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WORKING MEMORY AND READING COMPREHENSION ABILITIES IN GRADE 4 BOYS

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Abstract

WORKING MEMORY AND READING COMPREHENSION ABILITIES IN GRADE 4 BOYS

Amber Jean Sadler

The purpose of this study was to research the relationship between working memory and reading comprehension abilities in grade 4 boys. The need for this research can be traced, in part, to the poor performance of learners in literacy in South Africa. It has become imperative to explore ways of enhancing learners' ability to extract meaning from what they read and to give them the tools to enable them to be lifelong learners. Currently, there seems to be little research regarding working memory and reading comprehension ability conducted within a South African context. Accordingly, this study sought to better understand why learners do not always respond to reading intervention and to identify the specific educational needs that should be addressed in the classroom.

This study used the Hodder Group Reading Test and The Automated Working Memory Assessment (AWMA) to evaluate the learners' working memory and reading comprehension abilities. Data for this research was then analysed using statistical methods. The data analysis demonstrated a positive linear relationship between reading comprehension and working memory in grade 4 boys i.e. as reading comprehension increases so does working memory.
It is hoped that the knowledge gained in this study will add to South African perceptions regarding working memory and reading performance.

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“Life is all memory except for the present moment that flies by so quickly we can hardly catch it going by.”

- **Tennessee Williams**

CHAPTER 1

WORKING MEMORY AND READING

Introduction

Much of our childhood is devoted to developing complexly cognitive skills that, as adults, we may take for granted. For example, the cognitive skills involved in higher order thinking permeate even ‘basic skills’ such as reading and simple arithmetic (Meadows, 2012). Dealing with a mathematical problem, for example, consists of identifying the numerical symbols, accessing relevant knowledge that may be entirely mathematical or may be real-life general knowledge, and producing the appropriate solutions (Meadows, 2012). When people read a text, the reader employs a combination of identifying or decoding words, retrieving relevant linguistic information, topic facts and genre knowledge already stored in memory, and ‘high level’ general cognitive processes such as formulating inferences, observing connections, checking and organising text information and supplementary external information, deleting irrelevant material and so on, in order to construct a mental image the writer wanted to stimulate in the reader (Meadows, 2012). These skills allow us to obtain the greatest benefits from education and from life overall.

For many years psychologists have been interested in trying to identify cognitive processes that may underlie such intricate cognitive activities. One promising cognitive process is working memory (Minear & Shah, 2006). Those who cannot encode, store, or retrieve information must depend on others for their survival (Dehn, 2011). Over the past 35 years, in the study of human cognitive functions, working memory has been one of the most significant constructs (Dehn, 2011). It is difficult to define and disentangle working memory from similar cognitive processes such as reasoning (Dehn, 2011). From a broad viewpoint, working memory is a central cognitive process that is responsible for the efficient processing of information (Dehn, 2011). According to Lepine, Barouillet, and Camos (2005), working memory appears to be an essential capacity underlying complex as well as elementary cognitive processes. Working memory assists human cognitive processing by supplying an interface between perception, short-term memory, and goal-directed behaviour. Essentially, working memory is one of the principal cognitive processes underlying thinking and learning (Dehn, 2011). By utilizing the contents of various working memory storage systems, working memory assists us in learning and connecting thoughts and ideas (Dehn, 2011).

In the early school years, large parts of the curriculum are dedicated to reading or reading – related activities. To become proficient learners, students need to be able to assess what they need to learn and how to achieve their learning goals (*PISA 2009 Results*, 2010). In addition, they need to become skilled in a wide range of cognitive and meta-cognitive information-processing strategies to be able to develop effective ways of learning (*PISA 2009 Results*, 2010). Developing one's reading skills is essential to both school and professional success (Christo, Davis, & Brock, 2009). Reading is a foundational skill that is vital in acquiring content knowledge in academic spheres such as science and social studies (Christo, Davis, & Brock, 2009). In Lyon's (2001) statement *to the Subcommittee on Education Reform*, he states that, all through their schooling, and into young adulthood, children with reading difficulties, feel embarrassment and devastation when reading with difficulty in front of peers and teachers. It is clear from NICHD research (Lyon, 2001) that this type of failure affects children negatively earlier than was thought. By the end of first grade, children having difficulty learning to read begin to feel less confident about themselves than when they began school. As children progress through the middle school years, self-esteem and the enthusiasm to learn to read deteriorate even further. In many cases, the students are deprived of the opportunity to learn about literature, science, mathematics, history, and social studies as they are unable read grade-level material (Lyon, 2001). Bear in mind that by middle school, children who are proficient readers, read at least 10 000 000 words in the course of the school year. Conversely, children who experience difficulties with reading, read less than 100 000 words during the year (Lyon, 2001). Even when one considers, in this digital age, when students use the internet, whether it be to search for a site for information, to read material for interest and pleasure, or to scan a text for a class assignment, they must utilise reading comprehension strategies just as is required when they read print-based text (Cohen & Cowen, 2007). The ultimate goal is for students to understand what they read and to use the information in an efficient manner (Cohen & Cowen, 2007). Due to search engines like Google and Yahoo, the world has experienced a great transformation in how to seek, weed out, and absorb information (Alloway & Alloway, 2013). We live in the Google age and in cognitive terms, Google is wonderful. It has significantly decreased the amount of cerebral resources that we formerly had to devote to searching for facts before we could do something with them (Alloway & Alloway, 2013). As a result of Google and similar search engines, we no longer need to rely so much on crystallized knowledge—remembering facts, dates, or names—associated with IQ and the traditional notion of intelligence (Alloway & Alloway, 2013). With just a few clicks, we can access almost any information we require. The key to knowledge today is being able to connect those facts, prioritize the information, interpret and make sense of the information and utilize it in a productive manner in order to be effective (Alloway & Alloway, 2013).

Reading and school performance

Special attempts are made to identify those at risk for reading problems (De Jong, 2006). In classrooms every day there are children who have not completely understood what they have read. The RAND Reading Study Group[1] (Cohen & Cowen, 2007), examined major concerns regarding reading for understanding to determine what we still need to know about reading comprehension. The research findings indicate that more information needs to be known about this critical skill. An understanding of the process of reading is considered by some to be ultimately rewarding (Cain, 2010). Huey suggested (1909), that to completely analyse the processes applied when reading would be to describe many of the most intricate workings of the human mind.

According to the Department of Education's National Reading Strategy (2008), systematic evaluations conducted by the Department of Education, provincial Departments of Education and international bodies, only 51% of learners in South African schools could read at age appropriate levels. If learners do not comprehend what they read, it affects their performance in all subjects across all grades. Without adequate support, many children with reading comprehension difficulties may not be able to compensate for the numerous difficulties that they encounter in understanding what they read; however, suitable support can make a difference despite the many obstacles that may arise (Woolley, 2011). Considering the poor performance in literacy of students in South Africa, now more than ever, literacy proficiency appears to be essential. It is imperative to explore ways of enhancing learner's ability to extract meaning from what they read and to give them the tools to enable them to be lifelong learners. There is one

[1]" The RAND Reading Study Group (RRSG) is a non-profit institution that was charged with developing a research framework to address the most pressing issues in literacy" (Snow, 2001:1).

skill that can give them the advantage of organising all this information, namely, working memory.

Currently, there seems to be little research regarding working memory and reading comprehension ability conducted within the South African context. Therefore, the assessments of working memory could furnish the means to measure learners' ability to remember and to learn in methods that are culture-fair; not asscociated with the socioeconomic status of the child's family, to the nature of pre-school care or to the culture or home language of the learner (Gathercole & Alloway, 2008). In a country such as South Africa with vast cultural diversity and socioeconomic variations and with reported poor performance in reading as evidenced by achieving the lowest score of all 45 education systems in the Progress in International Reading Literacy Study (PIRLS, 2006), research into an important cognitive aspect of reading is vital.

Statement of the problem

In South Africa, over the past decade, one of the national preoccupations has been on the crisis in secondary schools. Lurking behind the significant problem of low pass rates and dysfunctional schools is the calamity of primary school education (Fleisch, 2008). Monitoring Learning Achievement (MLA) was one of the first substantial cross-national studies of quality in which South Africa participated. As part of the UNESCO/UNICEF 'Education for All' campaign, the study involved national samples of Grade four learners (Fleisch, 2008). The study consisted of more than 10 400 learners, in 400 schools over all nine provinces (Fleisch, 2008). The literacy task comprised of 30 items centering on word recognition; understanding of detail content; writing skills; spelling; grammar; retrieving information, and providing information.

Strauss and Berger (Fleisch, 2008), reported that almost 44 per cent of learners scored below 25 per cent, in the literacy area.

Research (Fleisch, 2008), has been conducted in South Africa concerning the link between socioeconomic status, poverty, underqualified teachers, the legacy of apartheid, and HIV/AIDS, and learning underachievement. Working memory problems, however, occur irrespective of socioeconomic status or quality of education. Research has shown that 10-15% of children in mainstream schools experience working memory difficulties. Many of the learning activities that children are involved within the classroom impose considerable burdens on working memory. The capacity to hold information whilst mentally engaged in other relevant activities is crucial to many learning activities, especially reading comprehension (Gathercole & Alloway, 2007).

There appears to be much confusion regarding which components of working memory have the most significant effect on reading comprehension. Baddeley (Fisher, 2008) stated that research should turn towards identifying both the central executive processes of working memory, and the individual roles that the phonological loop and visuo-spatial sketchpad (a detailed description of these concepts is presented in the following chapter), play in working memory performance. It may be beneficial to measure and assess each aspect of working memory individually, in order to fully comprehend the nature of working memory and determine where deficits may lie (Fisher, 2008).

Collectively much research exists regarding working memory and reading comprehension. However, the researcher believes that the assumptions made and conclusions reached in international research cannot be assumed to be applicable to the South African context, and need to be investigated in order to generalise to the South African population.

Purpose of the study

Based on the above-mentioned, there appears to be a strong relationship between some children's ability to understand text and their working memory capacity (Cain, 2006). Consequently, this research attempted to identify the relationship between these entities. To achieve this objective, it was the purpose of the study to focus on reading comprehension and its relationship to working memory of young schoolboys. Insights gained by such an investigation may provide opportunities for educators to enhance learning in children with working memory problems.

Motivation for the study

Acquiring the profile of boy's working memory strength and weaknesses is particularly valuable in identifying effective learning support for boys (Gathercole & Alloway, 2008). Gathercole and Alloway (2008) suggest that children with deficits in working memory struggle in the classroom because they are unable to hold in mind the required information to allow them to complete the task. As losing valuable information from working memory will cause them to forget many things, they will struggle to achieve standard rates of learning and so will make poor general academic progress. Many of the learning tasks that learners are engaged with in the classroom, whether concerned with reading, mathematics, science, or other spheres of the curriculum, impose substantial burdens on working memory (Gathercole & Alloway, 2007). A practical example of our use of working memory in everyday life is mental arithmetic, whereby, one attempts to multiply two two-digit numbers whilst not using a paper and pencil, or a calculator (Gathercole & Alloway, 2004). To successfully complete this arithmetic, the two numbers need to be stored and then multiplication rules systematically applied, storing the intermediate results that are created as we proceed through the steps of the calculation (Gathercole & Alloway, 2004). Completing such a mental activity is likely to result in the loss of all the stored information, with a minor disturbance such as an unrelated thought springing to mind or an interruption by someone else (Gathercole & Alloway, 2004). As learners show frequent breakdowns in four aspects of routine classroom activities, namely forgetting instructions, losing track in complex tasks, difficulty coping with simultaneous processing and storage demands and longer-term forgetting, these areas help teachers in early recognition of potential working memory deficits in learners (Further engagement regarding working memory in the classroom is presented in chapter 6) (Gathercole & Alloway, 2004).

The likelihood that children with working memory deficits will face academic difficulties in school was investigated by Alloway, Gathercole, Kirkwood, and Elliot (Alloway & Alloway, 2010) using the Automated Working Memory Assessment. These learners were more likely to perform poorly in key learning outcomes such as reading and were more likely to be inattentive, forgetful, and easily distracted, leading to careless mistakes. The inattentiveness of children with poor working memory occurs as children lose the essential information needed to guide the on-going task, and so attention is shifted away from the activity. In this way, working memory deficits may masquerade as failure of attention (Gathercole & Alloway, 2008).

Research has shown that 10-15% of children in a mainstream classroom will display working memory impairments that will jeopardise their academic success (Alloway, 2009). In a large-scale screening study (Alloway, 2011) of over 3000 typically developing learners, 1 in 10 students were struggling with working memory impairments.

Evidence suggests that working memory impairments in childhood are not the result of a ‘developmental lag’ (Alloway, 2012). In education there are significant applications for the remarkable growth of working memory during the school years. In a longitudinal study (Alloway & Alloway, 2010), working memory skills at 5 years old was a better predictor than fluid intelligence of literacy and numeracy six years later.

As working memory is not linked to the parents' level of education, socio-economic status, or financial background this mean that children irrespective of upbringing or environmental influence can receive the same opportunities to achieve their potential if working memory is assessed and intervention implemented where necessary (Alloway, 2011). This has powerful implications in a country such as South Africa where the inequalities of the past are well known.

The table below shows the relationship between the composite scores in the Automated Working Memory Assessment (AWMA) and socio-economic status (SES) indices such as maternal educational level, age the mother left school, and the child's pre-school experience. None of these associations were significant at an alpha level of .05 (Alloway, 2007). On the basis of 600 children aged between 4 and 12 years old, we can observe that performance on the AWMA is not strongly associated with failures in pre-school experiences or education, or with the quality of social or cerebral stimulation at home (Alloway, 2007).

Table 1

The correlation coefficients between performance on the AWMA and socio-economic status

SES factors	Verbal short-term memory	Verbal working memory	Visuo-spatial short-term memory	Visuo-spatial working memory
Age mother left school	.21	.14	.19	.12

Mother's educational level	.25	.23	.28	.18
Number of years in a pre-school	-.003	.06	-.01	.07

Source. (Alloway, 2007:61).

Engel, Santos and Gathercole (Alloway, 2011), compared rural, low-income children with those from wealthy, urban areas of Brazil in IQ and working memory tests. The urban learners far exceeded their rural counterparts in the vocabulary test used to measure IQ because they had more experience using the words on the test. Surprisingly, however, they were no better than the rural students on the working memory tests. This suggests that working memory measures provide nonbiased measures of cognitive abilities and offer a clinically valuable index of learning disabilities, regardless of socio-economic background (Alloway, 2007). The implications of this study are very relevant to the South African population as students from deprived backgrounds have the same ability to succeed. It is not an issue of IQ but a matter of giving these children the same opportunities to unlock their working memory potential (Alloway, 2011). The Department Of Education released a White Paper 6 (EWP6, 2001) on Inclusive Education which is based on the view that ‘All children can learn.’ The aim is to enable education structures to meet the needs of all learners.The finding that working memory is a more effective predictor of later academic success than IQ, has valuable implications for education (Alloway & Alloway, 2009) and the Department of Education's view that all children can learn. This is because working memory tests measure something different from IQ tests, they measure our potential to learn, whereas IQ tests measure knowledge that we have already learned. Many studies show that children with high IQ don't achieve well at school (Alloway, 2011). In the researcher's experience as a learning support teacher, it was noted that so many learners fail to make significant gains after individual or small group instruction over a period of 2 years or more. In a study conducted by Alloway (2011), of children from 8 to 11 years old who received extra educational support, like tutoring and special classes, their IQ and working memory were tested and their grades assessed. These learners received special tutoring in small groups for the next two years, however after this period they were still performing at the bottom of their grade. Importantly, it was their working memory scores and not their IQ scores that determined their grades. If they had low working memory scores, they struggled in reading, writing and maths. It did not even matter what their IQ scores were. Working memory was, according to Alloway (2011), the critical skill linked to their learning. This study is important as it appears that focusing on teaching reading and reading comprehension skills, is not enough.

Without early intervention, working memory impairments cannot be rectified over time and will continue to affect a child's likelihood of academic success. The practical implications suggest that identification of significant working memory problems can lead to effective management and support to bolster learning (Alloway, 2009).

Currently, there seems to be little research regarding working memory and reading comprehension ability conducted within the South African context. Thus, working memory assessments could offer a means of measuring learners' ability to remember and to learn in ways that are culture-fair; not related to the socioeconomic status of the learner's family, to the quality of pre-school care and to the culture or home language of the learner (Gathercole & Alloway, 2008). In a country such as South Africa with vast cultural diversity and socioeconomic variations and with reported poor performance in reading as evidenced by attaining the lowest score of all 45 education systems in the PIRLS study (2006), research into an important cognitive aspect of reading is vital.

Key research questions

The main aim of this study is to explore the relationship between working memory and reading comprehension ability in grade 4 boys.

The research questions are:

1. What is the reading comprehension ability of grade 4 boys?
2. What is the working memory of grade 4 boys?
3. Is there a relationship between working memory and reading comprehension of grade 4 boys?
4. Is there a relationship between verbal working memory and reading comprehension of grade 4 boys?
5. Is there a relationship between visuo-spatial working memory and reading comprehension of grade 4 boys?

Theoretical and conceptual frameworks

The theoretical framework for this investigation was Baddeley and Hitch's influential model of working memory (a detailed engagement regarding this model is explored in the literature review) which was first formulated in 1974 and subsequently refined by Baddeley in 2000. This model provides a theoretical framework with which to describe the relationship between the working memory system and reading comprehension. According to Lefrançois (2012) Baddeley's model of working memory attempts to clarify the process involved in paying attention, in learning, and in remembering.

The Baddeley and Hitch model suggests that because working memory is flexible, should the phonological loop reach capacity or is unusable, the other components, the central executive and visuo-spatial sketchpad, kick in (a detailed description of these concepts is presented in the following chapter) (Smith & Kosslyn, 2008).

This model of working memory has been validated by evidence from studies of children by Alloway, Gathercole, & Pickering (Alloway, 2007) and [2]neuroimaging investigations by Valler & Papagno (Alloway, 2007) and has survived more than 30 years of academic scrutiny (Pickering, 2006).

The working memory model is a prominent theory of memory devised to account for how we temporarily manipulate and store information during thinking and reasoning tasks (Henry, 2011). The model helps us comprehend how memory processes are used during day to day recurring activities, or during more demanding tasks that involve greater effort and new thinking (Henry, 2011). One approach in understanding working memory is to contemplate the types of memory we require while we read, do the crossword/Sudoku, or track the News headlines. One of the main concepts to understand about working memory is that it is limited in capacity, which implies that we cannot store and manipulate limitless amounts of information. Therefore, the types of thinking and remembering tasks we can undertake will be restricted by working memory resources.Working memory also limits, in part, the types of things we can handle simultaneously. Whilst there are some tasks that can be carried out concurrently, other types of tasks compete for the same resources within the working memory system and, therefore, impede each other. Working memory is vital because it supports skills in many other spheres, for example, reasoning, learning and comprehension (Henry, 2011).

[2] “Neuroimaging refers to measurement methods that provide anatomical localisation of neural activity” (Grondin, 2008:261).

Design and procedures

The research used convenience sampling to select the sample due to practical constraints. The research was conducted in a boys' primary school. The participants were Grade 4 boys who volunteered for the study. It was beneficial to source children from a comparable socio-economic group, as this would enhance the probability of obtaining a cohort receiving the same standard of education. As more boys than girls appear to experience deficits with working memory (Gathercole & Alloway, 2008) this study was conducted with boys in a primary school. In addition, the most recent administration of the Programme for International Student Assessment (PISA), male students were outperformed by female students in literacy in every country (Klinger, Shulha, & Wade-Woolley, 2009). 50 Grade 4 English language learners were assessed individually on the Automated Working Memory Assessment (AWMA) (Alloway, 2007) and the Hodder Group Reading Test 2 (HGRT-2) (Vincent & Crumpler, 2007).

Summary of chapter

Chapter 1 has provided an overview of the focus and aims of the current research, and it has provided definitions of the key concepts and terms used in this study. In addition, the motivation for this study, the specified purpose, and a brief overview of the methodology used was presented. A review of the related literature will be presented in Chapter two. Chapter 3 will present a description of the research design, including an annotation of the participants, the methodology for data collection, the manner in which that data was analysed, and the instrumentation used in this study. The results of the investigation outlined in Chapter 3 will be presented in Chapter 4.

CHAPTER 2: LITERATURE REVIEW

Introduction

This literature review focuses on previous and current research conducted in the fields of working memory and reading comprehension and the correlation between these two skills. While many theories have been proposed to explain working memory, this literature review will focus on Baddeley and Hitch's model of this construct which forms the framework on which this study is created. A brief historical overview of the development of the working memory construct is discussed and the varying individual differences of working memory capacity. The controversy surrounding which components of working memory have the most significant effect on reading comprehension, leads to a discussion concerning the measurement of working memory. The Baddeley and Hitch model (Alloway, Gathercole & Pickering, 2006), suggests a domain-general account of working memory capacity, whereas Miyake and colleagues propose a domain-specific account of working memory. An in-depth discussion ensues regarding the particular relationship between working memory and reading comprehension.

Reading Comprehension

Learning to read involves the acquisition of word-decoding ability and the ability to comprehend written text. In the early phases of learning to read, when text comprehension appears dependent on the ability to identify the individual words in the text, these skills are highly related. As reading acquisition progresses, the relationship between the two is inclined to weaken (De Jong, 2006).

