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Working Memory: Is it associated with socioeconomic status?

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A Research Report submitted to the Faculty of Humanities, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Arts in Psychology by Coursework and Research Report.

Johannesburg, March 2012

Declaration

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

It is submitted in partial fulfilment of the requirements for the degree of Masters of Arts in Psychology by Coursework and Research Report at the University of the Witwatersrand, Johannesburg.

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Azra Moolla (0509783R)	March 2012

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There are no words to match my gratitude,
However much like Shakespeare I might write.
Above all else, you've shaped my attitude,
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Knowledge is the least of what you taught,
Yet that least at least prepared my head.
Out of your heart I've learned the things I ought,
Underscoring words you never said.

~Nicholas Gordon

Abstract

It is well known that crystallized measures of intelligence are highly susceptible to educational, resource, language and socio-economic influences, and that the implications of using these kinds of measures are manifold affecting school and university entrance as well as employment opportunities. In South Africa, wherein tests are regarded with suspicion as a consequence of test misuse during the Apartheid era, there is an urgent need for the development of measures which are resilient to these influences. In answer to this, working memory measures have been identified as possible measures which minimize these biases. Consequently the following study investigated whether working memory tests were less susceptible to socioeconomic influences than the more traditional, crystallized measures of vocabulary and non-verbal IQ in a volunteer sample of 60 grade one learners from schools identified as high and low in socioeconomic status. The results demonstrated that working memory measures were consistently less affected by socio-economic status as compared to the traditional vocabulary and non-verbal IQ measures. However, socioeconomic status and language were found to be so closely correlated that it is not clear whether test performance in the vocabulary measures, was related one or both of these variables. In light of the fact that this study was correlational in nature, it is recommended that future studies focus on limiting the impact of extraneous variables to better understand the impact of socioeconomic status on test performance. Furthermore future studies should test children in their home language to avoid language contamination effects.

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Chapter 1
Introduction

Intelligence tests and measures of learning ability are often criticised for being biased in the sense that they tend to rely on prior experience and knowledge, and exposure to resources rather than on intellectual ability (Fagan & Holland, 2002). Members of diverse ethnic, cultural and economic groups, due to their different world experiences are often ill-equipped to optimally deal with traditional assessments (Campbell, Needleman & Janosky 1997). The implications of these biases are manifold affecting children's performance in schools; students entrances into universities (Fagan & Holland, 2002) and adults' job opportunities because people who perform better on intelligence tests and tests of learning ability are more likely to be granted school and university entrance, scholarships and bursaries and are ultimately, more likely to be employed.

The issue of test bias and its consequences is particularly relevant in the South African context, where the practice of testing has had a turbulent political history, with still many feeling mistrustful and suspicious towards it (Cohen & Swerdlik, 2010; Foxcroft, 1997; Foxcroft, Roodt & Abrahams, 2001). These negative attitudes toward testing are a result of the apartheid era, where testing was used by the government to further political ideologies by asserting the superiority of white people over other races. Intelligence testing was a particularly mistrusted area, as it was one of the tools by which the apartheid government accomplished this task (Foxcroft et al., 2001).

Yet the testing enterprise and specifically that of intelligence testing continues to flourish today, chiefly because of its ability to aid in decision-making (Foxcroft et al., 2001). Therefore there exists a need for the development of tests which can be used fairly in diverse contexts such as South Africa. According to Fagan and Holland (2002: p385), "*the failure to develop tests of intelligence that can be fairly applied across racial groups stems from a theoretical bias to equate the IQ score with intelligence rather than with knowledge. If we define intelligence as information processing and the IQ score as knowledge, the possibility of culture-fair tests of*

intelligence based on estimates of information processing arises." In line with this, it seems that for the enterprise of testing to become more objective, there needs to be a shift away from traditional crystallized measures of intelligence, which measure how much a person knows, in favour of tests which measure how a person makes sense of, or processes information.

Working memory measure fall into the latter type of assessment as they are based on information processing abilities (fluid abilities) rather than drawing on prior knowledge (crystallized abilities), and are thus resilient in the face of socioeconomic and cultural diversity (Engel, Santos & Gathercole, 2008). They offer a possible alternative to crystallized measures of intelligence which are highly susceptible to cultural and socioeconomic bias (Campbell et al., 1997). Moreover, because the test contents of working memory measures are usually equally unfamiliar to all test takers, these measures may provide a fairer way of selecting candidates for advanced education or employment (Fagan & Holland, 2002). This is particularly important in the new South Africa which is attempting to redress the wrongs of the apartheid era and therefore strives to allow equal opportunity to all races.

Nonetheless, the utility of working memory measures in South Africa has as yet not been investigated. Thus, this study attempted to ascertain whether working memory measures are more robust than traditional measures of intelligence in the face of socioeconomic diversity.

Chapter 2
Literature Review

Introduction

In light of the fact that the majority of South Africans are of non-Western origin and poor socioeconomic circumstances, the use of tests developed for Western middle class populations in the South African context is problematic. The use of tests which are biased has led to a widespread mistrust and suspicion of the practice of testing (Cohen & Swerdlik, 2010; Foxcroft, 1997; Foxcroft et al, 2001). There exists a need for the development and use of tests which are less biased in terms of culture, language and socioeconomic status. In response to this, this study aimed to investigate the suitability of working memory measures as alternatives to traditional intelligence, tests. The study compared the performance of children from high and low socioeconomic backgrounds on tests of working memory, as well as traditional measures of intelligence.

This chapter commences with some information with regards to the history of testing in South Africa and the controversial nature of intelligence as a construct.

History of Testing in South Africa

The history of South Africa has much to do with the negative perceptions toward intelligence testing today (Foxcroft, 1997). During the apartheid era, testing was used by the white government to further political ideologies by asserting the superiority of white people over other races (Foxcroft et al., 2001; Nzimande, 1995; Sehlapelo & Terreblanche, 1996). This was done by using intelligence tests to demonstrate that white people have superior intelligence and cognitive skills, compared to other races, and that black people are the least intelligent. This allowed the apartheid government to relegate black people to homelands and use them as a cheap "physical" labour force, whilst keeping white people in high level occupations and positions of power (Lurie, 2000). Moreover, test development and standardization, during the apartheid era,

was concentrated only on the white population. Tests were neither developed nor standardized for other races and testing remained a Western enterprise (van de Vijver & Rothmann, 2004). Consequently, testing came to be regarded as a means of oppression and segregation by the majority of South Africans and this attitude is still widely persistent today.

Additionally, the use of Western tests for individuals from non-Western cultures is a problematic enterprise as these tests are known to be culturally biased (Foxcroft, 2004). Much of the bias occurs because definitions of intelligence differ across cultures and so cultures display different characteristics of intelligence depending on what is emphasized as intelligent within the culture (Benson, 2003; Foxcroft, 2004; Sternberg & Grigorenko, 2004).

The Contested Nature of Intelligence

Intelligence tests are widely used throughout the world and have become pervasive in a number of settings. They are used to enhance decision-making in schools, for aiding the process of choosing university candidates, as well as job and military recruitment (Foxcroft, 1997). Consequently, it is undeniable that intelligence testing is an important part of our modern day society which provides some amount of ease and order in decision-making in many situations. However, intelligence testing remains the world over, a highly contentious issue for two reasons (Cohen & Swerdlik, 2010). Firstly the definition of intelligence is socially constructed and intelligence is equated with different behaviours and abilities in different cultures, and so each culture will promote certain types of abilities and give lesser import to others (Cohen & Swerdlik, 2010).

For example, whilst Western cultures tend to equate intelligence with quick thinking, Eastern cultures define intelligence as being thoughtful and respectful (Foxcroft, 2004). Moreover, although western cultures emphasize cognitive skills as expressions of intelligence, Asian and African cultures tend to focus on social aspects of intelligence as well. This is illustrated in Zambian cultures which are inclined to view obedience, social responsibilities and cooperation as central expressions of intelligence. Zimbabwean cultures associate prudence and caution with intelligence, whilst Kenyan cultures regard participation in social and family life as important characteristics of intelligence (Sternberg & Grigorenko, 2004). On the whole, African cultures tend to associate intelligence with more than just cognitive/academic skills; rather, they

also view social skills in terms of responsibility and respect as well as practical skills, which enhance survival and everyday functioning as important markers of intelligence (Benson, 2003).

The second reason why intelligence testing is contentious is related to the first. Most intelligence tests subscribe to a Western definition of intelligence, with the result that groups which do not subscribe to these notions are often disadvantaged (Claassen, 2001a). This was clearly emphasized by the former South African minister of education, Mr Blade Nzimande (1995) who stated that "*Psychology in South Africa is even more American than US psychology itself and it is this theoretical framework that provides the pragmatic basis for testing".* The Western conceptualization of intelligence is depicted in the implicit assumption central to intelligence tests, that all test-takers are aware that they should work fast and accurately. However as discussed above, in many non-Western cultures, values of caution and thoughtfulness are promoted (Nell, 1999).Thus these cultural values are incompatible with the assumptions made by intelligence tests and Western definitions of intelligence, and thereby disadvantage non-Western test-takers (Foxcroft, 2002). Relatedly, levels of test-wiseness are also known to affect performance on intelligence tests (Foxcroft, 2004; Nell, 1999). Test-wiseness is gained through schooling, which promotes familiarity with test-taking procedures, such as efficiency, sustained attention and pen-pencil dexterity. Schooling also equips individuals with problem solving techniques and familiarises individuals with test content. Although western test developers, such as David Wechsler accept that intelligence is complex and cannot therefore be fully defined (Cohen & Swerdlik, 2010), intelligence testing is still largely based upon western conceptualizations thereof, thereby disadvantaging many non-western test-takers. Moreover, there is still a widespread tendency to equate an IQ score with intelligence rather than considering the individual's experience and knowledge (Fagan & Holland, 2002).

In view of the above mentioned biases as well as the widely held negative perceptions toward testing, it is important to concentrate efforts in the development of tests which are fairer toward larger segments of the South African population. This is crucial in the South African context wherein we are trying to escape the repercussions of our past. Due to the apartheid era, many were disadvantaged in terms of the education received and employment opportunities accessed (Foxcroft, 1997; 2004). Thus in attempting to develop fairer measures of intelligence, fairness should be enabled by ensuring that those from non-Western cultures are not grossly

disadvantaged when taking intelligence tests. This has important ramifications for school and university entrance, employment and thus for ensuring equality (Fagan & Holland, 2002). Moreover, by addressing the needs of other cultures as well, it is possible to challenge and modify the negative perceptions toward testing.

General intelligence *'g'* has been shown by many studies to be very closely correlated with working memory and it has been further argued that working memory may well be the best predictor of *'g'* (Colom, Flores-Mendoza & Rebollo, 2002; Conway, Cowan, Bunting, Therriault & Minkoff, 2002; Engle, Tuholski, Laughlin & Conway, 1999; Sub, Oberauer, Wittman, Wilhelm & Schulze, 2002). The relationship between working memory and general intelligence is so strong that Kyllonen and Christal (1990) have claimed that they are one and the same thing. Yet, there is also evidence which suggests that although they are closely related they are unique constructs (Kane et al., 2004). The evidence supporting the strong relationship between working memory and general intelligence has been so convincing that Engel et al. (2008) have suggested that measures of working memory may be a possible alternative to traditional intelligence tests. Before reviewing the evidence for these claims, it is important to first understand the structure of working memory so that the logic and reasoning behind these claims can be understood.

The Multi-component Model

Although there are many models of working memory, the multi-component model by Baddeley and Hitch (1974) was used as the framework for this project, as a wealth of research has been conducted to verify and substantiate it, resulting in a large body of evidence both cognitive and neurological. Additionally, it is the most widely accepted method of conceptualizing working memory (Baddeley, 2003; Smith et al., 1996; Fassbender & Schweitzer, 2006).

Working memory can be described as a limited capacity cognitive system that is responsible for the manipulation and temporary storage of information needed for complex mental tasks such as reasoning, language comprehension and learning (Baddeley, 1992). It is a multi-component system controlled by a central executive module, which asserts attentional control over the other

components of working memory, namely the phonological loop, the visuo-spatial sketchpad and the episodic buffer (Baddeley & Repovs, 2006). In simple terms, working memory is that aspect of memory that is employed for temporarily holding the information that an individual is currently working with, thus making the information easily accessible (Reisberg, 2006).

The working memory system is controlled by the central executive which uses its low level assistants to execute its requests (Eysenck, 1984). These are the phonological loop, the visuo-spatial sketchpad and the episodic buffer. The central executive allocates attentional resources, which are in limited capacity to support both the activities of the working memory system, and those extrinsic to it (Engel et al., 1999). Thus, the central executive is that cognitive resource involved in the selection and launching of responses, the inhibiting and delaying of responses, and the planning of goals (Reisberg, 2006). Due to the fact that attentional resources are in limited supply, the central executive acts as an attention controlling system enabling the focusing of attention, the division of attention between tasks concurrently performed and attentional switching (Baddeley & Repovs, 2006). It is involved in the organizing, binding and integration of information, and it permits interfacing with long-term memory (Zilmer, Spiers & Culbertson, 2008). The central executive also allows for the manipulation and storage of information in working memory through supervising and co-ordinating assistant systems (Baddeley & Repovs, 2006). It is a domain general system that facilitates the on-going interaction of domain specific storage (i.e. phonological or visuo-spatial information) (Kane et al., 2004). This is accomplished by enlisting both the passive peripheral stores used in other activities, such as perception and speech, as well as the active stores. Passive processing is used for simple tasks such as the recall of information in the same mode in which it was memorized, thus in these stores, information is registered and then fades or is displaced. This passive processing of information was previously referred to as short-term memory. However, for complex tasks that require information to be integrated, changed or manipulated, active processing is necessary. In such instances, information is registered and then rehearsed, allowing the memory to be continually refreshed or updated (Baddeley, 1983). The central executive has been identified as the most likely component to determine individual differences in working memory span (Baddeley, 2003).

The existence of the central executive, although well established in terms of cognitive theory, is much harder to prove using neuropsychology, due to the intricate nature of its functions. Nonetheless, Baddeley, Logie, Bressi, Della Sala and Spinnler (1986) conducted an experiment using Alzheimer's patients, which confirmed the existence of a mechanism with the capacity to coordinate two or more concurrent activities. Alzheimer's patients show a deficit in a range of visuo-spatial and verbal working memory tasks thereby suggesting a central executive deficit rather than a deficit in one of the component slave systems. The study consisted of three groups i.e. probable Alzheimer patients, normal elderly subjects and normal young subjects, all of whom were required to complete a digit span tasks and a spatial tracking task on two different occasions. Task difficulty was adjusted so that all three groups were performing at an equal level. However when required to simultaneously perform the two tasks, the Alzheimer's patients showed a significantly greater decrease in level of task performance than the other two groups, demonstrating a disruption in the coordination processes of the central executive. Correspondingly another study by Baddeley, Bressi, Della Sala, Logie, and Spinnler (1991) demonstrated that the capacity of probable Alzheimer patients to coordinate dual tasks deteriorates significantly more than the capacity to perform tasks independently than in non-Alzheimer patients. These two studies demonstrate that the visuo-spatial and phonological components of working memory are distinct from a third component, which serves a planning and scheduling role and allows for the coordination of several tasks, namely the central executive.

Similar results were obtained in a study using patients with lesions to the frontal lobes (Milner, 1964 as cited in Baddeley, 1996). These patients were required to complete a box crossing task, a digit span task, the Wisconsin Card sorting task and a test of letter fluency, wherein they needed to generate as many words as possible beginning with the letters F, P and L, each within a one-minute period. The patients were divided into a dysexecutive and non-dysexecutive group by two neurologists. The results revealed that there were no significant differences in performance between the two groups when tasks were completed independently. However, the dysexecutive group functioned poorly during dual task performance. A parallel study by Alderman (1996) obtained comparable results. Since dual task performance is a basic executive function, it is expected that executive function deficits such as hampered dual task performance should be more widespread than in just Alzheimer patients, occurring also in individual's

displaying frontal lobe damage which is responsible for executive functions. This is indeed the case in patients with Parkinson's disease (Dalrymple-Alford, 1994) and those suffering from traumatic brain injury (Hartman, Pickering & Wilson, 1992).

The central executive, apart from being responsible for dual task coordination, is also known to control and divide attention. The existence of this mechanism which is impaired by limited attentional capacity has been confirmed by a study which evaluated the effect of tasks that disrupt the central executive, as well as the two slave systems in the playing of chess, which exerts heavy demands on the central executive (Robbins et al., 1996). Comparisons of performance between novices and experts revealed that articulatory suppression had no impact on performance, thereby indicating no role of verbal memory in playing the game. However, performance was disrupted by a visuo-spatial task and even more impaired by a central executive task involving generating random digits. Despite differing overall in performance, novices and experts displayed the same sensitivity to disruption, which indicates that the central executive is indeed responsible for the division of attention and coordination.

