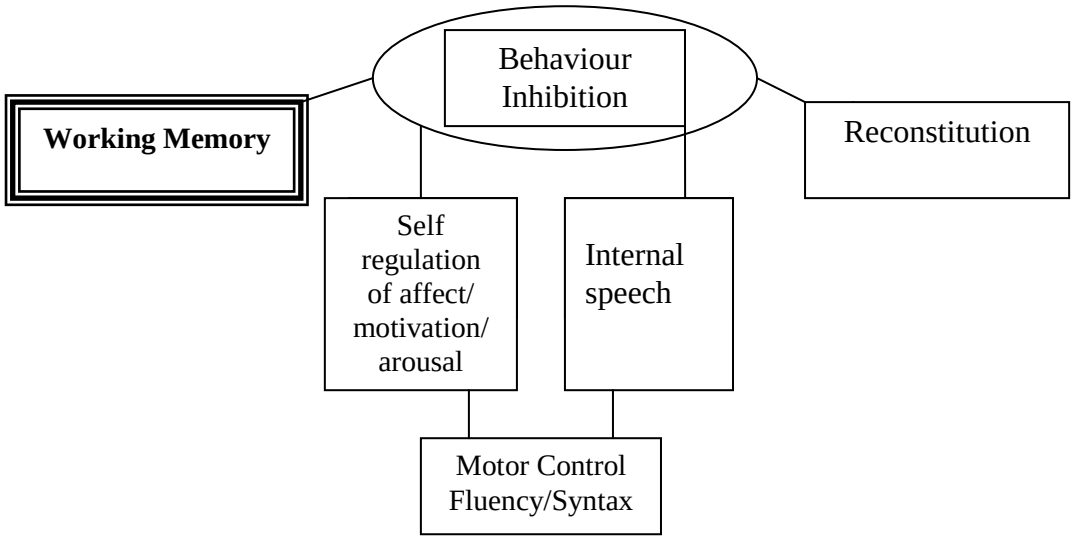


Figure 2: Barkely's (1997) integrative Model of ADHD Hyperactivity/impulsive subtype adapted from *Developmental Psychology from Infancy through Adolescence (4th ed.)*, (p.172), by C.Wenar & P.Kerig, 2000, Singapore: McGraw-Hill.

Barkley (1997) maintains that the primary deficit in the Hyperactive/impulsive subtype is the weakened ability to inhibit behaviour, and that all other deviations characteristic of ADHD are secondary to this reduced capacity, given that the four executive functions can only develop within a period of motor inhibition. It is important to note that delay or inhibition *allows* executive functions to develop, as opposed to *causing* them to develop. For example, internalized speech develops as a result of its own set of causal factors, such as changes in knowledge, processing strategies, processing speed, passive memory loss and storage capacity not because of motor inhibition per se (Wenar & Kerig, 2000). Thus, children diagnosed with the Hyperactive/impulsive subtype are more likely to show impairment in working memory relative to the inattentive sub-type, where poor inhibition of behaviour is not the primary diagnostic focus.

Barkley (1997) explicitly states that his behavioural inhibition model of ADHD refers only to the Combined and Hyperactive/impulsive subtypes. This is because he assumes the primary impairment of the Inattentive subtype to be inattention. Thus, his theory is not appropriate in

attempting to account for the problems of children with the Inattentive subtype. It appears that currently, no main theoretical model exists that provides a framework for understanding the Inattentive subtype (Milich et al., 2001).

In contrast to Barkley's (1997) model, Rapport et al.,(2001) propose that *working memory* is the core executive function deficit in children diagnosed with ADHD. In recent research, three commonly discussed executive functions, namely inhibiting, updating working memory, and shifting between tasks or mental sets were only moderately correlated and separable, supporting the hypothesis that attention problems may be differentially related to distinct executive functions (Friedman, Haberstick, Willcutt, Miyake, Young, Corley & Hewitt, 2007; Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000). However, researchers found that children diagnosed with ADHD show a great deal of variability with regard to their basic cognitive ability and executive functioning (Gathercole & Alloway, 2006; Loe & Feldman, 2007).

With respect to research examining differences in executive functioning between the different ADHD subtypes, several studies have examined whether these deficits also extend to the Inattentive subtype. Barkley et al. (1992) compared 12 boys diagnosed with the Inattentive subtype to 12 boys diagnosed with the Hyperactive/ impulsive subtype on various neuropsychological measures of frontal lobe functioning (i.e., pegboard performance, the trailmaking test, Poreus Mazes, the Stroop, and the Wisconsin Card Sorting Test). There were no group differences on any of these measures. However, despite these findings of equivalent performance there may still be executive functioning differences between the ADHD subtypes given that this study did not utilize a control group for comparison.

In contradiction to the null result for measures of executive functioning mentioned above, Klorman, Hazel-Fernandez, Shaywitz, Fletcher, Marchione, Holahan, Stuebing and Shaywitz (1999) compared 102 children diagnosed with the Inattentive subtype and 207 children diagnosed with the Combined subtype on two measures of executive functioning, namely the Tower of Hanoi and the Wisconsin Card Sorting Test. The Combined group exhibited deficits in executive functioning on both tasks. In comparison to the Inattentive group, the

Combined group made more non-perseverative errors on the Wisconsin Card Sorting Test, solved fewer puzzles and broke more rules on the Tower of Hanoi, than the Inattentive subtype. A study by Nigg (2000), found that the Inattentive subtype exhibited a deficit in set shifting on the Trail Making Test. Thus, there is a great deal of empirically based evidence supporting Barkley's (1997) hypothesis that sustaining attention over time may be the core deficit of children diagnosed with the Inattentive subtype, as opposed to the delayed motor response of children diagnosed with the Hyperactive/impulsive subtype.

In an attempt to establish the similarities between the different subtypes of ADHD and to delineate the essential features of the core deficits of ADHD, recent discussion has centered around the attention deficit hypothesis, as well as the more recently formulated attentional control argument (Roodenrys et al., 2001). This debate has arisen from the development of the view that attention is a multifaceted concept, and that different attention tasks tap different attentional processes in addition to other non-attentional processes (Roodenrys et al., 2001). The main premise of the attentional control argument is that individuals with greater working memory capacity are better able to control or focus their attention than are individuals with lesser capacity (Colflesh & Conway, 2007). In other words, as the capacity of working memory increases, so does the ability to control the focus of attention, and individuals with high working memory capacity are able to flexibly adjust attentional focus (Colflesh & Conway, 2007). In support of this argument, children diagnosed with ADHD (all subtypes), demonstrate diminished performance on tasks involving the use of self-regulation, planning, organization and executive processing and the allocation of attention. These tasks fall under the general rubric of executive processing and place demands upon the management or allocation of attentional control (Roodenrys et al., 2001).

Although theories and empirical studies have identified working memory deficits in children with ADHD, results and conclusions have been inconsistent across studies. This may be a consequence of differences in the definition of working memory that researchers have used participants with both subtypes of ADHD in a single group. Previous results have indicated that children with both subtypes of ADHD performed similarly on the memory tasks, but showed deficits in their ability to perform dual tasks. This suggests that ADHD may be

associated with deficits in the central executive/attentional control component of working memory, but not in the short-term storage component.

In sum, the suggestions offered by the literature indicate that the Inattentive subtype is comprised of qualitatively different behavioural patterns compared to the Hyperactive/ impulsive subtype, including difficulty in sustaining attention to prolonged activities and distractibility. It has been suggested that inattention may stem from an inability to hold mental representations active and use them to guide behaviour, a skill associated with working memory (Gathercole & Alloway, 2006). It may be possible that children diagnosed with the Inattentive subtype may have impairments of working memory. As the ability to mentally hold and manipulate information requires the use of controlled attention and children diagnosed with the Inattentive subtype may have difficulty performing tasks that require the use of central attention resources, it is hypothesized that performance on tasks that measure working memory would be poorer for the inattentive sample than for the hyperactive sample, supporting the theory that inattention affects working memory rather than inhibition. Ultimately, contradictory research results suggest that there may be not one blanket cause for working memory deficits in children diagnosed with ADHD, each child may show different impairments in different aspects of working memory such as verbal or visuospatial short term memory or working memory or the executive control system. A deficit in any one of these areas may result in a loss of inhibition or attention.

As the literature reviewed thus far demonstrates, various theoretical approaches have guided research on ADHD over the past three decades and, at times, have even influenced diagnostic criteria (e.g. ADD vs. ADHD). Numerous studies have been undertaken to determine which core deficits (i.e. inattention, disinhibition and executive function) best differentiates children with ADHD from comparison groups. Perhaps no single theoretical approach is adequate to account for the many difficulties exhibited by children diagnosed with ADHD, and different core deficits may account for different aspects of the cognitive and social impairments associated with ADHD. The general characteristics of ADHD are discussed below.

