CHAPTER 1

INTRODUCTION

According to Was and Woltz (2007), the construct of a limited capacity mental workspace has been central to many recent cognitive theories. This limited capacity mental workspace has typically been referred to as working memory. Jonides, Lacey and Nee (2005) maintain that working memory is a structure that can store a small quantity of information for brief periods of time, keeping that information immediately accessible and present for alteration by rules and strategies, while updating it regularly. Without working memory, one would find it difficult to function. Consequently, this memory is essential for many daily activities, such as keeping track of the flow of ideas or "when listening, we rely on memory to retain, however briefly, parts of the auditory signal so that it can be processed" (Neath & Surprenant, 2003, p.1). In order to understand how the working memory system functions, we need to be able to illustrate how information is retained, manipulated and stored. Working memory models have been designed to represent these structures and processes (Cohen, Kiss & Le Voi, 1993). Research has resulted in many theories, which propose models of working memory. However, to date, the most influential account of working memory has been provided by the multi-component model, originally posited by Baddeley and Hitch in 1974 and later modified by Baddeley (Pickering, 2001).

A key feature of this working memory model, according to Pickering (2001), is the presence of specialised components, which deal with different areas of working memory activity. There are four specialised components found in this working memory model. According to Cohen, Kiss and Le Voi (1993), this includes a central executive, which is a controlling attentional system. This system monitors and organises the operation of the other components. These other components include the phonological loop, visuo-spatial sketchpad (or scratchpad) and the episodic buffer. This model recognises that working memory is fundamental to many learning activities in the classroom (Marconi, 2006). Thus the role that working memory plays is significant and it is vital that South African teachers understand its place in academic achievement.

Children who have a poor working memory system may find it difficult to meet academic expectations (Reiff & Tippins, 2004). Children who are diagnosed with Attention Deficit Hyperactivity Disorder (ADHD) will show more academic difficulties than non-ADHD children (Goldstein & Goldstein, 1992). Consequently, those with a diagnosis of ADHD may display distractibility and lack of persistence (which prevents the child from retaining information taught in class) or impulsivity (which may cause the child to hurry through schoolwork), perhaps as the result of a poorly functioning working memory system. Meyer, Eilersten, Sundet, Tshifularo and Sagvolden (2004) maintain that education is becoming an area of particular importance, specifically in developing countries, such as South Africa. Consequently, teachers are becoming more cognisant of children at risk of developmental disorders such as ADHD, which interferes with a child's optimal academic achievement (Marconi, 2006).

According to Reiff and Tippins (2004), ADHD is the most commonly diagnosed developmental disorder in children, affecting, on average, 6% to 9% of children in schools. Moreover, it is a debilitating and chronic condition, the symptoms of which may continue in 60% to 80% of adolescents and in some cases, even into adulthood. It has been noted that ADHD in adulthood may cause a plethora of problems. Studies have suggested that this adult population appear to experience problems with mental illness (depression and anxiety) as well as in their relationships with others. Moreover, these individuals experience academic, antisocial and employment difficulties (Goldstein & Goldstein, 1992). Adults with ADHD often face their biggest challenges in higher education and thereafter within the workplace. Working adults need to create layers of structure at work, as well as integrate work demands with their competing personal responsibilities. These crucial workplace skills may be challenging for adults with ADHD. Thus, despite the fact that adults with ADHD may be employed and financially independent, "the quality of their work and their upward vocational mobility falls short of the normal population" (Goldstein & Goldstein, 1992, p.112).

The information noted above serves as a useful reminder of the importance of early detection and long-term treatment for those with a diagnosis of ADHD. It has been suggested that those with ADHD, who receive medical, educational, and behavioural treatments over the long-term, display improved adjustment and behaviour than those receiving no treatment (Goldstein & Goldstein, 1992). Considering that children receiving treatment for ADHD might fare better in the long run than those who do not, it seems important that South African educators understand and detect ADHD early on in childhood. If teachers are able to detect ADHD and it's associated problems in the early stages, suitable remediation practices can be put in place (Marconi, 2006).

It has been noted that the association between working memory function, behaviour and academic achievement has not been well documented in children (Aronen, Vuontela, Steenari, Salmi & Carlson, 2005). Moreover, the research that does seem to focus on these aspects yields conflicting results. Owing to this, this research considered it necessary to explore the relationship between working memory and ADHD. In more specific terms, it looked at the differences in working memory capacity between those children with ADHD and those without ADHD, over and above that which can be explained by IQ (measured by the Raven's Coloured Progressive Matrices – refer to Chapter 3, Measures section for more details). Furthermore, this research relates to the specific components implicated in Baddeley and Hitch's (1974) working memory model, specifically the verbal (phonological loop) and visuo-spatial (visuo-spatial sketchpad) components. Although Alloway, Gathercole and Pickering (2006) assert that a child's verbal and visuo-spatial capacities are separable, it has not been unequivocally established whether there is a difference in verbal and visuo-spatial working memory between those with ADHD and those without ADHD. Consequently, this research deemed it important to explore these relationships. According to Marconi (2006), if differences did indeed occur, it was theorised that it would prove necessary for South African teachers to devise specific remediation interventions. In conclusion, it is believed that this research will add to pre-existing knowledge of the working memory processes in children, particularly with regard to the South African context.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

There are several types of memory stores. Each store has its own distinct function and set of characteristics. A common characteristic is that they are uniquely temporal (Schacter & Tulving, 1994; Sherry & Schacter, 1987; Squire, 2004). Accordingly, some memories remain for a fleeting few seconds or minutes, whilst other memories remain forever. Working memory is an example of the former, where information is briefly held and manipulated in the mind. This type of memory is necessary for completing some cognitive functions. Some of these functions include the ability to organize, plan and sequence information. According to Marconi (2006) the failure to utilise working memory efficiently might suggest difficulty in performing such cognitive functions. A common problem with children diagnosed with Attention Deficit Hyperactivity Disorder (ADHD) is their inability to perform these aforementioned functions efficiently. Consequently, it might be possible to suggest that working memory is affected by the presence of ADHD.

ADHD can be thought of as neurobehavioural disorder. Reiff and Tippins (2004) maintain that ADHD is a disorder in which children are considerably limited in their ability to filter out immaterial input, focus, organise, prioritise, delay gratification, think before they act, or perform other so-called executive functions that most of us carry out automatically. According to the most recent edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM – IV- TR; American Psychiatric

Association, 2000) certain criteria need to be met for a diagnosis of ADHD to be made. These include the following: the symptoms of ADHD must be present for at least 6 months. Moreover, these symptoms must occur before the child reaches the age of 7 years. There must be some evidence to suggest that the symptoms experienced cause considerable impairment in the child's social or academic functioning. Furthermore, these symptoms must be present in at least two or more settings, such at home or school. Moreover, the ADHD symptoms do not only occur during the course of a pervasive developmental disorder, schizophrenia or another psychotic disorder. Lastly, the symptoms cannot be attributed to another mental disorder, such as mood, anxiety, dissociative or personality disorders.

ADHD can affect a child's ability to inhibit behaviour (impulsivity), regulate behaviour appropriately (hyperactivity) or perform adequately in certain activities (inattention). Today's current diagnostic consensus stipulates that attention constitutes one dimension, whilst hyperactivity and impulsivity share another dimension. These dimensions represent expressions of the same disorder (Reiff & Tippins, 2004). ADHD is made up of three behavioural subtypes, namely inattentive type, hyperactive/impulsive type and combined type. The ADHD group found in this research consists of children with ADHD, predominantly inattentive type and predominantly hyperactive/impulsive type. Consequently, focus will be placed on these two subtypes.

According to the DSM – IV-TR (APA, 2000), children with ADHD, predominantly inattentive type often find it difficult to sustain attention in tasks or play activities and tend to avoid activities that require prolonged mental effort. Moreover, these children tend to display difficulty organising tasks and activities and generally fail to pay close attention to details or make careless mistakes. These children seem not to listen when spoken to and fail to follow through on instructions. Furthermore, they often lose things and are easily distracted and forgetful.

According to the DSM – IV-TR (APA, 2000), children with ADHD, predominantly hyperactive/impulsive type often fiddle with their hands or feet, or wriggle in their seats. They find it difficult to remain seated and thus will often leave their seats and run about. Moreover, they tend to climb excessively. These children struggle to engage in quiet activities and appear as if they are constantly 'on the go'. There is a tendency to talk excessively and blurt out answers to questions rashly. Consequently, these children display an inability to wait their turn. Lastly, these children appear to impose themselves on others, for example, they may hastily interrupt someone mid sentence or disrupt others play activities.

Despite the extensive list of criteria above, the diagnosis of ADHD is not as simple as it would appear. The line between having or not having ADHD is not clear-cut; inattentive, hyperactive and impulsive symptoms can be seen in many children at one time or another. Consequently, choosing whether a child's behaviour indicates the presence of ADHD is therefore a complicated process that involves comparing a child's behaviours and abilities to function with those of other children of the same age (Reiff & Tippens, 2004). It has been noted that ADHD exists from birth but is usually difficult to recognise until the child reaches its first years of formal schooling. Before such time, children usually display inattentive, hyperactive and impulsive behaviours normal for their stage of development. When a child enters school, such behaviours tend to dissipate as the child begins to mature. However, children with ADHD do not grow out of these behaviours and this becomes more noticeable as the child grows up. It has been noted, in a study carried out by Savage, Cornish, Manly and Hollis (2006), that those children who experience developmental attention delays, display significant deficits in their working memory. Moreover, research by Kerns, McIrnerney and Wilde (2001) suggests that working memory is deficient in children with ADHD.

Working memory can be conceptualised as the moment-to-moment monitoring, processing, and preservation of information (Baddeley & Logie, 1999). Thus, working memory is a process whereby information is held temporarily in the mind and manipulated, for the purposes of performing certain cognitive tasks. This memory system has a limited capacity, storing at any one time an average of five to nine chunks of information (Miller, 1956). These chunks of information include units such as digits, letters, words and sentences.

Various theoretical models have been put forward to describe the structure of working memory. The most extensively researched and most frequently utilised model of working memory is the *multi-component model.* This model was originally proposed by Baddeley and Hitch in 1974, and was later adapted by Baddeley in 1986. Other models also describe the working memory system. Although the Baddeley and Hitch (1974) model is considered to provide the most detailed and all encompassing explanation of working memory, it is suggested that these other models are useful in their own right. Consequently, it will be argued that each model adds something important to the understanding of working memory (Marconi, 2006). This review will now turn to working memory, specifically its structure and functioning.

2.2 WORKING MEMORY THEORY

The ability to hold information over a short period of time appears essential to a broad range of everyday tasks (Logie, 1995). Consequently, there has been much research directed towards how information is stored temporarily in the mind.

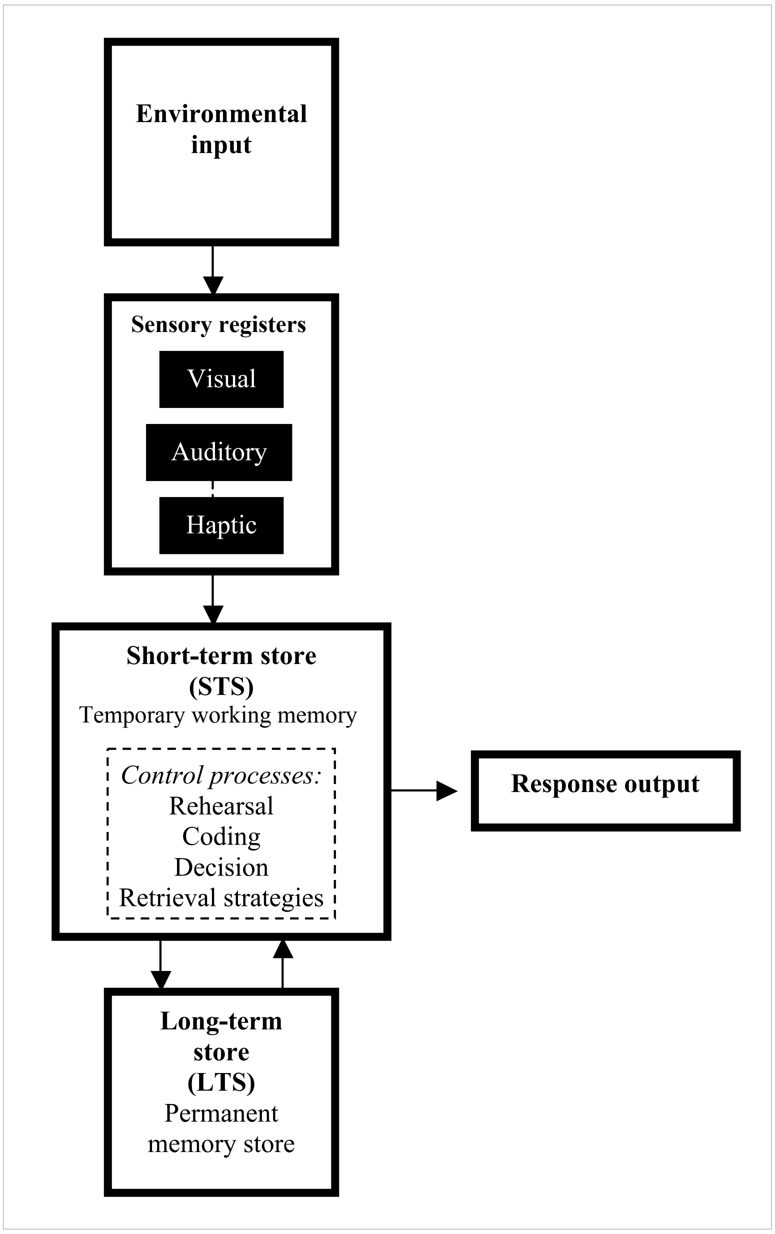
During the 1950's no distinction was drawn between short-term and long-term memory. Memory was described as a *single-store system,* thus one's ability to remember a telephone number and one's ability to learn text for an examination were considered to rely on the same system. However, a few years later, researchers by the name of Waugh and Norman suggested otherwise. They proposed the idea that memory, in fact, consists of two stores, namely *short-term* and *long-term.* Moreover, they suggested that without rehearsal, information would be lost and thus not permanently retained in the long-term store.