A PET study has confirmed that dual task performance involves the frontal lobes which are associated with executive function (Baddeley, 2003), but there are many inconsistencies about the exact location of the central executive. According to Gathercole, Pickering, Ambridge and Wearing (2004) central executive functions are associated with the frontal lobes and also some posterior (mainly parietal) areas. Baddeley (2003) also asserts that the executive functions are associated with the right prefrontal cortex (Baddeley, 2003), but he cautions that although the central executive acts as a simple unitary controller, the variations and intricacies of deficits in neuropsychological patients seem to indicate that the central executive is divided into sub-processes. In line with this, many other studies have arisen which indicate that sub-processes of the central executive occur in anatomically distinct regions. For example, it has been suggested by Baddeley, Della Sala and Robbins (1996) that organizing and encoding material occurs in the left frontal lobe and episodic retrieval occurs in the right frontal lobe. Yet other studies have confirmed that attentional switching is localized to the regions in the superior parietal and dorsolateral prefrontal cortex, whilst the maintenance of a task goal is controlled by the frontopolar cortex. These processes are aided by the supplementary motor and parietal areas which allow response inhibition and alternative response selection. Still other studies have found

that the anterior cingulate cortex is also active when individuals perform executive tasks. One proposal is that it signals to the prefrontal cortex when detecting errors or conflicts, which then issues orders (Fassbender & Schweitzer, 2006). It is apparent that there is much uncertainty about the exact location of the central executive. This is unsurprising as different tasks involve the activation of different brain areas specific to the task content, in addition to the central executive functions. Consequently, the brain areas activated during different tasks will vary.

It is clear that the central executive engages in many separate sub-processes, which from the above mentioned studies appear to occur in a variety of brain regions, mostly within the frontal lobe. Although the central executive is responsible for executing and coordinating a number of tasks, it does not conduct all tasks by itself. Rather, it uses the two sub-component systems to execute its commands.

As mentioned earlier, the phonological loop is one of the sub-components of the working memory system controlled by the central executive. It performs the task of learning and memorizing verbal information and is in charge of processing and storing, auditory and verbal information. This system consists of sub-vocal rehearsal processes and the phonological store (Eysenck, 1993). The content to be learnt is repeated (subvocalized) until it is loaded into the store where it is temporarily stored in acoustic form. This content begins to decay after 1-2seconds as the stores storage capacity is very limited because it operates in real time. Thus, the phonological store is constrained in its storage of items as only a certain number of items can be articulated in the time available before their memory trace fades (Baddeley & Repovs, 2006). The central executive must read (hear) the content before it decays and then instruct the articulatory loop to launch another cycle whereby it can pronounce the information and then hear it again (Reisberg, 2006). Articulatory rehearsal therefore allows information to be continuously updated and refreshed (Baddeley, 1983).

The primary function of the articulatory loop is speech perception and language acquisition, therefore speech and auditory input automatically enter it. Information from other modalities can only enter the phonological buffer after it is recoded into phonological form via articulatory rehearsal. Thus, the articulatory loop allows real world cognition by combining a passive storage system, the phonological buffer, with an active process of rehearsal via sub-vocalization (Baddeley, 1983). The phonological loop has been said to have evolved to facilitate the

acquisition of native language in children and second language acquisition in adults (Baddeley, 2001). Evidence of the phonological loop's role in language acquisition comes from a patient who had a very pure phonological memory deficit. The patient was required to learn new words in Russian, which was an unfamiliar language, and to learn to associate familiar words. Results depicted that whilst she was grossly impaired in learning new words, she was able to associate familiar words to each other (Baddeley, 1996). Other studies have reflected that the capacity to hear and repeat unfamiliar non-words, which is a process that draws directly on the phonological loop, is a predictor of vocabulary development for both first and second languages in children (Baddeley, 1996). Moreover, children with a specific language impairment are particularly impaired on non-word repetition (Baddeley, 2001). A study has also found that 8 years olds with normal non-verbal intelligence and the verbal development of 6 years olds displayed a level of non-word repetition of 4 year olds (Gathercole & Baddeley, 1990). These studies seem to validate the claim of the existence of a phonological loop as the ability for language usage and development seems to depend upon the ability to hear and rehearse words.

There is substantial experimental evidence for the existence of the articulatory loop. For example the phonological similarity effect refers to the phenomenon whereby during recall, words or letters that are similar are more difficult to recall, whereas visually or semantically similar letters and words are not. In the phonological loop, words are rehearsed to enable recall. However, when similar sounds are being repeated, confusion occurs within the phonological loop as to what the words are, hence, causing the phonological similarity effect. This phenomenon provides substantiation for acoustic or phonological coding (Baddeley, 2000). The word length effect refers for the tendency for strings of short words to be remembered better than longer strings. This supports the idea that words with more syllables saturate the phonological loop, taking longer to rehearse and recall, hence allowing more time for decay, than shorter words (Baddeley et al., 1996). Articulatory suppression refers to the decreased ability to remember items when individuals are prevented from rehearsing items, because they are required to repeat an irrelevant word. Since the phonological loop is not able to perform its normal rehearsal function, recall is markedly decreased (Baddeley et al., 1996). All of these phenomena strengthen the notion that the phonological loop is used to rehearse and recall verbal information because when rehearsal is prevented due to verbal interference or slowed due to complex lengthy words, recall is disrupted.

Consistent with the model of working memory, studies seem to implicate two separate systems in the phonological loop. The phonological loop has been found by neuro-imaging studies and studies of lesions, to reside in the left hemisphere in the inferior parietal areas (the phonological store), the anterior temporal frontal areas including Broca's area, the pre-motor cortex and the sensory motor association cortex (used for rehearsal) (Baddeley, 1996; Baddeley, 2003; Gathercole et al., 2004; Smith et al.,1996). Thus, it appears that verbal working-memory tasks activate the parietal areas that aid storage and frontal areas that implement rehearsal (Shivde & Thompson-Schill, 2004) Smith et al., 1996). Separate anatomical locations for the processing of verbal and acoustic information have also been identified. Brodmann's area 40, also known as Broca's area, is associated with the processing of verbal information, whilst area 44 is associated with the processing of acoustic information (Baddeley et al., 1996). Similarly, Smith et al (1996) found that impairments in verbal working memory are commonly associated with Brodmann's area 40. The phonological loop thus appears to be a highly evolved system necessary for the perception and production of speech, as well as for verbal learning.

The second sub-component of the working memory system controlled by the central executive is the visuo-spatial sketchpad. It is responsible for guiding visual and spatial attention and for the storage of visual information such as mental images and spatial information (Baddeley & Repovs, 2006; Eysenck, 1984). Like the phonological loop, it contains both active and passive components. It consists of the visual cache, which is a passive storage system and the inner scribe which permits visual and spatial rehearsal, manipulation and transformation by redrawing the contents of the visual cache (Logie, 1995). The visuo-spatial sketchpad consists of separate visual and spatial components (Baddeley & Repovs, 2006). Each sub-system possesses independent storage, maintenance and manipulation processes (Baddeley & Repovs, 2006). It has been asserted that many utilities of visual imagery are less automatic and practiced than phonological coding, thus tasks involving the visuo-spatial sketchpad seem to place heavier demands on the central executive (Baddeley, 1996).

There is considerable neuropsychological evidence for the existence of the visuo-spatial sketchpad. For example Baddeley (1992) found that patients who had difficulty recalling the visual features of objects, such as colour and shape, were surprisingly able to recall routes and

describe locations of towns on maps. This shows that visual and spatial information are dealt with by different areas of the brain. A similar pattern of results was found in an experiment where participants were required to spatially encode a series of sentences for immediate recall (Baddeley, 1996). The sentences were encoded via a 4x4 matrix (sentences such as "in the starting square put a one, in the bottom left square put a 2) and participants could recall up to 8 sentences. In another trial, participants used non-spatial verbal codes to remember the sentences (such as good, strong etc.). Using this method, participants relied on rote rehearsal and could recall only 6 sentences. Whilst performing these tasks participants were required to simultaneously carry out a spatial tracking task. Results depicted deterioration in the spatially encoded recall, whilst the verbal recall was unaffected. This shows that the phonological loop and the visuo-spatial sketchpad are independent structures. Similarly, Baddeley (2003) conducted a study wherein participants were required to remember an instruction sequence which could be remembered via verbal coding in one case and via a visual image in another case. Participants performed the memory tasks alone or whilst performing a spatial tracking task. It was shown that although the tracking task disrupted performance based on imagery, it had no effect on verbal performance, which reiterates the fact that the two sub-components of working memory are indeed independent structures.

Storage in the visuo-spatial sketchpad may be primarily spatial, pattern, as in colour and shape, motor or kinaesthetic. Moreover, the visuo-spatial sketchpad seems to use separate anatomical regions to store spatial and visual information (Fassbender & Schweitzer, 2006). A study which produced evidence of separate systems within the visuo-spatial sketch pad required participants to keep pointing at a moving sound source whilst blindfolded (spatial task) in one condition whilst experiencing simultaneous spatial interference. In the second condition participants needed to make judgements about the brightness of a screen whilst experiencing spatial interference. The results of the experiment depicted that the spatial imagery task was more impaired by the spatial interference than the judgement task. Once again, consistent with the model of working memory, the visuo-spatial sketch pad appears to consist of two separate components, which process different kinds of visual information and possesses independent storage, maintenance and manipulation processes (Baddeley & Repovs, 2006).

Further evidence of the existence of the visuo-spatial sketch pad was also shown in an experiment, where participants' ability to engage in concurrent visual spatial imagery whilst performing the Corsi block tapping task (a task requiring visuo-spatial imagery), was disrupted (Baddeley, 2001). It has also been shown that visual imagery is disrupted by unattended patterns or visual noise (Logie, 1986). These results tend to strengthen the notion of the existence of a visuo-spatial sketch pad as tasks performed by another component of working memory do not disrupt performance on a visuo-spatial task, whilst tasks that rely on the visuo-spatial imagery tend to lead to decrements in performance. This is in line with the model of working memory which clearly states that working memory is a limited capacity resource. It is also well-known that cognitive performance is limited by task specific resources as performing multiple tasks using the same modality draws on the same limited resource which is limited in capacity (Eysenck, 1993). Performing multiple tasks which draw on different resources is simpler as the cognitive capacity of each resource is not divided. Thus, it appears that performing concurrent tasks relying on the same sub-component of working memory exceeds the capacity of that sub-component, resulting in decrements in performance.

The visuo-spatial sketchpad was found in neuro-imaging studies to be distributed across a few areas in the right hemisphere, namely the occipital, parietal and frontal lobes (Brodmann's 6, 19, 40, 47 areas) (Baddeley, 1996; Baddeley et al., 1996). These areas are distinct from those occupied by the phonological loop. Studies have confirmed this finding as the occipital lobe is found in neuro-imaging studies to be activated in the representation of pattern information whilst the parietal lobe is activated in the representation of spatial information (Baddeley, 1993; Baddeley, 1996). The frontal lobes are thought to be responsible for co-ordination and control of visual and spatial imagery (Baddeley, 2001). Similarly to the uncertainty over the exact location of the central executive, the exact anatomical regions used by the visuo-spatial sketchpad also remain unclear as studies seem to implicate different but sometimes overlapping areas.

For example Gathercole et al (2004) asserted that spatial short-term memory is associated with right-hemisphere activation in the occipital and inferior frontal areas, whilst Smith et al (1996) identified Brodmann's area 19 in the occipital cortex and area 40 in the parietal cortex to be part of a network for encoding and storing spatial information. Additionally, Smith et al (1996) asserted that spatial tasks resulted in activation in occipital and ventrolateral frontal areas (areas

19 and 47, respectively), whilst Rama, Sala, Gillen, Pekar and Courtney (2001) found the dorsal prefrontal regions as well as the superior frontal sulcus to be involved in storing spatial information. It appears that evidence for the laterality of visual working memory is inconsistent, with some studies depicting a left-hemispheric predominance in the ventral prefrontal regions for non-spatial visual working memory, whilst others assert that activation occurs bilaterally or in the right prefrontal cortex (Rama et al., 2001). However it has been argued that laterality may be influenced by the method of encoding because participants may choose to encode and rehearse non-spatial information either verbally or using imagery (Rama et al., 2001). Alternatively, as discussed previously, these difficulties may occur because different tasks contain varying content, which therefore activate different brain areas together with those involved in functions of the visuo-spatial sketchpad.

Although the visuo-spatial sketch pad is a highly developed system, its functioning appears to be less automatic than that of the phonological loop. Still, it is imperative for the storage and manipulation of visual and spatial information (Gathercole et al, 2004). The visuo-spatial sketch pad has been suggested to make use of the occipital, parietal and frontal lobes, nevertheless, its exact location remains elusive (Baddeley, 1996; Baddeley et al., 1996).

The episodic buffer was the most recent component of working memory to be identified. It is a limited capacity store that permits multi-dimensional coding and is capable of integrating information from the phonological loop and visuo-spatial subsystem, which use different codes, into whole multi-dimensional representations that can be accessed by the central executive (Baddeley, 2001). The episodic buffer is dependent upon the central executive to integrate and maintain information and retrieve it in the form of conscious awareness. Information is retrieved in the form of conscious awareness because it is gathered from multiple sources and modalities some of which occur in real time. In addition to integrating information from the subsystems of working memory, the episodic buffer also integrates information between working memory and long-term memory, thus linking the two (Baddeley, 2000). It is responsible for creating integrated coherent episodes allowing real world cognition by binding information. The consequence of these processes is the ability to create and manipulate new representations, and the availability of a mental modelling space which permits the deliberation of probable outcomes (Baddeley & Repovs, 2006). Moreover the episodic buffer, by virtue of its ability to create

integrated coherent episodes, allowing real world cognition, holds much promise with respect to the binding problem of consciousness. The binding problem refers to the problem of how various bits of sensory information come to be integrated to present one coherent stream of experience (Baddeley, 2000).

The episodic buffer was suggested as a component of the multi-component model of working memory because there were gaps within the theory which could not be explained by the existing components (Baddeley, 2000). Firstly, there was a need for information from the phonological loop and the visuo-spatial sketchpad to be integrated and linked to existing representations in long-term memory. Secondly the model needed to allow for the temporary storage of material which exceeded the capacity of both the slave systems (Baddeley, 2003). Therefore, with these requirements in mind, the concept of the episodic buffer was developed.

Empirical evidence for this buffer stems from the fact that when individuals are required to rehearse and remember a sequence of visually presented numbers whilst repeating an irrelevant word, articulatory suppression should prevent the number sequence from being rehearsed and should thus have detrimental effects on recall. However, this does not occur. Although the visuo-spatial sketchpad may be responsible, Baddeley et al (1996) have suggested that this is unlikely for two reasons. Firstly, the visuo-spatial sketchpad is better at recalling single complex patterns rather than serial recall, and secondly if this were the case then visual similarity of the sequence should hamper recall. However, recall is not significantly hampered by visual similarity. Thus, there must be a storage mechanism which allows for the combination of visual and verbal information (Baddeley et al., 1996). The existence of the episodic buffer was also implied when a dense amnesiac displayed the ability to play and a win games of bridge. He was able to remember the rules of the game, the cards played, and was also able to carry information across games. This case clearly demonstrated that a mechanism exists which allows information to be integrated and stored. This allowed the amnesiac patient to draw on procedural knowledge whilst also temporarily keeping track of the game in memory, which allowed him to operate in real time (Baddeley, 2003). These studies tend to confirm the existence of the episodic buffer as the first study indicates that information is indeed integrated across working memory systems and the case of the amnesiac patient points to the availability of a mental modelling space which permits

the consideration of probable outcomes, which is not provided by the phonological loop, the visuo-spatial sketchpad or the central executive.

Yet another effect which points to the existence of the episodic buffer is that of chunking (Baddeley et al., 1996). When required to mentally hold strings of words, individuals typically hold an average of 5 or 6 words. However, when the words comprise meaningful sentences, memory capacity increases to 16 words. The explanation for this requires that information from long-term memory be used to assimilate the words into meaningful chunks, which in turn requires the words to be integrated and stored, which once again points to the existence of an episodic buffer (Baddeley et al., 1996).