ADHD is found in all social classes and ethnic groups, with the Hyperactive/impulsive subtype being more common in males than females (Barkley, 1997), and Inattentive subtype being more prevalent in females than males (Wenar & Kerig, 2000). A large percentage (35%) of children diagnosed with ADHD may have a comorbid disorder, such as Oppositional Defiant Disorder, Conduct Disorder, Autism Spectrum Disorders and Developmental Co-ordination Disorder (Radcliff, 2000; Savitz & Jansen, 2005). Children diagnosed with ADHD may also have a comorbid Learning Disability. These children often fail classroom learning activities that place heavy demands on working memory and evidence has suggested that children diagnosed with ADHD are weaker than their normal developing peers in processing lengthy and/or more complex language (Koch, 2003; Seargeant, Piek & Oosterlaan, 2006). Between 40 and 60% of children with ADHD have co-occurring oral language deficits that affect their academic progress (Martinussen, 2005). However, there is no extensive evidence of a causal link between impairments of working memory and learning difficulties (Alloway, Gathercole, Adams & Willis, 2005; Brocki & Bohlin, 2006; Gathercole & Alloway, 2004). Children showing symptoms of ADHD are usually diagnosed during the preschool or early childhood years. A large percentage of children do not show symptoms of ADHD until after the age of 7 years, hence the average age of the participants (8 years [SD = 1]) in this study (Wenar & Kerig, 2000). A diagnosis of ADHD is strongly associated with poor school marks, poor reading, poor math standardized test scores, and increased grade retention, and children diagnosed with ADHD are therefore more likely to leave school prematurely (Loe & Feldman, 2007).

A variety of treatment strategies, both pharmacological and behavioural, have been adopted to manage ADHD (Shokane, Rataemane & Rataemane, 2004). The most commonly prescribed medications used in the treatment of ADHD are psycho stimulants (methylphenidate and dextroamphetamine). Despite being heavily criticized, these medications remain the treatment of choice (Shokane et al., 2004). Whilst clinical trials indicate that psycho stimulants may result in a slight improvement in working memory (Sinha, 2005), typically, stimulant medication does not enhance the academic achievement of children with ADHD over the long term (Schachar, Tannock, Cunningham & Corkum, 1997). Cognitive based treatment programs have also been designed to target the behavioural

symptoms of ADHD, and teaching strategies have been implemented in the classroom to facilitate academic success (Rosenshine, 1997). Stevens, Quitner, Zuckerman and Moore (2002) found that reducing "multitasking" and increasing focus on one assignment resulted in improved academic performance in children diagnosed with ADHD. In addition, the use of strategies such as breaking down information into smaller pieces to facilitate memory for school material and instructions, have also proved helpful. Mnemonic strategies also appear to assist these children (Stevens et al., 2002). Such strategies also assist children diagnosed with a deficit in their working memory, suggesting that working memory is an area of difficulty for children with ADHD.

Current education strategies used to address deficits in children diagnosed with ADHD, whether it be the Inattentive or Hyperactive/impulsive subtype, do not appear to address the differences between the two subtypes. Simplistic suggestions such as organizing the classroom in a formal manner and using both positive and negative reinforcement seem to be the universal strategies employed by teachers, regardless of inattention, impulsivity, or hyperactivity among learners (Schlachter, 2008). Academic interventions for learners diagnosed with ADHD have not been as widely studied as behavioral treatments for these learners (DuPaul, 2007). DuPaul (2007) mentions various strategies that have proved beneficial as remedial strategies for children diagnosed with ADHD, however he does not differentiate between the Inattentive or Hyperactive/impulsive subtype. These strategies include computer-assisted instruction class-wide peer tutoring, home-based parent tutoring or homework support, self-regulated strategy for written expression, and directed note taking in enhancing specific areas of academic performance (DuPaul, 2007). As the different deficits of the different subtypes are not currently recognised, specific educational intervention strategies can not be targeted

1.8 *Rationale for the Current Study*

Based on literature confirming differential processing deficits between the different subtypes of ADHD, the premise for the current study is that there would be differences between the working memory functioning of an Inattentive and Hyperactive/impulsive group of children with ADHD. A review of available literature illustrates the necessity for further research in the field of working memory, especially with regard to ADHD. Not only does research indicate that children with ADHD show deficits in their working memory (Carnoldi et al., 2001; Martinussen, Hayden, Hogg-Johnson & Tannok, 2005), but it also indicates that these deficits may differ in children diagnosed with the Inattentive subtype and Hyperactive/impulsive subtype (Diamond, 2005; Douglas, 2005; Knouse, 2007; Milich et al., 2001). Studies investigating ADHD and working memory tend to focus on groups comprising Inattentive, Hyperactive/impulsive and Combined participants altogether rather than separating them (Klorman et al., 1999; Nigg et al., 2002; Henry, 2001), possibly leading to inconsistent findings and a lack of clarity with regard to working memory functioning in children diagnosed with ADHD (Klorman et al., 1999). In an attempt to provide more clarity in this regard, this study focused on comparing the verbal and visuospatial short term and working memory in children diagnosed with Inattentive subtype, Hyperactive/impulsive subtype and a control group, using the recently developed Automated Working Memory Assessment (AWMA), computer based tests, which are able to provide measures of all three major components of the Baddeley and Hitch (1974) three-component model (refer to Chapter 2, Method section for a more detailed discussion of this working memory assessment instrument).

By comparing short term and working memory between these three groups, this study aimed to establish whether there are significant differences in verbal and visuospatial short term memory and working memory between these groups thus providing valuable information that could be used to inform education strategies. Should AMWA scores indicate significant differences in the working memory functioning between the different subtypes, the AMWA may prove to be an important diagnostic tool, one that is able to identify deficits and thereby inform education strategies (Alloway et al., 2006).

This is necessary as current educational intervention strategies my not meet the needs of children with the different subtypes of ADHD.

Chapter 2
Method

2.1 Aim

The purpose of the present study was to explore whether there was a significant difference in the verbal and visuospatial short term and working memory performance between children who have been diagnosed with Predominantly Inattentive and Predominantly Hyperactive/impulsive ADHD and a control group. The following research questions were explored:

2.2 Research Questions

1. Is there a significant difference between the verbal working memory scores of children diagnosed with the Inattentive and Hyperactive/impulsive subtypes?

2. Is there a significant difference between the verbal working memory scores of children diagnosed with the Inattentive subtype and the control group?

3. Is there a significant difference between the verbal working memory scores of children diagnosed with Hyperactive/impulsive subtype and the control group?

4. Is there a significant difference between the visuospatial working memory scores of children diagnosed with the Inattentive and Hyperactive/impulsive subtypes?

5. Is there a significant difference between the visuospatial working memory scores of the children diagnosed with the Inattentive subtype and the control group?

6. Is there a significant difference between the visuospatial working memory scores of the children diagnosed with Hyperactive/impulsive subtype and the control group?

2.3 Research Design

A between-subject ex post facto research design was used in this study, as the psychological tests were administered to pre-defined groups. This research design is considered non-experimental since no attempt was made to decrease or remove threats to internal validity (Gravetter & Forzano,2003).

The independent variable in this study was ADHD, encompassing pre-existing groups of (i) Inattentive subtype, (ii) Hyperactive/impulsive subtype. This study also made use of a control group, which consisted of participants with no prior diagnosis of either subtype of ADHD. The dependent variable for this study was verbal and visuospatial working memory. Owing to the non-experimental nature of the research design, no causal conclusions could be drawn from significant differences in working memory scores between groups. However, significant differences in scores do imply an association between interval variables.

2.4 Sampling

Due to the fact that this is the age and year of school when ADHD is typically diagnosed, children from Grades one and two were targeted to participate in this study (Milich et al., 2001; Wenar & Kerig, 2000). Participants were selected from six English-medium schools who participated in the study, four of which specialized in special education and two which were mainstream schools. Two of the special education schools were private, the rest were government owned. It was originally anticipated that the sample would be obtained without difficulty at one English medium government special education school and one English medium mainstream government school. However, this proved to be a challenge due to the prerequisite that the children who took part in the study had to have been formally diagnosed with ADHD Inattentive or Hyperactive/impulsive subtype by a physician or mental health professional and had to refrain from taking their psycho-stimulant medication on the day of testing. As both

parents and teachers often report a vast improvement in children's behaviour when they are on medication (Koch, 2003), it was understandable that they were reluctant to allow the participants to refrain from taking medication on the day of testing. Thus, due to an insufficient number of participants being obtained from a single school, participants had to be recruited from three additional schools. The final non-probability convenience sample consisted of 72 children.

Permission to conduct this study was obtained from the Gauteng Department of Education to conduct research at the various primary schools (Appendix A). Permission was then obtained from the school principal of the relevant schools (Appendix B). All parents who had children in Grades 1 and 2 at the schools were given a letter explaining the research process and requesting the voluntary participation of their child (Appendix C). The parents were asked to complete a consent form agreeing to the participation of their child (Appendix D). Parents were also asked to complete a biographical questionnaire in order to assist in the analysis of the data (Appendix E). This biographical questionnaire contained questions regarding the sex, date of birth and school history of the participants. The participants were asked to state whether they had been diagnosed with ADHD Inattentive or Hyperactive/impulsive subtype. Each participant filled in an assent form on the day of testing (Appendix F). The participants were also given a withdrawal form, should they want to withdraw from the research whilst completing the tasks (Appendix G). All results were coded and any original documentation destroyed to ensure confidentiality.

2.5 Participant characteristics

2.5.1 ADHD

Participants for this study were selected on the based on strict inclusion criteria, the primary of which was the presence or absence of ADHD. Participants were divided into three groups (i.e. (i) Control (ii) Hyperactive/impulsive and (iii) Inattentive) accordingly.