Taking this on board, many researchers began to devise useful experiments to test this suggestion. By the 1960's most of the research into short-term memory was done in the laboratory. A great deal of models and theories had been proposed but relied predominantly on mathematical formulations. One of the most significant models devised in the 1980s was that of the Atkinson and Shiffrin (1986) model. An illustration of this model can be seen in Figure 1.

FIGURE 1

Schematic representation of the Atkinson and Shiffrin (1968) human memory model

(Adapted from Atkinson & Shiffrin, 1968)

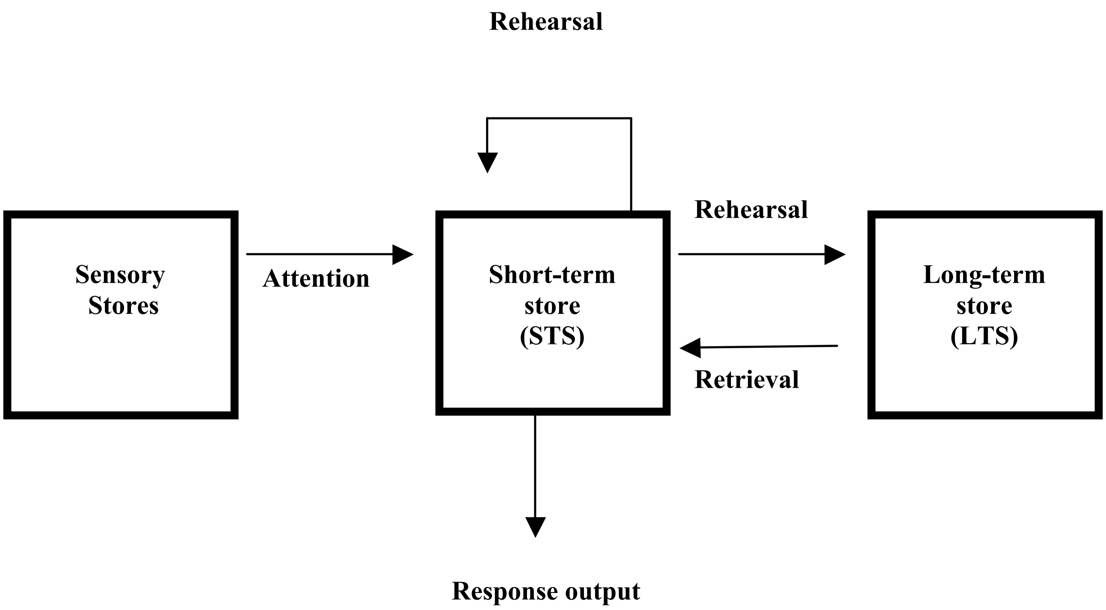


This model attempted to propose a more complex short-term memory system. This system constituted restricted storage capacity and numerous organising processes. These processes could be used for the encoding and retention of information. According to Logie (1995, p.11) this short-term memory system was seen "as a working buffer, rather than a passive storage system, and the control processes could include both verbal rehearsal and other coding strategies such as imagery". Despite Atkinson and Shiffrin's focus on the processes involved in the short-term memory store, it was argued this idea was not fully developed. In an attempt to understand these processes more clearly, Craik and Lockhart (1972) developed their own model. An illustration of this model can be seen in Figure 2.

FIGURE 2

<u>Schematic representation of the Craik and Lockhart (1972) Memory Model</u>

(Adapted from Craik & Lockhart, 1972)



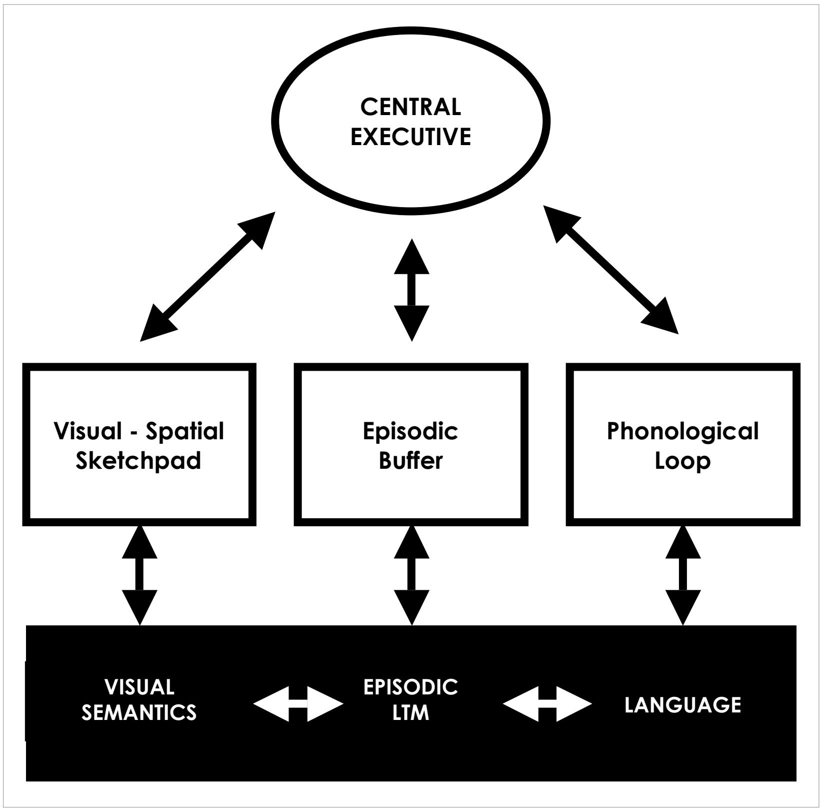
"Craik and Lockhart suggest that the more deeply an item is processed, the better it will be remembered, with information processed in superficial sensory terms giving rise to relatively short-lived traces, and phonological processing producing a somewhat more durable trace, while deep semantic processing produces the most durable learning" (Baddeley, 1998, p.47).

While Craik and Lockhart saw memory arising from the preservation of information at differing levels of processing, Atkinson and Shiffrin viewed memory as a solitary, multi-purpose working buffer or brief working memory, integrating both storage and a variety of processing functions (Logie, 1995). Consequently, it can be seen that the notion of the short-term store was being actively challenged and replaced with newer, more complex ideas. In particular, researchers were beginning to draw a distinction between a "more or less passive short-term memory system and a more dynamic working memory system" (Hutton & Towse, 2001, p.383). In 1974 Baddeley and Hitch suggested that while working memory shares commonalities with short-term memory, the two are nevertheless distinct memory systems. According to Gathercole and Alloway (2006), short-term memory is concerned with straightforward storage of information, whereas working memory is concerned with the storage and manipulation of information. Owing to this, short-term memory was conceived as a lower-order process of the working memory system. Thus, researchers proposed that the short-term store be replaced with that of the more complex working memory store (Eysenck & Keane, 1990). Accordingly, these researchers devised a *multi-component model,* which looks specifically at the working memory system. An illustration of this model can be seen in Figure 3.

This model incorporates two *slave systems,* which are controlled by an overarching *central executive.* According to Alloway, Gathercole and Pickering (2006), the central executive is primarily responsible for controlling and examining information processing across the *visual-spatial, phonological* and *episodic buffer* domains. Furthermore, this component is responsible for a variety of regulatory functions, namely the retrieval of information from long-term memory and the control of attention (Alloway et al., 2006). The two slave systems are the *visual-spatial sketchpad* and the *phonological loop.* The visual-spatial sketchpad is primarily responsible for the temporary storage of verbal information, whilst the phonological loop is responsible for maintaining and manipulating visual and spatial information.

FIGURE 3

Schematic representation of the most recent Baddeley (2000) working memory model
(Adapted from Baddeley, 2000)



Although Baddeley and Hitch only proposed two slave systems, it was suggested that other slave systems might exist (Logie, 1995). These slave systems would be used to perform specialised tactile, kinesthetic or olfactory functions. However, little research has been done to give credence to these other slave systems. Moreover, research by Ellis (1991) has suggested that these slave systems are poorly linked to memory functioning and performance.

According to Alloway et. al (2006), Baddeley and Hitch's model of working memory has been supported by evidence obtained from research involving children. Consequently, this review will now turn to a discussion of the components that constitute this model.

2.3 BADDELEY AND HITCH'S MULTI-COMPONENT MODEL OF WORKING MEMORY

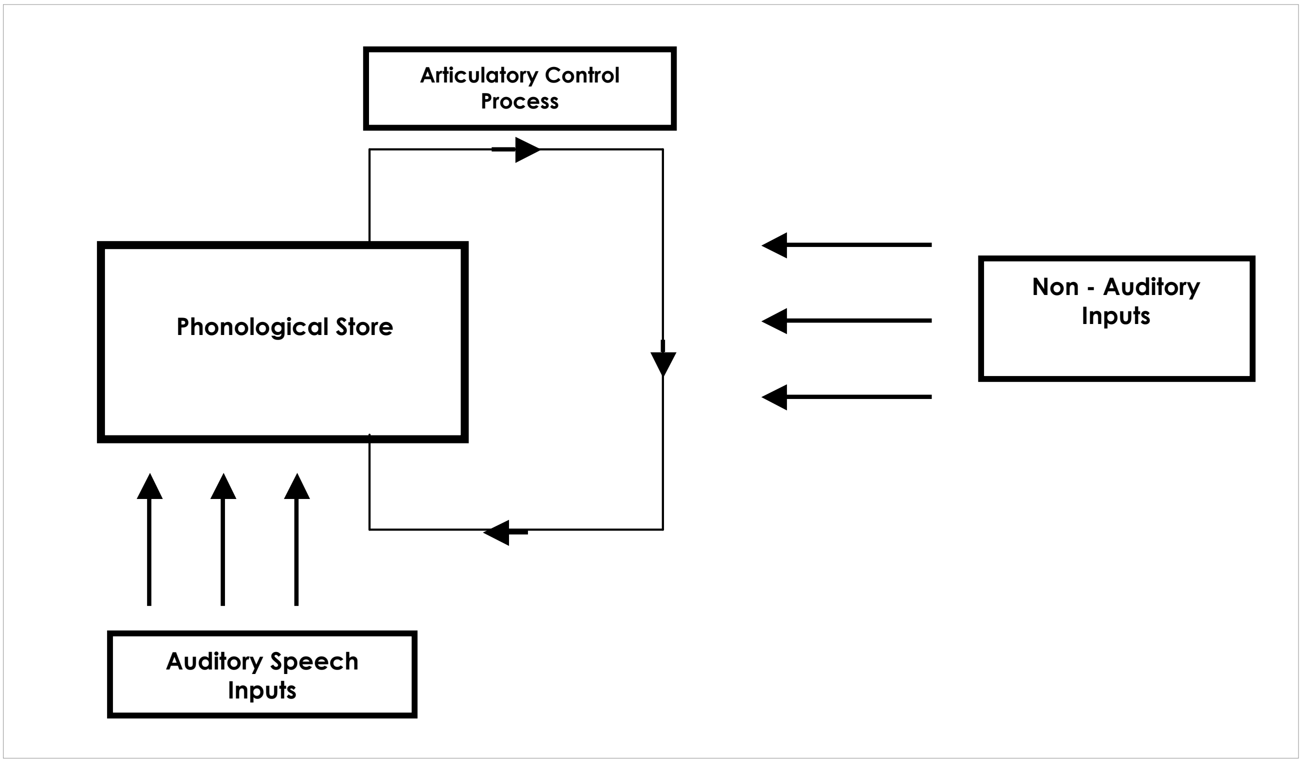
2.3.1 Slave system component: The phonological loop

According to Gathercole and Alloway (2006) the phonological loop is speech-based. It is responsible for the temporary storage of all verbal information, such as spoken words, printed words and identifiable objects. The phonological loop is made up of two sub-components, namely the *phonological store* and *articulatory control process.* An illustration of this component can be seen in Figure 4.

Baddeley (1990) maintains that the phonological store is primarily responsible for holding speech-based information. In order to be held, this information has to enter the phonological store. This information gains entry via direct auditory (spoken words) presentation or via indirect non-auditory (written or visual material) codes (Marconi, 2006). This information is retained in the phonological store for approximately one-and-a-half to two seconds. After such time, this information may be lost forever, unless it is 'refreshed'. This is accomplished via the process of accessing the memory trace left over in the articulatory control process (Marconi, 2006). The articulatory control process acts as an inner ear by maintaining information in its auditory form, where it is circulated in a similar manner to a tape loop. Accordingly, an individual is able to remember, for example, a telephone number just heard.

FIGURE 4

Schematic representation of the phonological loop component
(Adapted from Baddeley, 1986)



In order to provide evidence for the phonological loop, three supporting phenomena are discussed below. Initially, focus will be placed on the *phonological similarity effect.* According to Baddeley (1998), this effect occurs as the result of items having similar phonological codes. Consequently, similar codes will lead to confusion and thus impairment in performance. The *unattended speech effect* occurs as the result of extraneous information corrupting the phonological store. As a result of this, performance becomes disrupted. Lastly, the *word-length effect* can be thought of in the following way. The articulatory control process involves "setting up and running speech motor programs, which operate in real time, with the result that the longer the word, the longer it takes to run off" (Baddeley, 1998, p.58). If the articulatory control process maintains items in the phonological store and 'refreshes' them, then it might be assumed that the faster the items can be refreshed, the more items will be maintained and thus the longer one's memory span.