In earlier versions of the working memory model, immediate prose recall was initially attributed to long-term memory. However, this view was dispelled in an experiment involving a small sample of amnesiacs who had grossly impaired long term memories. These patients displayed the ability to perform at a normal level on the immediate prose recall, in a passage that contained 20 or more idea units, which is beyond the span of their phonological loop or visuo-spatia sketchpad (Baddeley, 2003). The ability of amnesiacs to recall a prose passage is surprising as it was assumed to require the activation of long-term memory representations along with the integration of these representations into an episodic structure, using long-term memory to aid in chunking (Baddeley, 2001). This is however not possible in amnesiacs who have impaired long-term memory. Yet amnesiacs display the ability for immediate prose recall but not delayed recall. Thus, the capacity of amnesiacs to maintain, integrate and temporarily store information during tasks such as playing bridge and prose recall, displays the capacity of the episodic buffer as well as the entire working memory system (Baddeley, 2001).

Recent studies of the episodic buffer have indicated that integrated verbal and spatial information activate different brain areas compared to the areas activated by the separate information types. Integrated information appears to activate the right frontal lobe, whilst unintegrated information shows activation in areas associated with verbal or spatial working memory (Baddeley et al., 1996). Although the exact location of the episodic buffer remains elusive, it has been asserted that it is unlikely that it will occupy a single anatomical location due to its multiple functions, but it is likely that the frontal lobe may be a possible location due to its co-ordinating role (Baddeley, 2001). Bearing in mind that the episodic buffer was only recently added to the working memory

model, it is unsurprising that its existence and neuroanatomical location have not been as well researched as the other components. However it is evident that the existing lines of research hold much promise and research into its existence and functions will surely increase.

Although the multi-component model of working memory has proved robust, it has been contended that the exact structure of this model may not be applicable to children. Relatedly, it has been found that spontaneous rehearsal does not occur in children younger than 7 years old, suggesting that only the phonological store exists at those ages. It has also been shown that children younger than 7 years use the visual spatial sketchpad to store physical and visually presented information, whilst older children typically recode it phonologically. Additionally, the frontal lobes associated with executive function only fully develop in adolescence and early adulthood. Thus, there was speculation about whether Baddeley and Hitch's (1974) multi component structure of working memory would be applicable to children. Gathercole, Pickering, Wearing and Ambridge (2004) investigated this in a sample of children ranging from 4 to 15 years of age. The results indicated that the structure proposed by Baddeley and Hitch (1974) seems to be in place by 6 years of age and does not appear to reflect further developmental changes between the components thereafter. However, there were linear increases in the developmental functions from 4 years to adolescence. This suggests that as children develop, they are better able to use the strategic and processing resources of the central executive to increase the storage capacities of the phonological loop and the visuo-spatial sketchpad.

Thus, in review of the above evidence, Baddeley and Hitch' (1974) multi-component model of working memory is deemed the best existing model of working memory, which is also applicable in young children. However, the multi-component model was not always considered the most appropriate model and its structure is not entirely novel, rather it was developed in response to earlier models of memory. More detail regarding the development of the multi-component model is discussed below.

The Development of the Working Memory Model

Atkinson and Shiffrin (1968) proposed a three component structure of memory, which consisted of a sensory register, the short-term store and the long-term store (Atkinson & Shiffrin, 1968).

The sensory stores, stored unprocessed information from the sense organs for less than a second. For example the visual system used iconic memory to store visual input whilst the auditory system uses the echoic system to store acoustic information. The short-term memory store is believed to be capable of holding and manipulating information both visually and acoustically for about 30 seconds (Atkinson & Shiffrin, 1968). Once the sensory memory stores information, information required for further processing is selected and fed into the short term memory store. The short term memory store is a limited capacity store which automatically but slowly transfers information to the long term memory store (Atkinson & Shiffrin, 1968). The model postulates that in order to learn, information has to be maintained in the short term memory. Greater learning occurs when maintenance is longer. The short term store is suggested to have a range of strategies for manipulating information and a phonological rehearsal process enables the storage of limited information for longer periods, thereby serving as a necessary means for learning.

Although this model was very popular in its time, many problems were identified in the sense that it was not able to account for some occurrences (Baddeley, 1983). For example the model posits that short-term memory is necessary for long-term memory functioning, but cases of patients were documented where the patients suffered from short-term memory deficits yet their long term memory seemed to be preserved, which implies that short-term memory may not be necessary for additions in long-term memory (Baddeley, 1983). Further, although repetition of information is suggested to be necessary for long-term encoding, it was found that long term rehearsal was ineffective without deeper semantic processing (Baddeley, 1983). Finally, additionally evidence which contradicts the Atkinson and Shiffrin model (1968) stems from the recency effect which is the phenomenon where items in a list which are recently heard tend to be remembered better during free-recall than other items. Although the recency effect is deemed to be a result of short-term memory, cases wherein the recency effect lasted for minutes or days seem to depict otherwise (Baddeley, 1983).

In response to the above criticisms of the Atkinson and Shiffrin model of memory, Shallice and Warrington (1970) proposed a two component model consisting of two verbal memory stores, short-term memory and long-term memory, which operate independently. According to this model, short-term and long-term memory did not depend on the same physical structures and information did not need to pass through short-term memory to be encoded into long-term

memory. Rather, information was encoded quite differently by them. This is evidenced by the fact that the two memory types were differentially affected by interference. More specifically, whilst short-term memory was subject to interference from acoustic input, long-term memory was subject to interference by semantic input, which suggested that whilst short-term memory was dependent upon acoustic methods of encoding, long-term memory relied on semantic encoding. Additionally long-term memory did not require rehearsal, for encoding whilst short-term memory did. As insightful as this model was, it merely depicted the independence of short-term and long-term memory. This model was unable to identify the exact mechanisms by which these components operate or account for how learning occurs (Baddeley, 1983).

Craik and Lockhart's (1972) levels of processing model was also postulated as an alternative to Atkinson and Shiffrin's (1968) model of memory. This model conceptualized short-term memory and long-term memory as belonging to one store with different coding processes, thereby emphasizing the processing of information rather than the structure of memory systems. It suggested that perception involved the swift analysis of stimuli at various levels. At preliminary stages of analysis, physical and sensory information was analysed. Later stages matched the incoming information to stored information from past learning, such as pattern recognition, whilst the final stage engaged in semantic processing (Craik & Lockhart, 1972). It was further argued that memory traces were merely a by-product of processing. Therefore, to have created a durable memory trace, deep processing at a semantic level must have occurred as memory traces from shallow, verbal or visual rehearsal are ineffective (Craik & Lockhart, 1972).

According to the levels of processing model, primary memory was said to be a limited capacity central processer which held information at one level by rehearsing it. This type of memory was analogous to Atkinson and Shiffrin's (1968) short-term memory. Although primary memory was a neutral processor, processing all types of input, coding depended upon the modality type of information received. Additionally its capacity varied with the level of processing. Information was held better when past knowledge and experiences were accessed, resulting in semantic processing. However, because the primary memory required attention to process information, when attention was diverted, information was lost at a rate dependent on the level of processing. Consequently, deeper processing resulted in a slower loss of information. Primary memory did

not lead to a permanent memory trace as information must have been encoded in long-term memory to last.

Although this model contributed to significant advances in the conceptualization of working memory, problems with the levels of processing model were also evident. Firstly, the definition of deep processing is contentious as what one person may regard as a deep processing task may be regarded as a shallow processing task for another. Additionally, the model is unable to specify whether it consists of discrete processing domains or continuums (Baddeley, 1978). It has also been shown that, contrary to this model, maintenance rehearsal (i.e. rote repetition) can lead to long-term memory and that superficial learning may result in durable memory traces. Finally it has been asserted that information is processed in parallel allowing an integration of information from different levels, rather than linearly as suggested by this model (Baddeley, 1978).

All of the above were precursors to the working memory model developed by Baddeley and Hitch (1974). It is clear from the reviews of the literature on working memory that none of the models posited were widely accepted or validated by a vast number of studies. Additionally none of the above mentioned models are able to fully account for the working memory system. A fuller more complete account of the working memory system, however was proposed by Baddeley and Hitch (1974) in response to the criticisms of the above mentioned models.

In recent years, working memory has been suggested to be highly related to intelligence. Nevertheless the exact relationship between general intelligence and working memory is a contentious issue, with some claiming that they are synonymous and others asserting that they are highly related but separate constructs. This issue is discussed in the subsequent section.

Intelligence and the Use of Working Memory Measures

General intelligence is the ability to think, analyze and problem-solve. Horn and Cattell (1966) divided it into two factors, namely, crystallized and fluid intelligence. Crystallized intelligence refers to the skills and knowledge acquired through experience, whilst fluid intelligence refers to the ability to reason, engage in abstract thinking and think flexibly (Horn & Cattell, 1966). Intelligence tests are heavily reliant on a testee's crystallized knowledge (Bedell, van Eeden & van Staden, 1999). As discussed earlier, these measures have been known to be structurally biased against those from different ethnic, cultural, or economic backgrounds to the developers

and creators of the test (Fagan & Holland, 2002). The reason for this bias is that traditional norm-referenced forms of assessment tend to rely on exposure to certain words, concepts and activities which derives from prior world experience (Campbell et al., 1997). Thus members of diverse ethnic, cultural and socioeconomic groups, due to their different world experiences, are often ill-equipped to deal with traditional IQ assessments as they typically assess crystallized intelligence which is dependent on the acquisition of skills and knowledge which is in turn affected by quality of education and access to resources.

In response to the criticisms of commonly used intelligence tests, the use of tests dependent on fluid intelligence or that are process-oriented has been proposed. These measures are said to assess basic learning ability and are designed to minimize socioeconomic, ethnic and cultural effects (Campbell et al., 1997). Working memory measures are such a form of assessment which are process-dependant, and are thus proposed to be resilient in the face of socioeconomic and cultural diversity.

Many studies confirm that working memory measures are more valid measures of intelligence and learning ability than the usual assessments of crystallized knowledge or at the very least, that they should be used in conjunction with the latter assessments (Alloway, Gathercole, Adams, Willis, Eaglen & Lamont, 2005; Campbell et al., 1997; Engel et al., 2008; Fagan & Holland, 2002, Gathercole, Brown & Pickering, 2003). Studies have also revealed that the reason why working memory measures are suitable for assessing intelligence is because of their close relationship to *'g'* (general fluid intelligence).

For instance, Engle, Tuholski, Laughlin and Conway (1999) conducted a study to differentiate between short-term memory and working memory, and to document the relationship of these constructs to general fluid intelligence. Their study involved 133 participants from the University of South Carolina who completed a battery of tests. Tests of short-term memory were claimed to test simple storage capacity (dissimilar word span task, similar word span task and backward dissimilar word span task), whilst working memory tasks were said to involve attentional switching and processing by the central executive as well as storage (operation span with words, counting span and reading span). The battery also included the Raven's Standard Progressive Matrices and Cattell's culture Fair Test, which are assessments of fluid intelligence. It emerged that working memory and short-term memory are different constructs albeit strongly associated

(r =0.68). However, although working memory was found to be significantly associated with general fluid intelligence (r =0.59), short term memory was not (r = -0.13).

Similarly, to investigate which construct best predicted general fluid intelligence, Conway, Cowan, Bunting, Therriault and Minkoff (2002) investigated the interrelationship between general fluid intelligence, working memory capacity, short term memory capacity and processing speed amongst 120 students first year students from the University of Illinois . This study used the same tests as Engle et al. (1999), but also included processing speed (digit symbol substitution test, digit and letter copying and pattern and letter comparison) as some theories held that the relationship between working memory capacity and *'g'* could be accounted for by it. Processing speed refers to the amount of information which can be processed in a specified amount of time (Conway et al., 2002). Structural equation modelling revealed that, when clearly distinguished from working memory, neither short-term memory nor processing speed (r =0.07) was a significant predictor of general fluid intelligence (r =0.18), and the relationship between processing speed and working memory was also non-significant (r = -0.06). However, there was a very strong association between general fluid intelligence and working memory capacity (r =0.60).

Another study by Sub, Oberauer, Wittmann, Wilhelm and Schulze (2002), explored the relationship between working memory and intelligence, and also found working memory to be the best predictor of intelligence. The study involved 113 students and 15 staff members who were aged between 18 and 46 years, from a University in Germany. This study required participants to complete an extremely large battery of intelligence and working memory tests. The results from a range of confirmatory factor analyses as well as structural equation models suggested that working memory is strongly related to intelligence, particularly to reasoning ability/fluid intelligence. This relationship is not dependent on any task feature as the relationship between working memory and reasoning ability holds over a wide range of tasks involving dual tasks (i.e. combinations of storage, processing, manipulation and coordination), as well as verbal, mathematical and spatial tasks. Hence, any working memory task is able to predict complex reasoning ability. It further appears that all types of working memory tasks are highly correlated, loading on one factor which indicates that working memory is one general

cognitive resource. This finding was reiterated by Colom, Flores-Mendoza and Rebollo, (2002) who explored the structure of working memory and its relationship to the reasoning or fluid facet of intelligence. The investigation involved 71 high school students from Brazil and 116 participants from Spain, who were both University and non-University students. The ages of the sample ranged from 14 years of age to 47 years. Participants were required to complete eight working memory tasks (matrix span, letter span, digit span, ABC numerical, ABCD Gram, alphabet test and digit ordering) and two intelligence tests (Ravens Progressive Matrices and the Berlin Intelligence Test battery). The results showed that working memory is not distinguishable from '*g*' after the results of several confirmatory factor analyses (r =0.70). Working memory was concluded to be one general cognitive resource as correlations between separate facets of working memory namely verbal and visual memory tasks were very high and once again loaded on a single factor.

Although the above studies have convincingly portrayed working memory as one general cognitive resource which is one of the best predictors of general intelligence, it must be noted that all of these studies subscribe to different models of working memory, which although were initially based upon Baddeley and Hitch's model (1974), have presently diverged considerably from it. The use of different models thus necessitates the use of different tasks to tap the construct of working memory. For example Engle et al. (1999) and Conway et al. (2002) use Cowan's (1995) model of working memory, and thus use the same small battery of working memory tasks. Cowan's (1995) model of working memory recognizes a single memory store wherein both long-term and short-term memory reside at different levels of activation. Short-term memory stores are the contents of long-term memory which are activated above a certain threshold. Working memory consists of short term memory, and the limited capacity attentional processes.

By contrast, Sub et al. (2002), employ a different model of working memory which consists of two facets which mirror the facets of intelligence as proposed by the Berlin Intelligence Structure Model. In this model working memory is differentiated according to contents and functions. The content facet consists of verbal, numerical, and spatial-figural working memory, whilst the functional facet is composed of the simultaneous storage and processing function, as well as the

supervision function, which is analogous to the central executive, and the coordination function which integrates information from different content domains. The large battery of tasks used in the study by Sub et al. (2002) were informed by their model of working memory in that they assessed each functional facet of working memory. Lastly, the study conducted by Colom et al. (2002) was entirely exploratory in nature with no apriori conceptualization of working memory and the choice of tasks was not explained.

In light of the diversity of working memory models, as well as the array of working memory tasks, the claims that working memory is one general cognitive resource which is one of the best predictors of general intelligence, can either be interpreted with scepticism or can be deduced to be highly plausible. Additionally, whilst the previously mentioned studies do provide evidence of working memory as highly predictive of, and possibly synonymous with intelligence, alternative hypotheses have been suggested. One is that working memory, despite sharing psychometric properties with intelligence, is a distinct capacity (Alloway & Alloway, 2010). A meta-analysis of 86 samples by Ackerman, Beier and Boyle (2005) has supported this, as the analysis revealed that working memory and intelligence share merely a 20% variance ($p=0.479$). Therefore, although the precise relationship between working memory and general intelligence remains unclear, an important question is whether working memory is able to predict academic performance. Several studies carried out to determine the capacity of working memory to predict academic attainment concluded that it is indeed a good predictor of educational attainment.

For example, a longitudinal study by Alloway involving 194 children from England aged between 4 to 5 and half years (2009), compared the predictive power of verbal working memory and IQ in children with learning difficulties. It found that working memory is strongly related to learning abilities and thus academic progress. The study involved testing children on measures of working memory (backward digit recall, counting recall and listening recall, non-word repetition, word recall, digit recall and sentence repetition), IQ (phonological abilities test and the Wechsler Preschool and Primary Scale of Intelligence-Revised) and learning outcomes (literacy and numeracy using the Stockton on Tees Baseline Scheme), and then retesting them two years later on the learning measures. Results indicated that working memory and domain specific knowledge at the initial test predicted learning outcomes two years later (correlations ranged

from 0.47 to 0.52), but IQ did not (r=0.31). Thus, the study suggests that verbal working memory predicts both current and future literacy and numeracy achievement. These findings were corroborated by Alloway et al. (2005), Gathercole et al. (2003) and Gathercole, Pickering, Knight and Stegmann, (2004), all of whom investigated whether verbal working memory measures were able to predict academic attainment.