The primary goal of reading, according to Vukovic and Siegel (2006), is reading comprehension. They emphasise that reading comprehension is a complex process that requires both the process of print and the construction of meaning of what is being read. To gain meaning from text, readers must not only read and understand the individual words in the text, but they must be able to read accurately and fluently, access the necessary background information, make inferences, hold information in memory, and employ self-monitoring skills.

Text comprehension is a complex cognitive skill that draws on a variety of processes.

“Reading is a complex cognitive skill that draws on a variety of processes. These include perceptual processes, word-level processes that encode the visual pattern of a word and access its meaning, sentence-level processes that compute syntactic parsing and semantic integration, and text-level processes that establish both the local and global organisation of the whole text” (Seigneuric & Ehrlich, 2005:617). Reading can be challenging. Readers may understand each word independently, but converting them into meaningful ideas often fails to happen as it should (McNamara, 2007).

According to Pretorius (Cekiso, 2012), reading is a powerful learning tool, a way of deriving meaning and obtaining new knowledge, however, poor reading comprehension is cited as a central feature of academic underperformance in South Africa. A pilot study conducted by Dreyer (Cekiso, 2012), in a multilingual classroom in the North West Province, showed a failure rate of approximately 75% on a reading comprehension test. Results from the The South African National Reading Panel systematic evaluation in 2008 (Cekiso, 2012), showed that amongst the Intermediate Phase learners, 63% of the learners were below the required standard for their age level, regarding reading comprehension.

When matched with control children on measures of reading accuracy and non-verbal ability, children with poor comprehension abilities perform substantially below that of the controls. A question then, is why these children find it so difficult to derive coherent meaning from what they have read (Pimperton & Nation, 2010). One explanation has been suggested in terms of underlying deficits in the working memory processes that are necessary for skilled reading comprehension (Pimperton & Nation, 2010).

In most circumstances, the ultimate goal of reading is comprehension. Working memory performs an important function in this process by storing the words that have been recognised for a sufficient amount of time to enable the reader to link the words together to construct a meaningful interpretation of the text (Gathercole & Alloway, 2008).

According to Van den Broek (Meneghetti, Carretti, & De Beni, 2006), current models of reading comprehension emphasise the importance of considering the function of different cognitive processes during text comprehension. He adds, for example, that the reader must store and manipulate information in working memory during the processing of the text and simultaneously refer to his/her prior knowledge to construct a coherent representation of the text.

Working memory has been the focus of much interest to researchers as it is invaluable in predicting higher order cognition such as academic achievement and sentence comprehension (Magimairagaj & Montgomery, 2012), in fact it has been stated that, “Working memory is one of the most heuristic and important concepts of cognitive psychology” (Barrouillet, Bernaerdin, Portrat, Vergauwe, & Camos, 2007:570).

The development of sufficient reading comprehension skills is crucial to learner’s success at school and to other essential developmental outcomes (Wigfield & Guthrie, 2010). Children who are proficient comprehenders, have the opportunity to learn content in many different school subjects (Wigfield & Guthrie, 2010). If learners cannot extract meaning from what they read this affects all subjects at all grades. Without adequate support, many children with reading comprehension difficulties may not be able to compensate for the many difficulties that they confront in understanding what they read, however, suitable support can make a difference regardless of the many difficulties that may arise (Woolley, 2011).

Working memory

Before discussing the evidence from literature connecting working memory with reading comprehension, it is necessary to first consider what is meant by working memory. Working memory is an extremely useful and adaptable system that we exercise in our everyday life. It is often described as a mental workspace where we can store important information whilst engaged in complex mental activities (Gathercole & Alloway, 2004). An example of a task that relies on working memory, in everyday life, includes measuring and mixing the exact amounts of ingredients (e.g. pour in 30g of butter and 200g of flour, and then add 2 eggs) when you have just read the recipe but are no longer looking at the page (Gathercole & Alloway, 2007). Substantial evidence suggests that working memory plays a crucial role in learning, especially during childhood (Gathercole & Alloway, 2004).

According to a News Reporter-staff News Editor at Pain and Central Nervous System Week (Acton, 2013:74), new research originating from Cape Town, South Africa, by NewsRX correspondents, researchers stated, “Working memory is a vital cognitive capacity without which meaningful thinking and logical reasoning would be impossible. Working memory is integrally dependent upon prefrontal cortex and it has been suggested that voluntary control of working memory, enabling sustained emotion inhibition, was the crucial step in the evolution of modern humans” (Acton, 2013:74).

Student’s often have to hold information in mind while simultaneously engaged in an effortful activity. For example they may have to remember a sentence they have to write whilst trying to spell the individual words (Gathercole & Alloway, 2007). Working memory is essential when dealing with novel information, problems or situations, trying to inhibit irrelevant information, maintaining new information, and consciously retrieving information from long-term memory (Dehn, 2011).

Baddeley and Hitch proposed the dynamic concept of working memory in their model which was first formulated in the year 1974 and was subsequently refined by Baddeley in 2000. The components of the Baddeley-Hitch model interact to provide a comprehensive workspace for cognitive activity (Smith & Kosslyn, 2008). This multicomponent model proposes that two domain-specific slave systems, namely the phonological loop and the visuo-spatial sketchpad, subserve the short term storage of verbal and visual information respectively (Pimperton & Nation, 2010). The operation of the two slave systems are controlled by the domain-general central executive and plays an important role in attentional control. Baddeley later modified the model to accommodate findings that the original model was unable to account for. This revision included the episodic buffer which is a limited-capacity storage system that integrates information from multiple mnemonic sources in order to generate multi-dimensional representations, or ‘episodes’ (Pimperton & Nation, 2010).

The central executive system

The central executive is the most crucial and complex component of working memory, but is the least understood (Baddeley, 2006). The component that most clearly differentiates the concept of working memory from previous conceptions of “short-term memory” is the central executive system (Smith & Kosslyn, 2008). The central executive system oversees the entire process involved in paying attention, in learning, and in remembering and supervises and controls our cognitive processing (Lefrançois, 2012). It is responsible for focusing, dividing, and switching attention and for the coordination of its auxiliary systems (the phonological loop and the visuo-spatial sketchpad) and retrieval of information from long-term memory (Nevo & Breznitz, 2011).

Specifically, "the central executive system (1) determines when information is deposited in the storage buffers; (2) determines which buffer- the phonological loop for verbal information or the visuo-spatial sketchpad for visual- is selected for storage; (3) integrates and coordinates information between the two buffers; and, most important, (4) provides a mechanism by which information which is held in the buffers can be reviewed, transformed, and otherwise cognitively manipulated. These functions all rely on the central executive's system to control and assign attention" (Smith & Kosslyn, 2008:259).

Studies involving the problem of dual-task coordination have supported the notion of the central executive system. This process involves simultaneously executing two discrete tasks, each of which typically requires storage of information in working memory (Smith & Kosslyn, 2008). The assumption is that controlling performance of the two tasks requires some sort of time-sharing. If the central executive system is specifically needed to manage the coordination – the time-sharing – of the two tasks, then it should be possible to find effects of dual-task performance in addition to those present when each of the tasks is performed in isolation (Smith & Kosslyn, 2008).

As it coordinates the storage and processing of incoming information, it is this component of working memory that is most strongly associated with reading comprehension (Cain, 2011).

The role of the central executive system in reading comprehension.

It is quite easy to see why there may be a relationship between reading comprehension and working memory capacity with regard to the functions of the central executive system (Cain, 2010). In order to read with understanding, readers need to integrate information from different sentences in a text and incorporate background knowledge and ideas (retrieved from long-term memory) to make sense of details. In addition, readers must monitor their understanding in order to make links between events and identify when inferences should be made. To engage in these processes the reader must retain the just-read wording in memory while simultaneously processing the same or other information (Cain, 2010).

Considering the complex processing demands of reading comprehension, studies leave little doubt that executive working memory is another primary determinant of effective comprehension (Dehn, 2011).

In addition to the central executive, there are at least two systems, referred to as slave systems, to maintain verbal and visual/spatial information. The two slave systems are labeled the phonological loop, which maintains verbal information, and the visual-spatial sketch pad, which is concerned with the processing of material that is visual or spatial.

The phonological loop.

The phonological loop is thought to be involved in language learning (Smith & Kosslyn, 2008). It is believed to store verbal and acoustic information utilising two subcomponents: a temporary storage system that stores memory traces for a few seconds, after which they decay unless refreshed by the second component, the subvocal rehearsal system. The subvocal rehearsal system maintains the held information and enables a visually presented item (Nevo & Breznitz, 2011).

In other words, verbal working memory involves both a ‘mind’s ear’ (that hears the information when you read it) and a ‘mind’s voice’ (that repeat’s the information in rehearsal) (Smith & Kosslyn, 2008).

The subvocalization uses inner speech to rehearse the items, successively retrieving them from the temporary storage and feeding the information back by means of articulation, hence the term “articulatory loop” (Baddeley, 2006). The clearest evidence for the articulatory rehearsal process is the word-length effect. Participants recall approximately 80% of sequences of single-syllable words correctly, whereas, performance drops to around 50% if word length is increased to supply sequences of polysyllabic words such as refrigerator, university and electricity. (Baddeley, 2006). The key feature seems to be the time it takes to pronounce the words and not necessarily the number of syllables per se. Performance is poorer for two-syllable words that contain long vowel sounds, such as harpoon and voodoo, than for two-syllable words with short vowel sounds, such as bishop and wiggle (Smith & Kosslyn, 2008). This fits the model neatly, based on the assumption that longer words take longer to articulate during rehearsal, allowing a greater degree of trace decay which results in poorer performance (Baddeley, 2006). This model accounts for the word-length effect by the postulation that pronunciation time affects the speed of silent rehearsal, which requires speech-based processing (Smith & Kosslyn, 2008).

Baddeley and Hitch’s model of phonological storage, with regard to the word length effect, accounted for the results of research conducted by Shallice and Warrington (Baddeley, 2003) by assuming that Short Term Memory patients do not access the phonological loop, presumably as one or more components is defective. This notion received support from Vallar and Baddeley (Baddeley, 2003), who studied a patient, PV, with a very clear phonological immediate memory deficit. She, like other such patients, had normal language production, and normal comprehension, provided that the text was not overly complex whereby comprehension depended upon retaining the surface structure of the sentence beginning, in order to allow subsequent disambiguation. This study suggests that the biological function of the phonological loop might be to serve as a backup to comprehension (Baddeley, 2003). However, a second hypothesis was that the system evolved in order to facilitate the acquisition of language. Studies of patients with lesions resulting in phonological loop deficits support the hypothesis of separate storage and rehearsal systems, with Brodmann area 44 being the cortical area associated with storage, while subvocal rehearsal appears to be associated with Broca's area (Brodmann areas 6 and 40) (Baddeley, 2003).

In formulating their model Baddeley and Hitch (Baddeley, 2012), referred to the loop and sketchpad as slave systems, borrowing the expression from control engineering. However, Baddeley suggests that it is becoming increasingly apparant that the loop can also supply a means of action control. The loop is, according to Baddeley (2012), perhaps the most developed and widely investigated component of working memory, it is, however, only one limited component of working memory.

It seems intuitive that the phonological loop performs a function in language processing, because it is incorporated with language comprehension and production systems (Smith & Kosslyn, 2008).

The role of the phonological loop in reading comprehension.

Much research has supported Baddeley and Hitch's phonological working memory as an important source of individual differences in reading (Berninger, Abbott, Swanson, Lovitt, Trivedi, Lin, Gould, Youngstrom, Shimada, Amtmann, 2010). According to Baddeley (Berninger, et al, 2009) the phonological loop functions as a language learning mechanism for pairing names (phonological buffer) with objects (visual-spatial sketch pad) or situations (episodic buffer) in early vocabulary learning. By means of the phonological loop, Baddeley proposes that acoustic speech information can be held momentarily under attentional control for the purposes of reading comprehension (Askildson, 2008). Evidence posits that the system is involved in both native language acquisition and second language learning in both children and adults (Baddeley, 2006). Several reading and working memory researchers propose that diminished working memory capacities, particularly in the phonological and verbal subcomponents, are associated with impaired development of decoding skills and reading comprehension (Dehn, 2011).

The visuo-spatial sketchpad.

"The ability to develop, inspect, and navigate through a mental image is considered to be a cardinal function of visuospatial working memory" (Smith & Kosslyn, 2008:256). The visuo-spatial sketchpad integrates spatial, visual, and possibly kinesthetic information into a cohesive representation that may be temporarily held and manipulated (Nevo & Breznitz, 2011).

The capacity for spatial visualization has been studied psychrometrically for several years, through tasks such as block counting, whereby, a two-dimensional depiction of a stack of blocks is displayed and the participant is required to decipher how many blocks are involved, including those that are out of sight (Baddeley, 2006). Studies suggest that mental navigation is essentially a spatial process (Smith & Kosslyn, 2008).

According to Baddeley and Lieberman (1980), the definite action of moving the mind's eye from one spatial location to another also implies that visuo-spatial working memory may possibly depend on brain systems that plot movements of the eyes (or perhaps other parts of the body), just as verbal working memory depends on brain systems concerned with shaping speech.

This movement planning system may also be the basis for spatial rehearsal, which is the process of mentally refreshing stored locations to keep them highly available. The idea is that when you rehearse spatial locations in working memory (think of mentally visualising directions to turn left at the next street, and then right at the robot) you are actually employing the same systems that would help you move your eyes or body toward that location. Just as rehearsal of verbal information does not require actual speech, it is believed that rehearsal of spatial information does not require actual eye (or body) movements. Rather, spatial rehearsal may involve covert shifts of attention to memorize spatial locations (Smith & Kosslyn, 2008).

Application of the visuo-spatial sketchpad to educational issues is still at a relatively early stage; however an encouraging start has been made in studying the development of visuo-spatial working memory (Baddeley, 2006).

The role of the visuo-spatial sketchpad in reading comprehension.

The sketchpad is clearly of less significance to language disorders than is the phonological loop. However, it seems likely that the system will be involved in everyday reading tasks, where it may be concerned with maintaining a representation of the page and it’s layout that will remain constant and facilitate tasks such as moving the eyes accurately from the end of one line to the beginning of the next (Baddeley, 2003).

An unforeseen role for the visuo-spatial sketchpad in reading comprehension was realised as part of a study of the grammatical capacity of people with William’s syndrome. This genetic condition is characterised by an unusual pattern of learning difficulties. The pattern includes relatively preserved verbal skills, together with impaired visuo-spatial processing (Baddeley, 2003). The results suggest that the cognitive capacities and the ability to maintain and manipulate information that is of a visuo-spatial nature is likely to perform an important function in language comprehension (Baddeley, 2003).

Murray and Kennedy (1988), have proposed that spatial working memory is important for place-keeping skills in reading comprehension. These place-keeping skills of fluent readers allow them to re-inspect text selectively, and children who are good readers are more adept at re-inspecting text selectively than poor reads. Although spatial working memory does not predict reading comprehension in adults, it may predict comprehension in children when these skills that depend on spatial working memory are developing, since the demands of the relevant memory systems may be greater (Oakhill, Yuill & Garham, 2011).

The episodic buffer.

All the work described thus far can be viewed as fitting with the original three-component Baddeley and Hitch model, however, over the years a number of phenomena have transpired that do not fit the pattern (Baddeley, 2006). A study by Baddeley and Wilson (Baddeley, 2006), of immediate and delayed text recall in a range of patients with amnesia suggested that only a small subsample were able to do relatively well on immediate text recall. What characterised these patients was a high level of preserved intelligence, good executive processes, or both. Baddeley and Wilson proposed that comprehending a text might involve creating and elaborating a representation of the content in long-term memory.

To account for this and a range of other related problems, a fourth component was proposed, namely the episodic buffer (Baddeley, 2006). This component is a buffer between working memory and long-term memory as well as between the two slave systems. This system is concerned with integrating information into a meaningful episode. It provides a temporary interface between the subsidiary systems and long-term memory (Nevo & Breznitz, 2011). The episodic buffer was a later addition to the model as the two slave systems cannot easily account for all the types of information that we process (Lefrançois, 2012).

The episodic buffer is believed to be a temporary representation accessible to conscious awareness. Rather than merely reflecting activated long-term memory, it is assumed to play an important role in binding information together in chunks (Baddeley, 2006). The episodic buffer is considered to be limited in terms of the number of multi-dimensional chunks it can hold at any one time (Baddeley, Hitch & Allen, 2009).

This system can serve as both an auxiliary store when the primary one's are overloaded or disrupted, and also as a location in which to integrate diverse forms of information such as verbal content within working memory (Smith & Kosslyn, 2008).

Alloway, Gathercole, Willis and Adams (2004) investigated the episodic buffer in children utilizing recall of spoken sentences. Repeating sentences involves the integration of information from temporary memory subsystems (to support the precise recall of individual words and their order) with the products of semantic and syntactic analysis by the language processing system. According to Baddeley (Alloway, et al, 2004), the integration of these two sources of representation is validated by the superiority in memory span for words in meaningful sentences than in unrelated word lists. This study makes use of the recall of spoken sentences in the Automated Working Memory Assessment.

Even though there is little research regarding the role of the episodic buffer in reading comprehension, it is possible that the beneficial effect of background knowledge may be better explained by the episodic buffer than the three component model (Eun-jou, 2011). There is considerable evidence that background knowledge pays a critical role in facilitating reading comprehension (Eun-jou, 2011). The benefit of background knowledge can be clarified with the working memory framework because it is believed that the availability of background knowledge from long-term memory can alleviate the cognitive load for a given reading task. Since working memory is a limited capacity store, the load is reduced for readers with more knowledge relevant to the topic (Eun-jou, 2011).

Neural basis of working memory

For more than the past decade, scientists have been using advanced brain imaging to study how working memory functions in the brain. Their results show that using working memory involves a number of areas in the brain (Alloway & Alloway, 2013).

"Working memory supports immediate brain processes involved in the storage and processing of information and plays a role in higher cognitive brain functions such as reading comprehension" (Osaka, Kimori, Morishita, & Osaka, 2007:130). Prefrontal cortex (PFC) is the home of working memory. Situated in the front of the brain, the prefrontal cortex coordinates with other areas of the brain through electrical signals and receives information from those regions so your working memory can make use of it (Alloway & Alloway, 2013). Brain-imaging scans demonstrate that when working memory is being used, the prefrontal cortex glows while it fires thoughts to and works with information from the different brain regions (Alloway & Alloway, 2013). Working memory is the main function of the prefrontal cortext. Though the prefrontal cortex is the region most often associated with working memory, it is important to note that scientists have also found activation in other areas of the brain, such as the parietal cortex and the anterior cingulate, when people execute a working memory task (Alloway & Alloway, 2013). The hippocampus is where the considerable amount of knowledge you have acquired over your lifetime is stored for long-term storage (Alloway & Alloway, 2013). It is the location of long-term memory (LTM). Your working memory permits you to sift through all the information you have stored in your long-term memory, and pull out the bits most appropriate to the task at hand (Alloway & Alloway, 2013). It gives you the capability to combine that stored knowledge with new information coming in, and to put new information into your long-term memory (Alloway & Alloway, 2013).

Neuroimmaging studies have explored the neural basis of 2 kinds of working memory systems proposed by Baddeley (1986). Verbal information is retained in the phonological loop is associated with activation in the left ventrolateral prefrontal cortex and visuo-spatial information is retained in the right homologues (Osaka et al., 2007). It has been proposed that the executive control system is located in the dorsolateral prefrontal cortex (Osaka et al., 2007). Neuroscientific studies of verbal memory suggest that performance on tasks that tap the phonological loop engage a set of brain regions that are thought to be involved in phonological processing (D'Esposito, 2007). For example, using functional neuroimaging techniques during verbal working memory tasks, the left inferior parietal lobe, posterior inferior frontal gyrus (Broca's area), premotor cortex and the cerebellum are typically activated (D'Esposito, 2007).

A main question in functional Magnetic Resonace Imaging (fMRI) experiments has been whether there is a domain-specific neural activity in prefrontal cortex, suggesting that the prefrontal cortex is separated by stimulus domain and responsible for temporary mnemonic representation, or whether the observed activity in prefrontal cortex is domain general and the domain-specific activity comes more from the posterior regions associated with the perception of the stimuli being used in the task (Conway, Moore & Kane, 2009).

Why some learners have poor working memory capacity is not well understood yet. It seems likely that genes play an important role in the frontal areas of the brain that support working memory (Gathercole & Alloway, 2007).

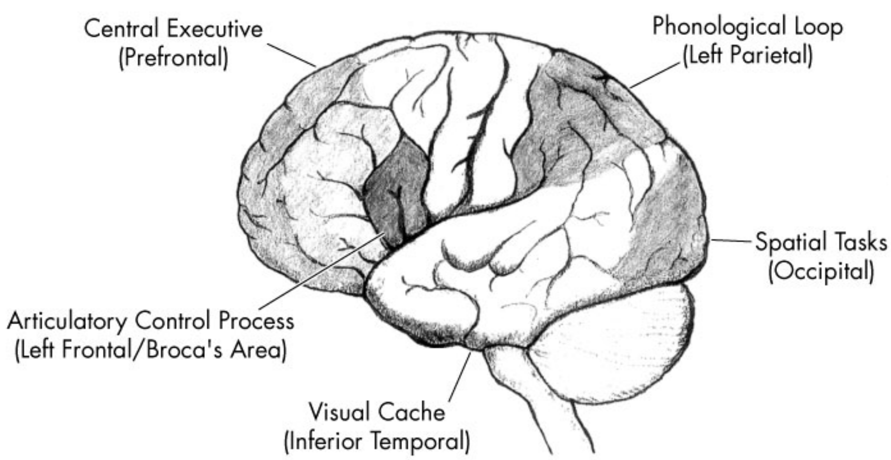

Fig. 1. **Working memory and the brain (source: Revlin, 2012:136).**

Alternative working memory models

Baddeley (2012) states that there are a number of ambitious models of working memory that he regards as broadly consistent with the multicomponent framework, although each has a different emphasis and terminology. Within a theory, there are likely to develop a number of more specific models, as models are an effort to give a more detailed account of phenomena (Baddeley, 2006).