2.3.2 Slave system component: The visuo-spatial sketchpad

The second slave system that constitutes the multi-component working memory model is the visuo-spatial sketchpad (sometimes referred to as the *scratchpad*). The visuo-spatial sketchpad is a specialised, temporary memory system responsible for the storage of visual and spatial information over a short period of time (Gathercole & Pickering, 2000). Moreover, this component is implicated in the direct manipulation of visuo-spatial information. According to Baddeley (1990), visual spatial information enters the visuo-spatial sketchpad either directly from the eyes or indirectly, through mental images.

Much debate has centred on the subcomponents of the visuo-spatial sketchpad. According to Marconi (2006), a main question that concerns working memory theorists, is whether the use of imagery is visual or spatial in nature.
Experimental psychologists' interest in imagery peaked in the late 1800s. However, interest into this area waned for some time and the study of imagery only made its

way to the forefront again in the 1960s. According to Logie (1995), numerous studies conducted by Brooks in the late 1960s provided a very helpful set of techniques for examining visualization, which have since been widely used to study visual working memory. Brooks devised a task, which was used to ascertain whether a person encodes information visually or spatially. The task involved a matrix layout. Results indicated that imagery tended to be encoded spatially, rather than visually or visual-spatially.

Other research into this area has suggested that imagery may not be based purely on visual or spatial cues, but may, in fact, be a combination of the two. In order to provide evidence for this assertion, Logie and Pearson (1997) conducted a study with children, using the *Corsi Block test*. Results provided support for the existence of two separate sub-components within the visuo-spatial sketchpad. Data from neuropsychological studies have also been used to dissociate visual and spatial working memory. Baddeley (1990) maintains that results from neuropsychological and animal studies suggest the presence of two separate sub-components within the visuo-spatial sketchpad. In terms of neuropsychological assessment, double dissociation provides the most convincing results. In research conducted by Farah (1988, as cited in Logie, 1995), findings showed a deficit in visual but not spatial working memory. In another study, conducted by Hanley (1991, as cited in Logie, 1995), the opposite was found. Results suggested a deficit in spatial but not visual working memory.

Most of the research into the area of working memory has tended to concentrate on the slave systems, primarily on the grounds that they appear to offer more tractable problems than the central executive (Baddeley, 1990). It may prove entirely reasonable to attempt to understand the complex working memory system bit-by-bit however, at the end of the day, the overarching component that controls the slave systems needs be understood. In recent years, researchers have begun to acknowledge that ADHD may not simply be an inattentive problem, but rather a developmental impairment of executive functioning (Brown, 2003). Consequently, this review will now turn to a discussion of the central executive.

2.3.3 Executive component: The central executive

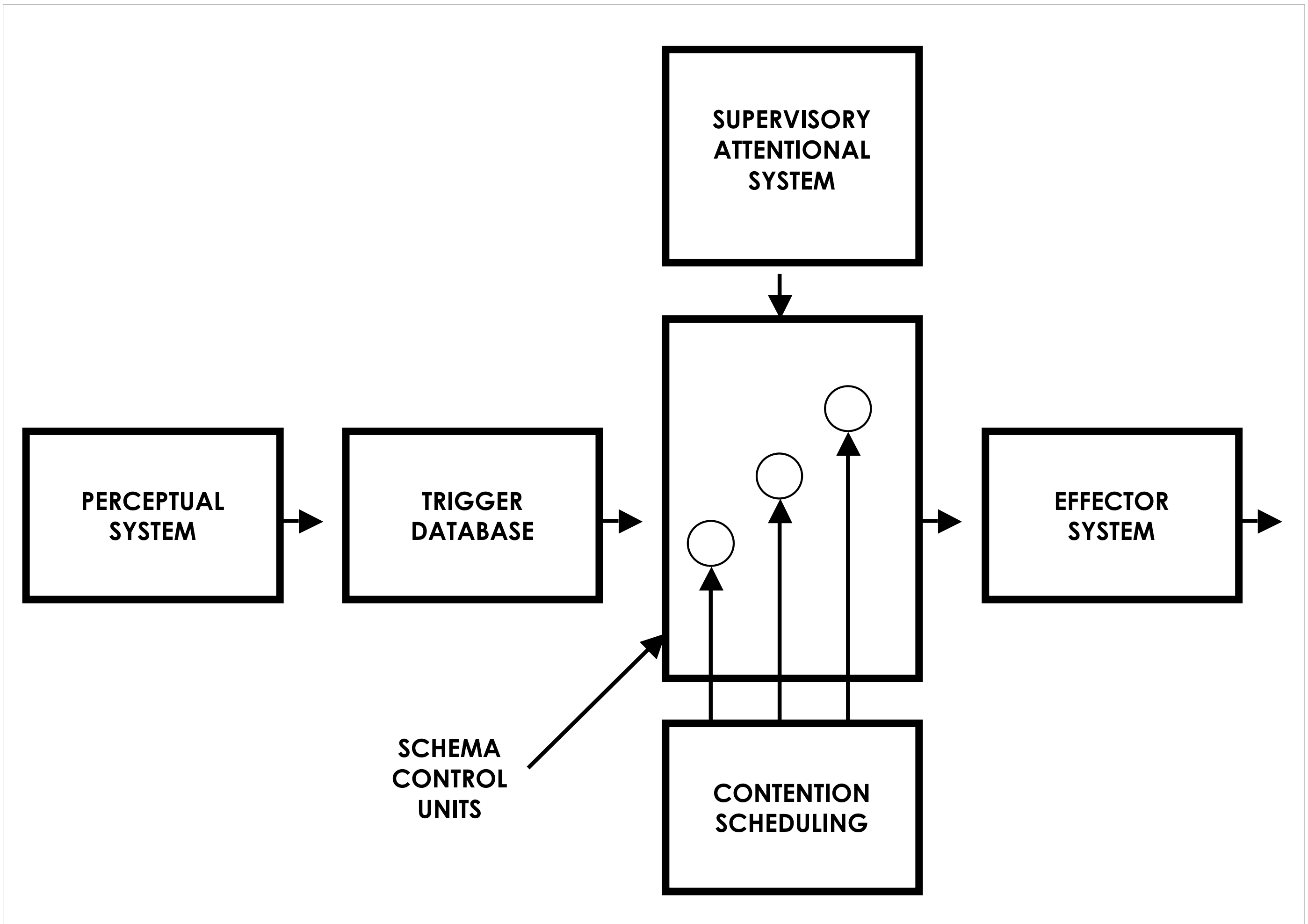
Despite the fact that little is known of the central executive component, Baddeley and Logie (1999) propose that this system is primarily responsible for the coordinating activity in the cognitive system. Consequently, the central executive is thought to be concerned with the controlling and monitoring of information processing, attentional control and regulatory functions (Marconi, 2006). Moreover, this component devotes some of its resources to increasing the quantity of information that may be held in the two slave systems. Baddeley (1982) maintains that the central executive comprises two sub-components, one of which is devoted to memory, the other, conscious attention. Baddeley (1990) asserts that it is the latter system that is likely to be accountable for controlling both the essential processes of memory and the other slave systems. Owing to the importance of conscious attention in this component, it proves necessary to provide a discussion of the theories of attention and their association with working memory. Consequently, the Schneider and Shiffrin (1977) model and the Norman and Shallice Supervisory Activating System (SAS) (1980) model will be critically discussed and subsequently linked to the Baddeley and Hitch (1974) model (Marconi, 2006).

Schneider and Shiffrin's (1977) model fought for a theoretical dissociation between controlled and automatic processes (Eysenck & Keane, 1990). Consequently, these theorists proposed that controlled processes require attention, whereas automatic processes do not. Schneider and Shiffrin tested their hypothesis with a series of experiments. In many of their experiments, the fundamental manipulation was the kind of mapping used, namely consistent versus varied mapping (Eysenck & Keane, 1990). According to Schneider and Shiffrin (1977) performance of the varied mapping tasks revealed the use of controlled processes, whilst performance on the consistent mapping tasks revealed the use of automatic processes. These automatic processes were thought to occur as the result of habituation (decrease in conscious attention due to repeated exposure to a stimulus). Further evidence from these experiments suggested that automatic processes function more efficiently and swiftly than controlled processes. Moreover, attention may be divided with more success when automatic processes are in use. Although Schneider and Shiffrin's work is significant in that it highlights the importance of attentional control in skilled behaviour, it nevertheless fails to propose a credible model for the operation of something as complicated as the central executive component of working memory (Baddeley, 1990). One model that does attempt to explore the workings of the central executive is the Norman and Shallice (1980) SAS model.

Whilst Schneider and Shiffrin's research was largely based in the laboratory, Norman and Shallice's research came from daily examination of mental lapses, or from the collapse in the control of behaviour shown in specific neuropsychological patients (Baddeley, 1990). Norman and Shallice (1980) proposed a model that made a distinction between fully automatic and partially automatic cognitive processes. This model consists of two separate control systems: *contention scheduling system* and *supervisory activating system.* An illustration of this model is can be seen in Figure 5.

FIGURE 5

Schematic representation of the Norman and Shallice (1980) SAS model
(Adapted from Baddeley, 1990, p.126)



The contention scheduling (CS) system is primarily responsible for control in routine situations. The CS is thought to constitute a hierarchically ordered system of action schemas (Cooper, 2002). According to Reber and Reber (2001), a schema is a cognitive plan that serves as a guide for action, as a structure for interpreting information or as a problem-solving structure. These schemas are thought to automatically control behaviour. Thus action takes place largely independently of conscious attention. Moreover these automated actions may occur simultaneously with other actions without causing any interference. This part of Norman and Shallice's model is akin to Schneider and Shiffrin's work. Although this aspect of the model is useful in that it provides some insight into habitual programmes, it leaves no place for willed control of action. Thus, Norman and Shallice thought it necessary to introduce the supervisory activating system (SAS), a system that Schneider and Shiffrin failed to account for.

The Supervisory Activating System is primarily responsible for more complex cognitive operations. The SAS system will intervene when routine control is inadequate. It organises, coordinates and examines schemas, with conscious attention, in order to master new and complicated tasks. Thus, this system acts as general planning component. It has been suggested that deficits in the Supervisory Activating System may be linked to frontal lobe damage (Baddeley, 1990, p.131). Consequently, those with damage to their frontal lobes appear very distractible and unable to concentrate on any particular activity for longer than a couple of minutes (Baddeley, 1990). These symptoms are seen in those diagnosed with ADHD. Research conducted by Farrow and Levy (2001) looked at working memory in children diagnosed with ADHD, with specific emphasis on their frontal lobe functioning. The children were tested using a *continuous performance task.* Results suggested that frontal lobe activation (part involved in attention) is dysfunctional in children diagnosed with ADHD.

Baddeley (1986) has suggested that the central executive is similar to the Supervisory Activating System. Owing to this, Baddeley has integrated the SAS system into his (1986) model of working memory with the attentional element being incorporated into the central executive (Marconi, 2006).

The central executive is assumed to control the episodic buffer. According to Barnard and Scott (2001), theoretical advancement with regard to Baddeley's work has included the introduction of an extra component to the working memory model, namely the *episodic buffer.* Consequently, this review will now turn to a discussion of the episodic buffer.

2.3.4 New component: The episodic buffer

Initially, the episodic buffer was thought to be part of the central executive (Baddeley & Logie, 1999). However, the episodic buffer is now seen as a separate component, which may be accessed by the central executive. Thus, the central executive may be able to manipulate the content of the episodic buffer by attending to a given source of information, whether perceptual, from the verbal or visuo-spatial components of working memory, or from long-term memory (Baddeley, 2000).

The episodic buffer is primarily accountable for binding information across informational areas and memory sub-systems (Baddeley, 2000). Consequently, it may be thought of as an intermediary between the verbal, visuo-spatial and central executive components and the long-term memory system. The episodic buffer is primarily responsible for accessing information from the long-term store in the form of conscious awareness. Moreover, it carries this stored information to the slave system components. Once this stored information is coupled with information already present in the slave system component, it may be manipulated or modified. Consequently, new representations may be created (Baddeley, 2003). The flow of information is not only one-way however, rather, information travels bi-directionally between the slave system components and long-term memory through the episodic buffer. This component is assumed to have a restricted capacity because of the computational demand of providing simultaneous admission (Baddeley, 2000). The exact parameters of this capacity have yet to be discovered however.

As one might see, discussion up until this point has focused predominantly on Baddeley and Hitch's (1974) and Baddeley's (2000) multi-component model of working memory. There are, however, other current models that include multi-component structures. Other multi-component models include Cowan (1999), and Oberauer, Suß, Wilhelm and Wittman (2003). In contrast to the multi-component models, Daneman and Carpenter (1980) and Engle, Kane and Tuholski (1999) suggest unitary models of working memory. Unitary models can be thought of as constituting one component. This component is primarily responsible for taking on many roles, namely storage and manipulation. This review will now focus on the above-mentioned models.

2.4 UNITARY MODELS

2.4.1 Daneman and Carpenter (1980)

One of the most influential studies in the area of working memory capacity was that done by Daneman and Carpenter (1980). These theorists maintain that working memory capacity is split between two functions, namely storage and processing. Thus, when one has to complete a task that involves both storage and processing, working memory capacity is divided in order for both functions to be carried out successfully. A *reading span task* was developed to monitor the relationship between storage and processing. This reading span task involves a series of sentences. One is asked to read a number of sentences and to remember the last word of each sentence. Consequently, the reader is essentially asked to divide their working memory capacity between storing the last word from a sentence and processing the sentence they are reading. Thus one might hypothesise that the greater one's working memory capacity, the greater one's ability to store and process information. Baddeley and Weiskrantz (1995) maintain that Daneman and Carpenter's model, although unitary in structure, is entirely compatible with the Baddeley and Hitch's working memory model as it offers a useful tool for analysing complicated but important real world tasks.