Relatedly, in order to verify that verbal working memory is a predictor of academic attainment, Gathercole, Alloway, Willis and Adams, (2006) investigated the degree to which poor working memory function contributed to the severity of learning difficulties in children with reading disabilities. The study involved 46 children aged between 6 and half years to 11 years of age, all of whom attended state schools in England. The children were required to complete the Wechsler Objective Language Dimensions Test and the Wechsler Intelligence Scale for Children–Third Edition, as well as three tests from the Working Memory Test Battery for Children (backward digit recall, counting recall and listening recall) and three measures from the Phonological Awareness Battery. The results from an array of regression analyses showed that verbal working memory alone predicted a reasonable amount of performance in reading (r^2=7.4% ; $p<0.001$). Verbal working memory also predicted to a lesser degree performance in mathematics via reading ability. The researchers thus concluded that poor verbal working memory was significantly related to the severity of learning difficulties in reading and maths.

The above mentioned studies consistently provide strong evidence of the ability of verbal working memory measures to predict educational attainment. Further these studies suggest that verbal working memory measures are strongly related to baseline assessments conducted in school, which measure progress towards learning goals in areas of mathematics, literacy, language, and physical and creative development. These assessments provide a means to evaluate the extent to which schools provide value added education as well as an assessment of children's individual competencies. This is interesting as baseline assessments are intended to measure academic ability or individual competencies, and working memory measures are supposed to measure general fluid intelligence or learning ability. These two constructs are very similar as they both measure the ability to learn, but whilst baseline assessments rely on traditional tests of crystallized intelligence which are prone to biases, working memory measures

rely on fluid intelligence which is less susceptible to biases. The high correlation between these two types of tests comes as no surprise as all these studies were carried out in the UK which is a Western country and tests of crystallized ability are developed primarily for use in these types of populations. Additionally, all children were assessed in English, the national language, which removes the possibility of a language bias. Moreover, unlike in South Africa where some racial segments of the population were previously disadvantaged both educationally and socioeconomically, in the UK, there was no such history. Thus, all children attending state schools are arguably of approximately the same socioeconomic standing and hence equally vulnerable to test biases arising from quality of schooling.

Socioeconomic Status and Language

Intelligence assessments have been known to be structurally biased against those from different ethnic, cultural, or economic backgrounds, because traditional norm-referenced forms of assessment tend to rely on exposure to certain words, concepts and activities which derives from access to resources, quality of education and prior world experience (Campbell et al., 1997; Fagan & Holland, 2002). The research on the impact of culture, ethnicity and socioeconomic status on performance on intelligence tests has been vast (Campbell et al., 1997; Fagan & Holland, 2002; Fuglini, 1997; Hoff, 2003; Hoff & Tian, 2005).

Socioeconomic status is obviously linked to education, especially quality of education, which impacts on levels of test-wiseness and thus performance on intelligence tests (Foxcroft, 2004; Nell, 1999). The development of test-wiseness is linked to experiencing situations wherein familiarity of the content and format of tests is established. For instance, individuals from a higher socioeconomic status are more likely to attend schools which have more resources, allowing for smaller numbers of children per class, better qualified teachers and higher teacher-learner ratios, thereby providing a better quality of education and generally superior learning opportunities (Claassen, 2001a; Nell, 1999). High socioeconomic schools also tend to encourage the learning of Western concepts and knowledge, and the types of experience which form part of, and contribute to, the development of Western intelligence (Grieve & van Eeden, 2010). For example, schools train children in the culture of test-taking to sit and pay attention for long

periods, facilitate pen-pencil dexterity and familiarize them with test format and content such as copying designs, and problem-solving (Foxcroft, 2004; Nell, 1999). They also encourage efficiency and impose time constraints to task completion. All of these qualities form a significant portion of the crystallized knowledge that intelligence tests measure (Nell, 1999). Thus high levels of education increase test performance as they have direct bearings on literacy levels, reading and writing skills and ultimately test-wiseness (Nell, 1999). Moreover, home environments of a high socioeconomic status are able to privilege off-spring with the necessary nutrition, stimulation and resources to facilitate the development of Western intelligence (Foxcroft, 2004; Meiring, van de Vijver, Rothmann & Barrick, 2005; Nell, 1999).

It is commonly known that South Africa is plagued by high rates of poverty resulting in poor nutrition and home environmental circumstances, as well as severe discrepancies in the quality of education provided by different government schools (Cockcroft, n.d; Shuttleworth-Edwards, Gaylard & Radloff, n.d.; Shuttleworth-Edwards, van de Merwe, van Tonder & Radloff, n.d). Unlike high socioeconomic schools, schools of a lower socioeconomic status do not possess optimum learning opportunities as they are often over-crowded, with poor teacher-learner ratios and limited resources (Claassen, 2001a & Nell, 1999). Consequently, some people receive a high standard of education whilst others receive an education which is of a very poor quality (Foxcroft, 1997).

In attempting to determine the effects of socioeconomic status upon learning, Hoff (2003) tested the hypothesis that socioeconomic status affects the rate of children's vocabulary development because of different language learning experiences. This investigation tested the growth in vocabulary in a 10 week period amongst 2 year olds from high socioeconomic and middle socioeconomic backgrounds. The results obtained from the video recorded transcripts of mother-child interactions, showed that vocabulary development was significantly better in children from high socioeconomic groups, than in children from middle socioeconomic groups. The difference was accounted for by properties of maternal speech, such as the number of utterances made by mothers, the length of utterances, word types used, word tokens used etc. Most of these properties were argued to be social properties of speech and thus a function of socioeconomic status. Similarly, as an extension to the Hoff (2003) study, Hoff and Tian (2005) investigated vocabulary and grammar development amongst 662 children aged between 2 and 4 years old,

from two communities in Shanghai. Caregivers of the children reported the children's vocabulary and grammar development during individual interviews which included the MacArthur Inventory for Mandarin. The investigators found that children belonging to high socioeconomic groups possess larger productive vocabularies than children from middle socioeconomic groups because of differences in their language learning experiences. These results were apparent in both Chinese and U.S cultures and could be attributed specifically to maternal education levels. The above mentioned studies thus seem to indicate that socioeconomic status does indeed affect crystallized ability (vocabulary) as it relates to the types of learning encounters an individual has experienced. Moreover, performance on vocabulary tests has also been found to be correlated with general intelligence (Lezak, 1995). Therefore vocabulary development seems to be an appropriate way in which to assess crystallized ability and was thus deemed a suitable measure for the purposes of the present study.

The issue of language has also been highlighted as a possible obstacle to performance on intelligence tests. This is particularly relevant in South Africa where the majority of the population does not speak English as a first language (Claassen, 2001a). There is a wealth of evidence that indicates that language is a moderator of test performance as it affects understanding and interpretation of test items and instructions (Bedell, van Eeden & van Staden, 1999; Foxcroft, 2004; Heaven & Pretorius, 1998; Heuchert, Parker & Stumpf, 2000; Meiring, van de Vijver & Rothmann, 2006; Nell, 1999; van de Vijver & Rothmann, 2004). This brings about issues regarding whether it is fair to test second language English speakers in English. For example, the WAIS-III was demonstrated to exhibit differences between Afrikaans and English speaking populations as English speaking whites performed better than their Afrikaans speaking counterparts. These differences were attributed to the fact that the Afrikaans group stemmed from rural areas, were poorly educated and were socioeconomically less advantaged (Claassen, 2001a). However, these differences may simply have arisen because the Afrikaans group did not understand the test instructions and content as well as the English speakers.

In the same vein, it was also demonstrated by Aston (as cited in Foxcroft & Aston, 2006) that although second language English speakers whose native languages were Xhosa and Afrikaans,

were able to understand the wording of the Wechsler Adult Intelligence Scale-3rd edition items, they interpreted items and instructions significantly differently to native English speakers. It was thus recommended by the users that the instructions and items be simplified and translated. These misinterpretations were found on the Picture Completion, the Digit Symbol Coding, the Block Design and the Matrix Reasoning subtests. Interestingly, these misinterpretations occurred despite the fact that all participants had a matric level of education in an English medium, and were screened for English proficiency in order to understand instructions. Furthermore all the subtests were from the non-verbal scale, which is supposed to have minimal reliance on verbal input.

The effect of language on test performance was also demonstrated in a study of the suitability of the Raven's Progressive Matrices (RPM) for non-western cultures. Although the RPM is theoretically supposed to be a fairer measure of general intelligence than verbal IQ tests because it does not assess crystallized intelligence, and does not contain culture specific information (Rushton & Skuy, 2000), Black South Africans people have been found to perform more poorly on the RPM than other races in many studies (Rushton & Skuy, 2000). Interestingly, Crawford-Nutt, (1976) found that by using special instructions which clarify what needs to be done, black and white groups perform very similarly. Thus it may be the case that second language English speakers simply do not understand the requirements of the test due to the fact that they are not functionally literate in the English language.

This is a contentious issue as Black South Africans have been shown to perform equally well as White South Africans and Western populations on some intelligence tests. For example, Shuttle-worth-Edwards, Gaylard & Radloff (n.d).found that English speaking white South Africans and English speaking black South Africans aged between 19 and 30 years, with an advantaged education performed comparably to the USA standardization sample on the WAIS-III. However, black students who had a disadvantaged education, performed significantly poorly. As an extension to this study, Xhosa speaking black students stratified by quality of education were compared to English speaking white students and test performance was found to positively associated with quality of education. The relationship between quality of education and test performance demonstrates that effects of acculturation are worth considering as moderators of test performance. This is especially true in South Africa, where the interplay of multiple

variables such as home language, access to resources, quality of education and other socioeconomic variables may operate to affect performance on intelligence tests (Foxcroft, 1997). Moreover these variables are all highly interrelated due to past apartheid laws which deprived non-whites of high paying jobs, a good quality of education and the resources to acquire a high proficiency in English (Foxcroft, 1997; Foxcroft et al., 2001.).

It is interesting to note that in the Shuttle-worth-Edwards, Gaylard & Radloff study (n.d), the Letter-Number Sequencing subtest of the WAIS III, which is a test of working memory was shown to be the most culture-fair subtest as it was impervious to race and quality of education, which are the major markers of socioeconomic status in South Africa. This provides additional support for the claim that processing-dependent measures may serve as more appropriate measures for non-western populations. In line with this, Campbell et al. (1997) have posited that although it is not possible to completely remove the consequences of prior experience and background knowledge in assessments, processing dependent measures may prove useful as assessment tools as they minimize the effect of cultural, ethnic and socioeconomic circumstances. The authors conducted a study using 156 randomly chosen boys aged between 11 and 14 years who were part of a broader study on delinquency. The study compared processing-dependent language measures to traditional knowledge dependent language measures. The Oral Language Scale (OLS) from the Woodcock Language Proficiency Battery-Revised was used as a measure of crystallized ability. It consisted of five subtests (memory for sentences, picture vocabulary, oral vocabulary, listening comprehension, and verbal analogies), all of which rely upon acquired vocabulary knowledge. The processing dependent measures consisted of the non-word repetition task which taps phonological working memory capacity, the Competing Language Processing task which taps both storage and processing components of phonological working memory, and finally, the Revised Token Test which evaluates auditory processing deficits was used. The results indicated that whilst minority (African American, native American and Asian) groups faired significantly worse than the majority (Caucasian) students on the knowledge dependent measure, they did not differ significantly from one another on the processing dependent measures.

Since performance on tests of crystallized ability is said to be affected by learning experiences which are mediated by socioeconomic status and access to resources, then performance on these

measures should not differ between socioeconomic groups when the learning experiences are made similar. In response to this question, Fagan and Holland (2002) conducted a study in the USA to investigate whether low socioeconomic status Black and high socioeconomic status White students would differ in their performance on an item of intelligence tests (meanings of words) when they were provided with equal opportunities to learn the meanings of novel words. The results showed that there was no difference in performance. The researchers concluded that cultural differences in the provision of information may account for the differences in performance in IQ tests. Differences in experience account for differences in acquired knowledge and this in turn could account for differences in IQ scores.

The study by Campbell et al. (1997) compellingly demonstrates the resilience of processing-dependent measures to socioeconomic status, and consistent with the proposal that socioeconomic status influences how information is learnt, Fagan and Holland (2002) have shown that when granted equal access to information, cultural differences in performance on IQ tests disappear. In summary it is evident that both socioeconomic status and language may be crucial moderators of test performance in South Africa. Both these variables appear to disadvantage some test-takers in ways which may have life-long repercussions. Therefore in the interest of ensuring that all members of the South African population are able to compete on an equal footing during test-taking, the development and use of tests which minimise bias is imperative. Working memory measures which are process and not product-dependent may be one type of assessment suited to this undertaking.

Working Memory and Socioeconomic Status

The literature reviewed so far has indicated that working memory capacity is one general resource, which predicts, or is correlated to general intelligence, because it is a measure of fluid intelligence that assesses basic learning ability or potential. Working memory and general fluid intelligence are so closely related, that some have claimed that they are the same construct (Kyllonen & Christal, 1990). If they are so similar and measure the same thing i.e. basic learning ability, then working memory ability must surely be impervious to socioeconomic, ethnic and cultural effects just as fluid ability is. The central aim of this study was thus to investigate

whether working memory is associated with socioeconomic variables, as well as to compare the relationship between working memory and socioeconomic status to the relationship between crystallized intelligence and socioeconomic status. For the purpose of this study, socioeconomic status will be defined as an indicator of economic, social and work status which is measured by income, education and occupation respectively (Dutton & Levine, 1989 as cited in Adler, Boyce, Chesney, Cohen, Folkman, Kahn & Syme, 1994). Although many studies have considered the impact of socioeconomic status on learning, there is limited research on whether working memory or processing-dependent measures are influenced by culture and socioeconomic status. Only one documented study has probed into this matter (Engel et al., 2008).

The latter study was designed to assess the effect of socioeconomic variables on tests of working memory and vocabulary. It involved learners from both high socioeconomic backgrounds and low socioeconomic backgrounds matched for age, gender and non-verbal ability. No significant differences were found between the two groups on the measures of working memory, but children from low socioeconomic backgrounds obtained significantly lower scores on measures of receptive and expressive vocabulary, which are said to be instances of crystallized knowledge. This particular study seems to suggest that working memory measures do indeed minimize structural biases, specifically those which arise as a consequence of socioeconomic circumstances. However, the results of a single study are hardly conclusive. Given the vast socioeconomic discrepancies in South African society, a replication of this study in the South African context provided an ideal opportunity to investigate this relationship further.

In summary, traditional IQ tests are biased against those who are from different ethnic, cultural and economic backgrounds to the IQ test constructors (Fagan & Holland, 2002). This bias occurs because IQ tests measure crystallized ability which is a product of resource access and prior knowledge (Campbell et al., 1997). Obviously those from backgrounds different to the western cultures of test developers have differential access to resources and life experiences, and thus different worldly or crystallized knowledge. By contrast, working memory is more strongly related to general fluid intelligence than crystallized ability and is therefore less likely to be influenced by differences in socioeconomic status, ethnicity or culture (Colom et al., 2002; Conway et al., 2002; Engle et al., 1999; Sub et al., 2002). Along with its robustness in the face of racial, cultural and socioeconomic diversity, working memory measures may well be one of the

best predictors of general fluid intelligence (Alloway, 2009; Gathercole et al., 2003). Studies concluding that working memory measures are able to predict educational attainment, due to their evaluation of storage and processing capacity and thus learning ability, as well as those that have concluded that working memory measures are also related to base-line assessments, which evaluate initial ability in school subjects, support this notion (Alloway et al., 2005; Gathercole et al., 2003; Gathercole et al., 2006).

In view of the paucity of research examining whether working memory functioning is independent of socioeconomic variables, this study thus aimed to replicate the study by Engel et al. (2008) as closely as possible. Its purpose was therefore to specifically compare the performance of children from high and low socioeconomic backgrounds on assessments of working memory, as well as on traditional vocabulary tests.

Chapter 3

Methods

The purpose of this study was to assess the effect of socioeconomic status on working memory measures in children. Working memory measures assess basic learning ability and seem to be impervious to socioeconomic influence. Thus, the central research question of this study was: is working memory performance in children, associated with socioeconomic status? A secondary question was: will the learners from the high socioeconomic group differ from those in the low socioeconomic group on measures of expressive and receptive vocabulary, which are evaluations of crystallized ability?