Osaka, Logie and D'Esposito (2007) proposed an alternative approach to address the inconsistencies associated with short- term memory, working memory and reading comprehension. In their novel model of short-term memory there exists dissociable semantic and phonological components, each of which have unique relationships with language processing. Based on patient and neuroimaging data Osaka, Logie and D'Esposito (2007), have proposed that maintenance of semantic representations is supported by left frontal areas, while phonological conservation can be localized to more posterior areas such as the inferior parietal lobe.

Daneman and Carpenter's (Baddeley, 2012), Individual Difference-based theories demonstrated that working memory span measures can predict comprehension has provided a major focus of research on working memory over the past 30 years. At a theoretical level, there has been substantial interest in identifying the feature of such complex span measures that allows them to predict cognitive performance so effectively. Purely correlational approaches to this issue have a number of limitations according to Baddeley (2012). The most promising work in this area comes from combining experimental and correlational methods to tackle the question of why some people are better able to maintain material under these complex conditions (Baddeley, 2012).

Gathercole and Pickering (2000) extended Baddeley's model and proposed a multicomponent model consisting of separate storage/recall (short-term memory) and processing (working memory) systems. This model includes two separate systems of short-term and working memory. Short-term memory is domain specific and consists of verbal and visuo-spatial components. It is used for the passive storage of verbal information within the phonological loop, and for the storage of visual and/ or spatial information within the visuo-spatial sketchpad. Short-term memory needed for tasks requiring no processing, or when the maintenance of sequential order information is necessary. In contrast, the working memory system, according to this model, is domain-general comprising of both verbal and visuo-spatial working memory. It is the processing resource which is involved in the simultaneous preservation and processing of information. Verbal working memory refers to the temporary memory capacity of the central executive which is utilized for storage and processing of verbal information. On the other hand, visuo-spatial working memory refers to the temporary memory capacity of the central executive which is used for the storage and processing of visual and/or spatial information.

By its very nature, a cognitive process such as working memory is entirely abstract. We are unable to see it, and therefore cannot certify which explanation is correct. The Baddeley model has been manipulated experimentally to observe the behavioural manifestations of the hypothesized model at work (Pickering, 2006). In recent years, correlations of such behavioural observations with data from brain scanning studies have been established, to provide neuroanatomical evidence on working memory functions (Pickering, 2006).

However, for the purposes of this study, Baddeley's model of working memory forms the framework on which this study was created.

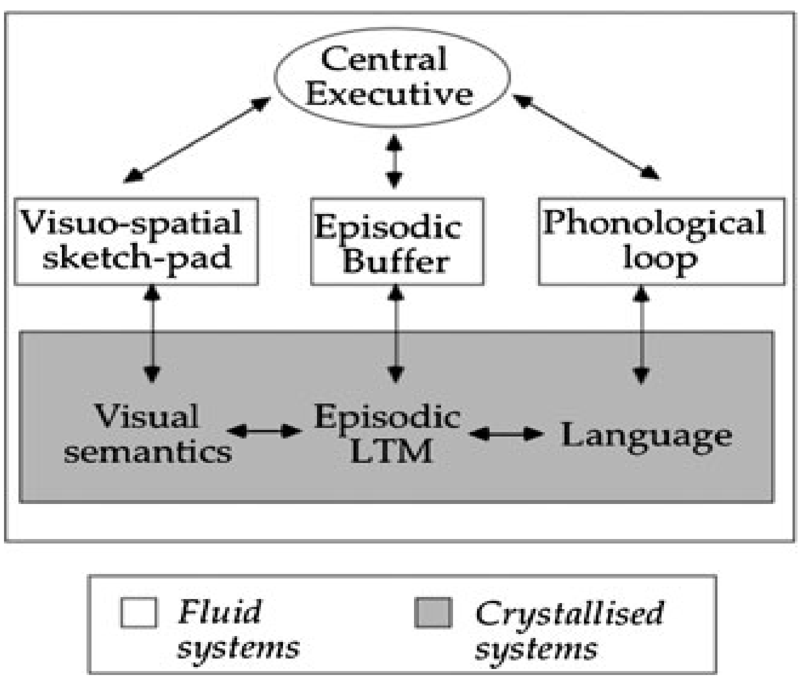

***Fig. 2.* Model of working memory (source: Baddeley, 2002:93)**

Development and variation of working memory

Historical overview of working memory.

The scientific study of memory dates back to the nineteenth century and the topic has generated a vast literature (Westwood, 2013). The science of psychology, still in its infancy in the nineteenth century, was quick to focus on memory models and measurement (Dehn, 2011). The classic digit span test, for example dates back to the 1880's (Dehn, 2011). Between 1885 and 1913, Ebbinghaus, as reported by Revlin (2012), sought to ascertain basic memory processes that are independent of people's past knowledge. To do this, Ebbinghaus used nonsense syllables, formed by adding a vowel between two consonants, as the items to be remembered, and established how many runs through a list of nonsense syllables it would take to recite a list perfectly (Revlin, 2012). In 1980 William James (Baddeley, 2007:1), proposed a distinction between a temporary primary memory, which he described as the 'trailing edge of consciousness', and the more durable secondary memory. However, by the middle of the twentieth century, the leading view within experimental psychology, was of a single memory system in which learning reflected the formation of associations, and forgetting was due to interference between competing associations (Baddeley, 2007). Until the late 1950's, in most accounts, memory was treated as a single unitary faculty. At about that time John Brown in England and Peterson and Peterson (Baddeley, 2006), in the United States, noted that small amounts of information would promptly be forgotten if the participant was prevented from rehearsing that information. By the late 1960's, there seemed to be growing evidence in favour of a clear separation between Short-term memory and long-term memory (Baddeley, 2006). A number of models were proposed, the best known of these, was proposed by Atkinson and Shiffrin (1968). Their modal model of memory assumed that information was processed by a series of temporary sensory memory systems and then fed into a limited capacity short-term store. Transfer of this information to long-term memory depended entirely on how long an item resided in the short-term store (Baddeley, 2006). In their model, the temporary system also served as a working memory system, a workspace necessary for activities such as reasoning and comprehension (Baddeley, 2003).

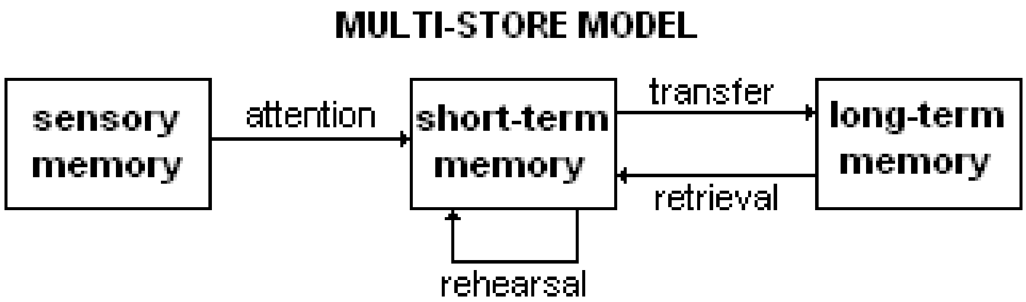

Fig. 3. **Atkinson and Shiffrin model of memory (source: Baddeley, 2007:3)**

The model, however, encountered two main problems. The first of these is that the model is essentially sequential. Neuropsychological data contradicted this assumption as information can gain access to the long-term memory system even when the short-term memory store was dramatically impaired (Smith & Kosslyn, 2008). The second problem with the modal model was that there was little evidence to suggest that simply holding an item in the short-term store would facilitate learning, and there was growing evidence to suggest that the degree of learning depended on the way in which information was processed by the participant (Baddeley, 2006).

In the 1980s communication-channel and computer metaphors of the mind gave way to more biologically plausible systems, such as neural networks (Conway, Moore & Kane, 2009). In 1983, Anderson proposed the idea that working memory could be modeled as the activated part of long-term memory. According to this view, long-term memory representations may be activated to in varying quantities by external or internal events, and when that activation reaches a limit, the information carried by that representation becomes available for further action, and possibly enters consciousness (Conway, Moore & Kane, 2009).

Just when the previously popular field of short-term memory was downsizing itself following criticism of the dominant Atkinson and Shiffrin model, Baddeley and Hitch began a 3-year research project concerning the relationship between short-term memory and long-term memory (Baddeley, 2006). Tentatively, Baddeley and Hitch published their three-component model of working memory in 1974, providing a simple but robust base for a variety of studies of working memory (Baddeley, 2006). They aimed to keep their proposed system as simple as possible, but at the same time, potentially capable of being applicable to a wide range of cognitive activities (Baddeley, 2012). Baddeley and Hitch (Baddeley, 2012), decided to split attentional control from temporary storage, which previous research suggested it may rely on separate verbal and visuo-spatial short-term memory systems, all of these systems were limited in capacity. They labeled the central controller as a ‘central executive” (CE), initially calling the verbal system the “articulatory loop” to emphasise storage rather than rehearsal. The third component they referred to as the “visuo-spatial sketchpad”, leaving open the matter of whether it was basically visual, spatial, or both (Baddeley, 2012).

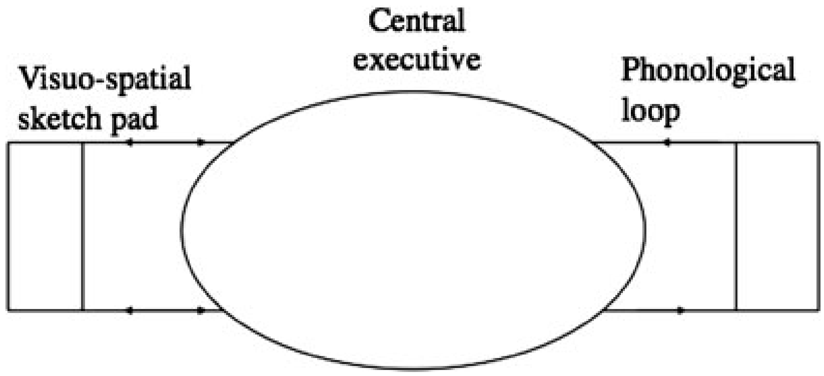

Fig.4. **The original Baddeley and Hitch (2012:6) working memory model presented in 1974.**

The following figure shows that Baddeley's (2012) current views are not dramatically different from the original model, apart from the episodic buffer.

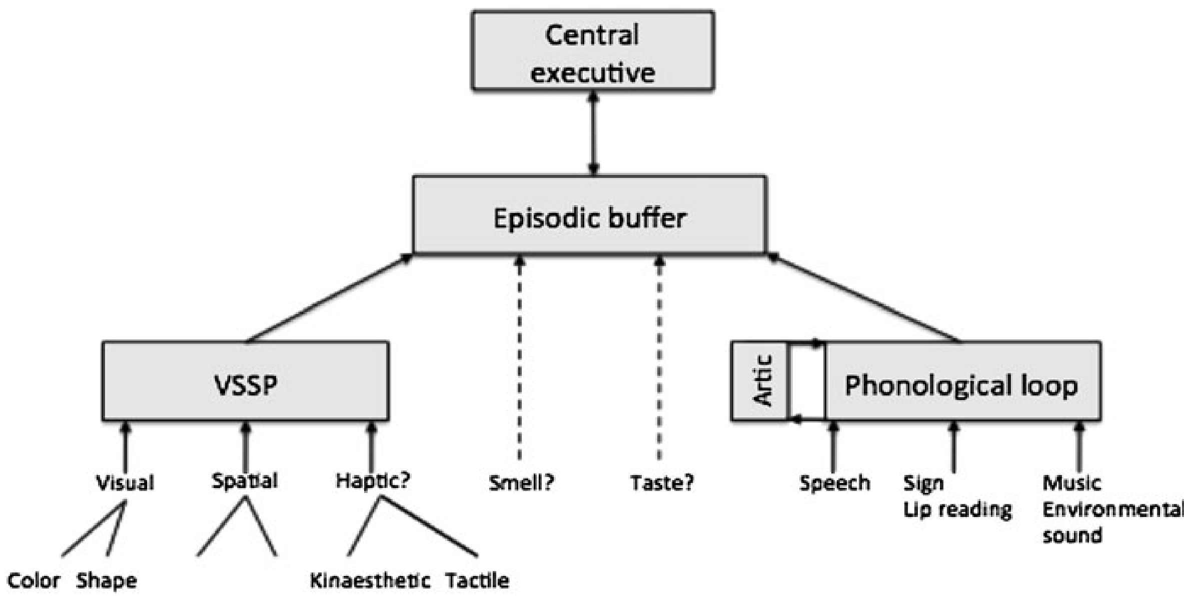

Fig. 5. **A speculative view of the flow of information from perception to working memory. VSSP, visuo-spatial sketchpad (Baddeley, 2012:23)**

It is important to note, that contemporary models of working memory are mostly influenced by Baddeley and Hitch's model who in turn were influenced by the cognitive renaissance of the

1950s, when the mind came to be viewed as an information-processing system, consisting of multiple stores, that transmit information from one to another (Conway, Moore & Kane, 2009).

Differentiation of short-term memory and working memory.

For the purposes of this study it is necessary to differentiate between short-term memory and working memory as these terms are often used interchangeably, however, the two concepts have a few noticeable differences.

The term short-term memory is “used to describe situations in which small amounts of information are held passively (e.g., digit span tests and word span tasks) and then reproduced in an untransformed fashion, whereas working memory is considered as a processing resource of limited capacity involved in the preservation of information while simultaneously processing the same or other information” (Nevo & Breznitz, 2011:74).

In other words, short-term memory is the ability to remember information, such as someone’s name at a party, this person’s occupation, or the title of a recommended book, for a very short period. We usually don’t keep this information in mind for long- a few seconds- or so and we would usually struggle to remember that person’s name or the book title the following day (Alloway & Alloway, 2013). Working memory gives us the ability to do something with the information at hand rather than just remember it briefly (Alloway & Alloway, 2013).

Alloway (2011) illustrates the distinction between these two concepts in the following example. *Imagine that you are driving to a new location for a meeting. You lose your way and stop at a shop to ask for directions. You may repeat the information to yourself repeatedly as you walk back to your car so you don’t forget. At this point, you are using your short-term memory to remember the directions. As you start driving you recite the directions to yourself, you look* *around and match them to the road names. Is this where you are supposed to turn right? Where do you take the second left? Now you are using your working memory as application of the information is needed.*

Short-term memory processes do not imply any manipulation or transformation of the information during the brief period it is stored –for example, in a digit span test the numbers are merely repeated back in the same sequence. Working memory goes way beyond this, and facilitates active processing and transformation of the information (Westwood, 2013). Daneman and Carpenter (1980), indicated that the essential difference between tests of working memory and those of short-term memory which are not, or only weakly, associated with comprehension skill, is that short-term memory tests only require the use of a passive storage buffer. They went on to suggest that both storage and processing of information in memory is critical in comprehension, and indicate that the process of working memory better accounts for the sharing of resources between the processing and storage demands of a particular task.

The study of working memory was initially based on the concept of a simple unitary temporary memory store (Short Term Memory) (Baddeley, 2007). However, over the years it has become increasingly evident that considerably more than simple storage is required for a system that effectively forms the critical interface between perception and memory, and between attention and action (Baddeley, 2007).

Sprenger in Westwood (2013), suggests that short-term memory is located in the frontal lobes of the brain, whereas working memory processes appear to function mainly in the prefrontal cortex of the brain.

Working memory is also distinctive from long-term memory. Long-term memory is the library of knowledge you have accrued over the years. Knowledge about countries, information about random news facts and memories about events from your school days (Alloway & Alloway, 2013). Information may remain stored in your long-term memory for between a few days to many decades (Alloway & Alloway, 2013).

Working memory is what allows you to retrieve that information and put it to good use. You can access information from your long-term memory, use that information in the moment, and then file it away again (Alloway & Alloway, 2013). Working memory is also the mechanism used to transmit new information into long-term memory, as when you are learning a new language (Alloway & Alloway, 2013).

Daneman and Merikle (Jincho, 2008), concluded from their meta-analysis that verbal working memory had a more predictive power for reading comprehension than did traditional tests for short-term memory.

Individual differences in working memory.

A recent focus of research in working memory is that of individual differences in working memory capacity (Smith & Kosslyn, 2008). People vary extensively in the ability to maintain items in working memory, and particularly in maintaining these items under conditions of interference (Smith & Kosslyn, 2008).

There exists a vast variation in working memory between individuals. Those with low working memory capacities will, therefore, struggle to meet the heavy demands made on this store in a variety of situations, of which the classroom is a prime example (Gathercole, 2008). Differences in working memory capacity between children of the same age can be substantial. Gathercole and Alloway (2007) suggested that in a typical class of 30 children aged 7 to 8 years old, at least 3 of them would be expected to have a working memory capacity of the average 4-

year-old child. Swanson and Beebe-Frankenberger (Alloway & Alloway, 2010), propose that individual differences in working memory tasks predict reading success independent of measures of phonological skills.

Research has largely supported the premise that increased working memory capacity is associated with increased comprehension (Swenson, 2008). Not only does research show that individual differences in working memory capacity affect reading comprehension but also that reducing the load placed on working memory increases comprehension (Swenson, 2008). Gathercole and Baddeley (2006) discovered that when the demand on memory is low, skilled comprehenders demonstrate higher recognition accuracy on a task than less skilled comprehenders.

Working memory may be useful and flexible, however, the information held in this store is easily lost through distraction or overload (Gathercole, 2008). As working memory is a limited-capacity system in which some resource is shared between processing and storage this leads to a phenomenon of trade off: Performance decreases when the concurrent memory load increases, and any increase in difficulty of processing causes a loss of information from short-term storage memory (Barrouillet, et al, 2007).

When children’s working memory becomes overloaded, crucial information is permanently lost and it will not be possible for the child to proceed with the activity unless they are able to repeat the activity or gain access again to the task information that is needed (Galloway, 2008). The child is therefore forced, at this point, to guess (which is likely to result in errors) or to abandon the task before it is completed. These activity failures represent missed learning opportunities for the child, often leading to delays in learning (Gathercole, 2008). Individual differences research proposes that greater storage capacity is associated with greater cognitive performance (Gabales & Birney, 2011). This is an important point as the results of storage load manipulations on an individual's performance may well depend on that individual's storage capacity (Gabales & Birney, 2011).

Daneman and Carpenter's (Gabales & Birney, 2011) early research involving the reading span task ascribed individual differences in performance to differences in processing efficiency. However what actually changes during the task is not the processing load (e.g. indicating whether each sentence makes sense) but rather the storage load (e.g. how many words must be recalled). Saito and Miyake (Gabales & Birney, 2011) support this in their conclusion that it is interference that makes the task challenging, not processing load per se.

Cognitive psychology stresses that the learner is an information-processing organism. According to this view, the learner is an active participant in the learning process, seeking to discover and organise, and capable of employing strategies for arriving at concepts and organising them in memory (Lefranҫois, 2012). Cognitive psychologists believe that " meaning results from actively processing input, builds on previous learning, and depends on relationships among concepts (sometimes labeled schemas) that are currently active" (Lefranҫois, 2012:195).

As there is, unfortunately, a limit to working memory capacity, these limits set the boundaries of learning potential. Instruction that makes efficient use of limited working memory will increase learning opportunities for learners. Recent research regarding cognitive load theory has been successful in explaining ways in which instruction can promote or hinder learning and that working memory capacity can be increased through training (Bethel & Borokhovski, 2010).

Cognitive load can be defined as "the proportion of time for which attentional focus is diverted from storage to the processing activity of the memory task" (Magimairaj & Montgomery, 2012:670). According to Barrouillet et al. (2007), Baddeley and Hitch have proposed that working memory is a limited-capacity system in which some resource is shared between processing and storage. Thus, as memory load increases, performance decreases. Within this theoretical framework, tasks vary in the cognitive load they place on working memory, that is, the amount of resources needed to carry them out, differ (Barrouillet et al, 2007).Cognitive load theory proposes a model of cognitive architecture that explains the mechanisms through which working memory contributes to learning. Research suggests that working memory capacity can be improved upon, thereby increasing learning capacity (Bethel & Borokhovski, 2010).

In the capacity model developed by Just and Carpenter (Vukovic & Siegel, 2006), individual differences in working memory can be explained by innate individual differences in the structure of working memory. Some individuals simply have a larger working memory capacity than others. This model proposes that individuals who encounter difficulties with reading comprehension might have a smaller cognitive capacity to store and manipulate information in working memory and thus experience more difficulty simultaneously processing and storing the text for later retrieval.