2.4.2 Engle, Kane and Tuholski (1999)

Another unitary model of working memory is that proposed by Engle and colleagues (1999). This model maintains that working memory capacity is facilitated by controlled attention and the ability to remain focused, despite interfering stimuli. There are some similarities between this model and the Baddeley and Hitch (1974) model of working memory. Although Engle and colleagues advocate for a non-domain specific working memory system, they do suggest the notion of a central, overarching component that works as a mediator between continuous processes of information and storage of information (Marconi, 2006). Moreover, consistent with Baddeley and Hitch (1974), Engle and colleagues (1999) argue that their model incorporates specific storage components; one for verbal information and one for visuo-spatial information. However, these models differ with regard to the connections between these specific storage components. In the Engle et al. (1999) model the controlled attentional aspect of working memory capacity is predictive of learning, whilst in the Baddeley and Hitch (1974) model, the central executive and the verbal and visuo-spatial storage components are predictive of learning.

Engle and colleagues' proposition that working memory capacity is non-domain specific was demonstrated through an experiment that made a comparison between two tasks, namely a working memory capacity task and a short-term memory task (Kane, Hambrick, Tuholski, Wilhelm, Payne & Engle, 2004). The working memory capacity task involved maintaining target stimuli whilst concurrently processing other information. The short-term memory task involved simple span tasks without concurrent processing of other information. Results indicated that working memory capacity tasks were more domain general than short-term memory tasks. Moreover it was found that verbal and visuo-spatial working memory capacity tasks shared a higher variance than verbal and visuo-spatial short-term memory tasks. Thus, these results suggested that verbal and visuo-spatial working memory capacity is not domain specific, whereas verbal and visuo-spatial short-term memory is more reliant on domain specific processes. Consequently, these results gave credence to the notion that working memory capacity, or executive attention, is best explained through a non-domain specific model (Kane et al., 2004).

2.5 OTHER MULTI-COMPONENT MODELS

2.5.1 Cowan (1999)

An example of a multi-component model is that of Cowan's (1999) Embedded Process Model. This model consists of three components namely, "an automatic attention orienting system, a central executive and a memory store" (Gathercole, 2001, p.331). The central executive is a system used to modulate attention. The memory store consists of three hierarchically embedded components. At the base of this system, lies long-term memory. This memory is assumed to have an unlimited capacity as well as some level of activation. During most short-term memory tasks, certain long-term memory representations are made active (Gathercole, 2001). At this point, the central executive comes into play. The central executive resources may be used to determine which stimuli should be attended to and which should be ignored. That which is attended to, becomes highly activated. According to Cowan (1999), active memory is the main area for the focus of attention to draw upon. This memory however has a limited capacity and unless focus of attention is maintained, decay occurs.

Cowan's (1999) model is to some extent compatible with Baddeley and Hitch's model of working memory. This model reserves the space for some of the components seen in the Baddeley and Hitch model. For example the activated components in memory approximately correspond to the passive stores (phonological store) and the focus of attention mirrors the storage ability of Baddeley's central executive (Mizuno, 2005). Moreover, information is retrieved from or activated in long-term memory when it is necessary for a task (Cowan, 1999). Consequently, this seems similar to the integration of information from long-term memory in Baddeley's episodic buffer component.

2.5.2 Oberaurer, Suß, Wilhelm and Wittman (2003)

Oberauer and colleagues (2003) maintain that working memory is divided into two dimensions. One dimension is related to *content domains,* whilst the other dimension is related to *cognitive functions.* The former dimension is assumed to constitute two broad categories namely, working memory for visuo-spatial information and working memory for language and numerical information (Oberaurer et al., 2003). These two categories can be likened to Baddeley and Hitch's domain specific slave systems. The latter dimension is made up of three categories, which ostensibly cover most of the functions associated with working memory. These categories are (1) the simultaneous storage and processing of information (2) supervision (also known as the executive process) and (3) coordination. Each of these categories is described below, in brief.

Oberaurer et al. (2003, p.169) define storage as “the retention of briefly presented new information over a period of time in which the information is no longer present” and processing as the manipulation of information or the creation of new information. These theorists maintain that storage and processing are two separate processes, but that working memory tasks generally require both. Consequently, these processes tend to work simultaneously. *Supervision* or the *executive process* involves the examination of continuing cognitive processes and actions, the selective initiation of significant representations and procedures and inhibition of immaterial, distracting representations (Oberaurer et al., 2003). *Coordination* is a limited capacity system that looks at building new associations between elements and integrating these elements into structures (Oberaurer et al., 2003).

As one may note, this model parallels Baddeley and Hitch’s model in terms of the central executive with its processes of dual-task coordination and task switching and the separate verbal and visuo-spatial slave systems, which involve the simultaneous storage and processing of information.

2.6 SUPPORT FOR THE BADDELEY AND HITCH (1974) MULTI-COMPONENT MODEL OF WORKING MEMORY

One main area of debate in the working memory literature is whether the unitary models or the multi-component models offer a more conclusive picture of working memory. Evidence supporting this debate has tended to provide support for the multi-component conception of working memory. More specifically, as noted by Barnard and Scott (2001), most research within the working memory framework has tended to concentrate on Baddeley and Hitch's (1974) multi-component working memory model.

Support for the multi-component model been found in studies with children. In 2004, Alloway, Gathercole, Willis and Adams assessed the usefulness of various working memory models. These models included a unitary (single component) and multi-component model of working memory. This study focused on these models in relation to the verbal and non-verbal abilities of children aged between 4 and 6 years. These theorists employed a structural equation model, specifically a five-factor model that consisted of such things as phonological awareness, the central executive, phonological loop and episodic buffer. The visuo-spatial sketchpad was not included as the assessment focused predominantly on the verbal aspects of working memory. The results of this study provided support for the multi-component working memory model. Additional empirical evidence in support of the multi-component model has been found in imaging studies of working memory.

In a study conducted by Owen, Herrod, Menon, Clark, Downey, Carpenter, Minhas, Turkheimer, Williams, Robbins, Sahakain, Petrides and Pickard (1999) it was found that blood flowed to different areas of the frontal cortex depending on the working memory task. On tasks that required only the maintenance or storage of information, it was noted that there was increased blood flow in the mid-ventrolateral frontal cortex. On tasks that required both the maintenance (remembering a series of numbers) and manipulation of information (comparing each number to the previously presented numbers and deciding whether they are the same of different), it was noted that blood flow increased in both the mid-ventrolateral frontal cortex and the middorsolateral prefrontal cortex (Owen et al., 1999). Both these studies maintained that working memory consists of a combination of storage, maintenance and manipulation processes as advocated by the multi-component model of working memory. Consequently, these researchers appear to justify conceptualizing working memory as multi-component rather than unitary. Moreover, each of the unitary and multi-component models appears to fit neatly into Baddeley and Hitch's framework of working memory.

As mentioned above, Cowan's (1999) Embedded Process model and Baddeley and Hitch's model both incorporate the central executive. This central executive is used to modulate attention. Oberauer and colleagues (2003) incorporate a central executive and content domains, which are similar to Baddeley and Hitch's visuo-spatial and verbal slave systems. Engle and colleagues (1999) concept of executive attention is akin to Baddeley and Hitch's central executive in that both involve attention as necessary in the completion of complex working memory tasks. Moreover both models incorporate specific storage components; one for verbal information and one for visuo-spatial information. Considering the fact that the Baddeley and Hitch's (1974) multi-component model is the most comprehensive, widely researched and most frequently utilised model of working memory (Miyake & Shah, 2007), it will form the theoretical basis of this research.

According to Andrade, Baddeley and Hitch (2002), the Baddeley and Hitch (1974) model of working memory is useful in explaining deficits in working memory that might be observed in children with developmental disorders, such as ADHD. Moreover, given that this model consists of three main components (central executive, phonological loop and visuo-spatial sketchpad), one might expect to find three different types of working memory deficits in those with ADHD, each relating to dysfunction within one of these components (Andrade, Baddeley, & Hitch, 2002).

2.7 ADHD AND DEFICITS IN WORKING MEMORY

It has been suggested that working memory skills are closely associated with academic achievement (Gathercole, 2006). Thus, an inability to utilise the working memory system efficiently may be linked to poor academic attainment. It has been suggested that a poorly functioning working memory system appears to prevent effective learning due to information overload. According to Colflesh and Conway (2007), those children with a greater working memory capacity are more able to control their focus of attention compared to those with a lesser capacity. Children with ADHD display difficulty with working memory capacity (Barkley, 1997). This is largely due to their inability sustain attention and thus they are easily distracted. Inattention may stem from an inability to hold mental representations active, whilst using them to guide behaviour (Gathercole & Alloway, 2006). The ability to hold information in the mind, manipulate it and use it to guide behaviour, according to Schweitzer, Hanford and Medoff (2006), is a key part of executive functioning. It has been suggested that children with impaired executive functioning often exhibit many of the problems associated with ADHD. Oosterlaan, Scheres & Sergeant (2004) maintain that children diagnosed with ADHD consistently exhibit deficits in their executive functioning.

In a study conducted by Pineda, Ardila, Rosselli, Cadavid, Mancheo and Mejia (1998), executive functioning was investigated. One hundred and twenty-four children ranging in age from seven to 12 years old were tested using the *Wisconsin Card Sorting* and *WISC-R* tests. The sample was divided into two groups: sixty-two children diagnosed with ADHD and sixty-two normal matched controls. Results were interpreted as supporting the hypothesis of executive dysfunction in children with ADHD. In a similar study, Martinussen and Tannock (2006) tested executive functioning in children diagnosed with ADHD. The sample consisted of 96 children: 62 diagnosed with ADHD and 34 matched controls. It was found that children with ADHD exhibited significant impairments in their executive functioning.

As mentioned previously, working memory and thus executive functioning is closely associated with academic performance. Consequently, it would prove useful to highlight some of the difficulties that those with executive dysfunction may face when in the classroom. In the classroom, learners who are unable to concentrate, inhibit distractions and focus attention will have trouble following the teacher and thus processing information. When engaged in a mathematical problem, learners may have considerable mathematics knowledge, but may not be able to come up with a solution. This may be due to their difficulty in organising their ideas, coming up with a suitable strategy and mentally integrating information to solve a problem. Moreover, some learners may be unable to come up with solutions spontaneously or may get stuck using only a method of problem solving that is ineffective. Overall, it would seem that those with executive dysfunction have problems with attention, planning, organising, reasoning, judgement and impulsivity.

Although it would appear that there is significant evidence to suggest that children diagnosed with ADHD display impairments in executive functioning, other research has suggested otherwise. In a study looking at executive functioning in children with ADHD, Scheres, Oosterlaan, Guerts, Morein-Zamir, Meiran, Schut, Vlasveld and Sergeant (2004) found that when compared to a control group, those with ADHD did not show any significant differences in their executive functioning. In a similar study conducted by Geurts, Verte, Oosterlaan, Roeyers and Seargeant (2005), ADHD children were assessed using a *self-ordered pointing task.* The children in the study ranged in age from 6 to 13 years. Results failed to suggest executive functioning deficits in those with ADHD compared to a matched control group. This finding is akin to the Scheres et al. (2004) study.

According to Andrade, Baddeley and Hitch (2002), there is evidence to suggest that specific populations, such as those with ADHD, are associated with impairments in verbal and visuo-spatial working memory. This review will focus, initially, on the verbal component of the working memory system.

Baddeley (1998) maintains that the phonological loop is useful in explaining working memory deficits. In particular, one might assume that a deficit in the phonological store, might lead to impaired memory span. An example of this can be seen in research conducted by Kourakis, Katachanakis, Vlahonikonis and Paritsis (2004). These researchers examined verbal working memory (phonological loop system) in ADHD children (mixed inattentive and hyperactive/impulsive type sample). The children were aged between 7 and 11 years. It was found that when tested with a *serial recall task,* these children took more time than their controls to retrieve and express formerly memorised collection of unrelated verbal stimuli (Kourakis et al., 2004). This finding is backed up by research conducted by Norrelgen, Lacerda and Forssberg (1998). These researchers examined phonological working memory in children with ADHD. Nine children constituted the ADHD group and 19 children constituted the control group. All the children were matched in age. The children were exposed to two to five syllabic non-word pairs with contrasting vowels in order to test working memory load. It was found that the ADHD group scored significantly lower than the control group, indicating a greater sensitivity to working memory load (Norrelgen et al., 1998).

There are certain cognitive tasks that make use of the phonological loop, in particular, comprehension. Baddeley (1990) suggests that the phonological loop develops in the process of comprehension. In a study conducted by McInnes, Humphrines, Hogg-Johnson and Tannock (2003), it was found that children with ADHD were not as good at comprehending inferences and monitoring comprehension of instructions compared to matched controls (McInnes et al., 2003). Moreover, listening comprehension was impaired in the ADHD group. Another task that is thought to make use of the phonological loop is learning to read. According to Baddeley (1986) however, there is insufficient evidence to unequivocally ascertain the link between reading and the phonological loop. Consequently, a more suitable explanation might be that the phonological loop matures as speech production develops (Baddeley, 1990). In a study conducted by Baddeley and Gathercole (1989, as cited in Baddeley, 1990), results suggested that the phonological loop plays a pivotal role in language acquisition. Consequently, those with deficits in their verbal working memory may have difficulty in acquiring language and thus comprehending and reading.