In order to address the two research questions, the study needed a suitable sample, research design, procedure and measures to test for differences in performance between the high and low socioeconomic groups. This chapter therefore discusses the methods involved in attaining the data.

Sample

The study involved young children in their first year of school and the sample was gathered using a non-probability convenience sampling strategy as all participants were volunteers (Whitley, 2002). The sample consisted of 60 participants with the high and low socioeconomic groups containing 30 participants each. The participants were assigned to either a high socioeconomic or low socio- economic group depending on their socioeconomic status, which was classified according to a Socioeconomic Status Questionnaire (See Appendix F) completed by the child's primary caregiver. Both male and female children aged between 6 and 8 years of age were eligible to participate. The low socioeconomic sample was drawn from a government school located in a working class area. The high socioeconomic sample was drawn from a private school which caters for a high socioeconomic group. The medium of instruction in both schools is English. Ideally participants should have been monolingual English speaking children,

but due to the fact that the majority of South Africa's population are native speakers of one of the African languages, this criterion was not met. Consequently home language was captured in the demographic questionnaire and used as a covariate in the statistical analyses. The demographic questionnaire also assessed whether children were diagnosed with learning or emotional difficulties, neurological, speech, hearing or motor impairments. Children with any of these difficulties were not eligible for the study (See Appendix E). Further, due to the fact that grade one learners are just beginning formal education, it was anticipated that some learners may not be adept at counting. The working memory measures employed in this study required the use of counting skills, thus it was imperative that the participants were able to count. To ascertain whether participants were indeed able to count, participants were required to count both backward and forwards before testing commenced.

Design

The design of this study was a non-experimental, cross-sectional, ex-post facto design (Whitley, 2002) as the aim was to explore the relationship between socioeconomic status and working memory rather than to manipulate performance. Socioeconomic status, language, working memory and vocabulary knowledge were the key variables. The design was ex post facto as socioeconomic status could not be manipulated. The participants were assessed only once, which resulted in a cross sectional study and the design was non-experimental and correlational, there were no real control groups- only a comparison of two socioeconomic groups-, and no random assignment, as participants were assigned to the high socioeconomic or low socioeconomic group based on their socioeconomic status.

Procedure

After receiving ethical clearance from the University (H110610) as well as the Gauteng Department of Education, letters were sent out to the parents of the learners, informing them about the nature of the study and inviting them to permit their children to participate in the study. Consent forms were attached to the letters. Although the learners themselves were far too young to give consent, they were required to give assent to participate in the study. Learners were only eligible to participate in the study if consent forms were signed by the main caregiver and

returned to the researcher, and verbal assent was granted by the learner. Learners participating in the study were given a letter informing their parents of the dates, times and expected duration of the data collection.

Participants from the two schools could not be assessed during the same month as the school calendars and vacation times differed. Therefore, the participants from the low socioeconomic school were assessed first and the high socioeconomic participants were assessed during the following month. All learners were assessed during the morning hours and each assessment took between 45 minutes to an hour. The order of the tests was kept constant to ensure a standardized procedure. Each child first completed the tests of crystallized intelligence, (the British Picture Vocabulary scale and then the Boston Naming Test) then the Ravens Coloured Progressive Matrices, and lastly the Automated Working Memory Battery (AWMA).

Measures

As previously mentioned, this study aimed to replicate the investigation conducted by Engel et al (2008). Therefore the measures used in this study, followed those used in the study conducted by Engel et al. (2008) as closely as possible.

Non-verbal ability.

The Raven's Coloured Progressive Matrices (CPM) (Raven, Court & Raven, 1998) was included as a measure of non-verbal intelligence to ensure that children from the high and low socioeconomic groups were comparable. The Raven's Coloured Progressive Matrices (CPM) which is a measure of non-verbal fluid intellectual ability and has been said to be the best measure of 'g' (Raven et al., 1998). It assesses the ability to think logically and problem solve. The test consists of 36 items, which progressively increase in difficulty and contains 3 sets. Each item requires the child to complete a geometric figure by choosing a missing piece from 6 possible options. One point is scored for a correct answer and 0 points for an incorrect answer and the maximum score is 36. Engel et al. (2008) used the Coloured Progressive Matrices which was adapted for children.

The CPM has been demonstrated to be reliable by a range of studies. The test-retest reliability of the CPM was shown to be 0.90 and this coefficient was consistent over the whole age range (Raven et al., 1998). The split half reliability of the RPM was shown to be 0.97 in a UK standardisation sample and 0.90 in an earlier standardization sample (Raven et al., 1998), and revealed no differences due to ethnicity. The internal consistency of the CPM in an Australian study of 618 children aged between 6 and 12 years, ranged from 0.76-0.88 and split-half reliabilities ranged from 0.81-0.90 (Cotton et al., 2005). However in non-Western settings, the reliability of the CPM is considerably lower. For example in Omani, the reliability of the CPM was reported to have ranged between 0.81-.091, whilst the test-retest reliability was found to be 0.56 and split-half reliabilities for the age ranging 5-11 years was 0.78 (Kazem et al., 2009). Similarly a Kenyan standardization of the CPM which involved 1222 children aged between 6 and 10 years found internal consistency of the CPM to be 0.87 and a test-retest reliability coefficient of 0.84 (Costenbader & Mbugua Ngari, 2001). The internal consistency of the CPM amongst 371 Xhosa students from Grahamstown, South Africa was 0.88 (Bass, 2000). Similarly, the validity of the CPM has also been well researched and research has shown content, construct, criterion validity for the CPM (Bass, 2000; Costenbader & Mbugua Ngari, 2001; Kazem et al., 2009; Raven et al., 1998).

Vocabulary tests.

British Picture Vocabulary Scale.

Vocabulary measures have been found to be strongly related to crystallized intelligence (Lezak, 1995). They were therefore deemed suitable to tap this ability in this study. The British Picture Vocabulary Scale, second edition (Dunn, Dunn, Whetton, & Burley, 1997) is a measure of receptive vocabulary which can be understood as the collection of words that a person is able to recognize and understand. The pictures contained in the BPVS II are drawings of actions and objects which are easily recognizable. This test requires the child to choose a picture from four others to match a spoken word. There are 84 items in total. Each correct response scores 1 point and an incorrect response scores a 0, with a maximum score of 84. Testing will stop after 8 consecutive errors. The information regarding the psychometric properties of this test is scarce as it is an old test. However, the psychometric information from the standardisation sample of 2571

is very good. The cronbach alpha was 0.93, the split half reliability was 0.83 and the re-test reliability taken from a sub sample of 173 6 and 7 year olds- was 0.75 (Dunn et al., 1997). Another study by Muter & Diethelm (2001) has found the split half reliability of this measure in a UK sample of 50 children to be 0.79. Early studies have also found that the BPVS II correlates well with reading tests. Lewis (1987 as cited in Dunn et al., 1997) has asserted that the BPVS II correlates with the Saltford sentence reading test (r = 0.43) and with the British Ability scales word reading test (0.51). Similarly Howlin and Cross (1994) found that the BPVS II correlates with the Reynell comprehension scale (r = 0.59), the test for reception grammar (r = 0.44), and the Expressive One word Picture Vocabulary Test (r = 0.72).

Boston Naming Test.

Engel et al (2008) used the Expressive One-Word Picture Vocabulary Test (Brownell, 2000), in which the child is presented with a line drawing of an object or action and is then required to name the object or action. Since accessing this was not possible, the Boston Naming Test (Kaplan, Goodglass & Weintraub, 1976) was used instead. Similarly to the BPVS II, the Boston Naming test provides line drawings of objects and requires the participant to name them. It is a test of expressive vocabulary which assesses the range of vocabulary which a person possesses. It consists of 60 items and becomes progressively more difficult. The BNT is widely used and has been reported to have consistent reliability amongst a range of people. Norms for the BNT have been established in children and this test has since been frequently used in samples of children (Bello, Caprici, & Volterra, 2004; Kaplan, Goodglass, & Weintraub, 1976; Kindlon & Garrison, 1984; Riva, Nichelli, & Devoti, 2000). Amongst elderly patients suffering from mild Alzheimers disease and dementia, the BNT has been reported to have a reliability coefficient of 0.90 (Graves, Bezeau, Fogarty & Blair, 2004). Similarly another study with elderly people has also reported excellent reliability coefficients of 0.94, re-test reliability of 0.94 and inter-rater reliabilities of 0.9974 (Keane, 2005). Split half reliabilities of the BNT are said to range from 0.71 to 0.82 in normal elderly people and are 0.97 for Alzheimer patients. However, norming for the BNT has typically been carried out amongst British and American populations thus information regarding its appropriateness for non-western populations is scant (Riva et al., 2000).

Working memory measures.

In order to obtain a comprehensive measure of working memory, the Automated Working Memory Assessment was used. This test was developed by Alloway (2007) and has been used extensively in many research studies (Alloway, 2009; Alloway et al, 2005, Gathercole et al., 2006; Alloway, 2009; Conway et al., 2002; Engel et al., 2008; Engle et al., 1999; Gathercole et al., 2003; Gathercole et al., 2004). The re-test reliability of the AWMA was established using a sample of 128 randomly selected individuals aged between 4 and 22 years. The study revealed that re-test scores were very closely related and consistent indicating no substantial practice effects. The AWMA was also found to be consistent and reliable in a sample of primary school aged children with working memory problems. Finally a study also revealed that scores on the AWMA were closely related to scores obtained on the working Memory Index of the Wechsler Intelligence Scale for Children Fourth Edition (WISC-IV). Seventy-five percent of children who displayed poor working memory on the AWMA obtained scores of 85 or less on the WISC-IV (Alloway, 2009). Performance on the AWMA has also been shown to predict academic attainment (Alloway, 2009; Alloway et al., 2005, Gathercole et al., 2003 and Gathercole et al., 2003). Additionally, the AWMA has also been shown not to be strongly related to the influences of socioeconomic variables such as pre-school experiences and education, maternal education levels or the nature of social and intellectual stimulation at home (Alloway, 2007).

Verbal short term memory.

The Digit Recall test is taken from the Automated Working Memory Assessment (Alloway, 2007) and is a simple span task which does not place heavy demands upon working memory as it requires only rote rehearsal. It consists of nine blocks each containing 6 trials. Each trial begins with one digit and increases to a nine digit sequence. A score of 1 is given for a correct answer and 0 is given for an incorrect answer. The maximum score is 54. A sequence of digits is verbally presented and the child is required to immediately repeat the sequence in the same order. In order to move on to the next block, the child must correctly repeat four trials. Testing

stops if the child fails on three trials in one block. This test was used by Engel et al. (2008); Gathercole et al (2003); Gathercole et al (2004) and Alloway, (2009). The re-test reliability for this test was found to be 0.89 (Alloway, 2009).

The Non-word Recall task is also a simple span task consisting of 40 non-words which range in length from 2-5 syllables which are presented verbally (Alloway, 2007). The child is required to repeat the non-word correctly. A correct response is scored as a 1. Incorrect responses score a 0 with a maximum score of 40. If a phoneme is consistently misarticulated due to the manner of the child's speech, the misarticulation is scored as a correct response. The Non-word Recall Test has been used in studies by used by Alloway et al (2005); and has been found to have a test-retest reliability coefficient of 0.69 (Alloway, 2009).

Verbal Complex Span.

The Counting recall test is taken from the Automated Working Memory Assessment and is a complex span task as it requires visual information to be stored verbally, thus placing heavy demands on the central executive (Alloway, 2007). The test consists of pictures containing triangles and circles. There are seven blocks. The first block contains one picture and the seventh block contains seven pictures. The child is required to memorize the number of circles in each picture and then recall the number of circles in each picture in the correct order. One point is allocated for each correct recall and the maximum possible score is 42. In order to move on to the next block the child must correctly recall four consecutive trials. Testing stops if the child fails tree trials in one block. The Counting recall test has been widely used (Conway et al., 2002; Engle et al., 1999, Alloway et al, 2005, Alloway, 2009) and has a test-retest reliability of 0.83 (Alloway, 2009).

The Backward Digit Recall test like the Counting Recall test, is a complex span task, and was taken from the Automated Working Memory Assessment (Alloway, 2007). A sequence of digits is verbally presented and the child is required to recall the sequence in reverse. The test consists of six blocks each containing six trials. The first block begins with two digits and increases to a seven digit sequence. A correct response is scored as a 1 and an incorrect response scored as a 0

with a maximum possible score of 36. In order to move on to the next block the child is required to correctly recall four consecutive trials. Testing will stop when the child fails to recall three trials in one block. This tests has been used by Alloway et al (2005), and Alloway (2009). The re-test reliability of the backward digit recall is 0.86.

Socioeconomic Status Questionnaire.

This measure was designed by the researcher to capture important demographic information, as well as to estimate the socioeconomic status of the participant. Demographic variables captured included age gender, race and home-language. The Socioeconomic Status Questionnaire included an estimate of the family's Living Standard Measure as well as the occupational, educational and marital status of the primary caregiver (See Appendix F). Questions pertaining to the number of parents in the household and the area of residence were also included. The questionnaire was adapted from the Living Standards Measure which was developed by the South African Advertising Research Foundation to determine standards of living based on geographic indicators and access to services and durables (SAARF, 2011). The occupational status of the main caregiver was indexed according to the classification method used by the British Registrar General in censuses. This classification system consists of six social classes: I- professional; II- intermediate; III- skilled (non-manual and manual); IV- partly skilled; and V- unskilled (Higgs, 2002). The educational status of the main giver was classified using a scale consisting of 7 options (Higgs, 2002). These are no schooling, less than primary school completed, primary school completed, secondary school not completed, secondary school completed, tertiary education or other. The marital status of the primary caregiver was assessed using a measure developed by Statistics South Africa (2010). It consists of five options which are married, living together as husband and wife, widow/widower, divorced or separated, never married.

Ethics

Permission to include the grade one learners of the public school in the study was sought from the Department of Education. Thereafter the school principal was informed of the study. Since private schools operate independently of the government, permission to include the grade one learners of the private co-educational school was sought directly from the principal (See Appendix D). Letters were then sent out to parents of all the grade one learners informing them that this study was being conducted to ascertain whether working memory measures may be used as a form of assessing learning ability (See Appendix A). The letters invited them to allow their children the opportunity to participate in the study. It was made clear that this study is not linked to the learners' progress in school in any way. The letters also clearly stated that confidentiality will be maintained as only the researcher would have access to the results. It also clarified that the school would have no access to the results. The letter informed the parent that participation is entirely voluntary and that the child would be allowed to withdraw from the study at any time without any penalty. Consent forms were attached to the letter requiring the parent to sign and return the letter to the researcher (See Appendix B). If the parent gave consent allowing the child to participate, the child was required to give verbal assent to participate in the study (See Appendix C).

Parents were informed that they would not have access to the individual child's results. However, they were assured that should the researcher find that there is a concern or problem regarding the child's performance, such that the child did not performing appropriately to his/her developmental level, the parent would be notified. Further, in the case of the private school, it was decided that the parents of children presenting with difficulties would be recommended to take the child to an educational psychologist. In the public school, it was decided that it would be recommended to the parent that the child be referred to the University of the Witwatersrand assessment clinic. Parents and the school were assured access to the final report either in the form of a summary of the findings or the final report itself, depending upon request.

Data Analysis

Although this study was correlational in nature, the research questions and the type of data collected required that analyses which are typically used to test hypotheses are used. This required that the variables be treated as independent or dependent variables. However during the analysis and interpretation care was taken such that no causal claims were made and that all conclusions were framed relationally. The methods of analysis used are presented briefly below.

The data collected in this study consisted of multiple variables which reflected the participants' scores on each of the tests. These were treated in the analyses as dependent variables. Socioeconomic status had two levels, namely high socioeconomic status and low socioeconomic status, and was treated as an independent variable in the analyses. Home language, which has also been shown to moderate test performance, was also included as an independent variable in the study and was categorized into English and other. However, simple correlations revealed that socioeconomic status and home language were so closely related that it was impossible to separate out their individual effects. The data revealed that there were merely 6 English speaking children in the low socioeconomic group and 4 children in the high socioeconomic group who cited both English as well another language as their home-language. Therefore, in this case socioeconomic status and home language were in all likelihood referring to the same construct and it was decided that language be removed from the analyses.

The first set of analyses performed was Pearson's correlations. These were conducted to determine whether tests of crystallized ability and working memory measures were associated. Thereafter, Fisher's z transformations were employed to confirm statistical differences in the correlations between the two groups of test as a result of socioeconomic status (Howell, 2006).