Another notable framework for conceptualizing the individual differences in working memory capacity is the long-term working memory (LT-WM) model proposed by Ericsson and Kintsch (1995). This model differs from the capacity theories in that it includes an additional component to the working memory system, namely the long-term working memory (LT-WM) system. The function of the LT-WM is the efficient retrieval of information from long-term memory that can be used to assist working memory performance. Prior knowledge can improve performance on a given task. Practice can enhance an individual’s ability to retrieve information from long-term memory to facilitate the working memory process. The LT-WM model suggests that good readers differ from poor readers in that their comprehension strategies produce more efficient retrieval and encoding processes in LT-WM.

Limits to working memory

It becomes apparent from the above discussion that working memory is limited in a number of ways, and can easily fail us when we need it (Gathercole & Alloway, 2007).

Miller states that procedures have yielded data demonstrating that a typical memory span is approximately 7 (between 5 and 9) unrelated items (Revlin, 2012). The number 7 is constant for lists of nonsense syllables, unrelated pictures, words, whatever you can think of, as long as the individual items are unrelated (Revlin, 2012).

The standard method of calculating the duration of information in short-term memory is called the Brown-Peterson task (Revlin, 2012). Two important outcomes related to the duration of short-term memory from research using the Brown-Peterson task have been established: First, the number of items that can be kept in short-term memory rapidly decays with the passage of time (nearly perfect recall occurs with a 0-second delay and only about 10-20% recall occurs with an 18-second delay). Secondly, the duration of items in short-term memory is related to the number of chunks that are present as the number of chunks influences our ability to keep information in short-term memory (Revlin, 2012). It appears that the more items (or chunks) in short-term memory, the more occasions there will be for them to become confused with one another. This confusion is called interference and is an important contributor to our ability to recall items (Revlin, 2012).

The following are situations that often lead to information loss from working memory (Gathercole & Alloway, 2007):

Distraction

Interruptions that can include someone speaking to us, unrelated thoughts, and noises, can be enough to divert attention so that the contents of working memory are rapidly lost.

Trying to hold in mind too much information

Working memory limitations mean that the amount of information that has to be stored for a task may exceed the capacity of most people's working memory.

Engaging in a demanding task

Activities that require difficult mental processing reduce the amount of space in working memory to store information. The effect can be a loss of other information that is already held.

Once information is lost from working memory, it is gone for good and the learner will have to start the process of entering information into working memory again (Gathercole & Alloway, 2007).

Measures of working memory

It is well established that working memory is involved in reading comprehension, however, the structural and functional role of working memory in reading comprehension is explained in different ways (Caretti, Borella, Cornoldi & De Beni, 2009). Each study, in the vast literature, has used different tasks and explored different memory components, making it difficult to draw conclusions regarding the relationship between working memory and reading comprehension.

It is not clear from the literature whether the relationship between reading comprehension and working memory reflects a general working memory system or a working memory specific to language. It is necessary to determine the nature of the relationship between working memory and reading comprehension as deficits in a general versus a language- specific working memory system have different implications for intervention and language remediation (Vukovic & Siegel, 2006). For example if a general working memory system is implicated, strategies to overcome or compensate for their limited working memory capabilities will need to be taught to children with reading comprehension difficulties. Conversely, deficits in a working memory specific to language would suggest that children need to be taught strategies for processing and remembering verbal information (Vukovic & Siegel, 2006).

The Baddeley and Hitch model (Alloway, Gathercole & Pickering, 2006), suggests a domain-general account of working memory capacity, whereby, the domain-general aspect, which is controlled by the central executive, coordinates information in two independent domain-specific storage components for verbal and visuo-spatial codes. Miyake and colleagues (Alloway, Gathercole & Pickering, 2006), provided an alternative account of working memory capacity. According to this view working memory capacity is supported by two separate pools of domain-specific resources for verbal and visuo-spatial information. Each domain, would then be independently capable of manipulating and keeping information active. Just and Carpenter's (Gibson & Fedorenko, 2004), single resource theory advocates one generic pool of resources for all verbally-mediated tasks. This approach suggests that linguistic working memory capacity directly constrains the operation of language comprehension processes, and that variation of the linguistic working memory capacity, within the normal population is a major source of individual differences in language comprehension (MacDonald & Christiansen, 2002). On the other hand, Caplan and Waters (Gibson & Fedorenko, 2004), propose at least two pools of resources for verbally-mediated tasks: (1) natural language processing; and (2) other non-linguistic verbally-mediated tasks, in their separate language interpretation resource theory.

Caplan and Waters (MacDonald & Christiansen, 2002), suggest that there are at least two different working memory capacities that subserve language use.

Research conducted by Beni and Palladino (Pimperton & Nation, 2010), posits that poor comprehenders' suppression weaknesses reflect a domain-general, central executive problem with regulating the contents of working memory. Consistent with this study Cain, Oakhill and Bryant (2004), established that a general working memory system seemed to characterise the relationship between working memory and reading comprehension.

According to Swanson and Siegel (Vukovic & Siegel, 2006), studies generally indicate that reading comprehension has a stronger relation to verbal memory tasks than to visuo-spatial working memory, and they have also found that studies investigating the relationship between visuo-spatial working memory and reading comprehension are limited and yield mixed findings.

There appears to be much controversy over which processes, components of working memory actually have the most significant effects on reading comprehension. The most reliable working memory predictors of reading comprehension are tasks that involve the coordination of storage and processing, namely, those involving executive working memory and verbal working memory (Dehn, 2011).

In a large sample study assessing each memory component by Alloway and colleagues (Alloway, Gathercole, Kirkwood & Elliot, 2011), using the AWMA, children aged 4-11 years, findings confirmed that, in line with Baddeley's working memory model, the processing aspect of both the verbal and the visuo-spatial working memory tasks was controlled by a centralised component (i.e., the central executive), while the short-term storage aspect was supported by a domain-specific component – the phonological loop for verbal information and the visuo-spatial sketchpad for visuo-spatial information. According to Pisoni, Kronenberger, Roman, and Geers

(2011), this is demonstrated by the forwards and backwards digit spans test. Digit spans are commonly used as capacity measures of immediate verbal memory. Digit Span tests consist of forward (repeating digits in the same order as they were presented) and backward (repeating digits in the reverse order from which they were presented) conditions, which are related because they share a component of short-term verbal memory (similar to the phonological loop component of working memory, proposed by Baddeley). However, measures of the backwards Digit Span test require not only rote immediate verbal memory but also include an additional processing component of simultaneous mental operations (i.e., reordering). This additional processing component requires divided attention, allocation of multiple mental resources/operations, and active control of conscious attention, which can be attributed to the central executive component of the working memory system (Baddeley, 2007).

There are contrasting results on whether or not a deficit in working memory in poor comprehenders is present regardless of task modality (Caretti, Borella, Cornoldi & De Beni, 2009). The current study assesses verbal and visuo-spatial working memory. Thus, according to Baddeley’s account of working memory the processing aspect of a task is controlled by a centralized component (i.e. the central executive) while the short-term storage aspect is supported by domain-specific components (verbal or visuo-spatial store), and the measurement of each of these aspects has specific necessities, and therefore requires an appropriate assessment tool. The tests used in the AWMA were selected on the basis of research establishing that they provide reliable and valid assessments of verbal and visuo-spatial working memory (Alloway, 2007). If working memory tests measure a capacity that is critical for academic learning, then working memory measures should be an essential part of every assessment for cognitive abilities (Dehn, 2011).

Even if working memory scores are not used to diagnose specific learning difficulties, they can still provide more insight into a student's strengths and weaknesses.

Working memory and reading comprehension

Westwood (2013), states that working memory is a central feature involved in reading comprehension and in understanding and communicating through spoken language. Intuitively, one can perceive why working memory is so important for reading comprehension performance: To construct a coherent representation of a text while reading it, it is necessary to hold online in temporary memory a mental model of the situation outlined in the text, as well as dynamically revise it as new information becomes available, especially if this new information is incompatible with previous information. Likewise, these dynamic and updating processes are required for grammatical comprehension, for example, resolving an anaphor from a temporally distinct series of options (Pimperton & Nation, 2010). Deficits in working memory affect performance on a variety of tasks, including reading comprehension. For example, working memory is essential for reading comprehension as the reader must simultaneously, decode words, interpret the meaning of words, integrate the meaning of the text, maintain and remember what has been read, as well as employ various comprehension strategies. Deficits in working memory could lead to comprehension failure at any stage in the comprehension process (Vukovic & Siegel, 2006). Children with low working memory capacity find it difficult to meet the storage demands of this process of interpretation while concurrently recognising the individual words (Gathercole & Alloway, 2008).

The relationship between working memory and reading comprehension possibly holds because a critical component of skilled comprehension is the ability to process the semantic and syntactic relations among successive words, phrases and sentences, in order to develop a coherent overall representation of the text (Oakhill, Yuill & Garnham, 2011). In all current models of reading comprehension, the processes of integration and inference are important in the structure of a coherent model of the text, both locally and globally. Working memory acts as a buffer for the most recently read propositions in a text, so that they can be incorporated with the model of the text so far, and also holds information accessed from long-term memory to facilitate its integration with the currently active text. It follows then that children with poor working memory capacities should be less able to undertake these types of processing than those with a greater working memory capacity (Oakhill, Yuill & Garnham, 2011). Baddeley (Seigneuric & Ehrlich, 2005), is in agreement with this view, and states that the essential ability in text comprehension is the construction of integrated mental representations. He goes on to argue that this skill makes heavy demands on both the processing and storage functions of working memory.

In order to establish a relationship between reading comprehension and working memory, studies have shown that working memory is not only related to reading comprehension, but that this relationship is apparent after controlling for variables that have well established relationships with reading comprehension (Vukovik & Siegel, 2006). Cain, Oakhill and Bryant (Eun-jou, 2011) conducted a longitudinal research assessing the progress of 102 seven- and eight-year olds in various areas, such as, word reading, vocabulary, and verbal IQ, in which individual differences for reading have been identified. Two working memory measures were used, namely the sentence span task (central executive) and the digit span task (phonological loop). Using reading comprehension as an independent variable they explored the variances that working memory and component comprehension skills explain after controlling for word reading, vocabulary, and verbal IQ. The results indicated that working memory explained significant variance in reading comprehension over and above the contribution made by the other variables at each time point, namely at eight, nine and eleven-years-old. Alloway (Lee, Lee Pe, Yin Ang & Stankov, 2009), also found that working memory provided a unique and long-term prediction of learning outcomes in reading even though differences in intelligence, prior knowledge, and skills were statistically controlled. Evidence from studies involving children representative of all levels of reading ability show that working memory is an important factor in explaining reading comprehension ability (Vukovic & Siegel, 2006). For example, in a sample of 102 fourth-grade children, Siegneuric, Ehrlich, Oakhill, and Yuill (Vukovic & Siegel, 2006), established that working memory measures involving sentences, words, and digits, accounted for a significant amount of variance in reading comprehension over and above reading fluency and vocabulary. The findings that working memory accounts for unique variance in reading comprehension independent of skills such as word recognition and fluency are consistent with those in a longitudinal study conducted by Vukovik and Siegel (2005). They investigated the relationship between reading comprehension and word reading skills, phonological awareness, rapid naming and working memory in fifth and sixth grade children. In both grades working memory contributed unique variance to reading comprehension independently of reading skills, phonological awareness and rapid naming. In sum, their findings indicate that working memory is an important variable in explaining reading comprehension in children from the ages 7 to 11.

Swanson's (2011), dynamic testing of working memory and reading comprehension, showed that skilled readers outperformed children with reading disabilities on measures of working memory. This occurred even though the children were statistically matched on a measure of fluid intelligence. In this study working memory was related to later performance on measures of passage comprehension. Swanson and O'Connor (2009) maintain that working memory plays a crucial role in moderating individual differences in reading comprehension because (a) it holds recently processed information to make connections to the latest input, and (b) it maintains the gist of information for the production of an overall representation of a text.

Macdonald, Just and Carpenter (Jincho, 2008) found that readers with low working memory capacity showed worse comprehension performance after reading sentences than those with high working memory capacity. Other studies such as this argue that high working memory capacity readers can hold multiple interpretations longer than low capacity readers, resulting in better performance, especially when processing demand is high (Jincho, 2008).

Swanson and O'Connor, (2009) investigated Shankweiler and Crain's model of reading comprehension. According to this model reading comprehension performance is compromised because inefficient phonological recoding creates a "bottleneck" that restricts the flow of information to higher levels of processing. They suggest that working memory has the task of relaying the results of lower level linguistic analyses upward through the language system. Phonologically analysed information is transferred (therefore freeing storage for the next chunk of phonological information) upward through the system to facilitate online extraction of meaning. The principal prediction of this model is that skills in word decoding play a more important role than working memory in reading comprehension. However, Swanson and O'Connor (2009) concluded in their study that (a) students with higher working memory yielded higher post test scores for text comprehension than those with lower working memory skills and (b) the linear model that partialed out pretest scores, vocabulary, and word-attack skills showed that working memory was significantly related to post-test outcomes in reading comprehension.

According to Chall (Tuckman & Monetti, 2011) people with good working memory abilities can shift their focus repeatedly from reading to thinking without having to reread the previous text to remember the gist of it. Daneman and Green (Jincho, 2008) suggested that readers with a high working memory capacity could acquire the meaning of an unfamiliar word because inferring the meaning of the unknown word from a context requires large working memory capacity. Developmental language literature exploring the relationship between working memory and comprehension is also emerging (Magimairaj & Montgomery, 2012). Engle, Carullo, and Collins (Seigneiric & Ehrlich, 2005) found a strong positive correlation between working memory capacity and text comprehension. A major result of Seigneuric& Ehrlich's (2005) study of working memory capacity and reading comprehension in children is that working memory capacity was found to directly influence the development of reading comprehension from second to third grade. Osaka and Osaka (Jincho, 2008) investigated the effect of working memory on reading performance utilising an eye-movement monitoring method. They concluded that low working memory capacity readers took longer to read a text and showed poorer comprehension performance than high working memory capacity readers. Cockcroft and Alloway (2012) state, in their study comparing working memory skills in South African and British children, that over the years, two abilities have consistently been shown to be related to reading achievement, namely phonological awareness and working memory.

Individual differences in working memory capacity are related to how efficiently readers perform reading processes such as determining relevant text and making inferences (Linderholm, Cong & Zhao, 2008). Work by Caretti and colleagues and Cain (Pimperton and Nation ,2010) support the idea that individuals with poor reading comprehension abilities have problems with working memory, and that these working memory deficits are related to difficulties in suppressing irrelevant information. Information that was initially relevant but subsequently became irrelevant was particularly difficult for poor comprehenders to suppress. Taken together, Pimperton and Nation (2010), suggest that these results indicate that poor comprehenders have underlying inefficient cognitive inhibition. They argue that it is likely that these weaknesses in inhibition lead to difficulties with regulating the contents of working memory, and consequently difficulties with reading comprehension. With regard to reading for different purposes, a verbal protocol investigation by Linderholm and Van Den Broek (Linderholm, Cong & Zhao, 2008), indicated that low working memory capacity readers emphasise a rereading strategy over a comprehension monitoring strategy when reading for study purposes, whereas, readers with a high working memory capacity do just the opposite. This study showed that low working memory capacity readers' recall was significantly lower than those with a high working memory capacity.

In contrast to the above findings, Stathard and Hulme (Cain, 2006) did not find a relationship between working memory and reading comprehension ability. However, evidence suggests that working memory impairments are commonly found in children with reading comprehension difficulties (Cain, 2006). Readers continually need to store a piece of information while simultaneously processing another to integrate the various pieces of information within a text (Cain, 2006).

Summary

In reviewing relevant literature, findings appear to indicate that working memory is an important factor in explaining reading comprehension in grade four learners. The chapter began with a discussion concerning comprehension and the structure of working memory. The multicomponent working memory model proposes a four-component system, comprising (1) an attentional controller, the central executive, and 3 temporary storage systems, namely (2) the phonological loop, (3) the visuo-spatial sketchpad, and (4) a more general integrated storage system the episodic buffer (Baddeley, 2007). The evidence suggests that the different components of working memory each play a part in reading comprehension. Several reading and working memory researchers propose that diminished working memory capacities, particularly in the phonological and verbal subcomponents, are associated with impaired reading comprehension (Dehn, 2011). The sketchpad is clearly of less significance to language disorders than is the phonological loop. However, it seems likely that the system will be involved in everyday reading tasks, where it may be concerned with maintaining a representation of the page and it's layout that will remain constant and facilitate tasks such as moving the eyes accurately from the end of one line to the beginning of the next (Baddeley, 2003). Baddeley's model of the structure of working memory led to a discussion regarding alternative models of working memory and a historical overview of the development of the working memory construct. Individual differences and the limitations of working memory were reviewed followed by an in depth evaluation of the literature regarding the relationship between reading comprehension and working memory. Chapter 3 examines the methodology employed to test the research questions in this study.

CHAPTER 3: METHODOLOGY

Introduction

This chapter presents the research design of the study, a detailed description of the sample and population of the study, the instruments used in obtaining the necessary data, the procedure followed and the methods employed for data analysis.

Research design

This study falls within the non-experimental, quantitative, descriptive paradigm. Punch (O'hara, Carter, Dewis, Kay & Wainwright, 2011) states that quantitative analysis in education is the process of representing and interpreting research participants' views, opinions and/or behaviours in a numerical fashion. Put another way, quantitative analysis examines the distribution of and relationships between the variables under investigation: how they are distributed, to what extent and in what ways they are related in a given text. Fielding and Gilbert (O'hara, Carter, Dewis, Kay & Wainwright, 2011) state that the main aim is to identify patterns and regularities in the data. The primary purpose of descriptive research is to provide an accurate description of the characteristics of a situation or phenomenon. The focus is on describing the variables that exist in a given situation and, sometimes, on describing the correlation between those variables (Johnson & Christensen, 2010). Descriptive research simply examines the phenomenon as it exists, no attempt is made to artificially manipulate any of the situations or conditions (Mertler, 2006).This is an appropriate approach as the focus of this research explores the relationship between working memory and reading comprehension in 50 Grade 4 boys. This study explores the phenomenon as it exists and there is no control group or manipulation of the independent variable. In this study the independent variable will be working memory and reading comprehension will be the dependent variable. To establish the strength of the correlational relationship between working memory and reading comprehension abilities, the Pearson Correlation Coefficient was used.

"The strength of the relationship between two variables is the degree to which one variable does tend to vary with the other" (Coolican, 2013:432).

For two variables measured on the interval or ratio level, the most common measure of association is the Pearson Coefficient, written as p for population and r for a sample (Boslaugh, 2012). Pearson's r has a range of (-1, 1,) with 0 signifying no relationship between the variables and the larger absolute variables indicating a stronger relationship between the variables (Boslaugh, 2012). The labels "strong" and "weak" do not have precise numerical definitions, however, a relationship described as strong will have a more linear relationship, with points clustered more closely around a line drawn through the data, than will data with a weak relationship (Boslaugh, 2012). In conducting any research with two independent groups, we will typically find that the two sample means differ by at least a small amount. It is important to ascertain, however, whether that difference is sufficiently large to justify the conclusion that the two samples were drawn from different populations. One of the most common uses of the t-test involves testing the difference between the means of two independent groups (Howell, 2010).

"A p-value expresses the probability that results at least as extreme as those obtained in an analysis of sample data are due to chance" (Boslaugh, 2012:69). P-values are typically reported for most research results comprising of statistical calculations, partly because intuition is a poor guide to how unusual a particular result is (Boslaugh, 2012). There is no statistical definition of what comprises "unusual" results, so this study will use the common standard that the p-value for the results must be less than 0.05 in order to reject a null hypothesis that there is no relationship between working memory and reading comprehension abilities in grade 4 boys.

Paired t-tests were performed to test whether or not the differences between the reading comprehension and working memory means are significantly different from 0. As testing was conducted in English only children with English as a primary home language and preferred testing language were eligible, as to minimise language bias in testing and an analysis of the effects of bilingualism were beyond the scope of this study.

Participants

Convenience sampling was used due to practical constraints. Convenience sampling is used by researchers when their sample people incorporates those who are available or volunteer or can easily be recruited and are willing to participate in the research study (Johnson & Christensen, 2010). The choice of using participants from this school was motivated by the fact that the researcher is a remedial teacher at the school and a major part of work at this school involves working with reading comprehension difficulties. It was also beneficial to source children from a comparable socio-economic group, as this would enhance the probability of obtaining a cohort receiving the same standard of education.

Grade 4 males were selected for participation as grade 4 is approximately the time when learners evolve from learning to read to reading to learn (Geske & Ozola, 2008). Seigneuric and Ehrlich (2005) found in their longitudinal study of the contribution of working memory capacity to children's reading comprehension, that decoding skills were a strong contributing factor in explaining reading comprehension variance in Grade 1. In Grade 2, both vocabulary and decoding were strong predictors and in Grade 3 working memory emerged as a significant predictor of reading comprehension abilities. In Grade 4 children, all variables were measured and working memory capacity was a direct predictor of reading comprehension when contrasted with vocabulary and decoding skills. Seigneuric and Ehrlich (2005) account for this process by explaining that word recognition becomes automated throughout grade levels, the direct predictive weight of linguistic-comprehension variables such as vocabulary and working memory capacity increases concurrently with the decrease in the association of decoding skills with reading comprehension. Considering as well that there exists a slightly greater proportion of males than females with working memory deficits (Gathercole, 2008) this study was conducted at a boys' school. The chosen school is a high functioning, self-directed government school that receives extensive support from the community and the parents.