According to Andrade, Baddeley, Hitch (2002), specific visual and spatial working memory impairments have also been reported. Research which noted a specific deficit in the spatial component of the working memory system, was that conducted by Karatekin and Asarnow (1998). Children (mean age 14 years) with a diagnosis of ADHD were tested using a *dot test.* Results indicated that children with ADHD display significant impairment in their spatial working memory. In another study conducted by Barnett, Maruff, Vance, Luk, Costin, Wood and Pantelis (2001), spatial working memory in children with ADHD was investigated. Findings showed that performance of children with ADHD was significantly worse on tasks involving spatial working memory than that of those in the control group.

Research that focuses solely on the visual component of working memory was conducted by Hill et al. (1999). Fifty children constituted the sample. Twenty-five children made up the ADHD group and 25 constituted the control group. Those children who made up the ADHD group were diagnosed according to the DSM-IV criteria. The researchers employed many visual and spatial tasks, namely *Children's Consonant Trigrams, Sequential Memory Test, WISC-III Digit Span, Mazes Subtests, Visual Two Back Memory Task, Temporal Order Memory, Memory and Verbal Learning Subtests, Visual Continuous Performance Task, Wisconsin Card Sorting Task* and *Controlled Oral Word Association.* Results from this investigation showed no significant differences between the ADHD group and the control group. Consequently, it appears that visual working memory does not seem to be impaired in those diagnosed with ADHD.

According to Westerberg, Hirvikoski, Forssberg and Klingberg (2004), few studies have measured both visual and spatial working memory in children with ADHD. Consequently, they deemed it necessary to investigate visuo-spatial working memory span in such children. The investigators employed a newly devised *visuo-spatial working memory* test and a *choice reaction time* test. A group of 80 children constituted the sample; 27 made up the ADHD group and 53 made up the control group, with a mean age of 11.4 years. Findings showed that deficits in visuo-spatial working memory are a major component of ADHD.

Another study investigating visuo-spatial working memory in children with ADHD was carried out by Rommelse, Stigchel, Witlox, Geldof, Deijen, Theeuwes, Oosterlaan and Sergeant (2008). Fourteen children constituted the ADHD group and 15 children without ADHD constituted the control group. The children were tested using a *memory-guided task* and results showed that visuo-spatial memory is impaired in children diagnosed with ADHD. In a further study conducted by Rapport, Alderson, Kofler, Sarver, Bolden and Sims (2008) visuo-spatial working memory was assessed in 23 children (12 ADHD, 11 controls) using tasks based on Baddeley's working memory model. Results from the study suggested that visuo-spatial working memory deficits were apparent in those diagnosed with ADHD.

According to Logie (1995) the visual aspect of visuo-spatial working memory is a passive system, containing information about fixed visual patterns. This part is thought to be associated with visual perception. The spatial aspect of the visuo-spatial working memory system holds dynamic information with reference to movement and movement sequences. This part is thought to be associated with the control of physical movement (Logie, 1995). Consequently, those children with visuo-spatial impairment may struggle to remember shapes or colours. Moreover, they may struggle to perform tasks, which involve planning of spatial movements, such as making their way through a complex multi-story school building or piecing together a puzzle.

The suggestions offered by the literature indicate that children with ADHD display deficits in their working memory. However, studies looking at the difference in working memory capacity between children with ADHD and those without an ADHD diagnosis offer conflicting results, possibly as a result of varying sample sizes. Consequently, it has not been unequivocally established whether there is a difference in working memory capacity between those with and without ADHD. Moreover, the difference in verbal and visuo-spatial working memory between these two groups also offer conflicting results and thus has yet to be firmly established. Considering these assertions, the present study aimed to investigate the differences in working memory between those with ADHD and those without an ADHD diagnosis. A secondary aim was to explore short-term memory deficits. As short-term memory and working memory largely share capacity limitations, it is suggested that these memories may tap, to some degree, the same construct (Colom, Shih, Flores-Mendoza & Quiroga, 2006). Consequently, it was deemed appropriate to look at and reflect on short-term memory deficits as well. There are several studies showing that working memory and intelligence are strongly related (Colom, Francisco & Rebollo, in press). As a result of this, this study used IQ as a covariate to ensure that the sample was equivalent in terms of general intelligence.

2.8. RESEARCH QUESTIONS AND HYPOTHESES

Are there significant differences between working and short-term memory capacities of children with ADHD and those without ADHD, over and above that which can be explained by the Raven's Coloured Progressive Matrices (IQ)?

- H_1 : The working memory capacity of children with ADHD will significantly differ from that of children without ADHD, over and above that which can be explained by IQ.

- H_2 : The short-term memory capacity of children with ADHD will significantly differ from that of children without ADHD, over and above that which can be explained by IQ.

Are there significant differences in verbal and visuo-spatial working and short-term memory between children diagnosed with ADHD and those without ADHD, over and above that which can be explained by the Raven's Coloured Progressive Matrices (IQ)?

- H_3: Children without ADHD will evidence better verbal short-term and working memory than children with ADHD, over and above that which can be explained by IQ.

- H_4: Children without ADHD will evidence better visuo-spatial short-term and working memory than children with ADHD, over and above that which can be explained by IQ.

CHAPTER 3

METHOD

3.1 RESEARCH DESIGN

In this study a quantitative, quasi-experimental design was implemented to assess the research questions. A quasi-experimental design is implemented without full control over the independent variables (Reber & Reber, 2001). The independent variable in this study is the presence or absence of an ADHD diagnosis whilst the dependent variables are the components of working memory. The experimental nature of this study implies a causal relationship between variables. Furthermore, the data obtained was interval.

3.2 SAMPLE AND SAMPLING

Approval in respect of request to conduct research was first and foremost obtained from the Gauteng Department of Education. Thereafter, a sample was located. In order to obtain a sample, a convenience sampling strategy was employed. Convenience sampling is a type of sampling procedure, which takes cases on the basis of their availability (Kelly, 1999). Owing to the fact that part of the sample consisted of children from a particular population, locating a large sample from one school was tricky. Consequently, three remedial schools were approached and included in this study. Furthermore, this study was proposed to several mainstream schools and learners from these schools constituted the control group (as described below). All the children that met criteria were invited to take part in the study. Once parental consent had been obtained from the parent/guardian, the child was included in the sample.

A sample of 92 Grade One and Two, first language English speaking children, where drawn from remedial and mainstream schools in Johannesburg; 27 were diagnosed (according to the DSM – IV- TR, 2000) with predominantly inattentive type ADHD, 25 were diagnosed with predominantly hyperactive/impulsive type ADHD, and 40 with no ADHD diagnosis. Each participant's diagnosis was located in his or her school file and every diagnosis was made by a psychiatrist. Those children diagnosed with ADHD constituted the ADHD group and those children with no ADHD diagnosis constituted the control group. Each sample group was largely matched relative to age and gender. However, it should be noted that the ADHD sample consisted of more males [33] than females [19]. This may be due to the fact that ADHD is two to nine times more common in boys than girls (Goldstein & Goldstein, 1992). The children ranged in age from 6 years and 8 months to 11 years and 3 months, with a mean age of 8 years and 2 months. Refer to Chapter 4, Table 1 for an illustration of the details above mentioned.

3.3 MEASURES

The Automated Working Memory Assessment (AWMA) and the Raven's Coloured Progressive Matrices (RCPM) were utilised in this study. An explanation of each follows:

3.3.1 The Automated Working Memory Assessment (AWMA)

The AWMA is a computerised instrument for evaluating short-term and working memory in children aged 4-11 years (Alloway et al., 2006). The test is made up of 12 subtests. Each subtest measures either short-term memory or working memory. Working memory subtests assess the child's ability to simultaneous hold and manipulate information, whilst short-term memory subtests are implicated in the child's ability to hold information in the mind. Short-term memory receives "minimal processing or interpretation" (Reber & Reber, 2001, p.426).

The AWMA consists of various tasks that assess verbal short-term memory, verbal working memory, visuo-spatial short-term memory and visuo-spatial working memory. The tasks are as follows; verbal short-term memory is measured by a *Digit Recall, Word Recall* and *Nonword Recall* tasks. In the Digit Recall task, the child hears a sequence of digits and has to recall each sequence in the correct order. The test-retest reliability for this task is 0.84 for children aged between 4.5 and 11.5 years (Alloway et al., 2006). In the Word Recall task, the child hears a sequence of words and has to recall each sequence in the correct order. The test-retest reliability for this task is 0.76 for children aged between 4.5 and 11.5 years (Alloway et al., 2006). In the Nonword Recall task, the child hears a sequence of nonsense words and has to recall each sequence in the correct order. The test-retest reliability for this task is 0.64 for children aged between 4.5 and 11.5 years (Alloway et al., 2006).

Verbal working memory is measured by a *Listening Recall, Counting Recall* and *Backward Digit Recall* tasks. In the Listening Recall task, the child hears a series of individual sentences and judges if each sentence is true or false. At the end of each trial, the child is asked to recall the final word of each sentence. The test-retest reliability for this task is 0.81 for children aged between 4.5 and 11.5 years (Alloway et al., 2006). The Counting Recall task involves a visual collection of red circles and blue triangles. The child is asked to count the number of circles shown. The test-retest reliability for this task is 0.79 for children aged between 4.5 and 11.5 years (Alloway et al., 2006). In the Backward Digit Recall task, the child hears a sequence of digits and has to recall each sequence in backwards order. The test-retest reliability for this task is 0.64 for children aged between 4.5 and 11.5 years (Alloway et al., 2006).

Visuo-spatial short-term memory is measured by a *Dot Matrix, Mazes Memory* and *Block Recall* tasks. In the Dot Matrix task, the child is shown the position of a red dot in a series of 4x4 matrices and has to recall this position by tapping the squares on the computer screen. The test-retest reliability for this task is 0.83 for children aged between 4.5 and 11.5 years (Alloway et al., 2006). In the Mazes Memory task, the child views a maze with a red path drawn through it. The task is to use a finger to trace in the same path on a blank maze presented three seconds later on the computer screen. The test-retest reliability for this task is 0.81 for children aged between 4.5 and 11.5 years (Alloway et al., 2006). In the Block Recall task, the child views a series of blocks being tapped and reproduces the sequence in the correct order by tapping on an image of the blocks. The test-retest reliability is 0.83 for children aged between 4.5 and 11.5 years (Alloway et al., 2006).

Visuo-spatial working memory is measured by an *Odd-One-Out, Mr. X* and *Spatial Span* tasks. In the Odd-One-Out task, the child views three shapes, each in a box presented in a row and has to identify the odd-one-out shape. The test-retest reliability is 0.81 for children aged between 4.5 and 11.5 years (Alloway et al., 2006). In the Mr. X task, the child views a picture of two Mr. X figures. The child is asked to identify whether the Mr. X with the blue hat is holding a ball in the same hand as the Mr. X with the yellow hat. At the end of each Mr. X trial, the child is asked to recall the location of each ball in the correct order, by pointing to a picture with eight compass points. The test-retest reliability is 0.77 for children aged between 4.5 and 11.5 years (Alloway et al., 2006). In the Spatial Span task, the child views a picture of two shapes. The shape on the right has a red dot above it. The child is asked to identify whether the shape on the right is the same or opposite of the shape on the left. At the end of each trial, the child is asked to recall the location of each red dot, by pointing to a picture with three compass points. The test-retest reliability is 0.82 for children aged between 4.5 and 11.5 years (Alloway et al., 2006).

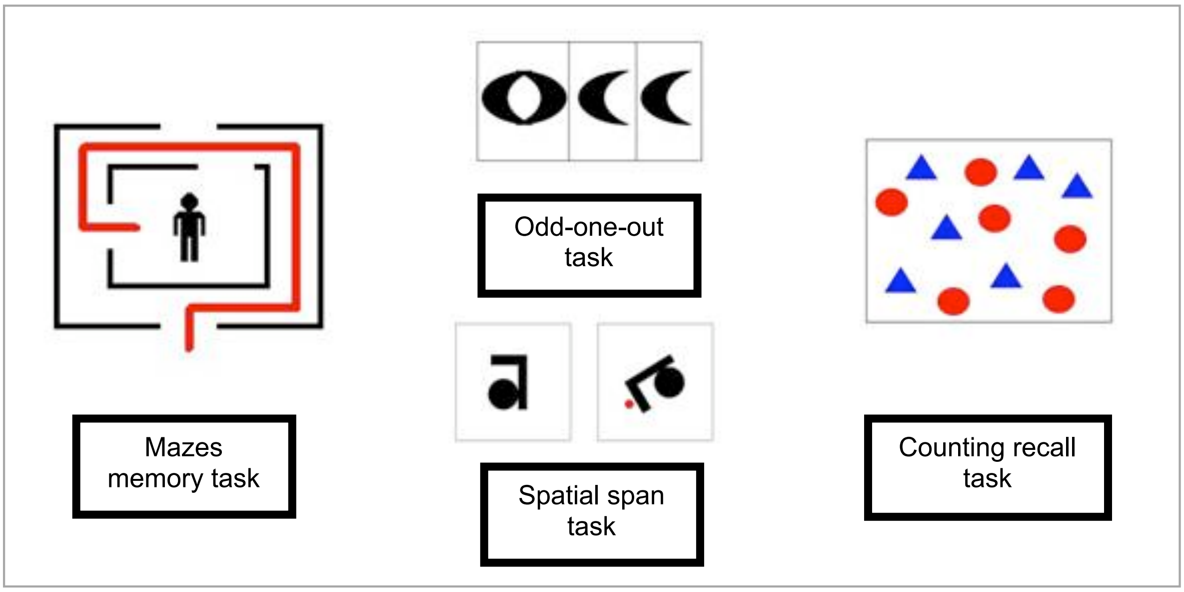
It can be seen from the above that valid and reliable tests of short-term and working memory are yielded. Up until the occurrence of Marconi (2006) research, the AWMA had not been used to assess South African children. A sample of North-East England primary school children were used in the standardisation of this test. Consequently, although previous research conducted by Marconi (2006) employed the AWMA to test a sample of South African children, caution should be exercised when generalising results to a South African population.