(i) Control group, with respect to the control group, none of the children in this group met the DSM-IV-TR diagnostic criteria for ADHD.

(ii) ADHD groups

The children assigned to the ADHD groups had all been diagnosed by a professional as having ADHD Predominantly Hyperactive/impulsive subtype or Predominantly Inattentive subtype. Thus, ensuring that diagnoses were based on the DSM-IV-TR criteria and the Connor's Rating Scale, a widely used diagnostic tool for ADHD (American Academy of Child and Adolescent Psychiatry 2002). Children diagnosed with ADHD Inattentive and Hyperactive/impulsive subtypes were excluded from the research if they had taken their medication on the day of testing. This was an important requirement for the study as research has shown that psycho-stimulant medication may interfere with experimental performance and although the effect of medication on working memory is slight, the validity of the study would have been affected (McInnes, Bedard, Hogg-Johnson & Tannok, 2005;Shokane, et al., 2004; Sinha, 2005; Stevens et al., 2002).

2.5.2 Social-cultural background

The participants in this study came from various socioeconomic backgrounds. As socioeconomic status has been shown to be associated with cognitive attainment in childhood (Noble, McCandliss & Farah, 2007), the varying socioeconomic backgrounds may have influenced the findings in this study. The participants home language and language of tuition was English.

2.5.3 Age

The age of the participants ranged from 80 to 135 months, with the average of the participants in the control group being 8 years (SD = 0) and the average age of the children diagnosed with ADHD being 8 years (SD = 1). The control group only consisted of children aged between 7 and 8 years of age. Some of the children

diagnosed with ADHD were older than the children in the control group as they had to repeat a year. The children in the former group were aged between 7 and 10 years. There was an 11 year old in the Hyperactive/impulsive subtype group. This discrepancy in age may have influenced the results of the study as it is necessary to take into account the development of working memory across childhood. Changes in knowledge, processing strategies, processing speed, attentional, processing capacity, passive memory loss and storage capacity, are expected to influence performance on working memory tasks (Pickering, 2001). Many studies have researched age-related growth in children's working memory and this research has indicated that their working memory spans increase progressively between 3 and 15 years of age (Cowan, 1997; Gathercole & Baddeley,1993).

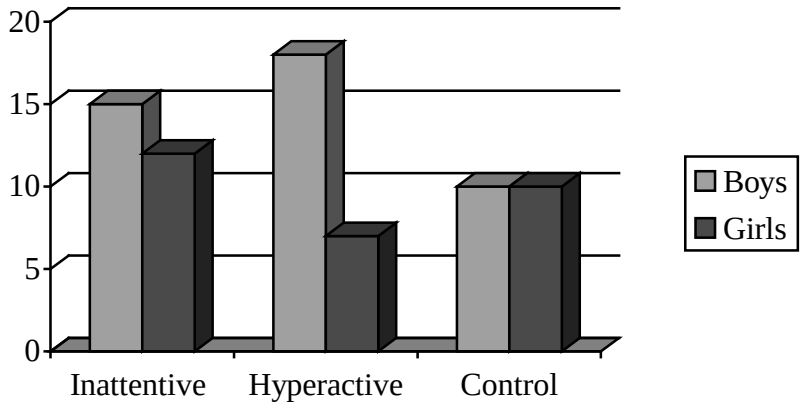


Figure 2: Bar Graph to illustrate gender differences in the sample

2.6 Data Collection

The data for this study was collected by an Intern Educational Psychologist who was trained in the administration of all psychometric instruments used in this study.

2.7 Instruments

2.7.1 The Raven's Coloured Progressive Matrices (RCPM)

As outlined in the literature reviewed for this study, depressed working memory scores are often associated with depressed scores in a number of other cognitive domains. Therefore, Gathercole and Alloway (2006) maintain that impairments of working memory should be identified independently of other aspects of a child's cognitive profile as working memory and IQ have separable links with learning even though they are typically positively related. In order to assess and control for possible differences in the participant's intellectual abilities (which may distort the findings of this study), the Raven's Coloured Progressive Matrices (RCPM) was used. The RCPM is a shorter and simpler form of the Raven's Standard Progressive Matrices, suitable for the age range of the participants taking part in this study. The test consisted of 36 items, grouped into three sets (A, Ab, B) of 12 items each. It was developed to be used with children (age 5.5+) (Spreen, 1998). This test can be used with people who, for any reason, cannot understand English, people who suffer from physical disabilities, aphasias, cerebral palsy or deafness (Spreen, 1998). The tasks are printed on coloured backgrounds in order to seize the participant's attention. The scale is arranged so that it can be presented in the form of illustrations in a book or as boards with moveable pieces. This assessment is culture-fair and the tasks are easy to understand and require minor verbal explanation (Raven, 1977). There is a correlation of r=0.61 found between the RCPM and WISC-R (Weschsler Intelligence Scale for Children-Revised) full scale score, indicating that this is a sound measure for general intellectual abilities (Raven, 1977).

2.7.2 The Automated Working Memory Assessment (AWMA)

The Automated Working Memory Assessment (AWMA) was used to assess the participant's working memory capacity. The AWMA, developed by Alloway and Pickering (2004), is a reliable computer based assessment tool consisting of a battery of tasks used to assess short term memory and working memory. One of the advantages of

the AWMA is that it is user friendly and automated in both presentation and scoring, thus eliminating inconsistency and minimising experimenter error. This assessment tool shows test-retest reliability. It is suitable for children aged 4 to 11 years, and was therefore appropriate for the participants in this study (Alloway et al., 2006).

The AWMA uses multiple tasks to assess the various components of the Baddley and Hitch (1974) multi-component working memory model. These tasks are presented in such a way that underlying cognitive functions are assessed rather than knowledge or intelligence. Due to the computer based nature of this assessment tool, it is able to be administered by professionals and non-professional's alike. Various tasks are used to assess verbal short term memory, verbal working memory, visuospatial short term memory and visuospatial working memory. These are as follows; verbal short term memory is assessed through Digit Recall, Word Recall and Non-Word Recall tasks. The Digit Recall task involves the participant hearing a series of words and recalling the series in the right order. The test- retest reliability for this task is $\alpha = 0.84$ (for children aged 4.5 and 11.5 years). In the Word Recall task the participant hears a series of words and is required to remember each series in the right order (test-retest reliability $\alpha = 0.76$) and in the Non-Word recall task the participant hears a series of non-words and has to recall each series in the correct order. The test-retest reliability for this test is $\alpha = 0.64$ (for children aged 4.5 and 11.5 years) (Alloway et al., 2006).

Verbal working memory is assessed using Listening Recall, Counting Recall and Backwards Digit Recall tasks. The Listening Recall task requires the participant to listen to series of spoken sentences, which they are then required to verify by stating 'true' or 'false' and recall the final word for each sentence in sequence. This task begins with one sentence and continues with supplementary sentences until the participant is unable to recall three correct trials at a block. Test re-test reliability for this task is $\alpha = 0.81$(for children aged 4.5 and 11.5 years). In the Counting Recall task the participant is shown a visual collection of red circles and blue triangle. Their task is then to count the number of circles that were shown (test re-test reliability $\alpha = 0.79$) (for children aged 4.5 and 11.5 years). The Backwards Digit Recall task required each participant to recall

a sequence of spoken digits in the reverse order. Beginning with two numbers and increasing the numbers until the child is unable to recall four correct trials. Test re-test reliability for this test $\alpha = 0.64$ (for children aged 4.5 and 11.5 years). (Alloway et al., 2006).

The Dot Matrix, Mazes Memory and Block Recall tasks are used to assess visuospatial short-term memory. In the Dot Matrix task, the participant is shown the position of a red dot in a series of four by four matrices and then has to remember this position by tapping the squares on the computer screen, test-retest reliability is $\alpha = 0.83$ (for children aged 4.5 and 11.5 years) (Alloway et al., 2006). The Mazes Memory task involves viewing a maze with a red path drawn through it for three seconds. The participant is then required to trace in the same path on a blank maze presented on a computer screen. In Block Recall, the learner views a video of a series of blocks being tapped and reproduced in the correct order by tapping on a picture of the blocks. For learners aged 4.5 and 11.5 years, the test-retest reliability is $\alpha = 0.81$, $\alpha = 0.83$ (Alloway et al., 2006).

The participant's visuospatial working memory is assessed using an Odd-One Out task, the Mr. X task and the Spatial Span task. The Odd-One Out task involves the learner viewing three shapes each in a box presented in a row and identifying the odd-one-out shape. At the end of each trial the learner then recalls the location of each odd one out shape in the correct order by tapping the correct box on the screen. The test-retest reliability for this test is $\alpha = 0.81$ for learners aged 4.5 and 11.5 years. The Mr. X task involves fictitious cartoon figures known as Mr. X, unfamiliar yet likeable to learners. The learner is presented with a picture of two Mr. X figures, the learner identifies whether the Mr. X with the blue hat is holding the ball in the same hand as the Mr. X with the yellow hat. The Mr X with the blue hat may also be rotated. At the end of each task, the learner has to recall the location of each ball in Mr. X's hand in sequence, by pointing to a picture with eight compass points. Both the Mr X figures and the compass points stay on the computer screen until the learner provided a response. The

test-retest reliability is $\alpha = 0.77$ for children aged 4.5 and 11.5 years (Alloway et al., 2006).