A total of 50 grade 4 boys participated in the study. Only children with English as a primary home language and preferred testing language were eligible, as to minimise language bias in testing and an analysis of the effects of bilingualism were beyond the scope of this study. To improve the face validity of the study, 2 questions were posed to the participants' parents or guardians regarding their home language and preferred language of testing.

Of the 86 informed consent letters distributed, 59 letters were returned to the researcher. Five learners chose not to participate in the study and four participants were excluded because English was not their home language. To improve the face validity of the study, 2 questions were posed to the participants' parents or guardians regarding their home language and preferred language of testing.

The participants ranged in age from 9 years and 4 months to 10 years and 9 months with a mean age of 10 years and 3 months.

Table 2

Respondent profile

Grade	4	50 participants

Age	9-10 years	18 participants
	10-11 years	32 participants
Race	White	31 participants
	Asian (Indian)	16 participants
	Black (African)	3 participants
Home language	English	50 participants

Psychological assessment in South Africa.

Since the election of South Africa's first democratic government in 1994, the application, control, and development of assessment measures have become a contested area. Due to South Africa's troubled past, the use of tests in education has been placed under the spotlight (Foxcroft & Roodt, 2009).

The Department of Education's release of (EWP6, 2001), policy on Inclusive Education states that psychological assessment will at times have to be done in order to determine the level of intervention that a learner may need. Landsberg (2001) states that the purpose of assessment should be to garner information about children's learning which will contribute meaningfully to their learning support.

The principal ethical consideration facing those who conduct psychological testing in the culturally and linguistically diverse African continent relates to how best to accommodate for this diversity so as to be sensitive to test-takers' cultural backgrounds and values during the test selection, administration, interpretation and reporting phases of the testing process (Foxcroft, 2011). Nevertheless, there is growing evidence in the literature that the value of using standardized tests is increasingly being recognized and documented in various African countries. Furthermore, Foxcroft; Mpofu and Nyanungo (Foxcroft, 2011), discuss the contribution that tests can make in educational settings in various African countries.

South Africa's multicultural society is in various stages of adaptation to a generally Western society (Foxcroft & Roodt, 2009). Shuttleworth-Jordan (Foxcroft & Roodt, 2009: 133), discusses "signs of a narrowing and possibly disappearing gap across race groups on cognitive test results in association with a reduction in socio-cultural differences' and takes this as an indication of similarities between people in terms of cognitive processes." Similar patterns have been found in the United States, where differences between children of diverse cultural groups are significantly different from those found between adults of the same groups. This suggests that differences are in a sense a barometer of educational and economic opportunity (Foxcroft & Roodt, 2009). Level of education, an essential part of socio-economic status, has always been an important variable when interpreting test scores (Laher & Cockcroft, 2013). Quality of education, according to Shuttleworth-Edwards, Van der Merwe, Van Tonder and Radloff (Laher & Cockcroft, 2013), is a more discriminating variable than race when considering performance on intelligence tests. By quality of education, they are referring to the difference between relatively advantaged education within the historically white private and/ or formal model C educational institutions, and the relatively disadvantaged education within the black and coloured township educational institutions. The participants in this study attend a former Model C school and have received a relatively advantaged education.

Foxcroft (2011) maintains that from an ethical perspective, test takers have the right to be assessed in the language of their choice, which is normally their home language. Home language is demonstrative of an individual's language proficiency. However, medium of instruction at school is probably a better indicator of a learner's language proficiency in English (Laher & Cockcroft, 2013). The participants all stated English as their home language and preferred language of testing (as indicated in the biographical questionnaire) together with the fact that English is their medium of instruction at school.

With regards to computer based testing, the primary issue is the level of familiarity with computer technology (Laher & Cockcroft, 2013). All the participants have regular access to computers within the school and receive computer instruction once per week as part of their academic program.

Instruments

Biographical Questionnaire.

To improve the face validity of the study, 2 questions were posed to the participants' parents or guardians regarding their home language and preferred language of testing.

Two tests were administered to all pupils and will be discussed below.

The Automated Working Memory Assessment (AWMA) (Alloway, 2007).

The AWMA is a computer-based assessment that screens for significant working memory problems in individuals aged between 4 and 22 years old. Test scores are calculated automatically by the computer programme and the learner's profile is generated upon completion. The development of the AWMA was based on the leading conceptualisation of working memory as a system which consists of multiple components whose coordinated activity provides the capacity for the temporary storage and manipulation of information in a various domains (Alloway, Gathercole, Kirkwood & Elliot, 2008). What makes the memory tests particularly suitable is the use of a span procedure in which the amount of material to be remembered is increased over successive trials (Alloway, 2007). This is achieved by progressively increasing the number of elements to be remembered until memory performance falls below a criterion level of accuracy (Alloway, 2007). As testing typically stops soon after the participant starts making errors, the majority of the test performance typically involves working within the individual's capacity, and hence focuses on success rather than failure (Alloway, 2007). The AWMA is in line with Baddeley and Hitch's working memory model. This tool provides a practical and convenient way for educational professionals and psychologists to screen for significant working memory problems. It provides a detailed profile of working memory skills necessary for targeting early intervention strategies. It is convenient for teachers as it requires minimal training for administration.

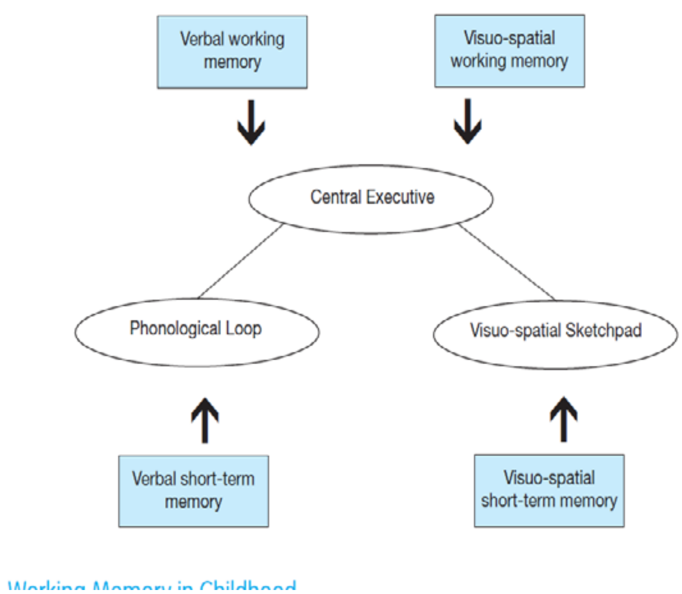

***Figure 6.* A diagrammatic account of working memory and its relationship to the AWMA (Alloway, 2007).**

Description of the test.

There are two tests in the AWMA screener. The memory tests comprise of immediate recall of information (verbal and visuo-spatial).The working memory tests include both processing and recall of information (verbal and visuo-spatial). Studies conducted by Isaacs and VarghaKhadem; Vandierendonck, Kemps, Fastame and Szmalec (Alloway, 2012) have confirmed that the added requirement to process information imposes a substantial processing load on the individual. In line with a substantial amount of prior evidence, verbal and visuo-spatial working memory are measured by means of tasks involving simultaneous storage and processing of information, whereas those tasks that only involve the storage of information are used to measure verbal and visuo-spatial short-term memory (Alloway, et al., 2008). Visuo-spatial working memory is assessed using spatial recall. The individual views a picture of two shapes where the shape on the right has a red dot above it. The individual identifies whether the shape on the right is the same or opposite of the shape on the left. The shape with the red dot may also be rotated. At the end of each trial, the individual attempts of recall the location of each red dot on the shape, in the correct order, by pointing to a picture with three possible positions marked.

Verbal working memory is assessed using listening recall. The individual hears a series of individual sentences and judges if each sentence is true or false. At the end of the trial, the individual attempts to recall the final word of each sentence, in the correct order.

Example of a 2-sentence trial:

Trial	Response	Recall
Bananas live in water	‘False’	
Flowers smell nice	‘True’	‘water, nice’

Memory tasks are included to assess the central executive control aspect of working memory, the individual will be required to simultaneously process and store increasing amounts of information until the point at which recall errors are made.

Reliability and validity of the AWMA.

All individuals in the standardization were English-as-first-language speakers. The data collected for the norms reflect a range of ethnic diversity in the United Kingdom, including those from Pakistan, Bangladesh, China, Africa and the Caribbean. According to Alloway (2006), ethnicity does not lead to significant differences in test performance.

Test reliability refers to the consistency with which a test can accurately measure what it aims to do. If an individual's performance remains consistent over repeated trials, it is considered to be reliable (Alloway, 2007). Test reliability of the AWMA was measured on 128 individuals randomly selected across schools and universities aged between 4.10 years to 22.5 years. After 4 weeks, they were retested. There was a close relationship between the first and the second time of testing, which indicates that there was very little change in the scores at the two testing times (Alloway, Gathercole, & Pickering, 2006). The accuracy of the processing aspect of the working memory tasks was also consistent across the two testing periods, suggesting that there was not a substantial practice effect association with this aspect of the task (Alloway, 2007).

Table 3

The correlation coefficients for test-retest reliability of the AWMA

AWMA tests	Retest sample (*n* = 128)
Verbal short-term memory	
Digit recall	.89
Word recall	.88

Nonword recall	.69
Verbal working memory	
Listening recall	.88
Listening recall processing	.84
Counting recall	.83
Backwards Digit Recall	.86
Visuo-spatial short-term memory	
Dot matrix	.85
Mazes Memory	.86
Block Recall	.90
Visuo-spatial working memory	
Odd One Out	.88
Odd One Out processing	.87
Mister X	.84
Mister X processing	.81
Spatial Recall	.79
Spatial Recall processing	.76

Note. (Alloway, 2007).

In addition, the stability of the AWMA was explored in a group of primary-aged children identified as having poor working memory. Individuals with working memory deficits were selected to investigate whether the AWMA could accurately identify those with persistent difficulties. In order to test whether there was any substantial change in working memory ability, the children were tested at the beginning and end of the school year (Alloway, 2007). The table below indicates a close relationship between the two testing times. This is valuable because it establishes both what the AWMA is able to consistently and accurately measure working memory capacity, and that working memory abilities are stable across the course of an academic year (Alloway, 2007).

Table 4

The correlation coefficients between memory components in the AWMA at the beginning and end of the school year in children with working memory deficits

AWMA tests	
Verbal short-term memory	.59
Verbal working memory	.53
Visuo-spatial short-term memory	.54
Visuo-spatial working memory	.60

Note. (Alloway, 2007).

According to standardization data for the 4-11 year old age group, a total of 746 children from 22 primary schools participated in the study. Schools selected for the normative sample represent a range of low, average, and high performance in the combined score of the test results. Schools were located in both urban and rural settings (Alloway, 2007).

There is a high degree of convergence in performance between the AWMA and the WISC-IV Working Memory Index (WMI). This was established in a group of low working memory (standard scores <86) and average working memory children (standard scores >95) selected on the basis of AWMA scores. Performance on the digit span test from the WMI was able to assign correct group membership for 91% of low and average working memory children (Alloway, Gathercole, Kirkwood, & Elliott, 2008).

It was noted in Cockcroft and Alloway's (2012) comparison of South African and British children, where the South African children who had English as their first language obtained higher scores on the AWMA relative to the British children in terms of visuo-spatial short-term and working memory, as well as verbal working memory. There was no significant difference on any of the memory measures of the AWMA between the English-as-second-language South African children and the British children. They proposed that the higher scores achieved by the South African children may be due to the fact that the South African, as was evident in the parental questionnaires, were engaged in far more sporting activities, both during school and extramurally, than their UK counterparts. Tentatively, Cockcroft and Alloway suggest that this may explain the better visuo-spatial working memory abilities of the South African children.

Hodder Group Reading Comprehension Test (Vincent & Crumpler, 2007).

The Hodder Group Reading Test 2 will assess learner's reading comprehension at word, sentence and text levels. The test has been standardised on over 13000 pupils. This assessment is capable of assessing, simultaneously children of very varied reading abilities, and thus is especially useful in this study as The Hodder group reading test will screen and monitor mixed-ability groups where some pupils may be much more advanced, or much slower, than the average.

This test includes questions which assess learner's, aged 7 to 12 years old, understanding of word meanings, culturally neutral sentence-completion questions, and higher-level 'cloze' tasks that require pupils to both comprehend and reflect upon the content and the context of continuous text.

Validity and reliability of the Hodder Group Reading Comprehension Test.

The test has been standardised on over 13000 pupils, giving dependable norms which express performance as standardised scores and reading ages. Internal reliability coefficients (KR20) and inter-form product moment correlation coefficients (r) for the tests are as follows:

Table 5

Internal reliability and correlation coefficients

Test	KR20		SEM	r
	Form A	Form B	Both forms	Inter-forms
HGRT 1	0.96	0.96	3.00	0.95
HGRT 2	0.95	0.95	3.35	0.92
HGRT 3	0.94	0.94	3.67	0.86

Note. (Vincent & Crumpler, 2007)

These indicate a generally high level of reliability. The preceding table also gives the standard error of measurement (SEM) for each test, in points of standardised score, based on the KR20 reliability. The test employs formats which have been extensively used over many years in group standardised reading tests. Such tests have consistently been found to correlate with concurrent validity criteria, such as teachers' judgments and other group and individual reading test batteries. A sub-sample of pupils who took HGRT 1 or 2 was given the Salford Sentence Reading Test (Revised) and a product moment correlation coefficient of 0.79 was attained. Approximately 20 per cent of the pupils made no errors on the Salford Test, although there was still a spread of HGRT scores in this group. Taking this into account, the result can be taken as good evidence in support of concurrent test validity for HGRT.

Procedure for use of test instruments

Participants were tested during the first term of their grade 4 school year in a quiet room in their respective classrooms during the reading comprehension assessment and in the researcher's classroom for the working memory assessment. All tests were administered by a fluent English speaker. Testing took place over two sessions to avoid fatigue. Appropriate informed consent from parents and school authorities was obtained for all of the participants. Ethical clearance was obtained from the relevant University Ethics Committee (Protocol On receipt of the signed consent form, each participant was assigned a number code to ensure confidentiality) and a certificate granted from KZN DoE regarding permission to conduct research in the KZN DoE institutions. For the reading comprehension assessment learners were assessed in a group with their class teacher present. The duration of the reading comprehension test was 30 minutes. All instructions were given at the beginning of the session with practice examples, and they then worked through the rest of the test at their own pace. The HGRT 2 is strictly timed to 30 minutes.

In the second session the AWMA was administered individually and lasted approximately 10 to 15 minutes per learner. Before each testing session, the researcher read the Child Assent Form (Appendix B) to the student. This form explained the process and assured the child that their participation was strictly voluntary. The AWMA test battery was administered in a fixed sequence on a computer. Instructions regarding the tests were automated followed by practice trials for each test. The learners' answers were recorded by the researcher using the right arrow key (for a correct response) and the left arrow key (for an incorrect response) on the computer keyboard. The order of presentation of the working memory and reading comprehension test was alternated across the classes to control for possible order effects.

Method of scoring and data analysis

The data contained within this study were collected using the Automated Working Memory Assessment and The Hodder Group Reading Test. Information regarding the participant's home language and preferred language of testing was collected from a short biographical questionnaire completed by the child's parent or guardian. The assessments were administered in the first school term with a two-week period between administering the two assessments, to cause minimum disruption to their academic programme. The results from the Hodder Group Test were collected and hand scored, with performance expressed as standardised scores and reading ages. The scoring of the AWMA was fully automated. The testing sequence was pre-set, test scores were calculated by the computer program and an interpretation of how their working memory scores will affect their learning was provided. The raw scores are converted into standardized scores. Standard scores are a way of describing an individual's performance with respect to the performance of others in the same age range (Alloway, 2007). An average standard score is where the majority of individuals tested (68%) received a standard score between one standard deviation below (85 – 100) and above the mean (100-115). A low standard score is in the range of 70 and 85. Only 14% of scores fall within this range. A standard score of less than 70 is extremely low and only 2% of scores fall within this range of performance. Standard scores in the range of 115 and 113 are above the average level of performance. Only 14% of scores fall within this range. A standard score of more that 130 is extremely high and only 2% of scores fall within this range of performance (Alloway, 2007).

The results were collected and fed them into the SPSS software in order to analyse the information utilizing the Pearson correlation coefficient.

As parametric techniques in data analysis rely on specific assumptions about population distributions and parameters (Weinberg, 2008) parametric statistical measures were considered appropriate for this study. “The Pearson Correlation Coefficient measures the direction and strength of the linear relationship between the numerical values assigned to the variables” (Weinberg, 2008:135).The Pearson Correlation Coefficients method will give an exact indication of the strength and the direction of the relationship that exists between working memory and reading comprehension in Grade 4 boys.

The data was analysed to determine if a relationship existed between working memory and reading comprehension abilities in the grade 4 boys. Descriptive statistics were generated on each of the 50 participants.

Ethical Issues

An assent form was sent to parents/guardians describing the nature of this study. The letter included a consent form in order for them to grant permission for their child to participate in this study. Participation was voluntary and parents/guardians were informed that they could withdraw at any time. Over and above parental consent, each child was informed, individually, that they were under no obligation to participate in this study. If the child agreed to participate they were asked to write their name on the child assent form (see appendix B) to indicate their willingness to proceed with the assessments. They were informed of their ability to withdraw from the study at any time. Each learner was allocated a number to ensure confidentiality. No results or findings whereby individual participants could be identified would be made public. Documents and assessments will be stored in a locked cabinet for 5 years. Any electronic data would be kept on a computer which is protected by a password.

The Principal of the school was given a description of this study as well as relevant information and signed consent was sought. Ethical clearance was obtained from the ethics committee at the University (see appendix D) and a certificate from KZN DoE regarding permission to conduct research in the KZN DoE institutions (see appendix E) was obtained.

Summary

This chapter described the methods and procedures used to provide insight into the relationship between working memory and reading comprehension. The research design, sample population, the use of assessments in South Africa and the instrumentation was presented. In addition, this chapter discussed the data collection process as well as the analysis of the data collected. The presentation of this data in chapter 4 will address the five research questions. Chapter 5 is a discussion of the results of this study as well as limitations of the study and recommendations for further research. Implications for education and conclusions regarding the study form the content for chapter 6.

CHAPTER 4: RESULTS

Introduction

This chapter begins with an overview of the analysis of the quantitative data collected from a boys' primary school. The end of chapter 4 will present a summary of the data findings as they relate to the research questions. The research questions are:

1. What is the reading comprehension ability of grade 4 boys?
2. What is the working memory of grade 4 boys?
3. Is there a relationship between working memory and reading comprehension of grade 4 boys?
4. Is there a relationship between verbal working memory and reading comprehension of grade 4 boys?
5. Is there a relationship between visuo-spatial working memory and reading comprehension of grade 4 boys?

As described in Chapter 3, the Hodder Group Reading Test (HGRT-2) and the AWMA was administered to the participants. The scores of the two subtests of the AWMA are automatically collapsed by the AWMA programme to reflect scores for verbal working memory and visuo-spatial working memory. The AWMA measured the central executive, phonological loop and visuo-spatial aspects of working memory.

Working memory and reading comprehension scores were collected for each of 50 students. The working memory scores were divided into verbal working memory scores (Listening Recall and Listening Recall processing scores) and visuo-spatial working memory scores (Spatial Recall and Spatial Recall processing scores). The working memory score was calculated as the mean of the above mentioned 4 working memory scores and the verbal and visuo-spatial working memory score as the mean of the above mentioned 2 verbal and 2 visuo-spatial working memory scores.

The statistical results are reported and where applicable tables and scatterplots are shown. The scatterplot is a useful means with which to explore the relationship between variables, and generally, creating scatterplots, for pairs of continuous variables is part of the exploratory phase of working with a data set (Boslaugh, 2012). A scatterplot is a graph of two continuous variables. When the research design specifies that one variable is independent and the other is dependent, as in this study, the independendent variable is working memory capabilities and the dependent variable is reading comprehension. The explanatory variable is graphed on the *x*- axis (horizontal) and the dependent variable on the *y*-axis (vertical) (Boslaugh, 2012). Each participant of the sample corresponds to one data point on the graph, described by a set of coordinates (*x, y*) (Boslaugh, 2012).

Scatterplots give you a sense of the general relationship between the two variables, including direction (positive or negative), strength (strong or weak), and the shape (linear, quadratic, etc.) (Boslaugh, 2012).

To establish the strength of the correlational relationship between working memory and reading comprehension abilities, the Pearson Correlation Coefficient was used.

"The strength of the relationship between two variables is the degree to which one variable does tend to vary with the other" (Coolican, 2013:432).

For two variables measured on the interval or ratio level, the most common measure of association is the Pearson Coefficient, written as p for population and r for a sample (Boslaugh, 2012). Pearson's r has a range of (-1, 1,) with 0 signifying no relationship between the variables and the larger absolute variables indicating a stronger relationship between the variables

(Boslaugh, 2012). The labels “strong” and “weak” do not have precise numerical definitions, however, a relationship described as strong will have a more linear relationship, with points clustered more closely around a line drawn through the data, than will data with a weak relationship (Boslaugh, 2012).

Research question 1

The first research question asked what the reading comprehension abilities are of grade 4 boys. Participants answered questions on a group reading comprehension test which assessed their reading comprehension abilities at word, sentence and text levels. To examine research question 1 the mean standardized scores were calculated to assess their reading comprehension abilities. The resulting analysis is presented in table 6.

Table 6

Summary of mean standard score for the reading comprehension abilities

	Reading comprehension
Mean	104.06
Variance	162.751
Observations	50

The standardized scores for the Hodder Group Reading Test are on a normative scale with a mean of 100. The interpretation of these scores show that the reading comprehension abilities of grade 4 boys in South Africa, with a mean of 104.06, are in the average range.

Research question 2

The second research question asked what the working memory capacities of grade 4 boys. Participants answered questions on the Automated Working Memory Assessment, which screens for significant working memory problems in individuals aged between 4 and 22 years old. The AWMA provides measures of verbal and visuo-spatial aspects of working memory. More complex memory tasks are also included to assess the central executive control aspect of the working memory. In these working memory tasks, the learner was required to simultaneously process and store increasing amounts of information until the point at which recall errors were made.

Administration (move on and discontinue rules) and scoring was fully automated. To examine research question 2 the mean was calculated to assess the working memory capabilities of grade 4 boys. On the AWMA scores are standardized to a mean of 100 with a standard deviation of 15 for each age band. Scores in the 70 – 85 range are below average, scores in the 85 – 100 range are low average, scores in the 100 – 115 range are high average, and those in the 115 – 130 range are above average. From the summary of means data it can be established that the mean standard scores of the two composite measures on the AWMA fall into the average range. The resulting analysis is presented in table 6.

Table 7

Summary of mean standard scores for working memory

	Working memory
Mean	99.4565
Variance	118.432
Observations	50

Research question 3

Research question 3 asks what relationship, if any, exists between working memory and reading comprehension abilities in grade 4 boys. The resulting analysis is presented in figure 4.

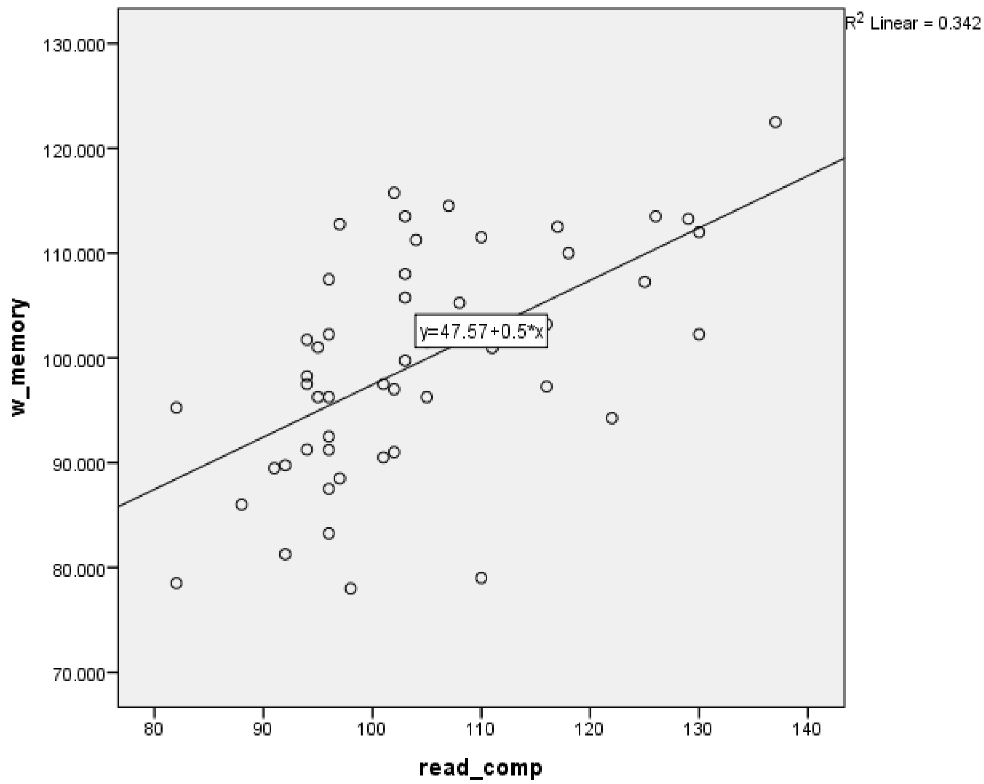

Figure 7. **Working memory versus reading comprehension**

The plot suggests a positive linear relationship between the two variables i.e. as reading comprehension increases so does working memory. The Pearson correlation between reading comprehension and working memory is shown in the table 8 that follows.

Table 8

Pearson correlation between reading comprehension and working memory

		Read_comp	W_memory
Read_comp	Pearson Correlation	1	.584**
	Sig. (2-tailed)		.000
	N	50	50
W_memory	Pearson Correlation	.584**	1
	Sig. (2-tailed)	.000	
	N	50	50

*Note.*** Correlation is significant at the 0.01 level (2-tailed).

As can be seen from the above table, the correlation between reading comprehension and working memory is 0.584 which is significantly different from 0 (p-value = 0.000). It should be noted that although the correlation coefficient between the variables is significantly different from 0, the strength of the relationship is, at most moderately positive.

In conducting any research with two independent groups, we will typically find that the two sample means differ by at least a small amount. It is important to ascertain, however, whether that difference is sufficiently large to justify the conclusion that the two samples were drawn from different populations. One of the most common uses of the t-test involves testing the difference between the means of two independent groups (Howell, 2010).

“A *p*-value expresses the probability that results at least as extreme as those obtained in an analysis of sample data are due to chance” (Boslaugh, 2012:69). P-values are typically reported for most research results comprising of statistical calculations, partly because intuition is a poor guide to how unusual a particular result is (Boslaugh, 2012). There is no statistical definition of what comprises "unusual" results, so this study will use the common standard that the p-value for the results must be less than 0.05 in order to reject a null hypothesis that there is no relationship between working memory and reading comprehension abilities in grade 4 boys.

Paired t-tests were performed to test whether or not the differences between the reading comprehension and working memory means are significantly different from 0. The results are shown below.

Table 9

T-Test: Paired Two Sample for means working memory and reading comprehension

	Reading comprehension	Working memory
Mean	104.06	99.4565
Variance	162.751	118.432
Observations	50	50
Pearson Correlation	0.584	
Hypothesized Mean Difference	0	
df	49	
t Statistic	2.985	
P(T<=t) one-tail	0.002	
t Critical one-tail	1.677	
P(T<=t) two-tail	0.004	
t Critical two-tail	2.01	

Since the p-value of 0.004 is very small (less than 0.01), there is, therefore, sufficient evidence to conclude that the reading comprehension mean is significantly greater than the working memory mean.

Research question 4

Research question 4 asks if there exists a relationship between reading comprehension and verbal working memory. A scatterplot of working memory versus reading comprehension together with the fitted least squares line is shown below.

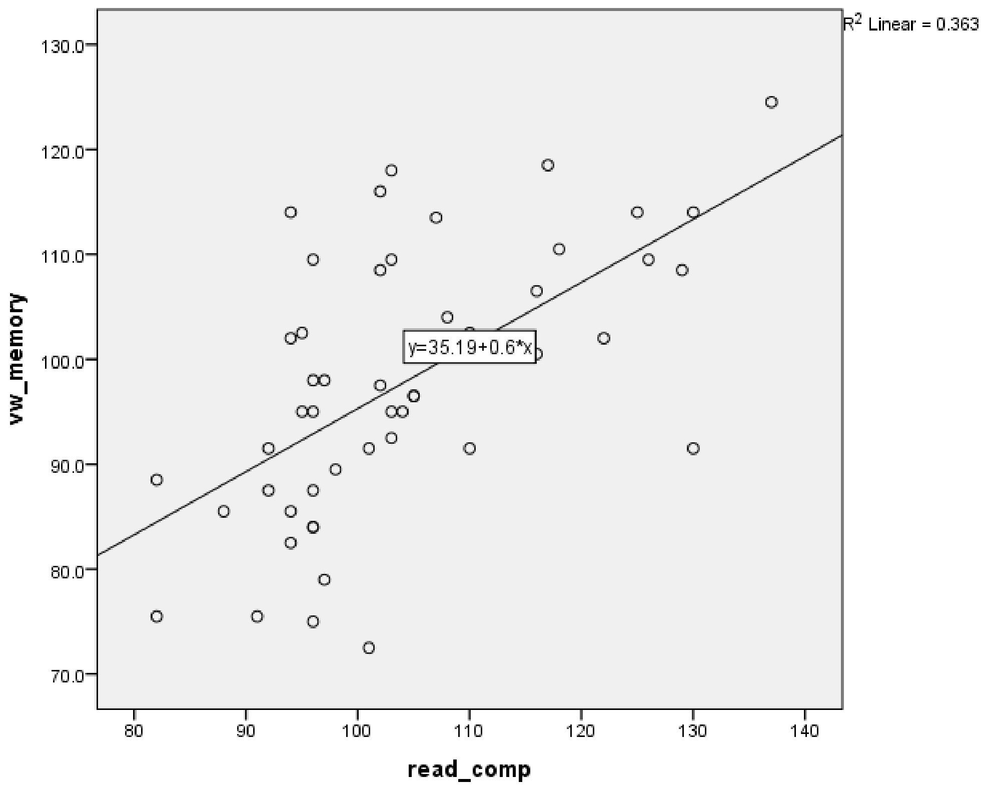

Figure 8. **Verbal working memory versus reading comprehension**

The plot suggests a positive linear relationship between the two variables i.e. as reading comprehension increases so does verbal working memory. The Pearson correlation between reading comprehension and verbal working memory is shown in the table that follows.

Table 10

Pearson correlation between reading comprehension and verbal working memory

		R_comp	Vw_memory
	Pearson Correlation	1	.602**
Read_comp	Sig. (2-tailed)		0.000
	N	50	50
	Pearson Correlation	.602**	1
Vw_memory	Sig. (2-tailed)	.000	
	N	50	50

Note. ** Correlation is significant at the 0.01 level (2-tailed).

As can be seen from the above table, the correlation between reading comprehension and verbal working memory is 0.602 which is significantly different from 0 (p-value = 0.000). It should be noted that although the correlation coefficient between the variables is significantly different from 0, the strength of the relationship is, at moderately positive.

Table 11

t-Test: Paired Two Sample for means of verbal working memory and reading comprehension

	Reading comprehension	Verbal working memory
Mean	104.06	97.75
Variance	162.751	162.217
Observations	50	50
Pearson Correlation	0.602	
Hypothesised Mean Difference	0	
df	49	
t statistic	3.924	
P(T<=t) one-tail	0.000135613	
T Critical one-tail	1.677	
P(T<=t) two-tail	0.000271226	
t Critical two-tail	2.01	

Since the p-value of 0.000271226 is very small (less than 0.01), there is sufficient evidence to conclude that the reading comprehension mean is significantly greater than the verbal working memory mean.

Research question 5

A scatterplot of visuo-spatial working memory versus reading comprehension together with the fitted least squares line is shown below.

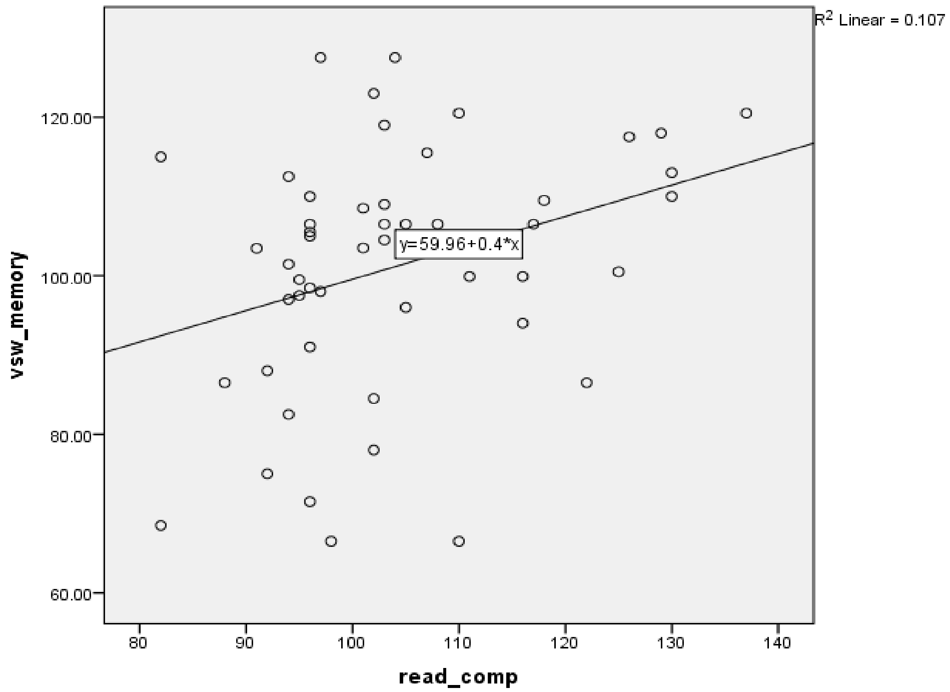

Figure 9. **Visuo-spatial working memory versus reading comprehension.**

The plot suggests a weak positive linear relationship between the two variables. The fitted line has a positive slope (broadly speaking reading comprehension and visuo-spatial working memory move in the same direction), but many of the plotted pointe are far from the line. The Pearson correlation between reading comprehension and visuo-spatial working memory is shown in the table that follows.

Table 12

Pearson correlation between reading comprehension and visuo-spatial working memory

		Read_comp	VS_wm
	Pearson correlation	1	.327*
Read_comp	Sig. (2-tailed)		.021
	N	50	50

	Pearson correlation	.327*	1
Vs_wm	Sig. (2-tailed)	0.21	
	N	50	50

Note. * Correlation is significant at the 0.05 level (2-tailed).

It can be seen from the above table that this correlation (0.327), although significantly different from 0, is considerably weaker than the previous two that were calculated.

Table 13

t-Test: Paired Two Sample for means of visuo-spatial working memory and reading comprehension.

	Reading comprehension	V-S working memory
Mean	104.06	101.163
Variance	162.7514286	239.1999806
Observations	50	50
Pearson Correlation	0.326607722	
Hypothesised Mean Difference	0	
df	49	
t Stat	1.239648787	
P(T<=t) one-tail	0.110504833	
t Critical one-tail	1.676550893	
P(T<=t) two-tail	0.221009667	
t Critical two-tail	2.009575237	

Since the p-value of 0.221 > 0.05, there is not sufficient evidence to conclude that the reading comprehension mean is significantly different than the visuo-spatial working memory mean.

Summary

This chapter began with an overview of the data analysis procedures and a discussion of the five research questions. The primary focus of this study was to determine if there was a relationship between working memory and reading comprehension abilities in grade 4 learners. The data suggested that a correlation between working memory and reading comprehension may indeed exist in grade 4 boys.

The insights gained from this study will hopefully contribute to the lack of quantitative data that exists in South Africa regarding working memory and reading comprehension. A more in depth discussion regarding the results of this study ensues in the following chapter.

CHAPTER 5: DISCUSSION

Introduction

This research was conducted to investigate the relationship between working memory and reading comprehension abilities in grade 4 boys. The results obtained from the standardised assessment tools were presented in the previous chapter. This chapter will present a summary of the purpose of the research, procedures, and findings. In addition, the relationship between the quantitative results and the literature will be discussed.

Summary of the purpose of the study

The purpose of this study was to quantitatively determine if a relationship exists between working memory and reading comprehension. The Automated Working Memory Assessment (Alloway, 2007) and the Hodder Group Reading Test 2 (Vincent & Crumpler, 2007) were administered to assess 50 grade 4 learners working memory capacities and reading comprehension abilities.

Research questions

Research question 1

In this study, the first research question asked what the reading comprehension abilities of grade 4 boys are. All participants answered the same reading comprehension questions assessed using the Hodder Group Reading Test 2. In this study, the findings revealed that grade 4 boys' reading comprehension abilities are within the average range of performance.

This finding is in contrast to the South African National Reading Panel's evaluation of reading comprehension abilities for Intermediate Phase Learners. Results from the South African National Reading Panel systematic evaluation in 2008 (Cekiso, 2012), showed that amongst the

Intermediate Phase learners, 63% were below the required competence for their age level, regarding reading comprehension. The study used participants of mixed reading abilities.

Teachers in South Africa have had their fair share of experiencing change since 1994, beginning with an intricate and contradictory curriculum – change process. This comprised of the National Department of Education's uncritical embracing of an outcomes-based education system, Curriculum 2005, which was employed for the first time in 1998 (Menken & Garcia, 2010). Jansen (1997) states that there were many difficulties with the implementation of this curriculum, ranging from inaccessible terminology to the impracticability of applying certain teaching methods in overcrowded classrooms. The curriculum was not all negative, however, as it included the introduction of constructivist, meaning-based teaching methods for literacy learning which, amongst other things, promotes reading for enjoyment through a 'literacy half hour' (Menken & Garcia, 2010). Bloch (Menken & Garcia, 2010) believes it is of great significance that there are opportunities that now exist to counter the prevalent rote-learning, isolated skills-based methods exercised widely in postcolonial Africa to teach literacy.

As noted in the literature review, in most circumstances, the ultimate goal of reading is comprehension. Working memory performs an important function in this process by storing the words that have been recognised for a sufficient amount of time to enable the reader to link the words together to construct a meaningful interpretation of the text (Gathercole & Alloway, 2008).

Research question 2

Research question 2 asked what the working memory capabilities of grade 4 boys are. The AWMA was administered to all the participants in the study. This battery assessed the verbal and visuo-spatial working memory of the subject. The verbal section of the test was divided into two subtests: listening recall and listening processing. The visuo-spatial portion of the test was also divided into two subtests: spatial recall and spatial processing.

Research has shown that 10-15% of children in mainstream schools experience working memory difficulties. In calculating the means of the participants' working memory scores, in the present study, 10% of the participants scored lower than 85 indicating working memory difficulties. This is in line with previous research regarding working memory deficits in mainstream schools. In Alloway's (2011) large scale screening study of over 3000 typically developing learners, 1 in 10 students were struggling with working memory impairments. Working memory was, according to Alloway (2011), the critical skill linked to their learning.

Until grade 3, children are generally learning to read. By grade 4, they should be reading to learn. After that the content becomes increasingly more difficult and reading becomes more challenging (Carnine, 2004). Sometimes students who make suitable progress in the early grades begin to experience difficulty in grade 4 (Carnine, 2004). Researchers suggest that reasons for this "fourth grade slump" could include fewer picture clues in texts, the increase in new vocabulary words, and an expectation that students extract meaning from the text rather than simply reading for plot (Chall, Jacobs, and Baldwin, 2009). Learners in the middle grades, according to Snow (2001), need to learn to process increasingly challenging texts, with denser grammar, unfamiliar words, and complex ideas. They need to learn how to learn from reading and to be critical of what they read. This study is important as it appears that focusing on teaching reading and reading comprehension skills, is not enough.

Without early intervention, working memory impairments cannot be made up over time and will continue to affect a child's likelihood of academic success. The practical implications suggest that identification of significant working memory problems can lead to effective management and support to bolster learning (Alloway & Alloway, 2009).

Early detection of learners with limited working capacity enables educators to plan classroom strategies to accommodate these learners. South African classrooms are faced with factors such as the new curriculum's allocated instructional time, large class sizes, underqualified teachers and lack of resources, which hinders educators' ability to recognize working memory failures in the classroom. Factors such as these often mean that instructions are not repeated, there is not enough time for students to ask questions to clarify their meaning of tasks and learners often become despondent. Recommendations and guidelines, with the aim of alleviating the disruptive consequences on learning of excessive working memory loads, have been presented to the teachers and will be discussed under the heading implications for classroom practice.

Research question 3

Research question 3 asked if there exists a relationship between working memory and reading comprehension abilities in grade 4 boys. The results from this study showed a correlation between reading comprehension and working memory of 0.584 which is significantly different from 0. The findings build upon previous evidence of relationships between these two constructs. Baddeley (Seigneuric & Ehrlich, 2005), states that the essential ability in text comprehension is the construction of integrated mental representations. He goes on to argue that this skill makes heavy demands on both the processing and storage functions of working memory. Evidence from studies involving children representative of all levels of reading ability show that working memory is an important factor in explaining reading comprehension ability (Vukovic & Siegel, 2006). For example, in Siegneuric, Ehrlich, Oakhill, and Yuill's study (Vukovic & Siegel, 2006) utilizing a sample of fourth-grade children, they established that working memory measures involving sentences, words, and digits, accounted for a significant amount of variance in reading comprehension over and above reading fluency and vocabulary. The findings that working memory accounts for unique variance in reading comprehension independent of skills such as word recognition and fluency are also consistent with those in a longitudinal study conducted by Vukovik and Siegel (2005).

The literature review presented evidence suggesting that working memory plays an important role in complex cognitive skills including reading comprehension. The results from this study suggest a positive correlation between working memory and reading comprehension abilities in grade 4 boys. According to the literature reviewed in this study, high-performing learners in language tend to have efficient working memory and that poorly performing learners tend to have limited working memory (Pinar, 2010). The implication that working memory is involved in reading comprehension requires that learners with specific comprehension difficulties need to be taught strategies for processing and remembering verbal information. The central role of automaticity in structuring a curriculum taking into account working memory deficits in South Africa, must be emphasized (Pinar, 2010). The more a learner can do automatically, the more free space there is within working memory which allows for concentration on the actual task at hand, rather than its preconditions. Neuroscience , according to Pinar, 2010, has to intersect with curriculum studies. It provides some insight into how we can structure teaching and learning to develop its higher functions in progressively more sophisticated ways.

Research question 4

Research question 4 asked if there exists a relationship between verbal working memory and reading comprehension in grade 4 boys. The results from this study showed a correlation between reading comprehension and verbal working memory of 0.602 which is significantly different from 0. The findings build upon previous evidence of relationships between verbal working memory and reading comprehension. Several reading and working memory researchers propose that diminished working memory capacities, particularly in the phonological and verbal subcomponents, are associated with impaired development of decoding skills and reading comprehension (Dehn, 2011).) Verbal working memory is considered by Westby and Watson (Irons, 2011), to be internalized language that is used to talk to oneself, to provide reflection, description, instruction and questioning, which then facilitates problem-solving, the development of rules, and moral reasoning.When these are related to prior knowledge and past experiences, accessed through the episodic buffer, enhanced comprehension is possible (Irons, 2011). Much research has supported Baddeley and Hitch's phonological (verbal) working memory as an important source of individual differences in reading (Berninger, Abbott, Swanson, Lovitt, Trivedi, Lin, Gould, Youngstrom, Shimada, Amtmann, 2009). According to Baddeley (Berninger, et al, 2010) the phonological loop functions as a language learning mechanism for pairing names (phonological buffer) with objects (visual-spatial sketch pad) or situations (episodic buffer) in early vocabulary learning. By means of the phonological loop, Baddeley proposes that acoustic speech information can be held momentarily under attentional control for the purposes of reading comprehension (Askildson, 2008).

Research question 5

Research question 5 asked if a relationship exists between visuo-spatial working memory and reading comprehension abilities in grade 4 boys. The results from this study showed a correlation between reading comprehension and visuo-spatial working memory of 0.327 which although is significantly different from 0, is considerably weaker than working memory in general and verbal working memory in particular. Since the p-value of $0.221 > 0.05$, there is not sufficient evidence to conclude that there is a relationship between visuo-spatial working memory and reading comprehension abilities in grade 4 boys. These findings are in line with previous research which suggests that the visuo-spatial sketchpad is clearly of less significance to language disorders than is the phonological loop (or verbal working memory). However, it seems likely that the system will be involved in everyday reading tasks, where it may be concerned with maintaining a representation of the page and it's layout that will remain constant and facilitate tasks such as moving the eyes accurately from the end of one line to the beginning of the next (Baddeley, 2003). The results of this study suggest a weak positive linear relationship between visuo-spatial working memory and reading comprehension. Murray and Kennedy (Oakhill, Yuill & Garham, 2011), have proposed that spatial working memory is important for place-keeping skills in reading comprehension. These place-keeping skills of fluent readers allow them to re-inspect text selectively, and children who are good readers are more adept at re-inspecting text selectively than poor reads. This is in line with the Baddeley and Hitch model which suggests that because working memory is flexible. Should the phonological loop reach capacity or is unusable, the other components, the central executive and visuo-spatial sketchpad, kick in (Smith & Kosslyn, 2008).

Individual working memory score patterns

In general, learners with poor working memory have a tendency to perform poorly on all of the working memory tests, regardless of whether they involve verbal or visuo-spatial material (Alloway, 2007). This corresponds with Baddeley's (Alloway, 2007), theory of working memory whereby the central executive is involved in processing and manipulating any sort of material, and so should contribute to both visuo-spatial and verbal working memory tasks. Therefore, a learner who has poor central executive function would be expected to have deficits in both types of working memory assessment. Generally, the individual participants' working memory score patterns were consistent with this theory. However, Alloway, (2007) suggests that some children have a much more uneven profile, with greater impairments in working memory performance for either verbal or visuo-spatial material. She goes on to explain that children with language impairments tend to have greater deficits in verbal working memory than visuo-spatial working memory, and children with motor coordination difficulties generally perform more poorly on the visuo-spatial than the verbal working memory measures. This may be due to the fact that these learners have basic deficits in processing material of that particular variety which then has knock-on consequences for storing hat material in working memory (Alloway, 2007). For these learners, the end result will be poor working memory for some, but not all kinds of information. According to Baddeley and Lieberman (Smith & Kosslyn, 2008), the distinct experience of moving the mind's eye from one spatial location to another also suggests that visuo-spatial working memory may possibly depend on brain systems that plan movements of the eyes (or possibly other parts of the body), just as verbal working memory depends on brain systems concerned with planning speech. However, there is a considerable variation in the working memory profiles even with these particular diagnoses, and the AWMA presents a convenient means of establishing working memory strengths and weaknesses (Alloway, 2007). The strengths of these learners are especially important as they provide an excellent basis for developing effective strategies that may compensate for areas of working memory weaknesses (Alloway, 2007). In this study, two particular participants' scores stood out. The first participant scored a mean verbal working memory score of 76 (a low standard score) and a mean visuo-spatial working memory score of 103 (an average standard score). The second participant also scored a mean verbal working memory score of 76 and a mean visuo-spatial working memory score of 115 (a high standard score). It is interesting to note, that both participants showed delays in reading comprehension ability. It was noted in Cockcroft and Alloway's (2012) comparison of South African and British children, where the South African children who had English as their first language obtained higher scores on the AWMA relative to the British children in terms of visuo-spatial short-term and working memory, as well as verbal working memory. There was no significant difference on any of the memory measures of the AWMA between the English-as-second-language South African children and the British children. They proposed that the higher scores achieved by the South African children may be due to the fact that the South African, as was evident in the parental questionnaires, were engaged in far more sporting activities, both during school and extramurally, than their UK counterparts. Tentatively, Cockcroft and Alloway suggest that this may explain the better visuo-spatial working memory abilities of the South African children. The participants in this study attend a school with a strong emphasis on sporting participation which may be a contributing factor to the higher visuo-spatial working memory scores. This may account for the slightly higher mean scores in visuo-spatial working memory (101.163) as opposed to verbal working memory scores (97.75) in the sample.

Limitations of the study

It is important to note that caution must be exercised when making generalizations based on the findings of this study, although every effort has been made to make the study as representative as possible. Limitations in the research design and methods of data analysis are discussed, and recommendations are made for future research, particularly within a South African context.

Inadequacies of the instruments.

According to the policy document of the Health Professions Council of South Africa regarding the classification of psychometric instruments (HPCSA, 2002:1) “few tests are available that have been designed and standardised for all South Africans… the practice has arisen of using tests developed for a white, westernised population with other cultural groups and “applying the norms with caution”.

As stated in chapter 3, however, level of education, an essential part of socio-economic status, has always been an important variable when interpreting test scores (Laher & Cockcroft, 2013). The participants in this study attend a high functioning, self-directed government school that receives extensive support from the community and the parents. As such they have received a high standard of education.

One of the limitations of the study was that performance on the tests was statistically aggregated. Put another way, the study did not account for individual differences in performance on the tests (Fisher, 2008). Logie (1995) argued that individual patterns of performance on cognitive-behavioural tests is seldom detailed in the literature, and may be integral to understanding unique strategic techniques within working memory task performance. For example, the kind of error produced by the participant encompasses a lot of important information, including the type of judgement-call made by the subject. Some subjects respond impulsively to almost all targets, which results in seemingly more accurate response to targets but exceedingly high commission error. In a clinical framework, impulsivity may be a marker for poor executive control or frontal lobe compromise. Individual differences are highly important and need to be investigated for performance on the tests to be more relevant (Fisher, 2008).

Weaknesses of the Automated Working Memory Assessment.

The standardisation of the Automated Working Memory Assessment is based on children selected from schools in the United Kingdom. The Automated Working Memory Assessment has been proven empirically to be a valid and reliable measuring instrument for the construct it proposes to measure (Alloway, 2012) However, this assertion applies to research conducted with primarily Western population groups. The application of the standardised scores may be inappropriate to the South African Context. This was amplified by the presentation of the instructions in a fairly heavy British accent.

Weaknesses of the Hodder Group Reading Test.

Standardisation concerns relating to the Automated Working Memory Assessment also apply to the Hodder Group Reading Test. While most of the participants who completed this assessment are likely to have been exposed to some degree of Western attitudes and education, it is unwise to assume that they have all been westernised to the same or a similar extent. In a country such as South Africa, a great variety exists in terms of the type and level of westernised education which individuals have received. The participant’s reasoning and perceptions are thus likely to differ according to their various cultural and educational backgrounds. It would not be appropriate to assume that only one reading assessment would be able to assess the reading comprehension abilities of grade 4 boys in such a diverse cultural setting as a South African primary school.

The inadequacy of the sample.

Convenience sampling was used in this study and although it is the most commonly used method in behavioural science (Gravetter & Forzano, 2010) it offers no guarantees of a representative and unbiased sample. A strategy that helps minimise potential problems with convenience sampling is to provide a clear description of how the sample was obtained and who the participants are (Gravetter & Forzano, 2010). A clear description of the sample is outlined in chapter 3. Readers should consider the current findings and conclusions with caution. In addition, the non-random structure of the current data suggest that the interpretation of results should be limited to the groups examined at the time of this research. In an attempt to include only children from similar socio-economic backgrounds in this study, convenience sampling resulted in the entire sample being obtained from an urban primary school in Durban. Consequently, the findings may be generalizable only to pupils attending an urban, primary school in the Durban area.

Threats to validity

As convenient, non-random sampling was used in a group of individuals from a certain socio-economic status, external validity was possibly negatively affected. The ‘privileged’ sample able to afford a high level of education and/or learning support, may not accurately reflect the nature and context of the general school-aged child in their grade 4 year of education and thus, the results may not be generalisable to other groups (Fisher, 2008).

Recommendations for future research

The application of the standardised scores may be inappropriate to the South African context. This was amplified by the presentation of the instructions in a fairly heavy British accent. For future research, the use of the Working Memory Rating Scale may be more applicable to the South African context. As standard cognitive assessments are associated with high costs, working memory impairments often go undetected in children growing up in poverty. A reliable and cost-effective measure like the Working Memory Rating Scale, that is quick to score and easy to interpret by a non-specialist, therefore represents a particularly valuable tool in countries like South Africa with a shortage of public health services, in order to determine whether referral for time-intensive and expensive cognitive assessment is warranted (Engle de Abreu, Nikaedo, Abreu, Tourinho, Miranda, Bueno & Martin, 2013). Informal screening in the classroom by teachers to see if further 'computerised' testing is called for is also recommended.

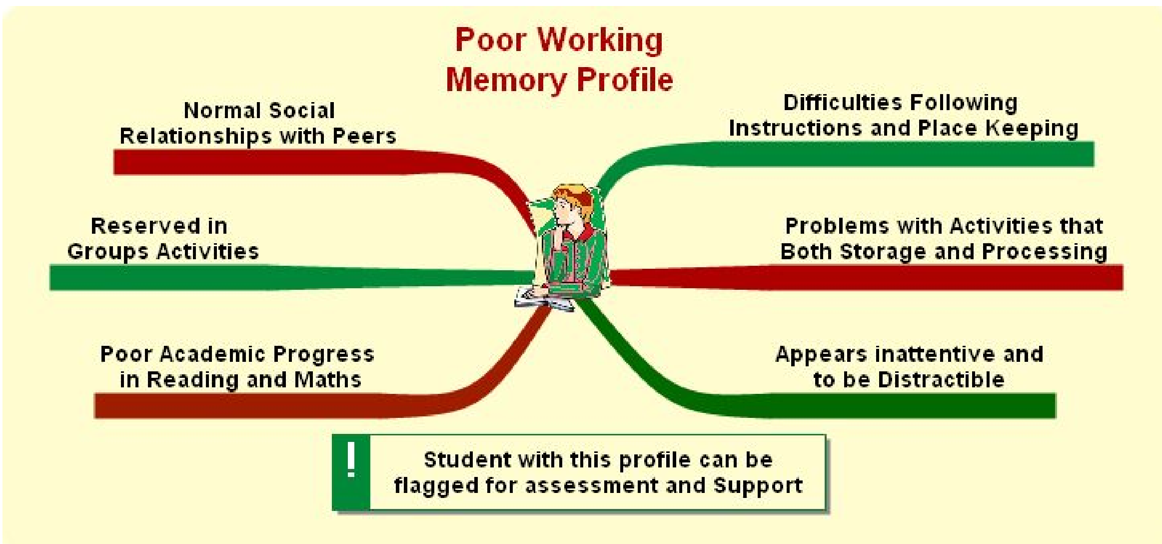

Figure 10. **Poor working memory profile (Tannock, 2013).**

It is also imperative for future studies that the AWMA is normed in South Africa to ensure that assessment results are accurate. The AWMA screener test was used to minimize disruption to the learner's academic programme, however, the researcher recommends for future research the utilization of the more comprehensive AWMA long form consisting of 12 tests.

A direction for future research and development of computer-based tests (as with the AWMA) would be to move towards touch screen computer-based assessment (Fisher, 2008). The Brain Resource Company (BRC) of Australia has developed a touch-screen-based set of neurocognitive tests (Fisher, 2008). The Brain Resource Company, report high reliability and validity between their computer-based versions and the original versions of the tests. Computerised Adaptive Testing (CAT) is another method of computer-based assessment that may be particularly useful in the South African context (Fisher, 2008). CAT warrants that if a test begins at a level that is too difficult for the test-taker, the computer modifies the level in accordance to the test-taker's response. If the level is too easy, the computer adapts the level of difficulty so that the test-taker begins at a higher level (Fisher, 2008).

New and varied research methodology has provided a holistic perception of working memory. Cowan (1997) believes that it is beneficial to incorporate these methodologies in order to direct future research. Carpenter, Just and Reichle (2000), state that neuroimaging studies have recently been used extensively in working memory and executive processes research and have greatly enhanced the investigation of working memory processes and components. One of the challenges for the interdisciplinary field of working memory research is to be able to merge different kinds of information so that they inform one another (Fisher, 2008). In other words, Lockhart (2000), determines that it is crucial that the theory of working memory informs physiological and neuroimaging investigations into working memory and vice versa. A recommendation from this study is that future research should attempt to examine working memory from an interdisciplinary position, so as to begin to understand the construct of working memory holistically (Fisher, 2008).

As discussed, that while most of the participants who completed the reading comprehension assessment are likely to have been exposed to some degree of Western attitudes and education, it is unwise to assume that they have all been westernised to the same or a similar extent. In a country such as South Africa, a great variety exists in terms of the type and level of westernised education which individuals have received. It would not be appropriate to assume that only one reading assessment would be able to assess the reading comprehension abilities of grade 4 boys in such a diverse cultural setting as a South African primary school. More reading assessments need to be normed for the South African population for future studies.

As the study included only children from similar socio-economic backgrounds, convenience sampling resulted in the entire sample being obtained from an urban primary school in Durban. Consequently, the findings may be generalizable only to pupils attending an urban, primary school in the Durban area. Future studies should be replicated with a larger sample selected from a more diverse population of students.

Reliability for the tests could not be assessed due to the time limits imposed by the study. Ascertaining the reliability of the tests is important for future development and it is both feasible and necessary to investigate the reliabilities of the tests in future research (Fisher, 2008). To assess test-retest reliability, there would need to be a large time gap between administrations of the tests and it would be required to assess whether practice effects have occurred between administrations, as practice effects have been consistently demonstrated on many of the tests (Fisher, 2008).

Discussion of computerised testing

It is important to note so of the advantages to computer-based test administration, as with the Automated Working Memory Assessment (Alloway, 2007). Davies, Foxcroft, Griessel and Tredoux (2005) discuss some of the advantages of computer-based testing whereby computerised tests have often been perceived to be more enjoyable than paper-based tests This has often increased the level of motivation of the test-taker to perform on a test. Gur, Ragland, Moberg, Turner, Bilker, Kohler, Siegel, and Gur (2001), propose that computer-based testing has also reduced the time that it takes to administer a test, which could help to diminish the effects of fatigue on test performance . Davies et al (2005) states that computerised administration has standardised the administration and instructions of a test so that data validity is improved, has enhanced the precision of timing, which has decreased the variability in timing on test validity. It has increased inter-rater reliability as recording and scoring of tests has been more accurate. Computer-based scoring has also reduced data-handling errors and has therefore increased the security of test results, as test information has been better documented and protected (Fisher, 2008).

Evaluation of the working memory model

Researchers today generally concur that short-term memory consists of a number of components or subsystems (McLeod, 2008). The working memory model has replaced the notion of a unitary short-term memory described in chapter 2. The KF case study (McLeod, 2008), supports the working memory model whereby brain damage form a motorcycle accident that damaged his short-term memory, was sustained. KF’s impairment was mainly for verbal information as his memory for visual information was largely unaffected. This demonstrates that there are distinct components for visual information (VSS) and verbal information (phonological loop)(McLeod, 2008).

Summary

This chapter was a discussion of the results presented in the previous chapter. In conclusion, findings contribute to an understanding of working memory, and its components, and its relation to reading comprehension within a South African context. It was the intention of this study to improve the understanding of working memory and its contribution to reading comprehension. The findings of this study revealed a positive linear relationship betweenthe two variables i.e. as reading comprehension increases so does working memory. Verbal working memory was more strongly correlated with reading comprehension than visuo-spatial working memory, which is in accordance with other studies related to this study. Vukovic and Siegel

(2006) support the notion that the verbal domain of working memory is asscociated with reading comprehension. Specifically, these researchers refer to the importance of verbal working memory, in particular, in relation to reading comprehension. (Irons, 2011). Although, this study supports Just and Carpenter's single resource theory (Gibson & Fedorenko, 2004), whereby one generic pool of resources is accessed for all verbally-mediated tasks, the relation between the visuo-spatial aspect of working memory and reading comprehension is not significant and it is unclear to what extent this resource plays a part in language comprehension. Although every effort has been made to make the study as representative as possible, it is important to exercise caution when making generalizations based on the findings of this study. Therefore, limitations in the research design and methods of data analysis were discussed, and recommendations are made for future research, particularly within a South African context. Recommendations for classroom practice and conclusions regarding this study form the content of the following chapter.

CHAPTER 6: RECOMMENDATIONS AND CONCLUSIONS

Introduction

This study extended previous research with regard to exploring the relationship between components of working memory and reading comprehension and in terms of the South African context it was conducted in. Statistical analysis determined that there is a positive relationship between working memory and reading comprehension in grade 4 boys. Furthermore, it is apparent that there exists a stronger relationship between verbal working memory and reading comprehension than that of the weaker positive linear relationship between visuo-spatial working memory and reading comprehension. This chapter discusses the implications of these findings for classroom practice and a guide for educators in identifying working memory difficulties. This chapter concludes with recommendations for enhancing this learner's educational support.

Recommendations for classroom practice

For a learner to achieve success in learning it is critical that they can remember the task set by the teacher. Learning failures hinder the probability of the child obtaining the knowledge and skills that build a foundation for complex cognitive activities, such as reading comprehension. It is therefore important to identify working memory difficulties as a source of learning difficulty in individual learners and to reduce the incidence of learning failures by minimizing the demands placed on working memory in the classroom (Gathercole, Lamont & Alloway, 2006).

In the present study, grade 4 teachers received guidance that will allow them to identify working memory failures in the classroom and they were shown the following recommendations, supplied by Gathercole & Alloway (2008), on how to minimize them for individual children. In each case the aim is to minimize the chances that the learner will fail to complete the intended learning activity successfully due to working memory failures.

Recognizing working memory failures

Working memory failures typically present as frequent errors of the following kinds:

- Incomplete recall, such as forgetting some or all of the words in a sentence, or of a sequence of words.
- Failing to follow instructions, including remembering only part of a sequence of instructions, or forgetting the content of an instruction.
- Place-keeping errors- for example, repeating and/or skipping letters and words during sentence writing, missing out large chunks of a task.
- Task abandonment – the learner gives up a task completely.

Monitoring the child

It is important to monitor the learner's working memory frequently in the course of demanding activities.

Evaluating the working demands of learning activities

Activities that impose heavy storage demands typically involve the retention of significant amounts of verbal material with a relatively arbitrary content. Some examples of activities with working memory demands that are likely to exceed the capacities of a child with working memory deficits include:

• remembering sequences of three or more numbers or unrelated words (e.g. 5, 9, 2, 6 or cat, lion, kangaroo)

• remembering and successfully following lengthy instructions. For example, put your paper on the brown table, books on the shelf, put your pencil away, and come and sit on the floor)

• remembering lengthy sentences containing some arbitrary information to be written down (e.g. To blow up parliament, Guy Fawkes had 36 barrels of gunpowder)

• keeping track of the place reached in the progression of multi-level tasks (e.g. writing a sentence down either from memory or from the teacher's board).

Student's under the age of 10 years old with working memory difficulties struggle to hold 3 or more items in storage. It is, therefore, helpful for educators to reduce the length of instructions and to use information that is meaningful. Allow extra time for thinking so that the learner has time to process what has been said. This will ease the demands placed on working memory.

Reducing working memory loads if necessary

Memory loads in structured activities should be reduced. This can be completed in a number of ways, including:

• reducing the overall amount of content to be stored for example, shortening sentences to be written or number of items to be recalled.

• increasing the meaningfulness and level of familiarity of the material to be remembered. Choose content within the child's scope of experiences. For example, do not use texts with reference to a typewriter as a typical grade 4 learner has never heard of one today. Students better remember information when it is familiar and meaningful to them. Using this strategy includes both activating students' prior knowledge as well as conferring with students the purpose of learning the information (Watson & Gable, 2011).

• reducing processing demands. For example, decoding, when reading, is such a effortful process that it consumes working memory capacity. Inferences are then often overlooked and the pupil does not engage in the text (Turner, Bodien & Collier, 2007). The use of cloze passages, sentence completion excercises and the use of diagrams as a prompt to guide the child, are workable strategies that educators can easily utilize to assess reading comprehension in the classroom.

Teach organization of text such as story structure to enable comprehension of narratives. This strategy can greatly enhance reading comprehension. It’s important to remember, however, that expository texts have different structures and are arranged in many different ways (e.g., compare and contrast). They are challenging to students with working memory deficits because students have to learn content knowledge at the same time they have to understand the organizational aspects of the material (e.g., cause and effect, problem and solution). Students benefit from explicit instruction of the various structural designs of expository texts because the information to be learned can be organized and mapped, making the text more meaningful and simpler to understand. Graphic organizers can provide students with a visual representation of the text portraying textual relationships (Watson & Gable, 2011).

• re-structuring multi-step tasks into separate independent steps, preferably supported by memory aids.

• making available and encouraging the use of external devices that act as memory aids for the child; these include ‘useful spellings’ on teacher’s boards and cards, providing number lines, printed notes, and dictaphones to save information that needs to be recalled. One way to do this, is to assist children in developing graphic organisers to enhance reading comprehension and writing exercises. This approach, which is based on visual processing strengths, promotes planning prior to composing. In addition, it also supports the detection of the main idea and specific details when reading.

Being aware that processing demands increase working memory loads

Although children may be capable of storing a particular amount of information in one situation, a demanding concurrent processing task will increase the load on working memory and so may lead to memory failure.

Frequently repeating information

It is effective to repeat information regularly. This is crucial to ongoing activities. As not all children require repetition, strategies such as partnering a child with working memory difficulties with a child with good memory skills could be beneficial in the classroom. Consider dividing study time into sessions. Alloting study and practice times across multiple teaching sessions helps students to remember and retain information. For example, students who practice solving new mathamatics problems three times a week for fifteen minutes are more likely to retain the information than students who practice solving new mathamatics problems only once for thirty minutes after teaching (Watson & Gable, 2010).

Encouraging the use of memory aids

Memory aids can help in several ways to reduce working memory loads as they may reduce the processing demands of the activity.

Developing the child's use of memory-relieving strategies

An important role for the educator is to support the child in encouraging them to develop strategies for overcoming memory difficulties. These will include:

- Use of rehearsal of small amounts of verbal information
- Use of memory aids

- Organizational strategies – breaking tasks down into competent parts where possible
- Asking for assistance when important information has been forgotten

Bailey and Pransky (2014) discuss how the flow and the volume of the curriculum often pull educators toward a fire hose approach to instruction, however, this can be resisted, despite the feeling of being swept along by the urgency of curriculum demands because of the sheer volume of work that must be covered. When there is a better understanding of working memory difficulties, educators understand how these learners are drowing in the instructional approach instead of drinking deeply.

It is hoped that this approach will enhance learning outcomes for children who are experiencing difficulties with poor working memory function (Gathercole, Lamont &Alloway, 2006). Gathercole and Alloway (2008) also emphasise the importance of teacher's patience.

Remediation of working memory deficits

Recently, researchers have been improving ways to remediate cognitive difficulties with educational programmes such as Fast ForWord and Tools of the Mind (Holmes & Gathercole, 2013). One approach that has gained popularity over the past decade is intensive training that focuses on specific cognitive skills, often referred to as 'brain-training' Mind (Holmes & Gathercole, 2013). Regular and sustained practice has been shown to lead to lasting changes in cognition. With positive training effects reported by Klingberg (2008), for children with disorders of memory and attention, this approach looks promising in providing a cost-effective method for remediating the cognitive difficulties associated with poor educational progress. Training programmes that directly target working memory provide important corroboration that it is possible to make long-lasting changes to these memory abilities (Holmes & Gathercole, 2013). There is also preliminary evidence of enhanced learning following training, with significant improvements in reading comprehension (Holmes & Gathercole, 2013).

Summary and findings

"Nearly every aspect of human life depends on memory…. Because learning depends on memory, deficiencies in any aspect of memory can prevent children and adolescents from acquiring the skills and knowledge necessary for success in life… Successful teachers have recognised the limitations of human memory and have discovered how to facilitate the construction of strong memory representations in their students. Therefore, those engaged in supporting learning can be more effective when they have expertise in memory" (Dehn, 2011:1). The PISA results indicate that children need to master a wide range of cognitive and metacognitive processing. This researcher sought to better understand why learners do not always respond to reading intervention and to identify the specific educational needs that should be addressed in the classroom. A major problem that South Africa faces in schools is poor literacy levels as indicated by the RAND and PISA studies. For many years, we have almost become complacent about South Africa's position at the bottom of the league tables regarding literacy rates. However, this study shows that there may be a way to overcome this. Many studies in the past have focused on the context of education in South Africa, quality of teaching, the legacy of apartheid and lack of resources and poverty. While these factors play a large role in this country's low literacy rate, working memory as an important role player, has not been explored much within the South African context. This study is a reminder that perhaps we should return to the basic organ of learning, which is the brain. One of the processes which is so important, and is eluded to by Dehn (2011), is memory, and even more important to reading comprehension is working memory.

Another important contribution this study can make is that working memory transcends class and race. Working memory deficits can affect any child regardless of his race or socioeconomic status. If you experience difficulties with working memory, it may have a significant impact on your ability to read and extract meaning from what you read.

Working memory needs to be considered when implementing support structures in the classroom. There are numerous factors that affect one's ability to read and it would be irresponsible to negate the influence of these elements in education today. However, strategies to improve working memory could be invaluable supplementary support with regard to improving reading comprehension. This knowledge is significant as students from deprived backgrounds have the same ability to succeed. It is not an issue of IQ but a matter of giving these children the same opportunities to unlock their working memory potential (Alloway, 2011). Another important factor, which cannot be overlooked is that working memory deficits often masquerade as failure of attention. The implications of this is that many learners are misdiagnosed and medicated unnecessarily. Incorrect interventions result in little or no progress and frustration for both the learners and their families.

As Lyon (2001), states in chapter 1, the consequences of poor literacy skills are dire. We are living in a largely literate society, weak literate individuals are isolated from so much in a literacy driven world and the obstacles that they may encounter are numerous. Both work and personal lives may be restricted in a society that highly values literacy and where access to higher education may not be possible. This study is relevant in today's society, where assisting learners in making sense of the vast amount of information they are presented with everyday is essential to their academic and overall well-being.

Much of the research over the past several years has concentrated on the teaching of specific comprehension strategies that reflect those used by good readers and this continues to be an central focus for researchers. However, there is renewed interest in other aspects of reading comprehension. For example, a current area of interest is how strategic processing interacts with specific domain knowledge when reading.

The topic of working memory has increased dramatically since Baddeley and Hitch's proposal of the working memory construct in 1974. Although other theories and models of working memory have been presented, this model has survived nearly 40 years of scrutiny. Baddeley's model of working memory consists of four components. The central executive is responsible for high-level control and coordination of the flow of information (Alloway, 2007). The central executive is accompanied by two slave systems specialized for storage of information within specific domains. The phonological loop supplies temporary storage for linguistic material, and the visuo-spatial sketchpad stores information of a spatial or visual nature. The fourth component is the episodic buffer, which is responsible for integrating information from different components of working memory and long-term memory into unitary episodic represenations (Alloway, 2007). Interest in working memory has substantially increased over the years with approximately 800 papers a year with working memory in the title and some 3700 papers in their titles, key words or abstract (Baddeley, 2007).

The main frameworks used to explain working memory are Baddeley and Hitch's (1974) model which was reformulated by Gathercole and Pickering in 2000 and supporters of the M-capacity, such as Just and Carpenter and Engle. Although these models vary in structure, they are regarded as complementary.

Chapter 2 presented evidence that suggests that working memory plays a crucial role in complex cognitive skills such as reading comprehension. The vast amount of research indicates that learners with working memory deficits experience difficulty with reading comprehension. Research has largely supported the premise that increased working memory capacity is associated with increased comprehension (Swenson, 2008). Not only does research show that individual differences in working memory capacity affect reading comprehension but also that reducing the load placed on working memory increases comprehension (Swenson, 2008).

Working memory is taxed by numerous classroom activities such as following instructions, performing tasks that require combining cognitive processing with storage, and seeing complex tasks to completion (Holmes & Gathercole, 2013). Poor working memory has quantifiable impacts on educationally relevant measures of children's performance (Holmes & Gathercole, 2013). It is a common facet of educational underachievement and a considerable majority of children with poor working memory skills fail to meet expected standards in either reading or maths, or generally, both (Holmes & Gathercole, 2013). Pickering and Gathercole (Holmes & Gathercole, 2013) ascertain that children recognized by their schools as having Special Educational Needs (SENs) are six times more likely to have working memory impairments than children without Special Educational NeedsApproximately 70 % of pupils with learning difficulties in reading obtain very low scores on tests of working memory that are rare in children with no special educational needs (Gathercole & Alloway, 2007). It is important to note that not all childen with special educational needs have working memory difficulties. Learners with problems in areas that are not directly related to learning, such as emotional and behavioural disturbances, typically have working memory capacities that are appropriate for their age (Gathercole & Alloway, 2007).

The findings of this study suggest that working memory plays an important role in reading comprehension. Working memory is important because it supplies a mental workspace in which we can hold information whilst mentally engaged in other relevant activities. The capacity to do this is critical to so many learning activities in the classroom. Children frequently have to hold information in mind whilst engaged in an effortful activity (Gathercole & Alloway, 2007). Children with working memory difficulties will struggle in these activities, simply because they are not able to hold in mind sufficient information to allow them to complete the task, whereby, there working memory is overloaded (Gathercole & Alloway, 2007). Insights gained through this study could provide educators with information regarding identification and appropriate support for those learners experiencing difficulties with reading comprehension and processing in the classroom. The findings from this study could prove beneficial in developing curriculums that structure teaching and learning to develop its higher functions in progressively more sophisticated ways. This may be achieved by taking into account that the more a learner can do automatically, the more free space there is within working memory which allows for concentration on the activity at hand.

Both of the assessment tools were easy to use. The reading comprehension test took approximately 30 minutes to administer and the scores were easy to tally. The AWMA was also

easy to use and administer and the report generated for each student was detailed and clear. The research used convenience sampling due to practical constraints. The research was conducted in a boys' primary school. The participants were Grade 4 learners who volunteered for the study. Grade 4 learners were selected for participation as grade 4 is approximately the time when learners evolve from learning to read to reading to learn (Geske & Ozola, 2008). A total of 50 grade 4 boys participated in the study. Only children with English as a primary home language and preferred testing language were eligible, as to minimise language bias in testing and an analysis of the effects of bilingualism were beyond the scope of this study. Considering that there exists a slightly greater proportion of males than females with working memory deficits (Gathercole, 2008) this study was conducted at a boys' school. The chosen school is a high functioning, self-directed government school that receives extensive support from the community and the parents.

With the exception of perhaps, Piaget and Bruner, cognitive psychology and the study of education have not always been close companions. In general those studying the cognitive psychology of learning and memory have tended to stay relatively close to the laboratory (Baddeley, 2006). Theoretical concepts can potentially be useful in providing a broad understanding of the processes underlying education. Such understanding, can in turn, be used to develop better methods of assessment that will allow teaching or remedial strategies to be optimally targeted. The concepts may also contribute to a better understanding of the whole process of teaching and, one hopes, ultimately, help to improve educational methods more generally (Baddeley, 2006).

Conclusion

The complex, cognitive skills that we, as adults, take for granted, this study has shown, are critical for the acquisition of reading skills. The study shows that cognitive processes, with regard to working memory, can be improved upon and developed through conscious efforts in the way that we teach and in the way we allow learners to practice this skill in the classroom.

Poor working memory appears to place a child at high risk of poor scholastic attainment. The study shows that effective comprehension can be achieved if remediation and intervention programmes utilise management strategies that ease the load imposed on working memory. This may lead to success in both schools and occupations outside of the school, as well as their personal lives.Those who can read and have high literacy memory will have better options for choosing careers, be able to access higher education and will generally lead more meaningful lives. Certainly, it will help the shift in grade 4, from learning to read, to reading to learn.

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Appendices

Appendix A

Dear Parent/Guardian

I am conducting research for a Masters degree in Education (Psychology) at the University of KwaZulu-Natal. The study is an important one as it examines how memory is related to comprehension ability in Grade 4 boys. The findings will enable me to improve my teaching of comprehension. I would like to invite you to allow your child to participate in my research. The research process will involve:

- Reading a comprehension and answering questions on the text.
- Asking your child to recall items showed on a computer screen and pressing computer keys to answer questions.

The activities will be done in two sessions of 30 minutes and 45 minutes respectively.

All activities will be conducted during school hours.

I will discuss suitable times with the principal and teachers so that your child's academic programme is not disrupted in any way.

If your child is identified as having difficulties in these areas, I will communicate with you to discuss possible solutions to the problem. It is anticipated that the results of this study will have implications for teaching practice to facilitate the development of reading comprehension and working memory in learners.

To permit your child to participate in the study, kindly fill in the consent form. Participation in this study is completely voluntary. You are not under any obligation to allow your child to participate. Should your child decide not to participate, or wishes to withdraw at any time during the study, your child will not be penalised or disadvantaged in any way. Your child's identity will only be known to me and will not be divulged to anyone in a written format or orally...

Permission to conduct this research study has been obtained from University of KwaZulu-Natal.

The supervisor of this project is Dr Nyna Amin from the University of KwaZulu Natal, School of Education and can be contacted at 031-2607255. You are also welcome to contact me on 084 449 4440 for further information.

Yours sincerely

Amber Sadler Nyna Amin

(Masters Student) (Supervisor)

asadler@dphs.co.za namin@ukzn.ac.za

Study: Exploring the relationship between reading comprehension abilities and working memory in Grade 4 boys.

I …………………………………...……… (Name and surname) hereby consent / do not consent (please underline you choice) to allow my child …………………………….. (Name) to participate in this study. Should I consent to the study, I furthermore, give the researcher, Amber Sadler permission to use the responses in the write up of the study, and in any further publications or presentations. I understand that I am free to refuse to participate, or withdraw my child and discontinue participation in this study at any time, without it being held against me or my child in any way.

I understand that privacy will be maintained and that any responses will remain strictly confidential and anonymous. I am also aware that if I have any questions at any time, they will be answered by the researcher.

Signature: ______________________

Date: __________________________

Appendix B

Study: Exploring the relationship between reading comprehension abilities and working memory in Grade 4 boys.

Hello, I am doing a study to see if there is a relationship between working memory and reading comprehension. Your parents already know about this study and they have signed this paper that says it is okay for you to help me if you want to. If you agree to help me, I am going to ask you to complete a few exercises on the computer. You will listen to some instructions and then do your best to answer the questions. The test will only take about 10 to 15 minutes. You will not get a grade for taking this test.

You can ask me questions at any time about the study that I am doing. Also, if you decide at any time not to finish the computer test, you may stop whenever you want. Signing this paper means that you have read this or had it read to you and that you want to be in the study. If you don't want to be in the study, don't sign the paper. Remember, being in the study is up to you, and no one will be mad if you don't sign this paper or even if you change your mind later.

Signature of Participant ____________________________

Signature of Researcher ___________________________

Amber Sadler	Nyna Amin
(Masters Student)	(Supervisor)
asadler@dphs.co.za	namin@ukzn.ac.za

Appendix C

Dear Mr. Pike

I am conducting research for a Masters degree in Education (Psychology) at the University of KwaZulu-Natal. The study is an important one as it examines how memory is related to comprehension ability in Grade 4 boys. Current research shows that boys are more likely to have problems with reading and comprehension than girls do. The findings will enable me to improve my teaching of comprehension to all students in general and boys in particular. I am seeking your permission for grade four boys in your school to participate in my research. The research process will involve:

- Reading a comprehension and answering questions on the text.
- Asking children to recall items showed on a computer screen and pressing computer keys to answer questions.

The activities will be done in two sessions of 30 minutes and 45 minutes respectively. All activities are designed to be part of the school curriculum and will not hinder or disrupt the school's programmes.

Permission for grade 4 participation has also been sought by parents and from the Department of Education. Participation in this study is completely voluntary. Children are free to refuse to participate and to withdraw at any time during the study. They will not be penalised or disadvantaged in any way. Furthermore, all responses will be confidential and the names of the children will not be divulged.

Permission to conduct this research study has been obtained from University of KwaZulu-Natal.

The supervisor of this project is Dr Nyna Amin from the University of KwaZulu Natal, School of Education and can be contacted at 031-2607255. You are also welcome to contact me on 084 449 4440 for further information.

Yours sincerely

Amber Sadler	Nyna Amin
(Masters Student)	(Supervisor)
asadler@dphs.co.za	amin@ukzn.ac.za

The **opposition / opportunity / oppression / optimism** was too good to ignore. 19

Smoke was pouring out of the volcano's **creature / cracker / crater / crest** . 20

Knead / Kneel / Need / Knock the dough for ten minutes and then leave it in a warm place to double in size. 21

The **inquisitive / inflated / invincible / edible** pony tried to discover what was in my pocket. 22

The **most / majority / percentage / plenty** of the class chose to go to the Activity Centre. 23

Despite being a **novice / notice / novelty / noise** , she won a bronze medal. 24

The injured bird was kept in **caged / treatment / captivity / aviary** until it had recovered. 25

Did you know...?

The fastest land mammal

The fastest animal on land is the cheetah. It can run 100 metres in less than four seconds.

It can race at 112 kilometres per hour. This compares with the **furthest first fastest failed** human sprinters 26

who can run at a speed of just over 40 kilometres per **kilogram mile our hour** . 27

The slowest mammal

If the cheetah makes even the fastest humans **appeal quickly appear quietly** slow, the three-toed sloth 28

makes all of us seem very fast. In trees, three-toed sloths **trivial travel tropical train** about four metres 29

in a minute. On the ground they only manage to move half this **distance weight height speed** ! 30

The largest land mammal

The largest land mammal is the African bush elephant. An average-sized **mane masculine male muscle** 31

is over 3 metres tall and weighs between four and seven tonnes. However, the largest ever

recorded received reasoned refused weighed more than 12 tonnes. 32

The tallest mammal

Giraffes live in areas of open woodland in Africa. The tallest giraffe on record was a male named George. George was sent from Kenya to Chester Zoo in England. When he was nine years old, his

'horns' almost **turned touched travelled taught** the roof of the Giraffe House. This was 6.1 metres high. 33

The Durian

Probably the most expensive fruit in the world is the Durian. It grows to about the size

of a football, it has a (spiky / sprinkle / speedy / spine) rough skin and is a lightish green in colour. 34__

This 'King of Fruits' grows in South East Asia (Malaysia, Thailand and Indonesia).

The flesh inside the fruit is light creamy yellow in colour and it has a sweet 'custardy' taste.

It is very (poppy / popular / people / popcorn) in Singapore, where it is not only eaten raw but is made into 35__

ice-cream and drinks. There are also many (receives / receipts / recipes / records) for preparing and cooking it. 36__

But the really exceptional thing about the durian is the TERRIBLE SMELL

it gives off when it is cut open. It is (advisable / adjustable / admirable / adorable) 37__

to hold your nose while eating the flesh of a fresh durian.

Many people have attempted to describe this smell.

'The odour of rotting onions and (stale / steal / stole / smell) cheese' or 38__

'unwashed socks on a very hot day' are descriptions which have been

used.

It is not (surrounding / suspicious / surprising / supplying) that in Singapore the fruit 39__

is banned from taxis, buses, (fabrics / ferries / fasteners / feelers) and airlines. 40__

Hotel (guests / guess / guides / guitars) are forbidden from eating durian in 41__

their rooms.

On the city metro (simple / town / system / sister) there are 42__

'No Durian' signs.

They show a crossed out durian in a (circus / circle / serial / serpent) ! 43__

Stepping ashore

It was seven in the morning when Mr Fogg, Alfred and William set foot upon the

American continent. They disembarked onto a [sinking / floating / flying / flowing] quay. 44

These quays, rising and falling with the tide, make it [eager / easier / easily / east] to load and unload 45

the vessels. [Alight / Alike / Alongside / Allow] them were clippers of all sizes and steamers of all nationalities. 46

There were also steamboats, with [seventh / several / serving / severe] decks rising one above the other. 47

The steamboats were heaped up with [products / profits / projects / programmes] to sell to South America, 48

Europe, Asia and all the Pacific islands.

Alfred, in his joy on [ready / reading / really / reaching] at last the American continent, [surprised / somersaulted / summer / somewhere] 49 50

onto the quay. However, he landed on some rotten planks and fell through them.

He [crying / cried / crawling / crossed] out, which so frightened the many birds that are always 51

[performed / permitted / perched / planted] upon these movable quays, that they flew [nosily / ninety / noisy / noisily] away. 52 53

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