The administration procedure of the AWMA is as follows. A child is invited to sit in front of a computer, following which, the assessor starts the AWMA testing programme. Initially, a blank screen appears while instructions are given via a computerised voice. Subsequently, the child is offered practice trials. After the practice trials are completed, the child begins the actual test. The tasks are age-appropriate and the complexity of each task increases proportionally to the child's correct answers. The assessor records the child's responses, thus it is necessary that the testing manuals be studied thoroughly. Correct answers are recorded using the left arrow key and incorrect answers are recorded using the
right arrow key. The computer records answers both as raw scores and standardised scores. If three or more errors are made, the task automatically ends and the programme returns to its main screen. Subsequently, a new task may be run.

FIGURE 6

<u>An example of some AWMA tasks</u>

(Adapted from Alloway et al., 2006)



3.3.2 <u>The Raven's Coloured Progressive Matrices (RCPM)</u>

According to Raven and Raven (2003), the RCPM was designed to assess a person's capacity to form perceptual relations and to reason by analogy independent of language and formal schooling.

The RCPM is a paper-based assessment, exclusively used to assess young children and specialised populations. The participant is shown a matrix containing a series of patterns where one pattern is missing. A number of possible answers are presented and the participant chooses the pattern believed to be the missing one. As the test advances, the matrix items become more difficult, requiring more developed cognitive skill. The RCPM yields a test-retest reliability of 0.9 and an internal consistency of 0.9. When it comes to validity, however, it yields a poor predictive validity for academic criteria; between 0.35 – 0.55. For the purposes of this research the RCPM was employed to assess general intellectual ability, not academic performance.

3.4 <u>PROCEDURE</u>

This study made use of archival data, which was collected by Marconi (2006) and students under the supervision of Dr. Kate Cockcroft in 2006. Permission was granted by Dr. Kate Cockcroft for the researcher to access and analyse this previously collected raw data. The following describes the procedure used in the aforementioned research.

Once approval in respect of request to undertake this research was obtained from the Ethics Committee at the University of the Witwatersrand and permission had also been obtained from the Gauteng Department of Education, several schools were approached. Written consent (refer to Appendix A) was then obtained from either the heads of the schools or from the school's clinical director. Thereafter, parents/guardians were sent letters asking if they would allow their child to take part in the study. Once parental/guardian consent forms (refer to Appendix B) had been returned to the researcher, each school allocated a place on their premises for assessment to take place.

It was clearly explained to parents/guardians that there were no risks or benefits attached to their child's participation in the research. Moreover, the parent/guardian was free to remove their child from the study at any point, if they felt it necessary. A testing schedule was planned for each school. This was done in order to make sure that testing did not interfere with the children's studies and caused as little disruption for the school as possible. All learners with ADHD who were on medication, were requested not to take their medication on the day of testing. Once testing was completed the child was given his/her dose of medication.

On the day of testing, each child was told that the researcher was a student at the University of the Witwatersrand and that she was doing some research on children as part of her course. The AWMA and the RCPM were explained as fun games/activities to be played. Once the child had agreed to participate in the study, he/she was made to sign an assent form (refer to Appendix C). Each child was made explicitly aware that they could stop playing the fun games/activities whenever they wished to. Moreover, each child was told that they would not receive any 'special rewards' for their participation in the study and that there were no negative consequences if they wished to drop out of the study.

The researcher had studied the testing manuals and was well versed in the procedures involved before administering the psychological tests. The AWMA and the RCPM were administered individually in a quiet room on each school premises. The AWMA lasted approximately 1 hour and the RCPM lasted approximately 15 minutes for each child. The researcher made all efforts to stick closely to the requirements of the test, so as to eradicate experimenter bias. Each child's results were either recorded on an automated spreadsheet (AWMA) or manually, on a data sheet (RCPM). Each child was allocated a code to ensure confidentiality. Anonymity, however, could not be ensured due to the nature of the testing procedure. All information obtained during testing was used purely for the purposes of Marconi (2006) research and this study.

After all testing had been completed, analyses were run. The results of this analysis were written up and discussed in a report. This report did not make any specific reference to an individual child, but identified group trends. The report was issued to all the heads of schools and was available on request to those parents/guardians who were interested.

3.5 DATA ANALYSIS

Normal, parametric statistical tests were run, as the variables in this study appeared to follow normal distributions with minor deviations. A preliminary correlation analysis was carried out between the AWMA and the RCPM tests, to determine if any variables were related. Thereafter, a one-way analysis of covariance (ANCOVA) procedure was used to test the hypotheses of this study. To be more precise, this procedure was employed to test the effect of ADHD on working and short-term memory, controlling for the effects of IQ.

3.5.1 Power Analysis

This research utilised G*Power to perform a statistical power analyses. The holding power was set at 0.95, with $\alpha = 0.05$. The expected effect size was calculated at 0.30. Results from this analysis suggested that a total sample of 90 children were required for the research. Consequently, the power was sufficient.

CHAPTER 4

RESULTS

This chapter provides the preliminary and main results for this research study. The preliminary results section provides the descriptive statistics for the independent variables, ADHD and non-ADHD, as well as for the dependent variables, short-term and working memory, which was measured by the AWMA and the RCPM (Ravens).

The main results section details an ANCOVA procedure, which was carried out to determine differences in performance on the AWMA, over and above that which can be explained by the RCPM. In addition to this, the ANCOVA procedure was carried out to identify whether there were any significant differences in verbal and visuo-spatial short-term and working memory between the ADHD and non – ADHD groups.

4.1 PRELIMINARY RESULTS

4.1.1 Descriptive Statistics

Marconi (2006) found no significant differences in children diagnosed with ADHD, inattentive type and ADHD, hyperactive/impulsive type on measures of short-term and working memory. As such, it was deemed justifiable to combine the ADHD subtypes and look at them as one variable. Furthermore, as the ADHD sample consisted of more males [33] than females [19], it was thought necessary to look at the means and standard deviations of the sample, according to gender.

Table 1 provides the means and standard deviations for the AWMA and RCPM, as well as the number of participants that contributed to each test, as per gender.

Table 1. Means and Standard Deviations of the ADHD and Non - ADHD Data

		ADHD			Non - ADHD		
		Mean	**Std**	**n**	**Mean**	**Std**	**n**
Male	**RAVENS**	18.70	6.83	33	25.89	3.61	18
	VSTM	13.79	3.44	33	20.56	3.79	18
	VWM	7.73	3.54	33	12.98	2.19	18
	VSSTM	15.01	4.82	33	19.44	2.02	18
	VSWM	8.90	5.31	33	13.43	2.35	18
Female	**RAVENS**	18.47	6.10	19	22.64	4.48	22
	VSTM	16.09	3.30	19	20.60	3.33	22
	VWM	7.71	2.50	19	12.64	2.36	22
	VSSTM	13.28	3.66	19	18.77	3.19	22
	VSWM	8.05	3.84	19	12.01	2.79	22
Overall	**RAVENS**	18.62	6.51	52	24.10	4.38	40
	VSTM	14.63	3.54	52	20.58	3.50	40
	VWM	7.74	3.17	52	12.79	2.26	40
	VSSTM	14.38	4.47	52	19.07	2.72	40
	VSWM	8.56	4.80	52	12.65	2.66	40
Total				**52**			**40**

Note. RAVENS = RCPM score; VSTM = verbal short-term memory average; VWM = verbal working memory; VSSTM = visuo-spatial short-term memory; VSWM = visuo-spatial working memory.

RAVENS

ADHD group

The descriptive statistics suggest that the male participants had an overall mean of (M = 18.70), with a standard deviation of ($S.D.$ = 6.83). The descriptive statistics also suggest that the female participants had an overall mean of (M =18.47), with a standard deviation of ($S.D.$ =6.10). Overall, the participants had a mean of (M = 18.62), with a standard deviation of ($S.D.$ = 6.51).

Non – ADHD group

The descriptive statistics suggest that the male participants had an overall mean of (M = 25.89), with a standard deviation of ($S.D.$ = 3.61). The descriptive statistics also suggest that the female participants had an overall mean of (M =22.64), with a standard deviation of ($S.D.$ =4.48). Overall, the participants had a mean of (M = 24.10), with a standard deviation of ($S.D.$ = 4.38).

VSTM

ADHD group

The descriptive statistics suggest that the male participants had an overall mean of (M =13.79), with a standard deviation of ($S.D.$ =3.44). The descriptive statistics also suggest that the female participants had an overall mean of (M =16.09), with a standard deviation of ($S.D.$ = 3.30). Overall, the participants had a mean of (M = 14.63), with a standard deviation of ($S.D.$ = 6.54).

Non – ADHD group

The descriptive statistics suggest that the male participants had an overall mean of (M = 20.56), with a standard deviation of ($S.D.$ = 3.61). The descriptive statistics also suggest that the female participants had an overall mean of (M = 20.60), with a standard deviation of ($S.D.$ = 3.33). Overall, the participants had a mean of (M = 20.58), with a standard deviation of ($S.D.$ = 3.50).

<u>VWM</u>

ADHD group

The descriptive statistics suggest that the male participants had an overall mean of (M =7.73), with a standard deviation of ($S.D.$ = 3.54). The descriptive statistics also suggest that the female participants had an overall mean of (M =7.71), with a standard deviation of ($S.D.$ = 2.50). Overall, the participants had a mean of (M = 7.74), with a standard deviation of ($S.D.$ = 3.17).

Non – ADHD group

The descriptive statistics suggest that the male participants had an overall mean of (M = 12.98), with a standard deviation of ($S.D.$ = 2.19). The descriptive statistics also suggest that the female participants had an overall mean of (M =12.64), with a standard deviation of ($S.D.$ = 2.36). Overall, the participants had a mean of (M = 12.79), with a standard deviation of ($S.D.$ = 2.26).

VSSTM

ADHD group

The descriptive statistics suggest that the male participants had an overall mean of (M =15.01), with a standard deviation of ($S.D.$ = 4.82). The descriptive statistics also suggest that the female participants had an overall mean of (M =13.28), with a standard deviation of ($S.D.$ =3.66). Overall, the participants had a mean of (M = 14.38), with a standard deviation of ($S.D.$ = 4.47).

Non – ADHD group

The descriptive statistics suggest that the male participants had an overall mean of (M = 19.44), with a standard deviation of ($S.D.$ = 2.02). The descriptive statistics also suggest that the female participants had an overall mean of (M =18.77), with a standard deviation of ($S.D.$ =3.19). Overall, the participants had a mean of (M = 19.07), with a standard deviation of ($S.D.$ = 2.72).

VSWM

ADHD group

The descriptive statistics suggest that the male participants had an overall mean of (M =8.90), with a standard deviation of ($S.D.$ = 5.31). The descriptive statistics also suggest that the female participants had an overall mean of (M =8.05), with a standard deviation of ($S.D.$ =3.84). Overall, the participants had a mean of (M = 8.56), with a standard deviation of ($S.D.$ = 4.80).

Non – ADHD group

The descriptive statistics suggest that the male participants had an overall mean of (M = 13.43), with a standard deviation of ($S.D.$ = 2.35). The descriptive statistics also suggest that the female participants had an overall mean of (M =12.01), with a standard deviation of ($S.D.$ =2.79). Overall, the participants had a mean of (M = 12.65), with a standard deviation of ($S.D.$ = 2.66).

Testing for assumptions

Assumption of normality

The assumption of normality of the data was analysed using the Shapiro-Wilk test. The results indicated that three of the variables followed a normal distribution, whilst two of the variables followed a non-normal distribution. The two non-normal variables were Visuo-Spatial Short-Term Memory Average and Visuo-Spatial Working Memory Average. Owing to the fact that there is evidence to suggest that boys perform better than girls on visual – spatial tasks (McGuiness & Morley, 1991), it is suggested that the distribution is unlikely to be normal in the population. Consequently, normal, parametric statistical tests were run, as the variables appeared to follow normal distributions with minor deviations. The analysis of covariance procedure is robust to minor violations of the assumptions of normality (Howell, 2002). Additionally, the sample is hypothesised to have deficits in this area. Such non-normality may be reflective of those deficits, which may skew the distribution.

Assumptions of homogeneity, homoscedasticity and multicollinearity

Other assumptions of homogeneity, homoscedasticity and multicollinearity were tested. A plot of residuals using predicted values was employed and results suggested that none of the above mentioned assumptions were violated. Alpha levels are reported at a significance of $p < 0.001$ or 1%.

4.1.2. Correlational Procedure

A Pearson's correlation analysis was conducted to determine whether there were any significant relationships between the RCPM test and subtest averages on the AWMA as per the complete sample ($n = 92$) (see table 2). The results indicated that there was a significant correlation between the RCPM test and Group ($r = 0.44$, $p < .001$). Furthermore, the results indicated that there was a significant correlation between the RCPM test and Verbal Short-Term Memory Average ($r = 0.32$, $p < .001$), Verbal Working Memory Average ($r = 0.42$, $p < .001$), Visuo-Spatial Short-Term Memory Average ($r = 0.52$, $p < .001$) and Visuo-Spatial Working Memory Average ($r = 0.53$, $p < .001$).