It was initially proposed that a multiple analysis of variance (MANOVA) would be most suitable for the aims of this study as it is used to test hypotheses about means using variances, when there is more than one dependent variable (Tabachnick & Fidell, 1983). In simpler terms, a MANOVA would determine whether the performance on the tests of working memory were statistically different to performance on the traditional tests of intelligence. This would allow the

simultaneous exploration of each variable independently without having to perform individual tests for each dependent variable of interest. Performing separate analyses for each dependent variable is problematic as it increases the likelihood of a type I error i.e. is concluding that a significant relationship exists between the independent variable and a dependent variable when it is not the case. Thus, performing a MANOVA would test the relationship between the independent variable and each dependent variable without increasing the chances of committing a type I error (Hand & Taylor, 1987). Additionally, a MANOVA is sensitive enough to detect some overlap in the frequency distributions of the two groups even when an ANOVA may not (Tabachnick & Fidell, 1983).

However, when the assumptions necessary to conduct a MANOVA were tested, it emerged that they could not be supported by the data. Nonetheless, a MANOVA was run to gain some idea of the likely results. Using a One-Way ANOVA it was found that the two socioeconomic groups were not matched for non-verbal ability. It was necessary to control for non-verbal ability in all subsequent analyses lest differences in performance on crystallized ability and working memory measures arise as a result of these differences in non-verbal ability. Therefore, the assumptions of an ANCOVA were tested and separate One-Way ANCOVA's were computed for each test (Howell, 2006).

The findings of the analyses are presented in the following chapters. Additionally, the relationship between the findings and the research questions, as well as their implications is also discussed. Directions for future research undertakings are also suggested.

Chapter 4

Results

In light of the criticisms that G_C measures are biased against those of non-Western and low socioeconomic backgrounds, the need has arisen for alternative methods of assessing intellectual ability. Working memory measures have been put forth as one possible alternative as they are said to be impervious to social influences such as socioeconomic factors. The purpose of this study was therefore to determine whether this is indeed the case. Thus, with this aim in mind a series of analyses were conducted.

Before commencing data analysis, descriptive statistics were collated and are presented below.

Table 1:
Test scores by Socioeconomic Status

	High SES (N=30)		**Low SES** (N=30)	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Boston Naming Test **(BNT)**	35.8	6.36	14.1	4.41
British Picture Vocabulary Scale **(BPVS)**	77.9	10.5	39.33	9.21
Raven's Coloured Progressive Matrices **(CPM)**	24.67	3.6	18.3	3.51
Digit Recall **(DR)**	26.13	5.39	21.87	3.51
Backward Digit Recall **(BDR)**	9.7	2.5	7.2	2.6
Counting Recall **(CR)**	13.4	3.45	11.3	3.24
Non-word Repetition Task **(NRT)**	17.07	3.78	13.83	4.18

The sample consisted of 60 grade one children, 30 of whom attended a private school (the high socioeconomic group) and 30 of whom attended a government school situated in a working class area (the low socioeconomic group). Of the 70 participants, 35 were female and 25 were male.

Only 6 of the participants from the low socioeconomic school spoke English as a home language, whilst 29 of the learners from the high socioeconomic school spoke English as a home language. The ages of the learners in both the schools were very similar. The mean age of the learners in the high socioeconomic group was 6.93 (standard deviation=0.25) and ranged from 6 to 7 years, whilst the mean age for the low socioeconomic group was 6.47 (standard deviation=0.68) years, ranging from 6 to 8 years.

Before inferential statistics could be computed, the appropriateness of the data for parametric analysis had to be judged based upon four assumptions, namely: random independent sampling, interval scale dependent variables, homogeneity of variance and normality of the data (Howell, 2006). All tests used displayed interval scales of measure. Normality of the test scores were assessed using Jaque Bera tests (Gujarati & Porter, 2010), and Levene's Test (Howell, 2006) was used to determine whether the scores of the two socioeconomic groups were similarly distributed. The distributions of the Raven's Coloured Progressive Matrices (CPM) (p~*N*~=0.25; Levene's-p=0.69), the Boston Naming Test (p~*N*~=0.05, Levene's-p=0.06) as well as all the working memory measures were normal (Digit Recall test-p~*N*~=0.35,Levene's-p= 0.06; Backward Digit Recall test p~*N*~= 0.84, Levene's=0.85; Non-word Recall test-p~*N*~= 0.22, Levene's-p=0.64; Counting Recall test- p~*N*~= 0.32, Levene's p= 0.46) and the scores all displayed homogeneity of variance. However the British Picture Vocabulary Scale (BPVS) (p-~*N*~=0.04, Levene's p=0.054) was not normally distributed but did depict homogeneity of variance. Despite the absence of normality in one of the scores, parametric analyses were performed as the sample size of 30 allowed for reliance upon the central limit theorem which posits that for a sample of a finite mean and distribution, as the sample size increases the distribution will approach normality. As a rule of thumb, sample sizes greater than 30 are assumed to be normally distributed (Howell, 2006). Although the sample size was not greater than 30, the assumptions were deemed suitably met to enable parametric analyses.

The first set of analyses was conducted to investigate the extent to which crystallized and working memory measures were correlated. For this purpose the correlations between tests for each socioeconomic group were computed to investigate the patterns of correlations as well as to

ascertain whether they differed between the high and low socioeconomic groups. These are shown in Table 2.

Table: 2

Correlations between tests by high and low socioeconomic status

		Low SES						
		British Picture Vocabulary Scale	*Boston Naming Test*	*Raven's Coloured Progressive Matrices*	*Backward Digit Recall*	*Digit Recall*	*Counting Recall*	*Non-word Recall*
High SES	*British Picture Vocabulary Scale*	1	0.80	0.44	0.47	0.07	0.35	0.22
			<.0001*	0.01*	0.01*	0.69	0.06	0.25
	Boston Naming Test	0.44	1	0.29	0.41	0.16	0.18	0.04
		0.01*		0.11	0.03*	0.40	0.33	0.83
	Raven's Coloured Progressive Matrices	0.29	0.47	1	0.31	0.13	0.34	0.17
		0.12	0.01*		0.09	0.49	0.06	0.38
	Backward Digit Recall	-0.11	0.16	0.31	1	0.06	0.15	0.08
		0.58	0.40	0.10		0.77	0.42	0.69
	Digit Recall	0.28	0.30	0.46	0.01	1	0.00	0.45
		0.13	0.11	0.01*	0.94		0.98	0.01*
	Counting Recall	0.00	0.21	0.25	-0.03	0.17	1	-0.29
		0.99	0.26	0.19	0.86	0.37		0.11
	Nonword Recall	0.48	0.39	0.36	0.05	0.78	0.21	1
		0.01*	0.03*	0.05	0.79	<.0001*	0.24	

*p<0.05

In both the high and low socioeconomic groups the British Picture Vocabulary Scale and the Boston Naming test were significantly correlated (low ses $r=0.80$, $p<0.001$; high ses $r=0.44$, $p=0.014$), which is expected since they are both crystallized vocabulary measures and previous studies have found expressive and receptive measures of vocabulary to be correlated (Howlin & Cross, 1994). Non-word Recall has been found to be strongly related to language learning ability (vocabulary) (Engel et al., 2008) and this finding appears to be supported by the results which show that the BPVS and the Boston Naming tests in the high socioeconomic group were found to be weakly, but significantly correlated with the Non-word Recall test (BPVS-NR $r=0.48$, $p<0.01$, BNT-NR $r=0.39$, $p=0.03$). However this finding was not replicated in the low socioeconomic group. In the high socioeconomic group, the Boston Naming test was weakly, but significantly correlated with Raven's Coloured Progressive Matrices ($r=0.47$, $p=0.0084$), whilst for the low socioeconomic group the BPVS was significantly, albeit weakly, correlated with the CPM ($r=0.44$, $p=0.0083$). Similarly, a significant correlation was observed in the low socioeconomic group is between the BPVS and the Backward Digit Recall test ($r=0.47$, $p=0.01$). This pattern was once again observed in the correlation between the Backward Digit Recall and the Boston Naming Test in the low socioeconomic group.

In the high socioeconomic group, the CPM was also significantly correlated with Digit Recall test ($r=0.46$, $p=0.01$), which is expected since they are fluid measures of intelligence. Remarkably the CPM was not significantly correlated with the tests of Counting Recall and Backward Digit Recall despite the fact that they, like the CPM, are fluid measures of intelligence. The Non-word Recall and the Digit Recall were also strongly correlated ($r=0.78$, $p<0.001$) in the high socioeconomic group and were significantly, albeit weakly, correlated in the low socioeconomic group ($r=0.45$, $p<0.01$), which is plausible as they are both assessments of short-term memory.

Thus the patterns of intercorrelations differ between the two socioeconomic groups. However from these correlations it is not possible to determine whether these differences are significant. Hence Fishers z transformations were also computed to determine whether the correlations between two tests differ significantly by socioeconomic status. In order to be thorough, the Fishers z transformation was computed for all possible test combinations. These are shown in Table 3.

Table 3:
Fisher's z statistics for test combinations

	High SES N=30	Low SES N=30	z	p
BPVS-BNT	0.56417	1.1009	-1.97	0.0486*
BPVS- CPM	0.29636	0.47733	-0.066	0.5061
BPVS-BDG	0.10549	0.51364	-2.27	0.0229*
BPVS-DG	0.28912	0.07513	0.79	0.4317
BPVS-CR	0.00305	0.36168	-1.32	0.1876
BPVS-NRT	0.52649	0.21877	2.74	0.0062*
BNT-CPM	0.51268	0.30746	0.75	0.4508
BNT-BDG	0.16225	0.431	-0.99	0.3234
BNT-DG	0.30789	0.16028	0.54	0.5876
BNT-CR	0.21591	0.18568	0.11	0.9116
BNT-NRT	0.41088	0.04024	1.36	0.1733
CPM-BDG	0.32104	0.32422	-0.01	0.9907
CPM-DG	0.49362	0.13266	1.33	0.1848
CPM-CR	0.25202	0.35763	-0.39	0.698
CPM-NRT	0.38134	0.16708	2.02	0.0439*
BDG-DG	0.0135	0.05586	-0.16	0.8763
BDG-CR	0.03406	0.1532	-0.069	0.4914
BDG-NRT	0.05039	0.07619	0.47	0.6419
DG-CR	0.17124	0.00364	0.62	0.538
DG-NRT	1.05598	0.47858	2.12	0.0339*
CR-NRT	0.221	0.30326	1.93	0.0541

Probabilities with an asterix * are significant at the 5% level.
Abbreviations Key
BPVS-British Picture Vocabulary Scale
BNT-Boston Naming Test
CPM- Raven's Coloured Progressive Matrices
DG-Digit Recall test
BDG-Backward Digit Recall test
CR-Counting Recall test
NR-Non-word Recall test

The results for the BPVS were inconsistent with some test combinations differing significantly by socioeconomic status whilst others did not. The patterns of correlations between the BPVS and the Backward Digit Recall test were significantly different ($z = -2.27$, $p<0.05$), indicating that the relationship between the two tests was different between the socioeconomic groups. Interestingly, the relationship between the two tests was stronger for the low socioeconomic

group. The same pattern of results was observed for the relationship between the BPVS and the Non Word Recall test ($z = 2.74$, $p<0.05$). This pattern has been corroborated by Engel et al. (2008) who reported that Non-word Recall is highly correlated with vocabulary acquisition. Contrastingly, the pattern of correlations between the BPVS and both the Digit Recall test ($z = 0.79$, $p>0.05$) and the Counting Recall test ($z = -1.32$, $p>0.05$) were not significantly different between the socioeconomic groups. The relationship between the BPVS and BNT correlations did differ significantly by socioeconomic group ($z = -1.97$, $p>0.05$), in favour of the high socioeconomic group.

Interestingly, the pattern of results depicted that the relationship between the BNT and all other tests (CPM $z = 0.75$, $p>0.05$; BDG $z=-0.99$, $p<0.05$; DG $z=-0.99$, $p<0.05$; CR $z=-0.54$, $p<0.05$; NRT $z=1.36$, $p<0.05$) did not differ significantly between the high and low SES groups.

Similarly, the correlations with the CPM and all other tests of both fluid and crystallized ability also did not differ significantly by socioeconomic status (DG $z=1.33$, $p>0.05$; BDG $z=-0.01$, $p>0.05$; CR $z=-0.39$, $p>0.05$; BPVS $z =-0.066$, $p>0.05$); suggesting similar patterns of correlations across the two groups.

Most importantly, the results of the Fishers z transformation revealed that relationships between all of the working memory measures, except one combination, did not differ across socioeconomic status groups. More specifically, the pattern of results depicted that the relationship between the Backward Digit Recall test and all other working memory tests (DG $z = -0.16$, $p>0.05$; CR $z=-0.069$, $p>0.05$; NRT $z=0.47$, $p<0.05$) was not significantly different between the high and low SES groups. Similarly results depicted that the relationship between the Digit Recall test and the Counting Recall test ($z = 0.62$, $p>0.05$) as well as the Counting Recall test and the Non-Word Recall test ($z = 1.93$, $p>0.05$) was not significantly different between the high and low SES groups. Interestingly the pattern of correlations between the Digit Recall test and the Non-Word Recall test did display significant differences, with the relationship for the high socioeconomic group being slightly stronger than the low SES group ($z=2.12$, $p<0.05$).

The results of the Fishers z transformation imply that working memory measures are not readily affected by socioeconomic status, as the correlations between working memory measures do not

differ by socioeconomic status. Although the relationship between tests were not significantly different by socioeconomic status for the CPM and BNT combinations, the relationships between tests for the BPVS combinations were inconsistently affected by socioeconomic status. Thus it was apparent that due to the inconsistencies found in other test combinations, more sophisticated analyses were required to determine whether the crystallized vocabulary measures differed by socioeconomic status.

Ideally a Multivariate Analysis of Variance (MANOVA) would have been the best way to determine whether there were significant differences between the socioeconomic groups in their performance on the tests. However, Box's M test revealed that the covariance matrices of the dependent variables were not equal across all the groups ($M=52$, $p=0.021$), and multicolllinearity between variables was observed, thus violating the assumptions of a MANOVA. Since the scores were all of an interval nature, it was decided that a MANOVA would merely be used to gauge the overall effect of socioeconomic status upon test performance.

Due to the nature of this investigation, it was important that the two socioeconomic groups first be compared in terms of their non-verbal intelligence to determine whether they were of comparable intellectual ability. A one-way Analysis of Variance (ANOVA) indicated that performance on the CPM differed significantly between the two socioeconomic groups although the effect size, calculated with cohen's d, was small ($F(1;58)=47.98$, $p<0.001$, $d=0.45$).

In order to determine the effect of socioeconomic status and language upon each test individually, two-way Analyses of Covariance (ANCOVA) were run. The CPM scores were entered as the covariate in order to control for the differences in non-verbal ability, between the socioeconomic groups so that any differences observed between the groups on both the crystallized and working memory measure, would not arise as a result of apriori differences in non-verbal performance. Language was initially intended to be used as a second independent variable, but the high socioeconomic group was primarily English speaking whilst the low socioeconomic group was chiefly second language English speaking. This posed the danger that socioeconomic status and home language, may have been referring to the same construct. To gain more insight into the strength and significance of this relationship, language and socioeconomic status were converted into dummy variables, and Pearson's Correlation Coefficients were computed. This analysis revealed that language (mean=0.42, standard

deviation= 0.50) and socioeconomic status (mean=0.50, standard deviation=0.50) were indeed significantly correlated (r= 0.78, p<0.001). Furthermore a Chi Squared test confirmed the association between language and socioeconomic status ($X^2(1)$=36.274, p<0.001). Language was therefore removed from the analysis as an independent variable and only socioeconomic status was used. Hence one-way ANCOVA's were computed with socioeconomic status as the independent variable and the scores of each of the tests as dependent variables.

Table 4 :
Home Language by Socioeconomic Status

		Socioeconomic Status		
		Low SES	**High SES**	Total
Language	**English**	6	29	35
	Other	24	1	25
Total		30	30	60

Overall, the results of the MANOVA revealed that the two groups' performance on the working memory measures and the intelligence tests were significantly different (F(1;58)=36.99, p<0.001). The results from several ANCOVA's depicted the overall trend anticipated. Highly significant differences between the high and low socioeconomic groups were observed on the Boston Naming Test in favour of the high socioeconomic group (F(1;58)=20.30, p=0.000), with the high socioeconomic group scoring more than two and a half times higher than the low socioeconomic group. The effect size calculated was large (*d*= 0.81). Similarly, on the British Picture Vocabulary Scale there was also significant effect of socioeconomic status (F(1; 58)=36.56, p=0.000). The effect size was moderate (*d*=0.80). The high socioeconomic group obtained scores that were on average, twice as high as those of the low socioeconomic group. These results suggest that tests of crystallized ability are very susceptible to socioeconomic influences.