In the Spatial Span task, the participant views a picture of two arbitrary shapes where the shape on the right has a red dot on it. The learner identifies whether the shape on the right is the same or opposite to the shape on the left. The shape with the red dot may also be rotated. At the end of each task, the participant has to recall the location of each red dot on the shape in sequence, by pointing to a picture with three compass points. Both the shape and the compass points stay on the computer screen until the participant provides a response. Test-retest reliability is $\alpha = 0.82$ for children aged 4.5 and 11.5 years (Alloway et al., 2006).

2.8 Procedure

The researcher tested each participant individually in a quiet area at the school first thing in the morning for a single session lasting up to 40 minutes, using the AWMA on a laptop computer. This memory test battery was administered in a fixed sequence which is designed to vary task demands as widely as possible across successive tests to reduce fatigue. After a break, the participants were then tested for 15 minutes using the RCPM. As mentioned earlier, all learners diagnosed with ADHD who were currently on medication were asked to refrain from taking their medication on the day of testing.

2.9 Threats to Validity

Validity can be defined as the "quality or state of being true" (Foxcroft & Roodt, 2001). A possible threat to the internal validity of this research could be fatigue as the tests took an hour to complete. Even though the participants rested in between the tests, most found the test to be long and became distracted near the end. The AMWA is a computer adapted test with instructions issued by a woman who has a British accent, at times the accent appeared difficult for South African children to understand. The small final

sample affected the type of analytical procedures that could be carried out, thus impacting on the statistical validity of the study.

2.10 Data Analysis

This section briefly describes the statistical analyses that were undertaken in order to investigate the research question, namely differences in the working memory functioning between children with Predominantly Inattentive ADHD, children with Predominantly Hyperactive/impulsive ADHD and a control group.

2.10.1 Komogorov-Smirnoff test of normality

Before starting the analysis of the data, it was necessary to establish whether the data collected was suitable for parametric analysis. Thus, the Komogorov-Smirnoff test of normality was used. This test compares the cumulative frequency from the data with the cumulative frequency that would occur if the data conformed to a specified distribution (Clarke-Carter, 2001).

2.10.2 Kruskal-Wallis Test

Since the data was not normally distributed, a non-parametric equivalent of the one way ANOVA, namely the Kruskal-Wallis was used to determine whether there was a significant difference between the groups.

2.10.3 The Mann-Whitney U test

The Mann-Whitney U test was then used to compare the differences between the means in groups to see where the differences lay. The Mann-Whitney U test is based on the ranks of the observed values of the variable rather than on the actual values. The assumption that the population variances of the two groups are equal also applies to the Mann-Whitney U test (Clarke-Carter, 2001).

2.11 Conclusion

This chapter has served to outline the method used in the present study. It described the demographic composition of the sample employed, justified and explained the use of the specific instruments utilized, outlined the procedure and research design adhered to, elucidated the statistical procedures employed for data analysis and discussed crucial ethical considerations. The following chapter presents the results of the data analysis.

Chapter 3
Results

3.1 Introduction

This chapter presents the results of the statistical analyses outlined in the previous chapter. Within this chapter, the research questions laid out in the previous chapter will be addressed and the results of the analyses used to answer them provided.

3.2 Normality of Data

In order to establish whether the data collected was suitable for parametric analysis, the Komogorov-Smirnoff test of normality was used, comparing the cumulative frequency of the data with the cumulative frequency with which it would occur if the data conformed to a specified distribution (Clarke-Carter, 2001). As can be seen in Table 3, the data pertaining to the verbal working memory and visuospatial working memory were not normally distributed. This is likely due to the limited sample size used in this study. In order to minimize error it was decided that the data collected should be analysed using non-parametric tests.

Table 3: Results of Kolmogorov - Smirnov Test of Normality

Kolmogorov-Smirnov Goodness-of-Fit Test for Normal Distribution (Df = 72)		
	Statistic (D)	***p –Value***
Verbal Short Term Memory	0.08	0.20
Verbal Working Memory	0.12	0.01**
Visuospatial Short Term Memory	0.08	0.20
Visuospatial Working Memory	0.11	0.00**

* $p<0.01$ ** $p<0.05$

3.3 Descriptive Statistics

Table 4 presents the range, mean and standard deviation for the Ravens Progressive Colour Matrices (RPCM) task used to assess intellectual potential of the three groups, namely the Inattentive subtype, Hyperactive/impulsive subtype and control group.

Table 4: Descriptive Statistics for the RPCM by Group

Subtype	***Range***	***Mean***	***Std.Dev.***
Inattentive (27)	3 – 34	17.15	6.92
Hyperactive/impulsive (25)	9 – 29	20.20	5.76
Control (20)	17 – 32	23.10	4.08

3.4 Analysis of the Ravens Coloured Progressive Matrices (RCPM)

The RCPM was used as part of this study in order to control for possible differences between the Inattentive subtype, Hyperactive/impulsive subtype and control group in terms of intellectual ability. To identify whether there was a difference between the three groups the Kruskal-Wallis test was run. These results are shown in Table 5 below:

Table 5: The Kruskal-Wallis Test: RCPM: Hyperactive/impulsive, Inattentive and Control Groups

	Kruskal-Wallis
Chi-Square	12.12
Df	2
Asymp. Sig.	.00**

* $p<0.01$ ** $p<0.05$

There were significant differences between the intellectual ability of the Inattentive, Hyperactive/impulsive and control groups ($p = .002$). To examine where these differences lay the Mann-Whitney U test was run. The results are shown in Table 6.

Table 6: Mann-Whitney Test : RPCM, Inattentive and Hyperactive/impulsive Groups

	Mann-Whitney U Test
Mann-Whitney U	228.50
Wilcoxon W	606.50
Z	-2.00
Asymp. Sig. (2-tailed)	.05**

* p<0.01 ** p<0.05

With regard to the Inattentive versus Hyperactive/impulsive groups significant differences in overall Ravens scores were found (U = 228.50; p<0.05). These results indicate that there are significant differences in this study between the intellectual ability of the children diagnosed with the Inattentive subtype and Hyperactive/impulsive subtype (p = 0.046). The Hyperactive/impulsive subtype performed better than the Inattentive subtype with regard to intellectual ability.

Table 7: Mann-Whitney Test : RCPM, Inattentive and Control Groups

	Mann-Whitney U Test
Mann-Whitney U	107.000
Wilcoxon W	485.000
Z	-3.513
Asymp. Sig. (2-tailed)	.00**

* p<0.01 ** p<0.05

With regard to the Inattentive subtype versus the control group, significant differences were found (U = 107.000; p<0.05). The control group performed better than the Inattentive group with regard to intellectual ability.

Table 8: Mann-Whitney Test : RCPM, Hyperactive/impulsive and Control groups

	Mann-Whitney U Test
Mann-Whitney U	192.000
Wilcoxon W	517.000
Z	-1.331
Asymp. Sig. (2-tailed)	.18**

* p<0.01 ** p<0.05

With regard to the Hyperactive/impulsive group versus the control group significant differences were found ($U = 192.000$; $p<0.05$). The control group performed better than the Hyperactive/impulsive group with regard to intellectual ability.

Since there were significant differences between most of the groups in terms of intellectual ability, it was necessary to control for these differences. The RPCM scores were adjusted to be 1 and the scores obtained for the short term memory and working memory psychological tests were then adjusted accordingly in relation to the RPCM score in order to standardise the results. Refer to means prior to the adjustment in Table 9 and refer to adjusted means in Table 10.

Table 9: Means and Standard Deviation of the Inattentive, Hyperactive/impulsive and the Control Groups

	Inattentive Subtype			***Hyperactive/Impulsive Subtype***			***Control group***		
Variables	***N***	***Mean***	***Std Dev***	***N***	***Mean***	***Std Dev***	***N***	***Mean***	***Std Dev***
RPCM	27	17.15	6.92	25	20.20	5.76	20	23.10	4.07
Digit Recall	27	22.15	4.19	25	22.15	4.19	20	25.65	4.84
Word Recall	27	12.52	4.34	25	12.52	4.34	20	17.80	3.98
Non-Word Recall	27	9.22	5.07	25	9.22	5.07	20	16.30	3.10
Verbal STM Ave	***27***	***11.66***	***8.67***	***25***	***14.63***	***3.24***	***20***	***19.92***	***3.37***
Listening Recall	27	7.59	6.31	25	6.72	6.30	20	10.80	2.93
Counting Recall	27	11.48	5.15	25	10.40	4.19	20	17.90	4.41
Backwards Digit Recall	27	5.37	3.52	25	5.60	3.86	20	10.75	2.40
Verbal WM Ave	***27***	***8.15***	***2.99***	***25***	***7.57***	***3.56***	***20***	***13.15***	***2.35***
Dot Matrix	27	15.74	3.21	25	17.80	6.28	20	18.15	3.94
Mazes Memory	27	11.15	5.80	25	11.80	9.35	20	18.25	3.74
Block Recall	27	14.89	4.76	25	15.24	5.06	20	19.15	4.60
Visuospatial STM Ave	***27***	***13.93***	***3.30***	***25***	***14.95***	***5.50***	***20***	***18.52***	***2.79***
Odd-One-Out	27	10.74	4.04	25	11.56	7.74	20	13.95	3.58
Mr X	27	6.52	3.82	25	6.04	5.27	20	9.20	3.14
Spatial Span	27	9.30	6.20	25	8.36	6.53	20	14.65	4.23
Visuospatial WM Ave	***27***	***8.85***	***3.79***	***25***	***8.64***	***6.02***	***20***	***12.60***	***2.79***

Table 10: Means and Standard Deviation of the Inattentive, Hyperactive/impulsive and Control Groups After Adjustment

	Inattentive Subtype			***Hyperactive/Impulsive Subtype***			***Control groups***		
Variables	***N***	***Mean***	***Std Dev***	***N***	***Mean***	***Std Dev***	***N***	***Mean***	***Std Dev***
RPCM	27	17.15	6.92	25	20.20	5.76	20	23.10	4.07
Digit Recall	27	1.70	1.74	25	1.17	0.51	20	1.13	0.23
Word Recall	27	0.96	1.21	25	0.67	0.38	20	0.79	0.21
Non-Word Recall	27	0.64	0.53	25	0.52	0.43	20	0.73	0.22
Verbal STM Ave	***27***	***1.10***	***1.09***	***25***	***0.79***	***0.38***	***20***	***0.89***	***0.20***
Listening Recall	27	0.63	0.85	25	0.36	0.44	20	0.48	0.14
Counting Recall	27	0.77	0.55	25	0.56	0.36	20	0.78	0.15
Backwards Digit Recall	27	0.38	0.40	25	0.27	0.16	20	0.48	0.13
Verbal WM Ave	***27***	***0.59***	***0.52***	***25***	***0.40***	***0.19***	***20***	***0.58***	***0.10***
Dot Matix	27	1.09	0.70	25	1.09	0.70	20	0.79	0.17
Mazes Memory	27	0.60	1.90	25	0.79	0.60	20	0.81	0.20
Block Recall	27	1.05	0.80	25	0.80	0.80	20	0.84	0.24
Visuospatial STM Ave	***27***	***0.98***	***0.65***	***25***	***0.65***	***3.76***	***20***	***0.82***	***0.14***
Odd-One-Out	27	0.73	0.44	25	0.58	0.32	20	0.61	0.14
Mr X	27	0.45	0.43	25	0.29	0.20	20	0.40	0.14
Spatial Span	27	0.60	0.45	25	0.39	0.28	20	0.64	0.18
Visuospatial WM Ave	***27***	***0.60***	***0.49***	***25***	***0.42***	***0.21***	***20***	***0.55***	***0.11***

Table 11 below shows the results the Kruskall-Wallis test once the scores had been adjusted to control for intellectual differences, to identify whether there was a difference between the three groups with regard to verbal short term memory.

Table 11: Kruskall-Wallis Test: Verbal Short Term Memory

Kruskal-Wallis Test				
	Digit Recall	***Word Recall***	***Non Word Recall***	***Verbal STM ave***
Chi-Square	4.658	3.350	8.052	6.846
Df	2	2	2	2
Asymp. Sig.	.097	.187	.018	.03**

* p<0.01 ** p<0.05

The results indicated that there were statistical differences between the three groups, namely Inattentive, Hyperactive/impulsive and Control groups in terms of verbal short term memory. A post-hoc Mann-Whitney U Test was then conducted (Tables 12,13, 14) in order to assess where these differences lay.

Table 12: Post -Hoc Test between Inattentive and Hyperactive/impulsive Groups in terms of Verbal Short Term Memory

Post-Hoc Mann-Whitney U Test				
	Digit Recall	***Word Recall***	***Non-Word Recall***	***Verbal STM ave***
Mann-Whitney U	238.000	263.000	277.500	207.000
Wilcoxon W	563.000	588.000	602.500	532.000
Z	-1.823	-1.365	-1.099	-2.390
Asymp. Sig. (2-tailed)	.068	.172	.272	.02**

* p<0.01 ** p<0.05

As per Table 12 there are significant differences between the verbal short term memory average scores of the Inattentive subtype and Hyperactive/impulsive subtype, but not between the subtests that make up this average.

Table 13: Post-Hoc Test between Inattentive and Control Groups in terms of Verbal Short Term Memory

Post-Hoc Mann-Whitney U Test				
	Digit Recall	***Word Recall***	***Non-Word Recall***	***Verbal STM ave***
Mann-Whitney U	184.00	241.00	200.50	259.00
Wilcoxon W	394.00	619.00	578.50	469.00
Z	-1.85	-.62	-1.50	-.24
Asymp. Sig. (2-tailed)	.06	.53	.14	.81

* p<0.01 ** p<0.05

These results revealed there are no significant differences in the verbal short term memory average scores between the Inattentive and control groups (p = 0.81).

Table 14: Post-Hoc Test between Hyperactive/impulsive and Control Groups in terms of Verbal Short Term Memory

Post-Hoc Mann-Whitney U Test				
	Digit Recall	***Word Recall***	***Non-Word Recall***	***Verbal STM ave***
Mann-Whitney U	249.50	177.00	117.50	160.00
Wilcoxon W	574.50	502.00	442.50	485.00
Z	-.011	-1.668	-3.03	-2.06
Asymp. Sig. (2-tailed)	.991	.10	.00*	.04**

* p<0.01 ** p<0.05

These results (p = 0.04) show there are significant differences in the verbal short term memory average between the Hyperactive/impulsive and control groups. The control group was significantly stronger in the Non-Word Recall task and the overall verbal short term memory average.

Next, the Kruskal-Wallis test was administered to detect whether there were significant differences between the verbal *working memory* of three groups (p = 0.00). See Table 15 below.

Table 15: Kruskall-Wallis Test: Verbal Working Memory

Kruskal-Wallis Test				
	Listening Recall	***Counting Recall***	***Backward Digit Recall***	***Verb WM ave***
Chi-Square	7.471	13.594	14.872	12.796
Df	2	2	2	2
Asymp. Sig.	.02**	.00*	.00*	.02**

* p<0.01 ** p<0.05

Since there were significant differences between the three groups as shown in Table 15, a Mann-Whitney U Test was then conducted between the Inattentive, Hyperactive/impulsive subtype and control groups, as per Tables 16, 17,18.

Table 16: Post-Hoc Test between Inattentive and Hyperactive/impulsive Groups in terms of Verbal Working Memory

Post-Hoc Mann-Whitney U Test				
	Listening Recall	***Counting Recall***	***Backward Digit Recall***	***Verbal WM ave***
Mann-Whitney U	254.000	212.000	296.000	225.500
Wilcoxon W	579.000	537.000	621.000	550.500
Z	-1.530	-2.299	-.761	-2.051
Asymp. Sig. (2-tailed)	.13	.02**	.45	.04**

* p<0.01 ** p<0.05

The first post-hoc test revealed significant differences in the verbal working memory average score between the Inattentive and Hyperactive/impulsive groups. The Inattentive group had a better verbal working memory average than the Hyperactive/impulsive group and was significantly stronger in the Counting Recall task.

Table 17: Post-Hoc Test between Inattentive and Control Groups in terms of Verbal Working Memory

Post-Hoc Mann-Whitney U Test				
	Listening Recall	***Counting Recall***	***Backward Digit Recall***	***Verbal WM Ave***
Mann-Whitney U	230.000	239.000	150.500	208.000
Wilcoxon W	608.000	617.000	528.500	586.000
Z	-.861	-.667	-2.572	-1.334
Asymp. Sig. (2-tailed)	.39	.51	.01*	.18

* p<0.01 ** p<0.05

There is no significant difference in the verbal working memory average score between the Inattentive group and the control group (p = 0.18). However, the control group was significantly stronger than the Inattentive group in the Backward Digit Recall task.

Table 18: Post-Hoc Test between Hyperactive/impulsive and Control Group in terms of Verbal Working Memory

Post-Hoc Mann-Whitney U Test				
	Listening Recall	***Counting Recall***	***Backward Digit Recall***	***Verbal WM ave***
Mann-Whitney U	122.000	77.500	73.500	88.000
Wilcoxon W	447.000	402.500	398.500	413.000
Z	-2.925	-3.941	-4.034	-3.700
Asymp. Sig. (2-tailed)	.00*	.00*	.00*	.00*

* p<0.01 ** p<0.05

The results indicate that there are significant differences in the verbal working memory between the Hyperactive/impulsive group and the control group. The control group was significantly stronger at Listening Recall, Counting Recall and Backward Digit Recall tasks, as well as at the verbal working memory average.

Table 19 below shows the results the Kruskall-Wallis test for visuospatial short term memory after the scores had been adjusted to control for the intellectual differences between the three groups, to investigate possible differences between the three groups.

Table 19: Kruskall-Wallis Test: Visuospatial Short Term Memory

	Kruskall-Wallis Test			
	Dot Matrix	***Mazes Memory***	***Block Recall***	***Visuospatial STM ave***
Chi-Square	6.350	7.909	2.712	4.206
Df	2	2	2	2
Asymp. Sig.	.042	.019	.258	.122

* p<0.01 ** p<0.05

The results indicated (p = 0.122) that there are no significant differences between the visuospatial short term memory of the three groups, namely Inattentive group, Hyperactive/impulsive group and the control group.

Table 20 shows the results of the Kruskall-Wallis between the visuospatial working memory scores of the three groups after the scores were controlled for intellectual differences between the groups.

Table 20: Kruskall-Wallis: Visuospatial Working Memory

	Kruskall-Wallis Test			
	Odd One Out	***Mr X***	***Spatial Span***	***Visuospatial WM ave***
Chi-Square	3.833	6.675	9.411	10.120
Df	2	2	2	2
Asymp. Sig.	.147	.07**	.01*	.01*

* p<0.01 ** p<0.05

As indicated in Table 20 there are significant differences in the average visuospatial working memory scores of the three groups. Thus, a post-hoc Mann-Whitney U Test was

then conducted between the groups as per Tables 21,22,23 in order to determine where the differences lay.

Table 21: Post-Hoc Test between Inattentive and Hyperactive/impulsive Groups in terms of Visuospatial Working Memory

Post-Hoc Mann-Whitney U Test				
	Odd One Out	***Mr X***	***Spatial Span***	***Visuo spat WM ave***
Mann-Whitney U	247.500	248.500	246.500	222.000
Wilcoxon W	572.500	573.500	571.500	547.000
Z	-1.649	-1.630	-1.667	-2.115
Asymp. Sig. (2-tailed)	.01*	.10	.10	.03**

* p<0.01 ** p<0.05

The results indicated that there are statistically significant differences between the visuospatial working memory average of the Inattentive and Hyperactive/impulsive groups (p = 0.03). The Inattentive group had a higher visuospatial working memory average and was significantly stronger in the Odd One Out task.

Table 22: Post Hoc Test between Inattentive and Control Groups in terms of Visuospatial Working Memory

Post-Hoc Mann-Whitney U Test				
	Odd One Out	***Mr X***	***Spatial Span***	***Visuo-spat WM ave***
Mann-Whitney U	229.000	230.000	218.500	234.000
Wilcoxon W	439.000	608.000	596.500	612.000
Z	-.882	-.861	-1.108	-.775
Asymp. Sig. (2-tailed)	.38	.39	.27	.44

* p<0.01 ** p<0.05

The results indicated that there are no statistically significant differences between the visuospatial working memory average of the Inattentive and control groups (p = 0.44).

Table 23: Post-Hoc test between Hyperactive/impulsive and Control groups in terms of Visuospatial Working Memory

Post-Hoc Mann-Whitney U Test				
	Odd One Out	***Mr X***	***Spatial Span***	***Visuo-spat WM_ave***
Mann-Whitney U	181.500	136.000	107.500	109.000
Wilcoxon W	506.500	461.000	432.500	434.000
Z	-1.565	-2.604	-3.256	-3.221
Asymp. Sig. (2-tailed)	.12	.01*	.00**	.00**

* p<0.01 ** p<0.05

There were significant differences in the visuospatial working memory between the Hyperactive/impulsive and the control groups (p = 0.00). The control group was significantly stronger in terms of visuospatial working memory as well as on the Mr X and Spatial Span tasks.

3.5 Conclusion

This chapter has presented the statistical analyses utilized to examine the research questions. The results indicate that after controlling for the differences in the nonverbal intellectual functioning of the different groups there were significant differences in the visual and verbal working memory of the Inattentive and Hyperactive/impulsive groups. The Inattentive group showed significant better functioning in these areas of working memory than the Hyperactive/impulsive group. No significant differences were found between the verbal and visuospatial working memory of the children diagnosed with the Inattentive subtype and a control group. Whereas significant differences were found between the verbal and visual working memory of the children diagnosed with Hyperactive/impulsive subtype and the control group. A discussion of the implication of these findings and their relationship to the literature is presented in the following chapter.

Chapter 4

Discussion

4.1 Introduction

This research aimed to contribute to the growing database of knowledge regarding working memory. In particular, it focused on the relationship between working memory and ADHD, specifically with regard to the distinctions between Inattentive and Hyperactive/impulsive subtypes, as few studies have examined these differences. Those studies that have investigated the issue have generally combined the two subtypes along with the combined type of ADHD and consequently have yielded conflicting results (Barkley, 1992; Frank & Ben-Nun, 1988; Gathercole & Alloway, 2006; Klorman et al., 1999; Nigg et al., 2002).

4.2 Discussion of Results

The purpose of the present study was to provide more clarity with regard to the working memory of children diagnosed with Predominantly Inattentive ADHD and children diagnosed with Predominantly Hyperactive/impulsive ADHD. This study focused on comparing the verbal and visuospatial short term and working memory in children diagnosed with Inattentive subtype, Hyperactive/impulsive subtype and a control group, based on the Baddeley and Hitch (1974) three-component model.

The RCPM was used as part of this study in order to control for possible differences between the Inattentive subtype, Hyperactive/impulsive subtype and control group in terms of intellectual ability. Although, this study involved children, it is important to be aware that there is substantial debate concerning the independence of working memory and IQ constructs in adults (Savage et al., 2006). Savage et al., (2006, p.368) maintain that “strong evidence of specificity of association between working memory components and behaviourally defined attention problems would be provided if the association remains significant even after IQ was partialled out.”

Researchers have found that children diagnosed with ADHD (type unspecified) show inconsistency with regard to basic cognitive ability (Gathercole & Alloway, 2006; Loe & Feldman, 2007). One of the findings of the current study was that the nonverbal intellectual functioning of the Inattentive group was significantly poorer than that of the Hyperactive/impulsive and control groups. One possible explanation for this may be that the RPCM tasks used to measure intellectual ability rely heavily on spatial reasoning. In the literature reviewed it was suggested that this was an area in which the Inattentive subtype had been known to perform significantly poorly, as a result of deficits in right hemisphere functioning, the area of the brain which is most proficient at comprehending spatial relationships (Martinussen, 2005). It was found, however, in this study that the visuospatial short term memory and visuospatial working memory of the Inattentive subtype functioned similarly to that of the control group as will be elucidated later on in this discussion.

The Hyperactive/impulsive group had significantly better intellectual functioning than the Inattentive group, however, their intellectual functioning was still significantly poorer than the control group. This result may have been attributed to a lack of inhibition or an inability to take the time to actively manipulate information (Barkley, 1997). These findings lend support to the hypothesis that children diagnosed with Predominantly Inattentive subtype may have different cognitive profiles to children diagnosed with Predominantly Hyperactive/impulsive subtype, with the Inattentive subtype showing cognitive and academic impairments and the Hyperactive subtype not necessarily showing cognitive dysfunction, but more behavioural inhibition (Martinussen, 2005).

Given these findings the working memory of both the Inattentive and Hyperactive/impulsive groups should have been poorer than the control group, as research has consistently demonstrated that significant relationships exist between working memory and intellectual functioning, due to the reliance of cognitive activities on moment-to-moment monitoring, processing and maintenance of task-relevant information (Abu-Ravia, 2003; Alloway et al., 2006; Baddeley & Logie, 2007;Hutton & Towse, 2000; Savage et al., 2006). However, in this study the Inattentive group performed significantly better than the Hyperactive/impulsive group on all measures of working memory after differences in nonverbal intelligence were controlled, these findings were not

consistent with Martinussen (2005) or Diamonds' (2005) hypothesis that working memory deficits should be more strongly associated with symptoms of inattention than with symptoms of hyperactivity/impulsivity.

In order to provide more clarity in this regard, each component of working memory was examined separately as pertaining to each individual group (i.e Inattentive, Hyperactive/impulsive and control). As mentioned in Chapter 1, the multi-component model of working memory comprises a limited capacity attentional controller, the central executive aided by two subsystems, one concerned with acoustic and verbal information, namely the phonological loop and the other performing a similar function for visual and spatial information, namely the visuospatial sketchpad. Various tasks were used to assess the phonological loop, the visuospatial sketchpad and the central executive. These tasks will be discussed separately, beginning with the verbal short term memory tasks.

The verbal short term memory specializes in the temporary storage of information therefore the tasks used to assess verbal *short term memory* were Digit Recall, Word Recall and Non-Word Recall tasks. When group differences in nonverbal intellectual functioning were statistically controlled for, the findings indicated that there were no significant statistical differences between the average verbal short term memory scores of the Inattentive and control groups. Thus, indicating that the Inattentive subtype functioned similarly to the control group with regard to verbal short term memory.

There were, however, significant differences in the verbal short term memory average between the Hyperactive/impulsive and control groups, the latter obtained significantly higher scores on the Non-Word Recall task. These findings suggest that the Hyperactive/Impulsive group's phonological loop may have functioned differently to the control group. These differences may lie in the phonological store or articulatory rehearsal mechanism. As this was the final test of the three subgroups (Digit Recall, Word Recall, Non-Word Recall), the Hyperactive/impulsive group may have also had difficulty sustaining attention by the time they were required to complete the task. Thus it is most

probable that there may be differences in the central executive functioning (whose main function is attention and monitoring) of the Hyperactive/impulsive group and control group.

The findings of the study also indicated that there were significant differences between the *average* verbal short term memory scores between the Inattentive and the Hyperactive/impulsive groups, suggesting that the Inattentive group may be better at passive short term storage, than the Hyperactive/impulsive group, and there may be differences in the functioning of the phonological loop of the Inattentive and Hyperactive/impulsive groups. It should be noted that collectively, the Inattentive group had a significantly better verbal short term memory average than the Hyperactive/impulsive group. However, when each task was assessed individually (Digit Recall, Word Recall and Non-word Recall) there were no significant differences between the individual tasks. This could be attributed to the fact that individually the differences were not significant, but when they were combined they became significant. The small sample could have influenced this result.

The tasks used to assess verbal short term memory involved the participants hearing a series of words and recalling the series in the right order, the Hyperactive/impulsive group had difficulty sustaining attention (self-regulation of affect) during these tasks. Lending support to Barkley's (1997) model, which places behaviour inhibition as the core executive function deficit in children diagnosed with Hyperactive/impulsive ADHD. This is in line with research that has shown that children diagnosed with Hyperactive/impulsive subtype appear to perform poorly in verbal short term memory tasks as opposed to the Inattentive subtype (Martinussen, 2005).

The Dot Matrix, Mazes Memory and Block Recall tasks were used to assess visuospatial short term memory. With respect to average visuospatial *short term* memory there were no statistical difference between the visuospatial short term memory of the Inattentive, Hyperactive/impulsive and control groups. This finding was after differences in nonverbal intelligence were controlled for by the RPCM, which has a heavy visuospatial component. The visuospatial short term memory tasks entailed passive storage that did not involve executive function and therefore were not reliant

on permanent knowledge structures to operate and required fewer underlying cognitive skills than visuospatial working memory tasks (Engle et al., 1992). Studies have shown that visuospatial short term memory improves over childhood and reaches its peak in adolescence. Given that the average age of the sample of this study was only 8 years (SD = 1) it may be that differences in visuospatial short term memory may emerge between the groups when the children are older (Alloway et al., 2006; Pickering, 2001). The current findings of this study suggest that all the participants in this study were able to maintain visuospatial information on a surface level, regardless of whether they had been diagnosed with ADHD or not. It was expected that the working memory results would be lower than the short term memory equivalent (Hutton & Towse, 2001), which will now be discussed.

There were significant differences in the average visuospatial *working* memory between the three groups. After differences in nonverbal intelligence were controlled for, the Inattentive and the control groups showed no significant differences in their visuospatial working memory, indicating that the Inattentive subtype functioned similarly to the control group in this regard. These results were surprising as it was expected that children diagnosed with the Inattentive subtype would have an impaired working memory, as proposed by Rapport (2001) and Diamond (2005). These results do not support Diamond's (2005) proposal that the primary deficit in children diagnosed with Inattentive subtype should be working memory. In contrast, the Hyperactive/impulsive group showed significant differences in their visuospatial working memory in comparison to the other two groups. These results were consistent with findings in other studies (Frank & Ben-Nunn 1988; Klorman et al., 1999; Nigg et al., 2002) and suggest that the Hyperactive/impulsive subtype may have an impaired central executive, the component of working memory responsible for controlling resources and monitoring information.

On closer examination it appears that the Inattentive groups' scores were significantly stronger in the Odd One Out task in comparison to the Hyperactive/impulsive subtype. This task involved the participant viewing three shapes each in a box presented in a row and identifying the odd-one-out shape in the correct order by tapping the correct box on the screen. The Hyperactive/impulsive subtype scores were poorer in terms of Mr X and the

Spatial Span task as opposed to the control group. Diamond (2005) proposed that the central executive of Inattentive group was deficient as they found it difficult to sustain focused attention on a given task. However, these findings do not lend support to Diamond's (2005) hypothesis that children diagnosed with the Inattentive subtype have a deficient central executive. They support Barkley's (2001) findings that children diagnosed with the Hyperactive/impulsive subtype may have difficulty maintaining and manipulating information due to difficulties with their central executive. These findings are also consistent with additional studies that have found that children with ADHD (sub-type not specified) have difficulty performing dual tasks, which can be associated with deficits in the central executive executive/attentional control component of working memory (Karatekin, 2004).

By the age of 8 (the average age of the sample studied) it would be expected that many children would use articulatory rehearsal to support some of their memory tasks (Hutton & Towse, 2001). Gathercole (2006) proposed that the Hyperactive/impulsive subtype may have difficulty converting information into a phonological code. This would have had an impact on the results. Difficulty in converting information to a phonological code could be attributed to an inability to maintain information via a choice of representational forms, this may have resulted in an inability to convert the visual information into a phonological code in order to facilitate processing. As, the Hyperactive/impulsive group performed significantly poorer than the other groups with regard to their verbal short term memory average score, the inability to passively store verbal information may have influenced the results obtained by the Hyperactive/impulsive subtype on the visuospatial working memory task. Various visuospatial images, such as pictures or familiar objects, are able to be coded in working memory using semantic representations, rendering genuine measures of visuospatial working memory difficult to develop (Pickering, 2001). Thus, it is difficult to identify exactly where, in visuospatial working memory differences were between the Inattentive and Hyperactive/impulsive groups.

There were no significant difference in the verbal working memory average score between the Inattentive and the control groups. Again, suggesting that the phonological loop

functioning of the Inattentive and control groups were similar. However, it is worth noting that the control group were significantly stronger in the Backward Digit Recall task. The tasks administered were Listening Recall, Counting Recall and Backward Digit Recall. As this was the last task of the three measures administered to test verbal working memory, it was probably the most demanding task of the three tasks. There were significant differences in the average verbal working memory between the Hyperactive/impulsive group and the control group, the control group were significantly stronger in all of the tasks, suggesting that the phonological loop functioning of the Hyperactive/impulsive group was different to that of the control group. Verbal working memory tasks required the modification and accommodation of new inputs and therefore would have tapped into the central executive. These results again suggested that the central executive of the Hyperactive/impulsive group may be significantly different to that of the Inattentive group and control group. However, it must be remembered that there would have been without doubt, involvement from other working memory components such as the phonological loop, articulatory rehearsal mechanism and phonological store and impairment could have occurred in any of these components (Baddeley, 1993).

Baddeley and Hitch (1996) assume that individual differences in the phonological loop reflect the amount of memory activation available. The results of this study did not clearly establish, whether the children in this study diagnosed with Hyperactive/impulsive subtype had impaired phonological loop functioning. Clearer findings in this regard, would have helped to clarify whether these children had an impairment of the central executive or an impaired phonological loop.

In sum, given that the Hyperactive/impulsive group showed significantly poorer visuospatial and verbal working memory functioning and working memory tasks rely heavily on executive functioning it could be suggested that the Hyperactive/impulsive subtype, have a poor central executive ability in relation to the Inattentive and control groups.

It should be noted however that, in this study the presence of comorbid language and learning disorders were not controlled for. In addition, it should be taken into account that all the children in the study were unique and therefore may show different impairments in different aspects of working memory such as verbal short term memory, visuospatial short term memory, working memory and central executive systems. A deficit in any of these areas could have resulted in a loss of inhibition or attention and this may vary across studies and across children (Gathercole & Alloway, 2006). The findings of this study do however, lend further support to the view that the Inattentive subtype and Hyperactive/impulsive subtype each show different patterns of impairment.

4.3 Limitations

Caution is necessary in interpreting the results due to important methodological limitations in this study. A small sample size of 27 children diagnosed with Inattentive subtype, 25 children diagnosed with Hyperactive/impulsive subtype and 20 normal control children participated in the study. As mentioned earlier in the methods chapter, non-parametric statistical procedures were used to analyse data. In light of the limited sample size, the results of this research report can not be generalized. Furthermore, owing to the non-experimental nature of the research design, causal conclusions about variables can not be made. In addition, there is a high comorbidity between ADHD and other learning disorders. Given that the children diagnosed with ADHD who participated in the study were attending special needs schools, there is a probability that they may have had comorbid learning disorders that were not diagnosed or accounted for. Thus, it is possible that an unmeasured third variable may have impacted working memory scores.

The internal validity of the study was potentially threatened in terms of fatigue and boredom. Another potential threat to the validity of the study is that the participants in the study who attend special needs schools receive Occupational Therapy and Speech Therapy and these participants may have received prior exposure to spatial span tasks and word recall tasks of a similar nature to those that form part of the AWMA test. It is

acknowledged that these aspects related to internal validity may have distorted test scores in various ways and impacted the findings of this study.

4.4 Contribution to Knowledge

Despite these limitations, this study makes certain valuable contributions. Deficits in working memory are known to hamper academic achievement (Gathercole & Pickering, 2004). Deficits in verbal storage are associated with language acquisition weaknesses including vocabulary and word decoding (Baddeley et al., 1998; Swanson & Howell, 2001), and weaknesses in visual spatial storage are associated with low academic achievement in literacy, comprehension and arithmetic (Gathercole & Pickering, 2000). Hence, the finding that children with Hyperactive/impulsive subtype exhibit deficits in multiple components of working memory has important implications. Academic progress may be hampered by working memory limitations as many typical academic activities rely heavily on working memory (Daneman & Carpenter, 1980). Therefore, it is possible that poor academic progress in children with Hyperactive/impulsive subtype may be due to working memory deficiencies rather than as a direct consequence of the behavioral symptoms of Inattention and/or Hyperactivity/impulsive (Rapport et al., 1999). Working memory deficits may also limit the efficacy of cognitive-based treatment programs that are designed to target the behavioural symptoms of ADHD. Consequently, specific strategies may be required to help these children encode, access and retrieve information in an organized fashion (Martinussen, 2005; Miyake & Shah, 2007). Strategies such as teaching information in small steps and using scaffolds to reduce executive loads on working memory may be beneficial when teaching children with Hyperactive/impulsive subtype. These children may also benefit from external support systems such as visual cues, checklists and coaching in order to help them remember specific goals and procedures.

In sum, one of the most useful outcomes of this research is the recognition that there were significant differences in working memory functioning between Inattentive and Hyperactive/impulsive subtypes and between Hyperactive/impulsive subtype and a control group but not between the Inattentive subtype and a control group. Working memory does

differ in children who have been diagnosed with Hyperactive/impulsive subtype and Inattentive subtype and a control group. By differentiating between the two subtypes of ADHD, this study was able to provide valuable preliminary indications regarding what appear to be clear differences in working memory functioning between children with different types of ADHD, which in turn may be used to inform more effective individualized intervention strategies that target specific type related deficits. However, further research is needed that explores these differences in greater detail, using a larger, more diverse sample group.

4.5 Directions for Future Research

Findings pertaining to the differences in verbal and visuospatial working memory between different ADHD subgroups were obtained from a small sample and further investigations with larger sample groups should be carried out to confirm or contest these findings with a more representative sample. It may also be beneficial to replicate this study with children of different age groups.

4.6 Conclusion

The aim of the study was to explore whether there was a significant difference in the verbal and visuospatial working memory performance between children who have been diagnosed with Predominantly Inattentive and Predominantly Hyperactive/impulsive ADHD and a control group. These aims were met by assessing the working memory of children using the AWMA and controlling for their intellectual ability using the RPCM. The finding that the working memory differs between the two sub groups provides greater insight into the nature and severity of working memory impairments in ADHD. They support the argument that Inattentive subtype may be a completely different disorder, with a different profile to the Hyperactive/impulsive subtype. One important finding is that working memory deficits are definitely present in children diagnosed with Hyperactive/impulsive

subtype, suggesting that strategies used to address working memory will benefit these children.

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APPENDIX A
PERMISSION LETTER FROM THE
GAUTENG DEPARTMENT OF EDUCATION

APPENDIX B
LETTER TO THE SCHOOL PRINCIPAL

UNIVERSITY
OF THE
WITWATERSRAND,
JOHANNESBURG

Department of Psychology
School of Human and Community Development
Private Bag 3, Wits 2050,
Johannesburg, South Africa

Ms A Lombard
Head Mistress
Delta Park School
Blairgowrie
Gauteng

8 February 2006

Dear Madam

UNIVERSITY OF THE WITWATERSRAND
RESEARCH REQUEST

My name is Karen Allsopp and I am a Masters student in the Department of Psychology, University of the Witwatersrand. I am investigating working memory in young learners who have Predominantly Inattentive ADHD and learners who have Predominantly Hyperactive ADHD, for the practical component of my course this year.

I am looking at a sample of 60 Grade one and two learners, of which 30 must be diagnosed with Predominantly Inattentive ADHD and 30 must be diagnosed with Predominantly Hyperactive/impulsive ADHD, and I would like to know whether Delta Park School would be willing to provide this sample.

Each child will be tested individually; participation will entail the completion of two tasks one task of general ability to be administered by the researcher, or researcher and her assistant. This task is presented to the learner as a 'game' and is generally perceived as fun by most children. The second task will be presented to the learner on a laptop computer and will also involve "game-like" activities. The total administration time of all the tasks is approximately one hour, which will be administered in two sessions. We would like to suggest that the tasks be administered during school hours on the school premises, during a school period convenient for both the teachers and the children.

Information letters will be sent to parents of Grade one and two learners, with biographical information forms to be completed. Both consent forms, to be signed

by the parents, and an assent form, to be signed by the children at the time of testing, will be completed for each participant. All learners taking part in the study, who are on medication will be asked to refrain from taking their medication on the day of testing.

Participation in the study will be entirely voluntary, and the parent and child's decision to participate or not participate will have no negative consequence or relationship to his/her scholastic performance. The participant may withdraw at any point, with no questions asked.

The results of performance on the tasks will be treated in a confidential manner, i.e. all results will be coded, with feedback being provided to the school in the form of general patterns observed. No feedback regarding the performance of any individual child will be given to the school. Parents/guardians may, on request, receive feedback regarding group trends on the tests.

Application for permission to conduct has been given by the Gauteng Department of Education.

Should you require any further information, please do not hesitate to contact me on 084 616 4200 or e-mail k.allsopp@absamail.co.za.should you require more details. You may also contact my supervisor, Dr Kate Cockcroft at 717 4511 or e-mail cockcroftk@umthombo.wits.ac.za.

Yours faithfully

Karen Allsopp

APPENDIX C
LETTER TO THE PARENTS

UNIVERSITY
OF THE
WITWATERSRAND,
JOHANNESBURG

Department of Psychology
School of Human and Community
Development
Private Bag 3, Wits 2050, Johannesburg,
South Africa

8 February 2007

Dear Parents

My name is Karen Allsopp and I am an Intern Psychologist at Delta Park School. I am conducting research on memory in Grade One and Grade two learners diagnosed with ADHD for the practical component of my course this year. Your child has been selected as a potential participant in this study.

Participation will entail the completion of one task of general ability and one task of memory. These tasks are presented to the child as 'games' and are generally perceived as fun by most children. The total administration time of all the tasks is approximately one hour which will be administered in two sessions. If your child is taking medication for ADHD, it will be required that your child refrain from taking medication on the day of testing.

The headmistress of the school has granted permission that the tasks may be administered during school hours on the school premises, during a school period convenient for both the teachers and the children. Please be assured that the test results will be treated with absolute confidentiality and anonymity. All answer sheets will be coded, and no child will be individually identified in any written or spoken report. All information will be used exclusively for research purposes and will not be shown to anyone but the researchers. Confidentiality is also ensured since only group trends will be determined, from which it will be impossible to identify any particular child. Feedback will be provided to the school in the form of general patterns in Grade 1 and 2, and if desired, a short general report regarding these trends will be made available to you, once the research has been completed.

Please note that participation in the study is entirely voluntary, that allowing your child to participate or not participate will have no negative consequence or benefit in relationship to his/her scholastic performance as this is not related in any way to the school curriculum.

Should you grant permission for your child to participate in the study, please discuss it with him/her and ascertain that he/she is willing to participate. Then please fill in the attached permission slip and questionnaire by 11 February 2007. If you experience any difficulties in completing the questionnaire, please do not hesitate to contact me. Should you or your child change your mind about participation in the study, you may withdraw at any point, with no questions asked. Due to time constraints, it is unfortunately only possible to include a limited number of children in this research.

Thank you for your interest and please do not hesitate to contact me on 084 616 4200 or email k.allsopp@absamail.co.za. should you require more details. You may also contact my supervisor, Dr Kate Cockcroft at 717 4511 or email cockcroftk@umthombo.wits.ac.za.

Yours sincerely

Karen Allsopp

APPENDIX D
PARENT CONSENT FORM

PARENT CONSENT FORM

Consent for child participation in a memory assessment

I, ……
(parent / guardian)

of ……
(child's name)

have discussed this study with my child and hereby give consent for him / her to participate in it. I acknowledge the confidentiality and anonymity of the test. As the test participation is completely voluntary he/she may withdraw at any time. I understand that all the information gained during the research is completely confidential and will not be disclosed to anyone besides the researchers.

……..
Signature

APPENDIX E
BIOGRAPHICAL QUESTIONNAIRE

Date

BIOGRAPHICAL QUESTIONNAIRE

CODE NO _____

Biographical Questionnaire
Please complete the following questionnaire in full to enable the researcher to have as much information about your child's background as possible.

Personal details

Full name of child……..

Date of birth…….

School ……

Ethnic Group…….

Therapy (Circle the applicable answer)
Is your child currently repeating Grade 1 or Grade 2?

Yes/No

Has your child ever had learning difficulties?

Yes/No

If yes, please indicate difficulties
……
……
……

Has your child been diagnosed by a professional with ADHD – Inattention sub-type?

Yes/No

Has your child been diagnosed by a professional with ADHD-Hyperactive/impulsive sub-type?

Yes/No

APPENDIX F
CHILD'S ASSENT LETTER

CHILD'S LETTER OF ASSENT

(To be read to the child and signed on the day of testing)

Hello ……..

Thank you for agreeing to do this project with me. I am at university and am doing this assignment for one of my subjects.

We will do two tasks together today.

We will stop for a break and have something to eat and drink, between our tasks.

If you get tired or don't feel like carrying on you can stop at any time you like.

Thank you for helping me with this project.

I, ……. (child's name) would like to do this
research and know that I can stop at any time if I don't feel like carrying on.

……..

Date

APPENDIX G
WITHDRAWAL FORM

WITHDRAWAL FORM

Withdrawal Clause

If at any stage you wish to withdraw your child from the study, please fill in the form below and he/she will be omitted without obligation.

I,……
…

wish to withdraw my son / daughter
……..

from the above-mentioned study.

Signed…….

Date…….

APPENDIX H

ETHICAL CLEARANCE FOR THE STUDY