Table 2. Correlation between the RCPM test and AWMA for the complete sample

	RAVENS	VSTM	VWM	VSSTM	VSWM
RAVENS	**1.000**	0.320*	0.421*	0.522*	0.533*
RAVENS		0.001	<.001	<.001	<.001
VSTM	0.320*	**1.000**	0.601*	0.418*	0.415*
VSTM	0.001		<.001	<.001	<.001
VWM	0.421*	0.601*	**1.000**	0.602*	0.690*
VWM	<.001	<.001		**<.**001	<.001
VSSTM	0.522*	0.418*	0.602*	**1.000**	0.730*
VSSTM	<.001	<.001	<.001		<.001
VSWM	0.533*	0.415*	0.690*	0.730*	**1.000**
VSWM	<.001	<.001	<.001	<.001	
Group	0.435*	0.647	0.669	0.525	0.454
Group	<.001	<.001	<.001	<.001	<.001

Note. RAVENS = RCPM score; VSTM = verbal short-term memory average; VWM = verbal working memory; VSSTM = visuo-spatial short-term memory; VSWM = visuo-spatial working memory.

* $p \leq 0.001$ (Correlation is significant at the 0.001 level (2-tailed))

4.2 MAIN RESULTS

4.2.1 ANCOVA Procedure

An ANCOVA was carried out to determine differences in performance over and above that which can be explained by the RCPM test (see Table 3). The findings showed:

VSTM

A one-way analysis of covariance was calculated comparing the ADHD participants with the non-ADHD participants on verbal short-term memory ability, as measured by the AWMA. The overall model was significant; $F(2, 91) = 32.21$, $p < .001$. However, the main effect of the covariate (IQ) was not significant $F(2, 91) = 0.28$, $p = 0.597$. The main effect of VSTM was significant; $F(2, 91) = 48.70$, $p < .001$. On VSTM, the non-ADHD group had a significantly higher mean (*M* = 20.58, *S.D.* = 3.50) than the ADHD group (*M* = 14.63, *S.D.* = 3.54), suggesting that participants in the non-ADHD group evidence significantly better VSTM abilities when compared to the ADHD group.

VWM

A one-way analysis of covariance was calculated comparing the ADHD participants with the non-ADHD participants on verbal working memory ability, as measured by the AWMA. The overall model was significant; $F(2, 91) = 39.12$, $p < .001$. However, the main effect of the covariate (IQ) was not significant $F(2, 91) = 3.48$, p = 0.065. The main effect of VWM was significant; F (2, 91) = 48.61, p < .001. On VWM, the non-ADHD group had a significantly higher mean (*M* = 20.58, *S.D.* = 3.50) than the ADHD group (*M* = 14.63, *S.D.* = 3.54).

VSSTM

A one-way analysis of covariance was calculated comparing the ADHD participants with the non-ADHD participants on visuo-spatial short-term memory ability, as measured by the AWMA. The overall model was significant; F (2, 91) = 27.50, p < .001. Furthermore, the main effect of the covariate (IQ) was significant F (2, 91) = 15.27, p < .001. The main effect of VSSTM was significant; F (2, 91) = 15.79, p < .001. On VSSTM, the non-ADHD group had a significantly higher mean (*M* = 20.58, *S.D.* = 3.50) than the ADHD group (*M* = 14.63, *S.D.* = 3.54).

VSWM

A one-way analysis of covariance was calculated comparing the ADHD participants with the non-ADHD participants on visuo-spatial working memory ability, as measured by the AWMA. The overall model was significant; F (2, 91) = 23.46, p < .001. Furthermore, the main effect of the covariate (IQ) was significant F (2, 91) = 18.89, p < .001. The main effect of VSWM was significant; F (2, 91) = 8.26, p < .001. On VSWM, the non-ADHD group had a significantly higher mean (*M* = 20.58, *S.D.* = 3.50) than the ADHD group (*M* = 14.63, *S.D.* = 3.54).

Table 3. ANCOVA analyses results by Group

		F - Value	Pr > F
VSTM	RAVENS*	0.28	0.597
	Group	48.70	<.001
	Total	32.21	<.001
VWM	RAVENS*	3.48	0.065
	Group	48.61	<.001
	Total	39.12	<.001
VSSTM	RAVENS*	15.27	<.001
	Group	15.79	<.001
	Total	27.50	<.001
VSWM	RAVENS*	18.89	<.001
	Group	8.26	<.001
	Total	23.46	<.001

Note. RAVENS = RCPM score; VSTM = verbal short-term memory average; VWM = verbal working memory; VSSTM = visuo-spatial short-term memory; VSWM = visuo-spatial working memory.

* Covariate

CHAPTER 5

DISCUSSION

5.1 SUMMARY OF RESULTS

The hypotheses in this study were supported by the results obtained. For each hypothesis, IQ was controlled for. Analysis of the data for the first hypothesis of the study indicated that there was a significant difference between the working memory capacities of children with ADHD and those without ADHD. The findings for the second hypothesis indicated that there was a significant difference between the short-term memory capacities of children with ADHD and those without ADHD. Results for the third hypothesis showed a significant difference in verbal short-term and working memory between children diagnosed with ADHD and those without ADHD. Lastly, the findings for the fourth hypothesis indicated a significant difference in visuo-spatial short-term and working memory between children diagnosed with ADHD and those without ADHD. Furthermore, results suggested that much of the observed IQ difference between the groups was attributable to spatial reasoning deficits.

Although the short-term memory tasks of the AWMA were included in the analysis, short-term memory is not the main aim of this study. The primary aim of this study was to identify whether there were any significant differences in working memory between children with ADHD and those without ADHD. Consequently, the short-term memory findings will be looked at and reflected upon, but will not constitute the main focus of this discussion. The above-mentioned results will now be addressed in more detail.

5.2 DISCUSSION OF RESULTS

The covariate, RCPM was used as a control measure to ensure that the children, who constituted the sample, were equivalent in terms of general intelligence. Preliminary results suggested differences in IQ between the ADHD and non-ADHD groups. According to Goldstein and Goldstein (1992), the possible differences in IQ may be attributable to an ADHD child's limited self-control and poor capacity to sustain attention. This, it is believed, may lower an ADHD child's ability to acquire certain intellectual skills.

Researchers have found that children who have a greater working memory capacity will be more able to control their focus of attention than those with a lesser working memory capacity (Colflesh & Conway, 2007). Barkley (1997) and Oosterlaan, Scheres and Sergeant (2004) assert that children with ADHD have impairments in their working memory capacity, largely due to their inability to sustain attention. Consequently, it was hypothesised that the working memory capacity of children with ADHD would significantly differ from those of children without ADHD. More specifically, it was considered that the presence of ADHD would impact negatively on a child's executive functioning capabilities.

The results for the first question indicated a global short-term and working memory capacity deficit for those children with ADHD. This implies that children with

ADHD may struggle to both hold and manipulate information in their minds. Owing to the fact that one's ability to hold and manipulate information is a key part of executive functioning (Schweitzer, Handford & Medoff, 2006), results suggest executive dysfunction in those with ADHD. This is consistent with the findings obtained by Martinussen and Tannock (2006) and Pineda, Ardila, Rosselli, Cadavid, Mancheo and Mejia (1998), who found executive dysfunction in children diagnosed with ADHD.

It has been noted that executive functioning is inextricably linked to academic achievement. Consequently, findings for the first question may suggest that children with ADHD will have problems with attention, planning, organising, reasoning, judgment and impulsivity. These skills are necessary for performing certain tasks in the classroom. Accordingly, children with ADHD may be unable to concentrate and thus will have difficulty following the teacher or completing a task. Moreover, these children may display particular difficulty in carrying out mathematical problems.

Although it would appear that there is significant evidence to suggest that children diagnosed with ADHD display impairments in their executive functioning capabilities, findings from studies conducted by Scheres et al. (2004) and Geurts, Verte, Oosterlaan, Roeyers and Seargeant (2005) have suggested otherwise. Results from these studies did not indicate executive dysfunction in those diagnosed with ADHD. According to Howell (2004), as a sample increases in size, the shape of its distribution inevitably approaches normal, no matter the shape of its original population. Consequently, the possible non-significant findings of the above mentioned studies might have been as a result of reduced power due to the small sample size used in each. The Scheres, Oosterlaan, Guerts, Morein-Zamir, Meiran, Schut, Vlasveld and Sergeant (2004) study included a total of 45 participants in their study; 23 with ADHD and 22 matched controls. The Geurts, Verte, Oosterlaan, Roeyers and Seargeant (2005) study included a total of 48 participants in their study; 32 with ADHD and 16 matched controls.

Another possible explanation for the non-significant findings in the Scheres et al. (2004) study is that some of the children who constituted the ADHD group had a comorbid Oppositional Defiant Disorder or Conduct Disorder. Symptoms of these disorders were not entered in as covariates. Consequently, the final results of this study might have been affected by the presence of these two disorders.

This research was based on Baddeley and Hitch's (1974) proposition that working memory can be measured in two ways, namely verbally and visuo-spatially. Evidence from the literature, which focuses on the differences in verbal and visuo-spatial working and short-term memory between those with ADHD and those without, yield conflicting results. Consequently, this study deemed it appropriate to test these differences.

The results for the third hypothesis indicated that much of the observed IQ difference between the groups was not attributable to verbal deficits. This may be due to the fact that less than 10% of the variance in verbal IQ is accounted for by ADHD (Goldstein & Goldstein, 1992). Thus, the population of those children diagnosed with ADHD may generally fall along a normal distribution in regards to intellectual ability. The results for the third hypothesis also suggested that there were significant group differences between VSTM and the ADHD and non-ADHD groups and between VWM and the ADHD and non-ADHD groups. On the VSTM measure, the non-ADHD group had a significantly higher mean than the ADHD group and on the VWM measure, the non-ADHD group had a significantly higher mean than the ADHD group. Ostensibly this would suggest that children without ADHD evidence better verbal short-term and working memory than children with ADHD. These results are consistent with the findings obtained by Kourakis, Katachanakis, Vlahonikonis and Paritsis (2004) and Norrelgen, Lacerda and Forssberg (1998), who found that children without ADHD performed better on verbal (phonological) working memory tasks than those with ADHD.

It has been noted that certain cognitive tasks make use of the phonological loop. Consequently, certain cognitive deficits arise when verbal working memory is impaired. Owing to the fact that children with ADHD evidence poorer verbal working memory than those without ADHD, it might be plausible to suggest that they may struggle with verbal working memory tasks in the classroom. It has been noted that the acquisition of language is directly associated with the verbal working memory system. Consequently, children with ADHD may display difficulty in acquiring language. As a result of this difficulty, these children may struggle with comprehension and possibly reading.

The results from the fourth hypothesis suggested that there were significant differences in IQ between the ADHD and non-ADHD groups. Raven and Raven (2003) maintain that the RCPM measures two aspects of general intelligence. The first aspect focuses on one’s ability to think clearly and make sense of complicated information. The second aspect focuses on one's ability to store information. Working memory can be thought of as the moment-to-moment maintenance of information (Baddeley & Logie, 1999). Consequently, it can be seen that certain aspects of the RCPM are akin to the working memory system. This assertion has been reinforced by study conducted by Klinberg, Forrsberg and Westerberg (2002), which notes that the type of complex reasoning found in the RCPM is similar to that found in the working memory system. Moreover, it has been suggested that the RCPM tasks rely heavily on spatial reasoning (Allsopp, 2008). Consequently, spatial reasoning deficits may account for much of the observed IQ difference noted between the ADHD and control groups.

The results from the fourth hypothesis also suggest that there were significant group differences between VSSTM and the ADHD and non-ADHD groups and between VSWM and the ADHD and non-ADHD groups. On the VSSTM measure, the non-ADHD group had a significantly higher mean than the ADHD group and on the VSWM measure, the non-ADHD group had a significantly higher mean than the ADHD group. This would suggest that children without ADHD evidence better visuo-spatial short-term and working memory than children with ADHD. These results are consistent with those obtained by Westerberg, Hirvikoski, Forssberg and Klingberg (2004), Rommelse, Stigchel, Witlox, Geldof, Deijen, Theeuwes, Oosterlaan and Sergeant (2008) and Rapport, Alderson, Kofler, Sarver, Bolden and Sims (2008), which found visuo-spatial working memory impairment in those diagnosed with ADHD.

To be more specific, the results from the fourth hypothesis suggest spatial working memory impairment in those with ADHD. This finding is consistent with the results obtained by Karatekin and Asarnow (1998) and Barnett, Maruff, Vance, Luk, Costin, Wood and Pantelis (2001), which noted particular impairment in the spatial element of the visuo-spatial component, in those with ADHD. As a result of this, it is suggested that children with ADHD may struggle to perform tasks associated with a particular movement or sequence of movements. These tasks involve making one's way through a complex school building or piecing together a puzzle.

The results from the fourth hypothesis also suggest a visual working memory deficit in those with ADHD. Consequently children with ADHD may struggle to perform visual working memory tasks in the classroom. Owing to the fact that the visual aspect of visuo-spatial working memory system contains information about fixed visual patterns, it seems plausible to suggest that those with ADHD may struggle to remember such things as shapes or colours.

This last finding, however, is not consistent with that obtained by Hill, Campbell, Yeo, Vigil, Seeger, Bailey and Yager (1999). These researchers suggest that visual working memory is not affected by the presence of ADHD. Again this non-significant result may be as a result of the relatively small sample size found in this study (n = 25 ADHD and n = 25 matched controls).

Owing to the fact that the presence of ADHD appears to have a detrimental effect on a child's short-term and working memory performance in the classroom, it seems reasonable to recommend suitable remediation practices.

5.3 RECOMMENDATIONS

According to Pickering (2006), remediation interventions have tended to focus on the behavioural problems noted in those with ADHD. However, it has been suggested that the working memory problems found in children with ADHD may also be responsive to treatment. Four major interventions have been proposed in the remediation of working memory deficits of those with ADHD (Pickering, 2006). These include, acting as surrogate executive controls, teaching of organizational strategies, working memory training and stimulant medications. Each will be described in below, in brief.

5.3.1 Acting as surrogate executive controls

It has been suggested that teachers (and parents) may be used to assist those with executive dysfunction by standing in as substitute executive controls. Essentially, this implies that teachers have to provide suitable activities. During these activities, teachers can offer advice and suggest possible goals, as well as other forms of planning, organizing, and thinking (Cox, 2006).

Standing in as a substitute can also be invaluable in helping ADHD children gain insight into the association between performance and result. For example, teachers can illustrate the possible consequences of inhibiting behaviour as well as the possible consequences of impulsive behaviours (Cox, 2006).

Teachers can work alongside parents to actively reinforce the interventions above-mentioned. This will inevitably improve a child's self-awareness and thus self-esteem.

5.3.2 The teaching of organisational strategies

An intervention that focuses specifically on executive performance in children with ADHD is the teaching of organisational strategies, namely *self-monitoring, verbal mediation* and various higher level problem solving strategies (Pickering, 2006). It has been suggested that this type of teaching occur in addition to other types of interventions, such as computerised working memory training.

5.3.3 Computerised working memory training

It has been suggested that working memory can be trained by intensive computer-based programs. In these programs, children are provided with repeated practice on computerised versions of either a verbal or visuo-spatial working memory tasks (Pickering, 2006). It is suggested that repeated practice will lead to improvement in children's working memory. An example of such a program is *RoboMemo.* The AWMA may also be used as a computerised training system.

5.3.4 Stimulant medications

According to Pickering (2006), stimulant medications have traditionally been used to treat hyperactivity. However, there is growing support for the notion that these medications may also be useful in treating certain working memory deficits. Methylphenidate, better known as Ritalin, is the most well recognised and commonly used stimulant medication. It has been shown to improve performance on certain tasks in the classroom. These involve both working memory and executive tasks (Pickering, 2006). Modafinil has also shown promise in improving working memory function in those with ADHD. However, more research is needed before sufficient evidence can be found in support of this medication

5.4 LIMITATIONS

Following the completion of this study, specific limitations were identified:

5.4.1 Limitations related to the sample

The sample in this study was drawn from numerous mainstream and remedial schools. The teaching strategies utilised in these schools may have differed somewhat and thus performance on the assessment tasks may have varied slightly. Consequently, one must exercise caution when generalising the results of this study to a larger population.

Owing to the fact that the ADHD participants were enrolled at remedial schools, it might have been possible that some may have had a comorbid learning or developmental disorder that the researcher was unaware of. Consequently, it is possible that these comorbid disorders may have impacted on the results obtained.

A further limitation centres on the fact that certain children in the sample had repeated a grade at school. Owing to this, these children had already gained some skills over and above that gained by those, who had not repeated a grade. Consequently, making comparisons between children in the same grade, may have distorted assessment scores.

5.4.2 Limitations related to data collection

Owing to the fact that this study made use of archival data, the following limitations were those acknowledged by Marconi (2006) and Allsopp (2008).

The full assessment took approximately one hour and fifteen minutes per child to complete. During this time, the child was not allowed to take a break. This was due to teachers' requests that children spend as little time as possible away from the classroom. The children found concentrating for this period of time to be particularly difficult, especially the ADHD children, who were off their medication. Consequently, these children would often mention that they were tired and needed to break or that the tasks were no longer fun. Moreover, some children were sick and thus had trouble concentrating. Some were hungry but were not allowed to exit the testing space to get some food. Lastly, some of the children that were tested closest to the middle of the day complained that they were hot and thus fatigued. These confounding effects may have altered the findings of this research.

As mentioned previously, the AWMA was standardised using North-East England primary school children. Consequently, the accent of the automated voice that is used to give instructions is British. Some of the children found it difficult to follow the instructions and thus would inevitably provide the wrong answer. As a result of this, the findings were then a reflection of a misinterpretation, rather than an indication of a poorly functioning working memory system.

Some of the children who were enrolled at the remedial schools had received or were receiving Occupational and Speech therapy. Consequently, these children may have been exposed to tasks similar to the ones in the AWMA. Owing to this, the practice effect may have come into play and thus children's performance on the tasks may have been better than expected.

Most children displayed particular difficulty with the *Listening Recall* subtest. Children struggled to provide answers for this task, even after further explanation. Consequently, it might be possible to suggest that this test is too advanced for those ranging in age from 6 to 9 years. As a result of this, the scores obtained from this test were not a true reflection of a child's verbal working memory abilities.

5.4.3 Limitation related to the analysis

As mentioned previously, there were significant differences in IQ between the ADHD and non-ADHD groups on the VSSTM and VSWM tasks. Accordingly, IQ may not, in fact, have acted as a covariate in this analysis. Consequently, the results obtained may have been imprecise.

CHAPTER 6

CONCLUSION

6.1 RELEVANCE OF THIS RESEARCH

As mentioned previously, South African teachers are becoming more cognisant of children at risk of developmental disorders, such as ADHD. Moreover, they are becoming aware that these developmental disorders interfere with a child's optimal academic achievement. Owing to this, this research deemed it important to study the effects of ADHD on short-term and working memory and link these effects to performance in the classroom.

The existing theoretical literature on ADHD and working memory offers a foundation for the findings of this research and thus generates a structure for suitable remediation practices. Owing to this, this research can aid in recognising the specific areas of working memory that are affected by the presence of ADHD and consequently offer classroom remediation practices that target these affected areas.

6.2 CONCLUSIONS

In conclusion, the hypotheses of this study were largely supported by the results obtained. Significant differences between working and short-term memory capacities of children with ADHD were found. Furthermore, significant differences in verbal and visuo-spatial working and short-term memory between children diagnosed with ADHD and those without ADHD were also found. Lastly, results suggested that much of the observed IQ difference between the groups was attributable to spatial reasoning deficits.

The results of this research were supported by many studies. These studies provide evidence of the associations between ADHD and working memory as well as the link between the RCPM and the working memory system. Owing to the fact that the hypotheses yielded significant results, it was recommended that certain remediation practices be put in place.

6.3 DIRECTIONS FOR FUTURE RESEARCH

It may be useful to incorporate IQ as a variable in future studies that explore the differences in short-term and working memory between those with ADHD and those without. To be more precise, it might prove useful to test IQ using other modalities, to unequivocally ascertain whether IQ is a deficit in those with ADHD or whether differences in IQ are attributable to spatial reasoning deficits. It may also be beneficial to test differences in performance on the AWMA and RCPM tasks, when children are both on and off their prescribed ADHD medication. Lastly, it may be useful to focus more closely on the effect that ADHD has on short-term memory.

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APPENDIX A

UNIVERSITY
OF THE
WITWATERSRAND,
JOHANNESBURG

School of Human and Community Development
Private Bag 3, Wits 2050, Johannesburg, South Africa
Tel: (011) 717-4500 Fax: (011) 717-4559

Dear Principal/Head of school

My name is Daniela Marconi, and I am conducting research for the purposes of obtaining an Honours degree at the University of the Witwatersrand. My area of focus is that of working memory, and how it is affected by Attention Deficit Hyperactivity disorder. This research aims to explore whether there is a difference in working memory between children diagnosed with ADHD, predominantly hyperactive/impulsive type and predominantly inattentive type. I would like to ask permission for your learners to participate in this study.

Participation in this research will entail each learner being tested by myself, both via computer and paper at a time which is most convenient for your school. The two tests combined will last for approximately one hour. With your permission a learner's results from the tests will be recorded and used, in combination with others, in my final research report. Participation is voluntary, and no learner will be advantaged or disadvantaged in any way for choosing to participate or not participate in the study. All of your learners' results will be kept confidential, and no information that could identify your learners will be included in the research report. The test material will not be seen or heard by any person at any time, and will only be processed by myself. Your learner may refuse to answer any questions and may choose to withdraw from the study at any point. There is no personal risk involved for the learner in participating in the study.

If you choose to let your learners participate in the study please fill in your details on the form below. I can be contacted telephonically at 082 841 0937 or via e-mail at dcmarconi@webmail.co.za. Contact with my supervisor Kate Cockcroft can be made via email: cockcroft@umthombo.wits.ac.za or telephonically: (011) 717 – 4511.

Your learners' participation in this study would be greatly appreciated. This research will contribute both to a larger body of knowledge on working memory, as well as the remediation and diagnosis of ADHD in the future. Feedback re: group trends on the tests will be given to the school on request.

Kind Regards
Daniela Marconi

Consent form

I……………………………………… as the principal/head of the school, provide permission for Daniela Marconi to test my learners for the purposes of her research report. I understand that:

- Learners' participation in this study is voluntary.
- Learners may refuse to answer any questions he/she would prefer not to.
- Learners may withdraw from the study at any time.
- No information that may identify learners will be included in the research report, and his/her responses will remain confidential.
- There is no personal risk involved in participating in the study.

Signed……………………………………

My contact details:
Tel: ……………………………………..
E-mail:…………………………………..

APPENDIX B

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

School of Human and Community Development
Private Bag 3, Wits 2050, Johannesburg, South Africa
Tel: (011) 717-4500 Fax: (011) 717-4559

Dear Parent/Guardian

My name is Daniela Marconi, and I am conducting research for the purposes of obtaining an Honours degree at the University of the Witwatersrand. My area of focus is that of working memory, and how it is affected by Attention Deficit Hyperactivity Disorder. This research aims to explore whether there is a difference in working memory between children diagnosed with ADHD, predominantly hyperactive/impulsive type and predominantly inattentive type. I would like to invite your child to participate in this study.

Participation in this research will entail each child being tested by myself, both via computer and paper at a time, which is most convenient for your child's school. The two tests combined will last for approximately one hour. With your permission your child's results from the tests will be recorded and used, in combination with others, in my final research report. Participation is voluntary, and no child will be advantaged or disadvantaged in any way for choosing to participate or not participate in the study. All of your child's results will be kept confidential, and no information that could identify your child will be included in the research report. The test material will not be seen or heard by any person at any time, and will only be processed by myself. Your child may refuse to answer any questions and may choose to withdraw from the study at any point. If at all possible, we would like your child not to take his/her prescription medication on the day of testing. Once testing is completed, your child can take his/her medication.

If you choose to let your child participate in the study please fill in your details on the form below, along with your child's details on the attached biographical form and place it in the envelope provided. It would be most appreciated if you could send the sealed envelope back to your child's teacher, from whom I can collect them. I will contact you if it is necessary, alternatively I can be contacted telephonically at 082 841 0937 or via e-mail at dcmarconi@webmail.co.za. Contact with my supervisor Kate Cockcroft can be made via email: cockcroft@umthombo.wits.ac.za or telephonically: (011) 717 – 4511.

Your child's participation in this study would be greatly appreciated. This research will contribute both to a larger body of knowledge on working memory, as well as the remediation and diagnosis of ADHD in the future. Feedback re: group trends on the tests will be given on request.

Kind Regards
Daniela Marconi

Consent form

I………………………………………….. provide consent for my child to be tested by Daniela Marconi for her study on working memory and Attention Hyperactivity Deficit Disorder. I understand that:

- My child's participation in this study is voluntary.
- My child may refuse to answer any questions he/she would prefer not to.
- My child may withdraw from the study at ant time.
- No information that may identify my child will be included in the research report, and his/her responses will remain confidential.
- There is no risk involved in my child's participation in the study.

Signed …………………………………………..

I will allow my child to be off his/her medication during testing, but placed back on it directly after testing. Please circle: **YES / NO**

Please provide contact details so that I can inform you of when your child will be tested.

My contact details:
Tel:………………………………………………
Cell:…………………………………………..
E-mail: …………………………………………..

To guarantee confidentiality, please ensure that you return this consent form, as well as the biographical questionnaire in the sealed envelope.

CODE:

Biographical questionnaire – ADHD and Working memory study

Name: ……………………………………………………………………………………

Surname: …………………………………………………………………………………

Sex: ………………………………………………………………………………………..

Date of birth: ………………………… Age: ……………………………………..

Grade (please specify if a grade has been repeated):

……………………………………………………………………………………………

Ethnic group: ……………………………………………………………………………

Home language: ………………………………………………………………………..

Diagnosis (please tick appropriate box):

ADHD: hyperactive/impulsive type ☐

ADHD: inattentive type ☐

ADHD: combined type ☐

Who diagnosed your child?

……………………………………………………………………………………………

Is your child on any medication? If so, please specify:

……………………………………………………………………………………………

Please specify your child's marks thus far in his/her schooling career (this information will remain confidential and will only be accessed by the researcher):

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APPENDIX C

Assent form

Hello children

My name is Daniela Marconi and I'm learning psychology at the University of Witwatersrand. I'm doing some research on children and I'm here to ask you if you would like to join in on my research. If you don't want to join you don't have to and you won't get any special rewards if you do join. If you take part, you will do a fun activity on the computer and you will look at some patterns on paper. I must make it clear to you, that no one but I will see your answers to the activities. If you want to participate, please write your name in the empty space below.

I……………………………………….. provide assent to be tested by Daniela Marconi for her study on working memory and Attention Hyperactivity Deficit Disorder. I understand that:

- Doing these tasks is my choice.
- I may stop at any time.
- No one but Daniela will see my answers.
- I will not be in any danger if I choose to join in on the study

Signed ………………………………………..