As expected, performance on the Digit Recall test was not affected by socioeconomic status, and a very small effect size (*d*=0.24) provided further evidence that processing dependent measures appear to be less affected by socioeconomic variables ((F1;58)=2.72, p= 0.06).

Similarly the Counting Recall test did not display a susceptibility to the effects of socioeconomic status (F(1;58)=0.97, p=0.35). A very small effect size of 0.15 was observed, and correspondingly, the groups differed by only 2.1 points, rendering this difference non-significant.

Contrary to expectations, on the Backward Digit Recall test, there was a significant difference in performance between the high and low socioeconomic groups (F(1;58)=1.90, p=0.02). However, the effect size was very small (*d*=0.23), again rendering this result of no practical significance.

A similar trend was observed on the Non-word Recall task, with significant differences between the high and low socioeconomic groups being apparent (F(1;58)= 3.70, p=0.005). The high socioeconomic speaking group scored the highest, but a small effect size of 0.15 was observed, and the two groups differed by merely 3.23 points, making this finding non-significant.

In light of all the analyses conducted, it is evident that as anticipated, the tests of crystallized ability, namely the British Picture Vocabulary Scale and the Boston Naming Test, are highly susceptible to socioeconomic influences. Surprisingly, the Raven's Coloured Progressive Matrices, which served to determine whether the two groups were matched for intellectual ability, was also found to be moderately influenced by socioeconomic status.

Although performance on the measures of working memory was expected to be equivalent for the high and low socioeconomic groups, in some cases, significant differences were found. However, on closer inspection of the results, it emerged that whilst the high socioeconomic group performed slightly better on some of these tests than the low socioeconomic group, the practical differences in performance were negligible as effect sizes were small and the groups differed at most by 4 points. Additionally, comparisons of the patterns of intercorrelations between working memory measures appeared to be the same across both socioeconomic groups suggesting that both groups were using similar skills to complete these tests and that these tests probably assess the same construct in both socioeconomic groups. Although similar results were found for some of the tests of vocabulary, when these results were looked at holistically, in comparison to the results of previous analyses, they were found to be very inconsistent, making

it difficult to reach a firm conclusion regarding their functioning across socioeconomic status groups.

Chapter 4

Discussion

The enterprise of psychometric testing has become well entrenched in South Africa, due to its ability to aid in decision-making (Foxcroft et al., 2001). In current times, wherein we are pressured by large scale organizational and academic needs to streamline selection and placement processes as well as to enhance personnel development, testing is regarded as an essential tool, and it is for these reasons that it continues to flourish today (Cohen & Swerdelik, 2010). Yet, in South Africa, testing, especially intelligence testing is a very controversial issue, with some keenly advocating its use and many regarding it with suspicion and mistrust. The pervasive negative attitude toward testing is a consequence of test misuse during the Apartheid era, wherein tests were used to justify the black population's relegation to physical labour on the basis that black people performed more poorly on intelligence tests than did their white counterparts (Lurie, 2000). However, these tests were biased against the former group who were deprived of economic resources, good educational opportunities and often did not speak English as a first language, all of which disadvantaged them during test-taking (Foxcroft et al., 2001; Nzimande, 1995; Sehlapelo & Terrblanche, 1996).

The implications of biased test use are widespread, affecting school and university entrance as well as employment opportunities, which in turn impinge upon future remuneration, socioeconomic status and therefore access to resources. Thus the use of biased tests perpetuates a vicious circle of disadvantage for those affected. This trend, although slowly changing due to the country's current Employment Equity Act (1998), which stipulates that all tests must be valid, reliable, fair and unbiased, is still persistent today. Nevertheless, it is now widely accepted that traditional measures of intelligence are highly susceptible to educational, resource, language and socio-economic influences. These biases also stem from the fact that tests are often developed for Western populations by Western test developers, therefore traditional intelligence measures tend to subscribe to Western conceptualizations of intelligence (Cohen & Swerdelik, 2010). However, South African cultures tend to hold very different definitions of intelligence, thus competencies and abilities necessary for the successful completion of Western intelligence tests are often not prioritized by South African cultures. Given South Africa's multicultural

population, there is an urgent need for the development of measures which are resilient to these influences. In answer to this, working memory measures have been identified as possible measures which minimize these biases as they are said to tap fluid reasoning ability which is concerned with the processing of information rather than crystallized ability which draws on prior knowledge (Engel et al., 2008). Consequently, the following study investigated whether working memory tests were less susceptible to socioeconomic influences than the more traditional measures of vocabulary in a sample of 60 grade one learners from high and low socioeconomic schools.

As a first step, correlations were run in order to determine whether the tests of crystallized ability were associated with those of working memory. It emerged that whilst the vocabulary measures were strongly associated with each other, they were only weakly associated with the measures of working memory. The former point is in line with previous findings that measures of receptive and expressive vocabulary are known to be highly related (Howlin & Cross, 1994).

In the high socioeconomic group, the Boston Naming test was significantly but weakly correlated with Raven's coloured Progressive Matrices whilst for the low socioeconomic group the BPVS was significantly, albeit weakly, correlated with the CPM. Although the Boston Naming Test and the British Picture Vocabulary Scale are verbal measures of crystallized intelligence, their correlation with the CPM which is a non-verbal fluid measure of intelligence, is expected since both types of tests assess elements of general intelligence.

Similarly, the BPVS and the Boston Naming Test were also significantly but weakly correlated with the Backward Digit Recall test in the low socioeconomic group. These correlations are unsurprising as crystallised and fluid measures of intelligence are related, as they both fall part of general intelligence. Therefore, although they are separate constructs, they do share some overlap.

In terms of the relationships between working memory and vocabulary measures, studies have found that Non-word recall is closely related to vocabulary acquisition, and is therefore related to performance in vocabulary measures (Baddeley, 1996; Baddeley, 2001; Gathercole & Baddeley, 1990). This finding appears to be supported by the results which show that the BPVS and the Boston Naming test in the high socioeconomic group were also found to be weakly, but

significantly correlated with the Non-word recall test. However, this finding was not replicated in the low socioeconomic group. This may be explained by the fact that the low socioeconomic group's performance in the G_C measures was so much poorer than their high socioeconomic counterparts, and they performed considerably more inconsistently than the high socioeconomic group on the Non-word recall test. The poorer performance of the low socioeconomic group in both the vocabulary measures and the Non-word Recall test may also be explained by the fact they were predominantly second language English speakers which would have disadvantaged them. Moreover, although the Non-word Recall test is a fluid measure of intelligence, the words in this test still adhere to the English orthographic structure, which is different to the orthographic structure of the home languages of the low socioeconomic group.

The results of the correlations also showed that the CPM was significantly correlated with the two measures of simple working memory span in the high socioeconomic group, but not with any measures in the low socioeconomic group, suggesting that the two groups were drawing on different skills when completing the CPM. The lack of correlation between the CPM and working memory measures in the low socioeconomic group is a possible result of this group's performance on the CPM being hindered by a language barrier which prevented them from fully understanding the requirements of the test. In support of this assertion, Israel (2006) found that first and second language English speakers despite performing equally well on the CPM, differed significantly in their error patterns which suggest that language influences reasoning ability by affecting the manner in which problems are approached.

The Digit Recall and Non-word Recall working memory tests were found to be significantly associated in both groups which is expected as both these tests are classified as simple working memory tasks involving only the short-term phonological aspect of working memory. The lack of correlation between the complex working memory tasks, namely the Counting Recall test and the Backward Digit Recall test is not altogether unlikely as they place different demands on the components of working memory. Whilst the Backward Digit Recall test involves phonological working memory, the Counting Recall Test involves counting a series of visually presented circles and holding them in memory which may be done using visual or phonological coding. Young children have been found to rely more on the visuo-spatial sketchpad to store visual information and it has also been asserted that children younger than 7 do not engage in

spontaneous phonological rehearsal as at this age only the phonological store exists (Gathercole et al., 2004). Hence, the lack of correlation between these tests may be attributed to different coding and rehearsal strategies employed in the two tests.

The next step in the analyses was to investigate whether the patterns of the correlations between the tests differed by socioeconomic status. To this end Fisher's z transformations were computed. The results clearly depicted that the correlations between measures of working memory did not differ between the socioeconomic groups. However, the relationships between the CPM and the vocabulary measures differed inconsistently between the groups.

For the purposes of gaining an improved understanding of the differences between socioeconomic status, and the vocabulary and working memory measures, it was obvious that more sophisticated methods of analyses were necessary. Hence, a MANOVA was conducted. The results showed significant differences in performance on these measures between the high and low socioeconomic groups.

A series of one-way ANCOVA's were computed to identify where there were significant differences between the socioeconomic groups. As anticipated, statistically significant differences were observed between the socioeconomic groups on the vocabulary measures, with the high socioeconomic group performing significantly better than the low socioeconomic group. This pattern of results was expected because socioeconomic background is known to affect vocabulary development because it moderates exposure to different language learning experiences. Therefore, those from high socioeconomic groups tend to acquire more sophisticated vocabularies (Hoff, 2003; Hoff & Tian, 2005).

With regards to the working memory measures, performance on the Digit Recall and Counting Recall tests did not differ significantly between the socioeconomic status groups. Although statistically significant differences were found between the groups' performance on the Backward Digit Recall test and the Non-word Recall test, the effect sizes were miniscule which rendered these results non-significant and implied that the groups did not differ in their performance on these tests.

Although the current study encountered instances where the relationship between measures of working memory and socioeconomic status were significant, the effect sizes were very small.

Thus, working memory measures do appear to be impervious to socioeconomic influences. The poorer performance of the low socioeconomic group when compared to the high socioeconomic group, on the Backward Digit Recall test may have occurred because of second language issues in the former group that may have affected the task of having to repeat the sequence backward, as well as comprehension of instructions. Additionally their poor performance on the Non-word Recall test may be attributed to the fact that, despite being nonsense words, the words in this test still adhere to the English orthographic structure. Perhaps if they were required to recall non-words which possessed similar structures to their home language they would fare better. Differences in performance may also have been precipitated by the fact that all measures of working memory were administered using a computer, which the majority of the low socioeconomic group do not have access to at home. Moreover, the instructions to the measures of working memory were spoken by a British female avatar; hence it is likely that the lack of familiarity with the computer administration, as well as a difficulty in understanding the accent of the avatar may have hampered test performance in the low socioeconomic group. In support of this, the familiarity with the mode of administration, test format and the understanding of instructions have been proven to affect test performance (Foxcroft, 2004; Nell, 1999). Despite these barriers, the present study suggests that working memory measures do indeed minimize structural biases, specifically those which arise as a consequence of socioeconomic circumstances. Overall, the results found in the current study closely emulated those found by Engel et al. (2008), who found no significant differences in performance between the high and low socioeconomic groups on the measures of working memory, which are tests of fluid ability, but found that children from low socioeconomic backgrounds obtained significantly lower scores on measures of receptive and expressive vocabulary measures of crystallized knowledge.

It must be acknowledged that the present study and that of Engel et al. (2008) are but two studies conducted in two entirely disparate contexts. Thus, these results are hardly conclusive. Similar studies which examined the resilience of processing-dependent measures, such as the study by Campbell et al. (1997) and that of Shuttle-worth-Edwards et al. (n.d) compellingly demonstrate the resilience of processing-dependent measures to socioeconomic status, race and quality of education as compared to traditional knowledge dependent language measures. This provides some support for the claim that processing-dependent measures may serve as more appropriate measures for non-western populations and low socioeconomic populations.

These studies, together with those specifically investigating the relationship between working memory and socioeconomic status, provide evidence pertaining to the usefulness of working memory measure as possible alternatives to traditional content-based intelligence tests. Despite these promising findings, the present study, by virtue of its correlational design, could not rule out the role of many other extraneous factors, such as language which is known to moderate test performance because it affects the understanding and interpreting of test items and instructions (Bedell et al., 1999; Foxcroft, 2004; Foxcroft &Aston, 2006; Heaven & Pretorius, 1998; Heuchert et al., 2000; Meiring et al., 2006; Nell, 1999; van de Vijver & Rothmann, 2004).

It is worth noting that the high and low socioeconomic groups differed in their performance on the Raven's Coloured Progressive Matrices (CPM) despite the classification of this test as a non-verbal one that assesses fluid ability. Although the differences in performance may be interpreted as being reflective of differences in intellectual ability between the two socioeconomic groups, it may otherwise be interpreted as an artefact of language ability. This conclusion is supported by Israel's (2006) study which was previously mentioned. Similarly Rushton and Skuy (2000) found that on the RPM, black participants performed more poorly than white participants, despite the fact that it doesn't contain culture specific information or assess crystallized intelligence. Reasons for these differences in performance have been attributed to the poorer quality of education and access to resources that black children endured during Apartheid. This may have been the case in this study as the majority of the low socioeconomic group in this study were black and all the participants from the high socioeconomic group were white, except for one. However, Crawford-Nutt, (1976) found that by using special instructions to clarify the test requirements, black and white groups perform very similarly. Thus it is most likely that in the current study, the low socioeconomic group, the majority of whom were second language English speakers, did not understand the requirements of the test due to the fact that they are not functionally literate in the English language.

Test-wiseness and test familiarity may have also contributed to differences in performance on the CPM. Those from the high socioeconomic group are privileged with a better quality of education which probably facilitates their engagement with the kind of exercises and thinking necessary to complete the CPM. Exposure to exercises such as "brain teasers" and puzzles facilitate the kind

of logical reasoning underlying the CPM. In support of this, many of the participants from the high socioeconomic school expressed excitement on seeing the CPM and likened it to completing a puzzle. They also grasped the requirements of the test quite easily. However, those from the low socioeconomic group were unfamiliar with the logic of CPM and the requirements of the test were not readily grasped. Indeed communicating the requirements of the test took considerably longer amongst the low socioeconomic group.

Although this study sought to understand the relationship between working memory and socioeconomic status it is probable that the variable of socioeconomic status encompassed other variables such as language and quality of education as well. Due to the structure of the South African population and our Apartheid history these variables are all highly interrelated owing to past apartheid laws which deprived non-whites of high paying jobs, a good quality of education and the resources to acquire a high level of proficiency in English (Foxcroft, 1997; Foxcroft et al., 2001). This interrelationship makes separating out the effects or contributions of these variables to test performance very difficult. Related to this, this study initially intended to examine the association of both socioeconomic status and language with test performance. However, a correlation analysis and Chi Squared test of association revealed that language and socioeconomic status were so interrelated in this sample that they appeared to be referring to the same construct.

The relationship between language and test performance is complicated by research which asserts that socioeconomic status impacts on vocabulary acquisition (Hoff, 2003; Hoff & Tian, 2005). This assertion suggests that socioeconomic status impacts on language proficiency which in turn affects test performance. However, an alternative explanation may be that be that the majority of South Africa's population are second language English speakers and of a lower socioeconomic status due to the injustices of the apartheid system. This was clear in the data which reflected that only 20 % of the low socioeconomic group spoke English as a first language as compared to 97% of the high socioeconomic group. Thus, in the South African context socioeconomic status is likely to reflect home language as well. Consequently the two variables are so inextricably intertwined that it is impossible to discern whether test performance in the vocabulary measures, was related one or both of these variables in the present study. Others have contended that it is the quality of education rather than one's home language which moderates

test performance, as when provided with similar qualities of education, Caucasian and ethnic groups perform comparably. However, even this explanation implies an association between socioeconomic status and home language, as quality of education is mediated by socioeconomic status (Fagan & Holland, 2002). Undoubtedly socioeconomic status and language moderate test performance, nevertheless, the exact mechanisms of this relationship remain uncertain.

It is clear that performance on crystallized measures of intelligence are influenced by the interplay of many variables, but it seems that processing-dependent measures such as working memory measures are able to escape many of these. Additionally, working memory ability is able to predict educational attainment, which is highly useful in academic settings (Alloway, 2009; Alloway et al., 2005, Gathercole et al., 2006; Gathercole et al., 2003 and Gathercole et al., 2003). Most importantly, working memory is able to predict reasoning ability over a wide range of tasks as well as simultaneous tasks (Colom et al., 2002; Engel et al., 2008; Sub et al., 2002). Although it is not possible to completely remove the influence of prior experience and background knowledge in assessments, processing dependent measures may prove useful as assessment tools as they minimize the effect of cultural, ethnic and socioeconomic circumstances (Campbell et al., 1997). This is crucial in the South African context which consists of an abundance of cultures, ethnicities and spoken languages. In a context riddled with vast socioeconomic disparities and discrepancies in standards of education, there exists a dire need for unbiased assessments as well as a responsibility to ensure that all groups are equally represented in employment, educational and various other settings. In this regard, working memory measures currently hold much promise as a superior means by which to assess general fluid intelligence.

Limitations

This study was correlational in nature and as such, merely compared the performance of two groups of children from different socioeconomic backgrounds, on tests of working memory and intelligence. It also consisted of a small sample. Since the study was not an experimental one, no claims of causation can be made. Moreover the non-experimental nature of this study leaves room for the operation of many extraneous variables such as quality of education, test-wiseness and environmental circumstances and language. Although all these variables are linked to socioeconomic status, their individual effects were not controlled for or explored and thus remain unknown.

In this study it is highly plausible that home language may have contributed to the differences in performance observed between the two socioeconomic groups, because it was so highly correlated with socioeconomic status that they could have been referring to the same construct. Almost all participants from the lower socioeconomic group did not speak English as their home-language, whilst all participants from the higher socioeconomic group spoke English at home. Yet, all participants, both those who spoke English as a home language and those who did not, were tested in English, which introduces the possibility of a language bias. It is well-documented that language affects test performance because it affects understanding and interpretation of test instructions and test items (Bedell et al., 1999; Foxcroft, 1997; Foxcroft & Aston, 2006; Shuttleworth-Jordan, 1995). This study, being a replication of that conducted by Engel et al. (2008), did not use measures which tap the visual component of working memory. Tests and activities involving visual working memory may be less susceptible to socioeconomic influences as they are less likely to be moderated by language and are not commonly used in schools, which tend to focus on tasks requiring verbal aspects of working memory.

Conclusion

Although this study attempted to replicate the findings of Engel et al. (2008) it was quite novel as it is the first study in South Africa to compare performance in working memory and intelligence tests across different socioeconomic groups. In the South African environment, much work needs to be done in order to improve intelligence assessments so as to minimize cultural and language and educational biases. This study contributes to the efforts to develop fairer means to test intelligence by proving the usefulness of working memory assessments as worthy alternatives to traditional intelligence tests. Working memory measures offer much promise as a potentially culturally and socioeconomically reduced manner in which to assess general fluid intelligence. Although they are not completely free of socioeconomic and cultural influences, they do display commendable resilience to them. In a country as diverse as South Africa wherein the field of assessment is fraught with challenges and endeavouring to escape the repercussions of the Apartheid era, working memory measures, offer a welcomed alternative to tests of crystallized ability. Working memory measures are yet young and unfamiliar alternatives to traditional tests, but with time and much further research, perhaps these measures will become widely acknowledged as the much needed assessments for multicultural (cosmopolitan) populations.

In light of the study's limitations, it is recommended that future studies focus on limiting the impact of extraneous variables, by using more powerful research designs, to better understand the impact of socioeconomic status on cognitive performance. More specifically, future studies would do well to find samples which have a mix of learners such that all races are equally represented in both the high and low socioeconomic groups, and that English is the home language for all participants. This will ensure that language and race do not operate as extraneous variables. However in the South African context, most of the population do not speak English as a home language thus future studies should perhaps make efforts toward testing children in their home language in order to minimise language effects. Also, forthcoming studies should attempt to replicate this study using larger samples. It must also be noted that thus far studies of working memory measures have tended to use only verbal working memory measures. This is likely due to the fact that verbal working memory is necessary for most academic tasks and that the use of

verbal working memory measures is more automatic than the capacity to utilize visual working memory. Nevertheless, future studies would do well to investigate whether visuo-spatial measures of working memory can be used as tests of general fluid intelligence as well. This will be useful as the visual aspects of working memory are less likely to be susceptible to socioeconomic influences due to the fact that they are far less commonly used in schooling than verbal aspects of working memory, and they do not rely on language proficiency. Furthermore, children younger than age 7 are known to rely more on the visuo-spatial sketchpad than the phonological loop because at this stage, only the phonological store exists whereas the processes of rehearsal do not. Finally both the present study and that conducted by Engel et al. (2008) used vocabulary measures as proxies for intelligence however it would be interesting to conduct similar studies which use different proxies of intelligence to investigate whether measures of working memory consistently emerge as the less biased forms of assessment.

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Appendix A

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

School of Human and Community Development

Private Bag 3, Wits 2050, Johannesburg, South Africa

Tel: (011) 717-4500 Fax: (011) 717-4559

Working memory: Is it associated with socioeconomic status?

Dear Parents

My name is Azra Moolla and I am a student completing a Masters degree in Research Psychology at the University of the Witwatersrand. I am conducting a study to determine whether working memory measures are associated with socioeconomic status.

Traditional intelligence tests are known to be culturally, racially and socioeconomically biased as they rely on prior knowledge and access to resources. Thus those from poorer or non-Western backgrounds usually under-perform in these assessments. There is a need to develop tests that are fairer and less affected by race, socioeconomic status and culture. Working Memory measures are acknowledged as a form of assessment that is culturally, racially and socioeconomically less biased because they rely on the ability to process information, and are equally unfamiliar to all children.

I would like to invite your child to participate in this study. Due to the purposes of this study only children who do not have any learning, cognitive or communication difficulties will be allowed to participate.

Each child will be required to complete cognitive assessments and working memory assessments. The entire process should not take longer than 90 minutes and the child will be allowed breaks between assessments. Assessment will take place at a time agreed upon by both the parents and the school. Parents will be required to complete a demographic questionnaire and a socioeconomic index questionnaire.

Participation is entirely voluntary thus refusal to participate and the child's withdrawal from the study at any time will be without any consequences. There are no benefits or harms in participating in this study. The confidentiality of each child is guaranteed and all results will be published in terms of group trends only. Therefore no findings that could identify any individual participant will be published. The raw data will be accessed by me only, and kept in a secure place.

Appendix A

Please find a consent form attached. If you agree to allow your child to participate please complete the form and return it to me.

If you have any questions or would like to discuss anything please feel free to contact me.

Student	Supervisor
Azra Moolla	Prof. Kate Cockcroft
072 796 2276	011 717 4511
azra.moolla@gmail.com	kate.cockcroft@wits.ac.za

Appendix B

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

School of Human and Community Development

Private Bag 3, Wits 2050, Johannesburg, South Africa

Tel: (011) 717-4500 Fax: (011) 717-4559

Working memory: Is it associated with socioeconomic status?

Consent form

I _____ agree to allow my

child_____ to participate in this study carried out by Azra Moolla under the supervision of Prof. Kate Cockcroft.

I understand that my child is allowed to withdraw at any time without any consequences and that this study will neither benefit nor harm my child in anyway. Further I understand that my child's results will be entirely confidential and that this study is in no way related to the school or schoolwork of any kind.

_____

Name

Tel No _____

Cell No _____

Email_____

_____

Signature

_____

Date

Kindly return to your child's class teacher by _____/05/11_____

Appendix C

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

School of Human and Community Development

Private Bag 3, Wits 2050, Johannesburg, South Africa

Tel: (011) 717-4500 Fax: (011) 717-4559

Working memory: Is it associated with socioeconomic status?

Assent form

Date: ……

Hello

I would like to do some tasks with you to see how good your memory is. It has nothing to do with your school work. It is only to help me with my university work. You can ask me about anything you don't understand and we can take a break if you're tired. If you don't want to continue we can stop whenever you want. Only I will know how well you did. Your teachers and friends will not be told anything about your tasks.

I _____agree to participate.

Name of child

_____

Azra Moolla

_____

Child's name

Appendix C

Appendix D

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

School of Human and Community Development

Private Bag 3, Wits 2050, Johannesburg, South Africa

Tel: (011) 717-4500 Fax: (011) 717-4559

Working memory: Is it associated with socioeconomic status?

Dear Principal

My name is Azra Moolla and I am a student completing a Masters degree in Research Psychology at the University of the Witwatersrand. I am conducting a study to determine whether working memory measures are associated with socioeconomic status. Traditional intelligence tests are known to be culturally, racially and socioeconomically biased as they rely on prior knowledge and access to resources. Thus those from poorer or non-Western backgrounds usually under-perform in these assessments. There is a need to develop tests that are fairer and less affected by race, socioeconomic status and culture. Working Memory measures are acknowledged as a form of assessment that is culturally, racially and socioeconomically less biased because they rely on the ability to process information and are equally unfamiliar to all children. This study will aid the development and use of working memory measures as an alternative to traditionally biased intelligence tests.

I would like to invite all the grade one children aged between 6 and 8 years of age to participate in this study. In order to participate in this study, every child will have to grant verbal assent. Each child will be required to complete cognitive assessments and working memory assessments. The entire process should not take longer than 90 minutes. Assessment will take place at a time agreed upon by the parents and the school that will not disrupt the school process.

If you are willing to allow me to conduct my study at your school, I would appreciate it if you could distribute the information letters, which I will provide, to the parents as their consent is imperative. Parents will be required to complete a demographic questionnaire and a socioeconomic index questionnaire. The demographic questionnaire will contain information such as the age and gender of the child as well as whether the child has any disabilities or disorders. The socioeconomic status questionnaire will ask questions such as the area of residence, the occupational, educational and marital

Appendix D

status of the primary caregiver as well as questions pertaining to the family's standard of living. These questionnaires can be completed and returned in a sealed envelope that will be provided.

In order to ensure the integrity of the data collected I will require a quiet classroom or office with a desk, two chairs and a power source.

Participation is entirely voluntary thus refusal to participate and the child's withdrawal from the study at any time will be without any consequences. There are no benefits or harms in participating in this study. The confidentiality of each child is guaranteed and all results will be published in terms of group trends only. Therefore no findings that could identify any individual participant will be published. The raw data will be accessed only by me and will be kept in a safe place.

I will contact you soon to establish your decision. Please feel free to contact me with any questions or queries.

Yours Sincerely,

Azra Moolla

Researcher

Azra Moolla

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Supervisor

Prof. Kate Cockcroft

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Appendix E

Demographic Questionnaire

Name:

Surname:

Age of Child/Ward:

Sex:

Home Language:

Has your child been diagnosed with any disorders?

Please tick where applicable

ADHD/ADHD	
Learning difficulties	
Communication disorders	
Cognitive disorders	
Speech/language disorders	
Motor disorders	
Other (please specify):	

Appendix F

Socioeconomic Index

1. Educational status of main/primary caregiver

Please tick where applicable

Level of Education		**Details**
No schooling		
Less than primary school completed		
Primary school completed		
Secondary school not completed		
Secondary school completed		
Tertiary education completed		
Other		

2.Occupational status of main/Primary caregiver

Please state your occupation.

_____

3. Marital status of main/primary caregiver

Please tick where applicable

Married	
Living together as husband and wife	
Widow/widower	
Divorced/separated	
Never married	

4. Number of parents in the household

Appendix F

Please tick where applicable

0	
1	
2	

5. Area of residence

_____

Appendix F

6. Living Standards Measure

Please circle the correct answer

Question	Answer	
1. I have the following in my household:		
TV set	TRUE	FALSE
VCR	TRUE	FALSE
DVD player	TRUE	FALSE
M-Net/DStv subscription	TRUE	FALSE
Hi-fi/music centre	TRUE	FALSE
Computer / Laptop	TRUE	FALSE
Vacuum cleaner/floor polisher	TRUE	FALSE
Dishwashing machine	TRUE	FALSE
Washing machine	TRUE	FALSE
Tumble dryer	TRUE	FALSE
Home telephone (excluding a cell)	TRUE	FALSE
Deep freezer	TRUE	FALSE
Fridge/freezer (combination)	TRUE	FALSE
Electric stove	TRUE	FALSE
Microwave oven	TRUE	FALSE
Built-in kitchen sink	TRUE	FALSE
Home security service	TRUE	FALSE
3 or more cell phones in household	TRUE	FALSE
2 cell phones in household	TRUE	FALSE
Home theatre system	TRUE	FALSE
2. I have the following amenities in my home or on the plot:		
Tap water in house/on plot	TRUE	FALSE
Hot running water from a geyser	TRUE	FALSE
Flush toilet in/outside house	TRUE	FALSE
3. There is a motor vehicle in our household	TRUE	FALSE
4. I am a metropolitan dweller	TRUE	FALSE
5. I live in a house, cluster or town house	TRUE	FALSE
6. I live in a rural area outside Gauteng and the Western Cape	TRUE	FALSE
7. There are no radios, or only one radio (excluding car radios) in my household	TRUE	FALSE
8. There is no domestic workers or household helpers in household (both live-in & part time)	TRUE	FALSE

Appendix G

Histograms for all tests used

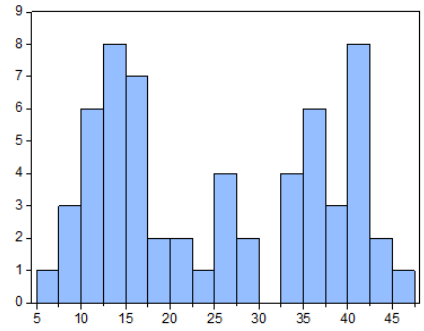


Figure1: Histogram for Boston Naming Test

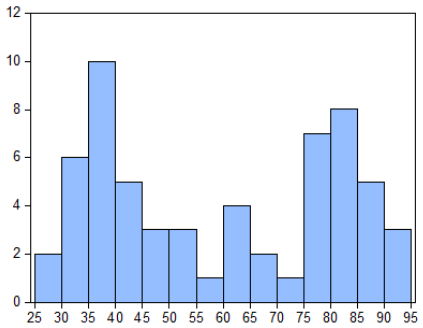


Figure 2: Histogram for British Picture Vocabulary Scale

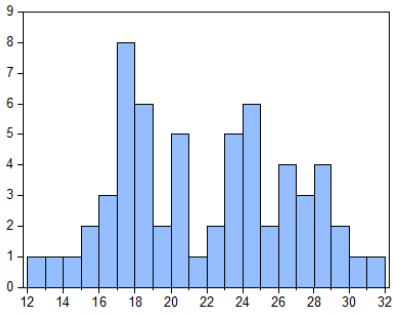


Figure 3: Histogram for Raven's Coloured Progressive Matrices

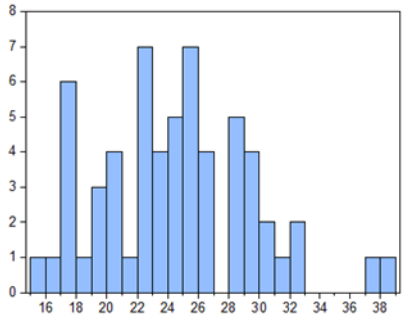


Figure 4: Histogram for Digit Recall test

Appendix G

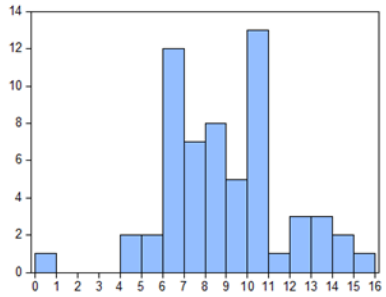


Figure 5: Histogram for Backward Digit Recall test

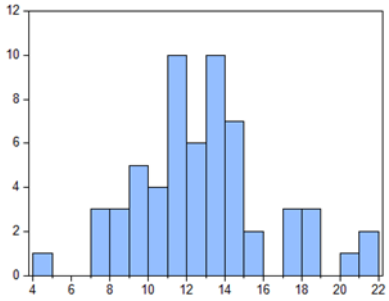


Figure 6: Histogram for Counting Recall Test

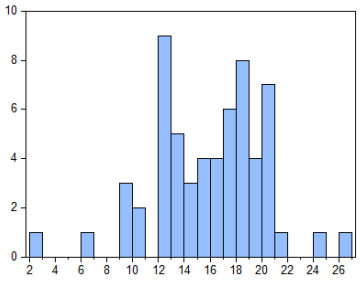


Figure 7: Histogram for Non-Word Recall test

Appendix H

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON MEDICAL)
R14/49 Moolla

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER H110610**
PROJECT	Working memory: is it associated with socio-economic status?
INVESTIGATOR(S)	Ms A Moolla
SCHOOL/DEPARTMENT	Human & Community Development/Psychology
DATE CONSIDERED	10/06/2011
DECISION OF THE COMMITTEE	Approved unconditionally
EXPIRY DATE	22/06/2013

DATE 23/06/2011 **CHAIRPERSON** .....
(Professor R Thornton)

cc: Supervisor : Professor K Cockcroft

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10005, 10th Floor, Senate House, University.

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

Signature **Date** 17 / 07 / 11

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES