WORKING MEMORY
AND
PHONOLOGICAL AWARENESS

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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 Master of Arts in Psychology by Coursework and Research Report at the University of the Witwatersrand, Johannesburg.

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Abstract

Phonological awareness, and working memory, as a component of phonological awareness, have been found to be highly correlated, not only with the acquisition of reading skills, but also with each other. Existing data does not address this aspect of emergent literacy in South African children, for whom bilingualism may impact on their levels of phonological awareness, and possibly working memory. This research study was designed and conducted in an attempt to identify the relationship between these two skills in a sample of seventy-nine South African Grade 1 children (mean age 86 months). The sample consisted of two language groups, namely first-language English (EL1), an opaque orthography (n=42) and second-language English with first-language one of the nine official African languages of South Africa (EL2), a transparent orthography (n=37). The primary aim was to examine the relationship between phonological awareness (comprising a sound categorisation task, a phoneme deletion task, and a syllable splitting task) and working memory (comprising a verbal short-term memory task, a visuo-spatial short-term memory task, a verbal working memory task and a visuo-spatial working memory task). A measure of non-verbal intelligence was included as a control. Separate analyses were run for the two language groups in order to draw a comparison between their performance on the tasks. Results generally supported existing literature that showed that the relationship between working memory and phonological awareness appears to be dependent on the depth of analysis of phonological awareness, which determines the level of demand made on working memory, yet the relationship differed between the language groups, indicating that the EL2 children draw more on general or apparently unrelated skills to conduct working memory and phonological awareness tasks. A secondary aim of this study was to explore the predictive power of firstly, the four memory skills on phonological awareness; secondly, the sound categorisation skills on phoneme deletion and finally, non-verbal intelligence on working memory. Results again differed between the language groups, suggesting that a broader range of working memory skills predict performance on phonological awareness tasks in the EL2 group than in the EL1 group. The implications of these results are discussed in detail.

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CHAPTER 1. LITERATURE REVIEW

1.1 Introduction and Rationale

Academic success is clearly linked to reading skills in children, and it is therefore important to identify variables that could predict reading success. Phonological awareness, or the ability to manipulate sounds, has been found to be highly correlated with the acquisition of reading skills (Adams, 1990), particularly in the early stages of reading. Likewise, working memory, a component of phonological awareness (Bradley & Bryant, 1985), is an essential part of reading and the acquisition of literacy (de Jong, 1998; Gathercole & Alloway, 2004). This research was conducted in an attempt to identify the relationship between these two skills, both essential for literacy acquisition, and thus academic success.

Phonological awareness is highly predictive of reading ability, and its use in word reading is important as it is linked to the ability to read regular and irregular words by means of the analysis and blending of the letters in words. These processes constitute the foundation stage of reading development that enables the acquisition of spelling patterns (Seymour, Aro & Erskine, 2003). Although it appears to be an isolated skill, consisting of the ability to manipulate segments of speech, phonological awareness is actually a constellation of cognitive abilities that are related to the child's understanding of the segmental nature of the language (Goswami & Bryant, 1990). Both phonological awareness and short-term memory measures reflect a common phonological processing substrate due to the significant verbal component of working memory (Gathercole, Alloway, Willis & Adams, 2006).

The role of working memory in reading ability is important, as it provides a mental workspace in which to hold information whilst mentally engaged in other relevant activities. Working memory was found to be significantly associated with severity of reading difficulties in 6- to 11-year-olds (Gathercole et al., 2006). Thus, children with small working memory capacities will struggle with reading and writing activities, simply because they are unable to hold sufficient information in mind to allow them to complete the task.

For many young South African children, starting school means entering a new culture, learning a new language, and most significantly, learning to use it for the purposes of cognitive, academic and social development (Clegg, 1996). Socio-political change in South Africa has resulted in an increasing number of children for whom English is a second language entering English medium government schools, although English is only the third most commonly spoken language in South Africa, following Zulu and Xhosa (Raidt, 1999). For these children, their bilingualism may impact on their levels of phonological awareness, and possibly working memory, and thus their acquisition of literacy skills.

Consequently, this research investigated the relationship between working memory and phonological awareness by assessing South African Grade 1 children, firstly utilising a recently developed standardised working memory assessment tool, the Automated Working Memory Assessment (AWMA) (Alloway, Gathercole & Pickering, 2004) and secondly, utilising various phonological awareness tests. Non-verbal intelligence was also assessed in order to control for this aspect, if necessary. It was expected that the results of this research could make a valuable contribution to education, within the diversity of South Africa's demographics, by identifying possible differences in the relationship between working memory and phonological awareness in first- and second-language English speaking children.

1.2 Bilingualism

Bilingualism in South Africa is the norm rather than the exception, with numerous different languages spoken, but it is predominantly English that is the language of instruction in schools, with 51% of schools selecting English as their medium of instruction, despite first-language English-speaking South Africans constituting only 5.7% of the population (Webb, 2002). The majority of the South African population speaks an African language as their first language, and many black children learn to speak at least two languages from birth. In adulthood, most urbanised Zulu-, Xhosa-, Sotho- or Tswana-speakers speak more than one African language, as well as English or Afrikaans, or both (Raidt, 1999).

Bethlehem, de Picciotto and Watt (2003) observe that the term 'bilingualism' is open to numerous interpretations, and this, according to Hamers and Blanc (1989), entails not only the individual's competence in two languages, but also factors such as cognitive organisation, age of acquisition, exogeneity, sociocultural status and cultural identity. Children whose first language is one other than English are often referred to as bilingual, irrespective of their English language ability, yet how and when a child was exposed to each language will have significant implications for phonological awareness and its development, and assessment (Gutierrez-Clellen, Restrepo, Bedore, Pena, & Anderson, 2000). For example, San Francisco, Carlo, August and Snow (2006) found that unbalanced bilinguals dominant in either English or Spanish scored better on English phonological awareness tasks than balanced bilingual children, and thus it is important to define the various forms of bilingualism, some of which are discussed hereunder.

A distinction may be made between the "balanced" bilingual, with equivalent competence in both languages, and the "dominant" bilingual, who is more competent in one language than the other (Hamers & Blanc, 1989). Children have also been distinguished as either "simultaneous" bilingual, which learn both languages from babyhood, or "sequential" bilingual, which learn the second language after acquiring a general knowledge of the first. Some researchers have even made a distinction between monolingual and bilingual status. In a Spanish study, those children receiving least of their daily language input (less than 20%) in English were classified as predominantly Spanish speaking, and those who received more than 20% in English, as bilingual (Pena, Bedore & Rappazzo, 2003). More specific definitions are proposed by De Groot (1996) and Grosjean (1992). De Groot defines bilinguals as those who have an approximately equal level of proficiency in two different languages, irrespective of their degree of expertise, which corresponds with the concept of the “balanced” bilingual. Grosjean (p. 51) places less emphasis on proficiency, and defines bilingualism as the ‘regular use of two languages in those people who need to use two languages in their everyday lives’, which would exclude those people who use their second language only infrequently. This is in line with Pena et al.’s (2003) definition of bilingualism.

A sample of South African Grade 1 scholars would thus include both balanced and dominant, as well as simultaneous and sequential bilingual scholars, who could be classified according to both their level of mastery of the English language, and the age at which they acquired the second language. These distinctions are necessary as a child’s particular language experience will have a significant impact on his or her phonological knowledge.

Bilingual children tend to have better meta-linguistic skills than monolinguals (Bruck & Genesee, 1995; Lesaux & Siegel, 2003). For example, Bruck and Genesee found that children exposed to more than one phonological system [or orthography] are likely to have heightened levels of explicit phonological awareness, since bilingualism appears to facilitate the acquisition of language-related skills (Lesaux & Siegel). In addition, they found that the development of reading skills in children who speak English as a second language is very similar to the development of reading skills in native English speakers. Thus, bilingualism may impact on phonological awareness, and therefore also on the acquisition of language-related skills such as reading and writing.

South African research has addressed cross-language issues relating to phonological awareness skills (Brokenshire, 1999) and reading skills (Cockcroft, Broom, Greenop & Fridjhon, 2001) in children, but to date limited, if any, research has been conducted on the relationship between working memory and phonological awareness within the South African context. The current study thus compared the relationship between working memory and phonological awareness in Grade 1, first-language English-speaking children (EL1), and second-language English-speaking children whose first language is one of the nine official African languages (EL2). Each of these aspects that is, home language (opaque and transparent orthographies), working memory and phonological awareness is discussed in detail below.

1.3 Orthography

As this is a cross-linguistic study, it is appropriate to discuss the orthographies of the EL1 and EL2 children.

Alphabetic orthographies, or writing systems, although all based on the principle of grapheme-phoneme correspondence, display more or less ambiguous relations between sound and spelling patterns, and are defined as being either ‘opaque’ or ‘transparent’, depending on the ease with which a word’s pronunciation can be predicted from its spelling (Besner & Smith, 1992). South Africa currently has eleven officially recognised languages, namely English, Afrikaans, Ndebele, North Sotho, South Sotho, Swati, Tsonga, Tswana, Venda, Xhosa and Zulu (Raidt, 1999), all of which are considered to be transparent orthographies, with the exception of English, an opaque orthography.

In languages with a transparent orthography, the spelling can be predicted from the pronunciation and vice versa, whereas in languages with an opaque orthography, pronunciation-spelling mappings are often quite unpredictable and ambiguous. As an opaque language, English does not always have a one-to-one relation between graphemes and phonemes, and letters can represent more than one phoneme. As a result, English contains many irregularities, and thus words are not always pronounced as they are spelled, for example “ache” and “yacht” (Smith, 1994). In contrast, as transparent orthographies, the nine South African indigenous languages have far more predictable grapheme-phoneme correspondence rules than English, so that most words can generally be read correctly by sounding them out. This allows for the facilitation of [reading and] writing acquisition once a learner has acquired grapheme-phoneme correspondence (de Manrique & Sinorini, 1998).

In addition to the impact bilingualism may have on phonological awareness, as previously discussed, phonological input provided by different languages, that is, transparent or opaque orthographies, may affect the progress of phonological awareness at different levels of phonological development (Goswami, 1999). Phonological strategies will depend on the level of orthographic depth of a given language (Katz & Frost, 1992) and thus bilingual children may show increased phonological awareness in those phonological units that reflect the input of the two languages in which they are proficient. Consequently, it would be expected that the EL2 children in the current study would show higher levels of phoneme awareness than the EL1 children, as the phoneme is more salient in the home languages of the EL2 children, that is, the Nguni and Sotho languages (Guma, 1971), than in English.

Studies have suggested that the sequence of phonological development, that is, of syllabic and onset/rime awareness, which precedes an awareness of phonemes, is similar for children who are growing up in different linguistic environments (e.g. Cockcroft et al., 2001; Gorman & Gillam, 2003; Goswami, 1999). However, the rate of maturation of phonological systems in children may differ between those whose first language is an opaque orthography, and those whose first language is a transparent orthography. A South African study conducted by Cockcroft et al. on English- (an opaque orthography) and Afrikaans- (a transparent orthography) speaking children in Grade 0, Grade 1 and Grade 2, revealed no substantial difference between first-language English- and Afrikaans-speaking children in their performance on phonological awareness and reading tasks, either prior to formal reading instruction or in Grade 1. By Grade 2, as reading competency improved, orthography seemed to influence performance on blending and segmentation skills as the Afrikaans group was found to perform better than the English group on these tasks. Thus, the depth of orthography does not seem to influence initial levels of phonological awareness, but it is suggested that the rate of phonological development in speakers of a transparent orthography would be more rapid.

Research has also addressed the possibility of the transfer of phonological awareness skills between languages. International research, assessing Arabic-English speaking children found that, despite the different nature of the two orthographies, they do not appear to have negative consequences for the development of reading skills in either language (Abu-Rabia & Siegel, 2002). Gorman and Gillam (2003) suggest that this may be due to the fact that different sources of linguistic information, or cues, compete to determine how language processing develops. These cues differ among languages, and the language development of a child in either a predominantly opaque or transparent language environment will be driven by the most salient and reliable cues of that language, which according to Gorman and Gillam may be applied to their second language in the case of sequential bilingual children. Several studies have shown that phonological awareness skills may be transferred from a transparent to an opaque language, and vice versa (Durgunoglu, Nagy & Hancin-Bhatt, 1993; Gottardo, 2002). In terms of bilingualism, children who receive competing language cues, attend to and process language differently from monolingual children. For example unique patterns of phonological awareness development, such as phonological translation, namely the ability to hear a word in one language and convert its phonological form into another language, have been found to predict reading in bilingual children (Bialystok, 1991). A South African study on Grade 1 children (mean age 79 months) conducted by Robertson (2005), found that Northern Sotho phonological awareness transferred to English word and non-word reading. International research, conducted on high school students, found that skill in a native language serves as an indicator of learning ability in a second language, and also that a deficit in one native language component can lead to similar problems in the second language. The researchers hypothesized that the transfer of phonological awareness is dependent on the structural similarity between the two languages (Sparks & Artzer, 2000). In conclusion, it appears that phonological awareness can be understood, not as a language-specific skill, but rather as a universal skill that may transfer across alphabetic languages. Both the local and international findings, as discussed above, have relevance for the current study in terms of comparison between an opaque and a transparent orthography, as it is implied that irrespective of the depth of orthography phonological awareness may be transferable.

Considerable research has implicated working memory in phonological awareness (Gathercole et al., 2006; Gillam & van Kleeck, 1996) and the following section will discuss a model of working memory within which the relationship with phonological awareness may be contextualised.

1.4 Working Memory

Since the inception of the concept over 25 years ago, working memory continues to be actively researched within many areas of cognitive science, including mainstream cognitive psychology, neuropsychology, neuroimaging, developmental psychology and computational modelling (Baddeley, 2000).

Working memory can be defined as the ability to hold and manipulate information in the mind for a short period of time, and can be understood as a flexible mental workspace in which you are able to temporarily store important information in the course of performing complex mental activities. Consider, for example attempting to multiply two, two-digit numbers (for example, 71 and 49) without using a pencil and paper. To do this successfully, it is necessary to store the two numbers, and then systematically apply multiplication rules, storing the intermediate products that are generated as you proceed through the stages of the calculation. It is only if you manage to meet both the storage and processing demands of the activity that the correct answer can be reached. A minor distraction, such as an unrelated thought springing to mind, is likely to result in complete loss of the stored information, which no amount of effort will allow you to remember (Gathercole & Alloway, 2004).

A number of models of working memory have been postulated since the mid-1950s when researchers separated the concepts of long- and short-term memory (Baddeley, 1986), yet two main schools of thought predominate the literature, with one proposing a domain-specific model and the other a domain-general model. Firstly, in terms of a domain-specific working memory model, Shah and Miyake (1996) propose a model in which working memory capacity is supported by two separate pools of domain-specific resources for verbal and visuo-spatial information. In addition to the individual verbal and visuo-spatial storage components, each domain is independently capable of manipulating and keeping information active, thus implying the domain-specificity of the central executive, as well as of the passive short-term storage aspect of working memory. The second model, as proposed by Baddeley (2000), is domain-general. He postulated a model comprising a single domain-general executive resource, supporting the two individual domain-specific components, namely visuo-spatial short-term memory and verbal short-term memory. Domain-general accounts of working memory capacity have also been advanced by other theorists, such as Engle, Tuhloski, Laughlin and Conway (1999), Gathercole and Pickering (2000), and Kane et al. (2004).

It is relevant at this stage to make the distinction between two particular domain-general models of working memory, that is Baddeley's (2000) tripartite model, and Gathercole and Pickering's (2000) modification of this model.

Baddeley (2000) proposed a multi-component model of short-term memory, which is currently referred to as working memory (Baddeley, 1986; Baddeley & Hitch, 1974). It is based principally on data from adults and neuropsychological patients (Baddeley, 2000), and comprises a domain-general (modality-free) controlling central executive, or attentional control system, that is aided by domain-specific subsidiary slave systems ensuring temporary maintenance of different kinds of information. Among these slave systems, the phonological loop has been the most thoroughly explored. This system is specialised for processing verbal material and is composed of two subsystems: a passive phonological input store and an articulatory rehearsal process. Less information is available about the visuo-spatial sketchpad, which is composed of two parts: the visual cache and the inner scribe, and is responsible for the processing of visual and spatial information. These two subsystems are limited in capacity to a few items and decay is very rapid (within a few seconds). Items can be maintained in each system for short periods of time by using modality-specific (domain-specific) rehearsal mechanisms. A key feature of this model is the existence of specialised components for dealing with different aspects of working memory activity. The concept of the episodic buffer (Baddeley, 2000) was later incorporated. This model is discussed in more detail later in this chapter.

Gathercole and Pickering's (2000) working memory model is based on that of Baddeley (1986,2000) and, in addition to the episodic buffer, includes four components, namely a verbal and a visuo-spatial short-term memory component, and a verbal and a visuo-spatial working memory component. This model was based on research that indicated that, unlike short-term memory, complex working memory tasks are assumed to place heavy demands on the central executive and, therefore, tap mental resources not relied on when performing short-term memory tasks. As a result, in line with Baddeley's model, short-term memory and working memory are identified in this model as two separate processes. Gathercole and Pickering's working memory model will be discussed in detail, following an in-depth discussion of Baddeley's model.

Baddeley's (1986, 2000) Working Memory Model

As previously mentioned, this model consists of four components, namely the central executive, the phonological loop, the visuo-spatial sketchpad and the episodic buffer. Each is described in detail below.

Central executive

According to Baddeley, Emslie, Kolodny and Duncan (1998) the central executive (an attentional control system) is the working memory component responsible for controlling resources and monitoring information processing across informational domains. These include a range of regulatory functions including the retrieval of information from long-term memory, regulation of information within working memory, attentional control of both encoding and retrieval strategies, and task shifting (Baddeley, 1986), and is thus associated with a variety of high-level abilities, including language and reading comprehension in both children and adults (Gathercole & Pickering, 2000). The central executive coordinates the functions of the phonological loop and the visuo-spatial sketchpad, which mediate the storage of information.

Phonological loop

The first slave system to the central executive of working memory is the phonological loop, which is probably the best developed component of the working memory model (Baddeley, 2000), and is assumed to have developed on the basis of processes initially evolved for speech perception and production. It is understood to comprise a short-term, limited capacity phonological store that is capable of holding speech-based information, that is speech perception, and an articulatory control or rehearsal process based on inner speech, that is speech production. Memory traces within the phonological store are thought to fade and become unretrievable after about one-and-a-half to two seconds, but this decay of representations in the store can be offset by a serial subvocal rehearsal process, and can be refreshed by reading off the trace into the articulatory control process, which then feeds it back into the store (hence the name feedback loop, from which the phonological loop - originally called the feedback loop - gets its name). This is the process underlying subvocal rehearsal. The articulatory control process is also capable of taking written or visual material, converting it into a phonological code, and registering it in the phonological store. Thus, the phonological loop plays an important role in learning to read (and hence phonological awareness), the comprehension of language and the acquisition of vocabulary (Baddeley, 1990). According to Baddeley (1986), within the working memory model, it is the phonological loop that is responsible for maintaining phonological information necessary for reading, in that it retains the words, phrases, or sentences while they are being processed, for brief periods in order that longer units of text can be comprehended. Reduced phonological storage capacity, inefficient rehearsal abilities, or both, can result in poor comprehension when sufficient amounts of incoming information cannot be immediately and readily retained in the phonological store for processing (Montgomery, 2000).

Visuo-spatial sketchpad

The second slave system to the central executive of working memory is the visuo-spatial sketchpad, which is responsible for setting up and manipulating visuo-spatial images over brief periods, and plays a key role in the generation and manipulation of mental images (Baddeley, 2000). It is generally accepted that the sketchpad can be fractionated into two components, one visual and one spatial (Logie, 1995). According to Gathercole (1996), it is probable that the sketchpad is a relatively complex, limited capacity system that involves the active utilisation of parts of these two components, namely the temporary visual store and the temporary spatial store that have been identified as responsible for coding information about the identification of objects and their spatial location. The visual component, that is the visual cache, is a passive system that stores visual information and spatial locations in the form of static visual representations. The inner scribe, or spatial component, is an active spatial rehearsal system that maintains sequential locations and movements and that also serves to refresh decaying information in the visual cache (Thierry, 2004). Neuropsychological evidence supports this structural assumption of separate visual and spatial components to mental imagery, with different anatomical locations within the brain responsible for each (Gathercole, 1996). These stores, like the phonological loop, can be fed to long-term memory via the episodic buffer, either directly through perception, or indirectly, through the generation of a visual image.

The central executive, in addition to coordinating the functions of the phonological loop and visuo-spatial sketchpad, is assumed to control the episodic buffer (Baddeley, 2000).

Episodic buffer

According to Baddeley (2000), the addition of the episodic buffer to the above model allows for the integration of information from a variety of sources. It is assumed to be a limited-capacity, temporary storage system controlled by the central executive. It is episodic in the sense that it holds episodes or information that have been bound from a number of sources where information is integrated across space and potentially extended across time. It is a buffer, in that it is assumed to be capable of storing information in a multi-dimensional (visual or phonological) code, providing a temporary interface between the slave systems and long term memory. Although the episodic buffer is isolated from long-term memory, it represents a 'crystallized' cognitive system capable of accumulating long-term stored knowledge, which is an important stage in long-term learning.

In summary of Baddeley's model, storage demands of complex memory tasks depend on appropriate subsystems, with processing demand supported principally by the central executive (Baddeley & Logie, 1999). Although short-term memory and working memory clearly share a close relationship as both refer to transient memory, it has been argued on both empirical and conceptual grounds that there are nonetheless important distinctions to be made between them. Unlike short-term memory, working memory tasks are assumed to place heavy demands on the central executive system and, therefore, tap mental resources not relied on when performing more passive short-term memory tasks (Alloway, Gathercole & Pickering, 2006). So, whereas working memory involves both the storage and processing of information, short-term memory is specialised purely for the temporary storage of material within particular informational domains (Gathercole & Alloway, 2006). Thus, Baddeley's working memory model was reconceptualised by Gathercole and Pickering (2000) as a multi-component working memory model consisting of separate memory/recall (short-term memory) and processing (working memory) systems.

Gathercole and Pickering's Working Memory Model (2000)

Gathercole and Pickering's (2000) working memory model includes two separate systems, namely a storage system (short-term memory) which is located within the informational domains, and a processing system (working memory) which is located within the central executive. The processing aspect of working memory is quite distinct from the storage aspect in that the two slave systems, namely the phonological loop and the visuo-spatial sketchpad, appear to serve much more specific memory functions (Baddeley, 1996). The short-term memory system comprises the domain-specific components of verbal and visuo-spatial short-term memory, and is used for the storage of verbal information within the phonological loop, and for the storage of visual information, spatial information, or both, within the visuo-spatial sketchpad. Short-term memory is utilized only for those tasks that require no processing, and often require just the preservation of sequential order information, and involve situations where small amounts of material are held passively (minimal resources from long-term memory are activated to interpret tasks, such as digit/word span tasks) and then reproduced in a sequential fashion. This passive memory capacity is thus measured by simple tasks that require only storage of information for a short period of time. The working memory system is understood to be a domain-general composite of both verbal and visuo-spatial working memory, and refers to the processing resource involved in the preservation of information while simultaneously processing the same or other information. Verbal working memory refers to the capacity of temporary memory which is used for storage and processing of verbal information, within the central executive. Visuo-spatial working memory refers to the capacity of temporary memory which is used for storage and processing of visual information, spatial information, or both, within the central executive. Assessment of this active memory capacity involves complex span tasks that require simultaneous short-term storage of information while processing additional and sometimes unrelated information, namely completing an additional processing task before each to-be-remembered item becomes apparent.

Thus, Gathercole and Pickering have applied their own terminology to Baddeley's (1986, 2000), working memory model in which the term *short-term memory* is used in place of the passive components of Baddeley's model, namely the concepts of the phonological store and the visual cache, and the term *working memory* is used in place of the active components, namely the concepts of articulatory rehearsal and the inner scribe.

In research designed to corroborate the above, Alloway et al. (2006) conducted an assessment utilising the AWMA on 709 British children, aged 4 to 11 years, grouped into three age bands, using complex span tasks that require simultaneous short-term storage of information while processing additional, and sometimes unrelated, information. Confirmatory factor analysis indicated that the processing components of working memory tasks were supported by a common resource pool (the central executive), while storage aspects depended only upon domain-specific verbal or visuo-spatial resources, as previously discussed. The identification in Alloway et al.'s study of a domain-general processing aspect for verbal and visuo-spatial working memory tasks in 4- to 6-year-olds is surprising, as earlier research has identified separate verbal and visuo-spatial working memory systems in children aged eleven to fourteen years (Jarvis & Gathercole, 2003, as cited in Alloway et al., 2006) and in adults (Kane et al. 2004). A possible explanation for these results is that younger children draw more on executive resources (or controlled attention) than older children, even to perform short-term memory tasks (e.g. Cowan et al., 2005). This could possibly be due to the differential rate of development of cognitive mechanisms, that is, developmental fractionation (Hitch, 1990), which needs to be taken into account in any study examining working memory in children, such as the current one.

Earlier studies (e.g., Jarvis & Gathercole, 2003, as cited in Alloway et al., 2006), confirm the relative independence of verbal and visuo-spatial short-term memory from a more domain-general verbal and visuo-spatial working memory component in older children (11- and 14-year-olds). The development and inclusion of a separate visuo-spatial working memory test in the AWMA has allowed for the separate assessment of visuo-spatial short-term memory and visuo-spatial working memory in the sample of children in the current study (6- to 8-year-olds). In terms of verbal memory, Alloway et al. (2006) found that verbal short-term memory consisted of a storage-only component, whereas verbal working memory measures required executive resources for the processing aspect of the task, which was consistent across all age groups. Thus, evidence for the dissociation of the verbal and visuo-spatial components, as found in studies on older children (Jarvis & Gathercole, 2003, as cited in Alloway et al., 2006) and adults (Kane et al., 2004) was generalisable to younger children.

Thus, according to this account of working memory the processing aspect of a task is controlled by a centralized component (i.e. the central executive or controlled attention) while the short-term storage aspect is supported by domain-specific components (verbal or visuo-spatial store), and the measurement of each of these aspects has specific requirements, and therefore requires an appropriate assessment tool.

AWMA

Working memory data for this study were collected using the AWMA. Unlike earlier working memory assessment tools, the AWMA, in addition to assessing verbal and visuo-spatial short-term memory and verbal working memory, includes subtests specifically designed to assess visuo-spatial working memory. Earlier assessment tools for use with young children, such as the Working Memory Test Battery for Children (WMTB-C) (Pickering & Gathercole, 2001) did not include a separate assessment of visuo-spatial working memory, as working memory tasks were exclusively verbal in nature, for example listening span and counting span tasks. Although Gathercole and Pickering's (2000) model, based on that of Baddeley's (1986, 2000) model, is a tripartite structure, the inclusion of visuo-spatial working memory tasks is supported by Shah and Miyake's (1996) domain-specific working memory model in which each domain (verbal and visual) is independently capable of manipulating and keeping information active (Alloway et al., 2006).

In terms of bias, performance on the working memory tests is independent of general background factors such as socio-economic status and preschool education (Gathercole & Alloway, 2004). Campbell, Dollaghan, Needleman and Janoscky (1997) established that the degree of cultural and environmental bias in test performance is considerably diminished for information-processing measures, such as a test of short-term memory, in which the material to be processed or stored is equally unfamiliar to all individuals, rather than for knowledge-based measures where performance is strongly influenced by differential degrees of familiarity across individuals. AWMA test materials were designed to be equally unfamiliar to all participants, in order that no child will benefit from previously acquired knowledge. Performance on working memory tests is thus independent of general background factors such as socio-economic status and preschool education (Gathercole & Alloway). Inclusion of the AWMA in the battery of tests utilised in this research provided data from which the relationship between the various components of working memory and phonological awareness in young South African children could be established, and will be discussed in more detail in chapter 2.

In summary, discussion of the various models of working memory may have resulted in a lack of clarity regarding definitions, as terminology has in some instances become ambiguous, and possibly confusing. In an attempt to avoid ambiguity within the current study, the term *working memory* is reserved to refer to Gathercole and Pickering's current form of the original Baddeley model of short-term memory, with its tripartite structure. The same term will also refer to that component of memory which taps the central executive, that is the combined processing and storage aspect; and the term *short-term memory* will be reserved for that component of memory which relates to only the passive, or storage, aspect of memory and which is subsumed by working memory.

Development of Working Memory

Since this study concerns children, and the model described above refers to working memory in its mature form, it is important to discuss the development of working memory. Working memory capacity increases gradually from ages 6 to 19, after which there is a gradual decline (Siegel, 1994), and therefore it is not surprising that performance on working memory tasks is weaker in younger children than in older children, despite some structures for memory, such as the phonological store, being intact in children as young as three years of age (Gathercole & Pickering, 2000). Verbal working memory capacity develops dramatically over the middle childhood years, with a two- to three-fold increase in memory span between the ages of 4 and 11 years, with no developmental change in the relationship between verbal short-term and verbal working memory during these years (Alloway et al., 2006).

The cross-sectional study by Alloway et al. (2006) addressing the development of working memory found that there are distinct developmental trends for the visuo-spatial domain of working memory. Data revealed that the association between the domain-specific visuo-spatial construct and the domain-general processing construct was higher in the 4- to 6-year age group than in children aged 7 to 11 years, indicating that younger children draw more on executive resources (or controlled attention) than older children when performing visuo-spatial short-term tasks. This may be due to developmental fractionation (Hitch, 1990), or cognitive mechanisms developing at different rates. Pickering, Gathercole, Hall and Lloyd (2001) proposed that this developmental fractioning depends on whether the tasks are presented in a static or dynamic format, the latter involving executive functions. A second explanation for the dependence on executive resources could be that the brain areas related to higher-level cognition are still developing in the younger group of children (Nelson, 2000).

1.5 Phonological Awareness

Since working memory has been correlated with reading success, it follows that phonological awareness, a precursor to successful reading, would be related to working memory (e.g. Gathercole et al., 2006; Gillam & van Kleeck, 1996). Phonological awareness is a comprehensive term for a variety of skills on a broad continuum, and may be defined as an understanding of the structural characteristics of a language, or the awareness of the sound structure of words and the ability to manipulate these sounds. These skills vary in degree of complexity and gradually develop as an infant matures and is exposed to spoken and written language, as well as to more opportunities to experiment with language (Cockcroft, 2002a).

According to Adams (1990), phonological awareness is comprised of a number of specific skills; namely syllabic tasks which require the segmentation of words into specified units, that is onset/rime segmentation which requires the splitting of a word into its onset and rime components and phonemic tasks which involve making connections between graphemes and phonemes. Thus a word such as ‘crash’, a monosyllabic word, can be split into its onset /cr/ and rime /ash/. The rime can be further split into its nucleus /a/ and coda /sh/. Phonemic awareness involves splitting the word into its phonemic components, /c/, /r/, /a/, /sh/, and finally awareness of graphemes involves the identification of individual graphemes in the word, /c/, /r/, /a/, /s/, /h/. Phonological awareness assessment thus requires three operations namely, ‘hear, act and respond’. The child must firstly, hear the spoken item, then, perform an operation on this speech segment, for example, say an item after removing a phoneme from it, and thirdly, respond verbally. This process utilises working memory and general cognitive ability (Bradley & Bryant, 1985; Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004) both of which have also been identified as strong predictors of phonological awareness (McBride-Chang, 1995; Oakhill & Kyle, 2000).

Adams (1990) proposed that graphemes and words are the basic units of representation in written text. Before children can grasp the significance of these units, they must acquire an awareness of their oral correspondents, that is, phonemes and spoken words. Research has shown that generally, children initially become aware of larger units of sound such as clauses or propositions, followed by an awareness of words, an awareness of syllables, an awareness of onsets and rimes, and finally an awareness of phonemes, the smallest phonological unit. A longitudinal study conducted by Treiman and Zukowski (1991) established that seven-year-old children in Grade 1 were able to perform on syllabic awareness tasks, rime tasks, and phoneme awareness tasks. At age six the same children had been able to perform on only syllabic awareness tasks and rime tasks, and at age five, only syllabic awareness tasks. These findings suggest that different levels of phonological awareness develop hierarchically over time, since with increased phonological awareness skills, children become sensitive to smaller and more abstract phonological units, such as phonemes.

Development of phonological awareness

According to Adams (1990) at least five different levels of phonological awareness can be identified and assessed. She theorised that these types of phonological awareness develop hierarchically. The first and most primitive level refers to a level of implicit knowledge of speech sound units, such as rime patterns (eg. Little Jack Horner Sat in the Corner); measurement at this level is based on knowledge of rhyming words. The second level focuses attention on the sound components of words, for example oddity detection tasks which require the child to compare and contrast the sounds of words for rime or alliteration and demand not just sensitivity to similarities and differences in the overall sounds of words, but also the ability to focus attention on the components of the sounds that make them similar or different. The third level focuses on blending and syllable-splitting. The latter tasks require that the child has an awareness of the notion that words can be subdivided into small, meaningless sounds corresponding to phonemes. The fourth level focuses on full segmentation of component phonemes, generally tapping tasks, or segmenting words into syllables/phonemes. These tasks require that the child has a thorough understanding that words can be completely analysed into a series of phonemes. The fifth, or final, level of phonological awareness is phoneme manipulation, which focuses on the ability to segment or isolate syllables or phonemes before manipulating the units (for example, "say lamp without the /m/"). The phoneme manipulation tasks require that the child be able to add, delete, or move any designated phoneme and regenerate a word (or a non-word) from the result. Stanovich (1992) proposed that phonological awareness be regarded as a continuum ranging from "shallow" to "deep" sensitivity, developing from syllable awareness, which requires a more implicit form of analysis, to phoneme awareness which requires a more explicit form of analysis. The general sequence of phonological awareness development was found to be universal across languages (Anthony & Francis, 2005).

Children have a working, or implicit, knowledge of phonemes long before it becomes a conscious knowledge (Adams, 1990). The awareness of larger units, such as syllables is usually present by age three (Goswami, 2002), and the higher levels of phonological awareness, that is phoneme manipulation, are generally attainable by only those children who have receive some formal reading instruction, and who by the end of Grade 1, should be able to count the phonemes in a word or syllable. Thus, the relationship between reading and the development of phonological awareness may be seen as a reciprocal causal one which continues to develop into the ability to segment, rearrange and substitute phonemes throughout a child's early schooling.

As discussed, the development of phonological awareness occurs in stages, and tasks which require the segmentation of words into phonemes is difficult for most young children (under the age of five years). Fowler (1991) proposes that, throughout the preschool years, the child's phonological awareness undergoes constant reorganisation as a result of the increase in vocabulary and that this process is only complete at approximately seven years of age. Syllable awareness appears to be strongest in young children, then onset awareness followed by rime awareness, and preschoolers may not be sensitive to phonemic segments. Thus, as phonological awareness develops, children are able to distinguish between the different types of phonological tasks. Tasks that are initially perceived as related by virtue of their focus on the sound structure of rimes become differentiated into tasks which require different phonological abilities such as deletion, blending or segmentation. According to Fowler, the ability to segment syllables into phonemes appears to reflect both a maturation of the phonological system, as well as the impetus provided by exposure to reading instruction. As previously mentioned, reading plays a vital role in the development of phonological awareness, with which it enjoys a reciprocal causal relationship (Hogan, Catts & Little, 2005; Manrique & Signorini, 1998). Manrique and Signorini refer to this reciprocity as two levels of phonological awareness, namely basic metaphonological skills, including rhyming, syllable awareness, and sound matching, which children often learn indirectly as they master speech sounds and are exposed to songs and word games. With formal literacy instruction, children acquire the second level of more complex segmental awareness skills, such as sound-letter identification, blending, phoneme segmentation and manipulation, spelling and reading (LaFrance & Gottardo, 2005).

As different tasks assess phonological awareness at different levels McDougall, Hulme, Ellis and Monk (1994) believe that phonological awareness should not be considered as a unitary ability. Oakhill and Kyle (2000) found that sound categorisation tasks had a higher verbal working memory (also known as phonological working memory) demand, while phoneme deletion tasks had a lower verbal working memory demand. In addition, verbal working memory predicted performance on the sound categorisation task, whereas it did not predict performance on the phoneme deletion tasks. Thus, the relationship between working memory and phonological awareness appears to be dependent on the depth of analysis of phonological awareness, as discussed above, which determines the level of demand made on working memory.

Both working memory and phonological awareness, as discussed above, are identified as predictors of reading success, and in order to address the relationship between the two, a brief discussion of the relationship between phonological awareness, working memory and reading follows.

1.6 Reading

Phonological awareness plays a vital role in reading (e.g. Hulme et al., 2002), and thus as a component of phonological awareness, working memory too, is essential for literacy acquisition (e.g. Seigneuric & Ehrlich, 2005).

Phonological awareness is essential to reading and the acquisition of literacy (Chow, McBride-Chang & Burgess, 2005) as it involves the association of sounds with letters (that is, the understanding of grapheme-phoneme conversion rules and their exceptions). The beginner reader needs to realize that words can be broken down into phonemes and that the phoneme is typically the unit in the speech stream that is represented by symbols (letters) in alphabetic writing (Cockcroft et al., 2001). Phonological awareness enables the child to understand the association between the sounds in words and the orthographic symbols that represent these sounds, whereas phonological decoding transforms letters into the corresponding sounds. The extent to which children are successful in developing phonemic awareness will influence their ease of acquisition of an alphabetic strategy for reading and spelling. During and after the initial stages of reading development, reading ability and phoneme awareness are likely to continue to facilitate one another (Gathercole & Baddeley, 1993). The relationship between phonological awareness and children's abilities to acquire language skills is well-documented internationally (Hulme et al., 2002), particularly in terms of phoneme deletion (Durand & Hulme, 2005) and phoneme manipulation (Hatcher et al., 2006), and within the South African context (Hugo, le Roux, Muller & Nel, 2005).

Some of the local research has shown a significant relationship between phonological awareness and reading success. Hugo et al. (2005) conducted a longitudinal study on a group of 71 South African pre-school children (Grade 0) whose home language was Afrikaans. A phonological awareness pre-test which consisted of five subtests, including identification of rime words and syllables, identification and counting of phonemes, and a word comparison task was administered during the initial phase. Approximately one year later, towards the end of the learners' first formal school year, the reading levels of the same group were assessed. Findings supported international research in which a statistically significant relationship between phonological awareness and later reading success was indicated (e.g. Bayliss, Jarrold, Gunn & Baddeley, 2003).

Notwithstanding the above, the assumption that phonological awareness skills affect reading achievement must be clarified. According to Adams (1990), it is neither the ability to hear the difference between phonemes nor the ability to distinctly produce them that is significant, but the understanding that they are abstractable and manipulable components of language that has important implications for learning to read. Developmentally, this awareness appears to depend upon the child's inclination to pay conscious attention to the sounds of words, as opposed to the meanings of words. As mentioned earlier, bilingual children tend to become aware of the sound structure of words earlier than monolingual children (Lesaux & Siegel, 2003) and hence it was expected that the EL2 children would perform better than the EL1 children on the phonological awareness tasks.

Considerable research has implicated working memory in phonological awareness (e.g. Alloway et al., 2005; Gathercole, et al., 2006) As a component of phonological awareness, working memory is an essential part of reading and the acquisition of literacy (Bradley & Bryant, 1985; Gathercole & Alloway, 2004). According to the Baddeley (2000) working memory model, the memory system specialised for the task of maintaining phonological information necessary for reading is the phonological loop. The greater the child's verbal memory capacity, the more readily she/he will be able to acquire new words, and establish long-term memory representations of the sound structures of these words. The central executive also plays an integral role in reading and may be conceptualised as retrieving information from long-term memory about syntax, word meanings, and grapheme-phoneme conversion rules (Siegel, 1994). Thus it was anticipated that phonological awareness measures would particularly be correlated with the verbal working memory and verbal short-term memory components of the AWMA in the current study.

A number of studies, both cross-sectional and longitudinal, have identified links between aspects of working memory, such as the phonological loop and the central executive (that is between both verbal short-term memory and working memory skills) and learning attainment. For example, Gathercole, Pickering, Knight and Stegmann (2004) assessed working memory abilities (central executive, phonological loop, and visuo-spatial sketchpad) in seven-year old British children, and found that working memory skills, particularly those required for performance on tasks that tap into the central executive, were excellent predictors of performance on both English and maths assessments. In a longitudinal study conducted by Gathercole, Brown and Pickering (2003) working memory abilities were further found to be excellent predictors of children's success in national assessment of scholastic abilities up to three years later. Bayliss et al. (2003) too, found that the ability to coordinate the processing and storage aspects of working memory span tasks contributed to the prediction of reading and arithmetic ability in children. This was supported by findings that established links between both the central executive and the specialised storage systems, namely the articulatory store and visual cache, and academic attainment (Pickering & Gathercole, 2004).

The role of both working memory and phonological awareness in reading may be clarified by a study conducted on 633 children aged between 4 and 6 years who were starting formal education in the United Kingdom (Alloway, Gathercole, Willis & Adams, 2004). This study reported a strong correlation between phonological awareness and verbal short-term memory, and the results suggested that both phonological awareness as assessed using two sound categorisation tasks, namely a detection of rime task and an alliteration task, and verbal short-term memory capacity, as assessed using the digit recall test and the word recall test of the WMTB-C (Pickering & Gathercole, 2001) made separate contributions to success in the earliest stages of reading development. This suggests that verbal short-term memory may play a role in learning letter-sound correspondences and in storing generated phonological sequences prior to blending and output during phonological recoding, while phonological awareness may be crucial in segmenting phonological representations of words to be spelled.

1.7 Working Memory and Phonological Awareness

As the aim of the current research was to examine the relationship between working memory and phonological awareness, research studies in this area were consulted. However, only a limited number of available studies investigated the same aspects as the current study did.

A British study in which the relationship between working memory and phonological awareness was investigated, conducted by Oakhill and Kyle (2000), has bearing on the current study. Similar, though not identical, working memory and phonological awareness measures to those used in the current study were administered to 58 children of a similar age (97 months, which is comparable to the mean age of the sample in the current study, 86 months). The sound categorisation task was an adaptation of Bradley and Bryant's (1983) task by Cain, Oakhill and Bryant (2000), and the phoneme deletion task, an adaptation of Bruce (1964), also by Cain, Oakhill and Bryant. The memory tasks included a word span task (short-term memory) and a sentence span task (working memory). A non-verbal intelligence measure was not included in the assessment of these children. Through correlational and multiple regression analysis, the researchers found that verbal working memory (v-WM) is one determinant of performance on the sound categorisation task. However, performance on the phoneme deletion task was not similarly related to working memory skill. These findings suggest that, while neither the short-term nor the working memory task could be expected to provide a pure assessment of phonological skills, the phonological awareness tasks have different memory processing demands and, in particular, the sound categorisation task makes heavier demands on the central executive. This may be explained by the substantial memory component of the sound categorisation task. This task has simultaneous processing and storage demands as the words need to be sorted in memory and simultaneously compared for phonological similarity which is not adequately assessed by short-term memory.

A study conducted by Alloway, Gathercole, Adams and Willis (2005) examined the predictive value of working memory and phonological awareness skills on teacher ratings of children's progress towards learning goals. Results reported the relationship between working memory, short-term memory, phonological awareness and non-verbal ability (as assessed by the non-verbal scale of the Wechsler Preschool and Primary School Scale of Intelligence-Revised). Working memory tasks, namely three short-term memory tasks (digit recall, word recall and nonword repetition) and three working memory tasks (backwards digit recall, counting recall and listening recall) were taken from the WMTB-C (Pickering & Gathercole, 2001), the antecedent to the AWMA, and phonological awareness tasks included both a rime detection task and an initial consonant detection task. There were no tasks equivalent to Rosner's Test of Auditory Analysis Skills (RTAA) used in the current study which measures syllable splitting and phoneme manipulation skills. The sample consisted of 194 children, aged 4 to 5 years, who, although chronologically younger than the sample in the current study, were also enrolled in their first year of formal education. Confirmatory factor analyses exploring the cognitive structure of the measures found that working memory, verbal short-term memory, sentence repetition, phonological awareness, and non-verbal ability were distinct but associated latent constructs within the sample. A significant correlation was found between working memory and phonological awareness, which supports earlier suggestions that the processing component of the central executive is involved in the encoding and storage of phonemes in phonological awareness tasks (e.g. Hecht, Torgesen, Wagner & Rashotte, 2001).

Alloway et al.'s findings support the distinction between the phonological loop (working memory) and phonological awareness, which is consistent with Gathercole, Willis and Baddeley's (1991) proposal that, although both these processes are constrained by the efficiency of phonological processing, they reflect distinct cognitive systems. In addition, the specific role of the phonological loop in supporting the long-term learning of the phonological forms of new words in the course of vocabulary acquisition (Baddeley, Gathercole & Papagno, 1998) was reinforced by these findings. Thus, although the main aim of the study by Alloway et al. related to the predictive value of both working memory and phonological awareness on teacher ratings of children's progress in the areas of reading, writing, mathematics, speaking and listening, and personal and social development, a number of findings, in terms of the relationship between working memory and phonological awareness, relate to the context of the current study.

In summary, the relationship between working memory, particularly verbal short-term memory and verbal working memory, and phonological awareness has been identified. The current research aimed to extend these findings to a South African population, particularly one that includes both EL1 and EL2 children.

1.8 Rationale for the Current Study

It is evident from the above discussion that both working memory and phonological awareness are highly correlated with the acquisition of literacy (Alloway et al., 2004; Gathercole et al., 2004; Oakhill & Kyle, 2000). It is also apparent that recent literature addressing the relationship between these two predictors is limited, although data on the relationship between working memory components (e.g. Alloway et al. 2006) and between phonological awareness components (e.g. Anthony & Francis, 2005) is available. In particular, research into the relationship between the two is limited in the South African context and specifically research focusing on a comparison between EL1 and EL2, and thus formed the rationale for this study.

The current study, in addition to addressing developmental considerations when assessing working memory, used as its sample bilingual (EL2) and monolingual (EL1) children in the South African context and aimed to contribute both towards supporting international findings, and investigating this relationship within a local sample.

Statistics, as discussed (Webb, 2002), indicate that a large proportion of young scholars in South Africa for whom English is a second language are being educated in English, alongside first-language English speaking children. As discussed earlier this bilingualism may impact on their levels of phonological awareness, and possibly working memory, and the current study has therefore attempted to identify any differences in performance on the tasks between the two groups.

Firstly, the study attempted to establish the relationship between working memory and phonological awareness in EL1 and EL2 children, in order to identify possible differences which may relate to the orthography of the languages. As part of this, a test for non-verbal intelligence was included as a control measure to ensure that the EL1 and EL2 groups were comparable in this regard. Secondly, the predictive value of working memory, short-term memory and non-verbal intelligence on the phonological awareness measures was assessed. Thirdly, the predictive value of Bradley and Bryant's Sound Categorisation Task on Rosner's Test of Auditory Analysis Skills was determined, and finally the predictive value of non-verbal intelligence on working memory was examined.

1.9 Aims of the study

The broad aim of this research was firstly to investigate the relationship between working memory and phonological awareness in EL1 and EL2 children, and secondly to examine similarities and differences in their relative levels of performance and in the concurrent correlates and predictors of these constructs. These aims are operationalised in the following hypotheses.

Hypothesis 1. In terms of performance on the non-verbal intelligence measure there will be no significant difference between the EL1 children and the EL2 children.

Hypothesis 2a. In terms of performance on the working memory measures and on the phonological awareness measures there will be no significant difference between the EL1 children and the EL2 children.

Hypothesis 2b. The working memory measures, the phonological awareness measures and non-verbal intelligence will be significantly correlated with one another for the EL1 children and for the EL2 children, and there will be no significant difference between the correlations for the two groups.

Hypothesis 3. Performance on the working memory measures and non-verbal intelligence will predict performance on the phonological awareness measures for both the EL1 and EL2 children.

Hypothesis 4. Performance on the Bradley and Bryant Sound Categorisation Tasks will predict performance on Rosner's Test of Auditory Analysis Skills for both the EL1 and EL2 children. The inclusion of this hypothesis was prompted by the fact that the developmental progression of phonological awareness skills is hierarchic, and according to Fowler (1991) tasks that are initially perceived as related by virtue of their focus on the sound structure of rimes, become differentiated into tasks which require different phonological abilities such as deletion, blending or segmentation. This hypothesis addresses this natural hierarchic progression.

Hypothesis 5. Performance on the non-verbal intelligence measure will predict performance on working memory overall, and on the four working memory measures.

The next chapter will discuss the methods employed to test the above hypotheses.

CHAPTER 2. METHOD

This chapter presents the research design of the study, the descriptive statistics of the sample, the instruments utilised in obtaining the necessary data, and the procedure followed. Limitations, or threats to the validity of the findings, are also discussed.

2.1 Research Design

The research design implemented to compare working memory and phonological awareness was a non-experimental, ex post facto, cross-sectional, two group design due to the following factors: there was no control group, no random assignment, non-probability sampling was used, the variables to be observed occurred naturally, were pre-existent, and the researcher was not required to control or manipulate the independent variable (Babbie, 2004). The dependent variables were working memory, phonological awareness and non-verbal intelligence. The independent variable was home language. With the exception of the demographic data, which were nominal, all of the other data were at least interval. The design was correlational because the research question implies an association between variables.

2.2 Sample

The sample was a non-probability, convenience sample, and consisted of Grade 1, volunteer participants. It was recruited from four English-medium, Gauteng Department of Education (GDE) primary schools and therefore, it was assumed that these children would have sufficient proficiency in English to carry out the tasks.

A total of 81 Grade 1 children participated in the study. The original intention was to draw the entire sample from only one school; however inclusion criteria, particularly finding sufficient EL2 respondents, necessitated the inclusion of a number of schools in the study. Criteria for inclusion in this sample were that the children were enrolled in Grade 1, were not repeating the year, and displayed no speech, language or hearing difficulties. The participants were divided into two groups, with the first group comprising 42 first-language English-speaking children and the second group comprising 39 second-language English-speaking children. Of the 81 children assessed, two were excluded from the final study due to poor English comprehension skills, as they were unable to follow the instructions necessary to complete the tasks. Thus, a total of 79 children (EL1 = 42; EL2 = 37, Male = 34: Female = 45) yielded data for this study.

2.3 Procedure

Permission to carry out this research was obtained from the Ethics Committee of the University of the Witwatersrand and from the Gauteng Department of Education.

An information package was sent to parents via the schools (refer to Appendix A) which included an information letter (refer to Appendix B), a consent form (refer to Appendix C) and a withdrawal form (refer to Appendix D). The package also included a biographical information questionnaire (refer to Appendix E). On receipt of the signed consent form and completed biographical information questionnaire, each subject was assigned a code to ensure confidentiality. Prior to assessment, each child was advised that they could withdraw at any time during assessment, without prejudice, and written assent (refer to Appendix F) was obtained.

Children were tested individually in a quiet area of the school at a time that did not interfere with their school work. Tests were administered over two sessions, with a short break during each session. The duration of the initial session was approximately twenty-five minutes, during which the RCPM, the Bradley and Bryant's Sound Categorisation Task and Rosner's Test of Auditory Analysis Skills were administered. The second session, during which the Automated Working Memory Assessment was administered, lasted approximately forty-five minutes.

2.4 Descriptive statistics

Demographic information, as provided by the children's parents on the biographical questionnaire, provided information for the independent variable (home language) as well as for age, allowing for a description of the sample.

Age

The biographical information forms yielded the following descriptive information. Forty-two children had English as their home language (53%) and 37 spoke English as their second language (47%). The mean age of the total sample was 86.88 months (7 years, 2 months) with a standard deviation of 6.5. The mean ages, standard deviations and sample sizes for each of the language groups are presented in Table 1.

Table 1

Demographic variables of sample

Group	N	%	Age (in months)		
			Range	Mean	SD
Total					
Sample	79	100%	74-106	86.68	6.53
EL1	42	53%	77-98	87.14	5.26
EL2	37	47%	74-106	86.16	7.77

Home Language

The only language criterion for inclusion in the EL1 group was that English was the first language of the participants. The home languages of those children comprising the group who spoke English as their second language (EL2) included eight of the nine official African languages of South Africa, as detailed in Table 2. Of the 37 EL2 participants, three were exposed to two African languages at home, namely, Zulu/Sotho, Zulu/Tswana and Zulu/Xhosa.

Table 2

Home languages spoken by the sample

Language	EL1 (N = 42)	EL2 (N = 37)
English	42	
North Sotho		3
Sepedi		3
Sotho		1
Swazi		1
Tswana		1
Venda		1
Xhosa		3
Zulu		21
Sotho/Zulu		1
Xhosa/Zulu		1
Zulu/Tswana		1

2.5 Measures

Four tests were administered to all participants, each conducted in English. These are described below.

Raven's Coloured Progressive Matrices (RCPM) (Raven, Curt & Raven, 1977)
The RCPM was included in this battery in order to assess non-verbal intelligence and to provide a baseline measure to determine whether the EL1 and EL2 children were comparable in this respect. It is designed for use with children aged 5 to 11 years, and as it requires little verbal communication can be administered to children of different language backgrounds, and is thus said to be culture-fair (Owen, 1992; Raven, Raven & Curt, 1998).

The RCPM consists of three sets of twelve coloured figural matrices. Success in Set A depends on a person's ability to complete continuous patterns which, towards the end of the set, change first in one, and then in two directions at the same time. Success in Set Ab depends on a person's ability to see discrete figures as spatially related wholes, and Set B contains problems involving analogies. Each task consists of an incomplete matrix (from which a section is missing) and the child is required to select a piece from a number of possible alternatives to complete the matrix. The RCPM covers all perceptual reasoning processes, including the ability to perceive difference and similarity as well as to organise spatial perceptions into systemically related wholes (Raven, 1985). The maximum possible score is 36. The test-retest reliability from the original norm sample for the Raven's Coloured Progressive Matrices was $r = 0.9$, with no difference for ethnicity or gender (Raven et al., 1998).

Phonological awareness tests
The phonological awareness assessment tools, as utilised in this study, assess two of the five levels of phonological awareness, as identified in Adams' task complexity rating (Adams, 1990): the first level being the ability to remember

rhymes or rhyming words; the second, which requires more focussed attention to sound components relates to blending, or the ability to identify and manipulate patterns of rime and alliteration in words; the third being the knowledge that syllables can be divided into phonemes (segmentation tasks), as well as a familiarity with the sounds of isolated phonemes; the fourth, deletion, occurs in tasks that require full segmentation of component phonemes; and finally the fifth level, reversal and transposition, relates to the addition, deletion or moving of phonemes. Bradley and Bryant's Sound Categorisation Task is positioned at the second level of task difficulty, and Rosner's Test of Auditory Analysis Skills at the fourth and final levels, thus incorporating different developmental levels of difficulty representative of the range of possible phonological awareness skills.

Bradley and Bryant's Sound Categorisation Task (1983)

Bradley and Bryant's oddity tasks measure the child's onset and rime awareness. These tasks consist of strings of four three-phoneme words, all of which are mono-syllabic with the majority conforming to a consonant-vowel-consonant structure, for example 'bud, bun, bus, rug'.

In terms of administration of the test, the child was encouraged to participate in some word games with the tester, prior to attempting the practice items which precede the ten test items of each of the three tests. It was explained to the child that they would hear four words and must say which the odd-one-out is. In the initial test (refer to Appendix G i), the focus is on the onset sound, for example /r/ in rug. The second test (refer to Appendix G ii) focuses on the middle sound, for example /o/ in log, and the third test (refer to Appendix G iii) focuses on the end sound of the word, for example /ink/ in sink. The first task assesses onset awareness; and the second and third tasks that is, middle and end sound tasks, jointly indicate rime awareness. These tests conform to Adams (1990) second level of phonological awareness. Each test was scored out of ten, providing a composite score out of thirty. In order to determine the reliability, or degree of consistent measurement of the tests, reliability estimates were established. The Cronbach coefficient alpha calculated for BBSC was found to be $\alpha = 0.83$ in the sample in the current study, that is South African children (mean chronological age 86,68 months), as compared with α = 0.88 (Cockcroft, 2002a) for this set of phonological awareness tests on a South African English-speaking sample of Grade 0, Grade1 and Grade 2 children.

Test of Auditory Analysis Skills (Rosner, 1975)

'…spoken words not only have meaning, they also consist of concrete sensory components (sounds) that are independent of semantics. Being able to identify these sensory components and their relative position in spoken words is evidence of auditory analysis skills' (Rosner, 1993, p.42). Rosner's Test of Auditory Analysis Skills is primarily an elision task, that assesses the child's ability in both syllable splitting and phoneme manipulation (refer to Appendix H). The syllable splitting test consists of three practice items and five test items of bi-syllabic words, in which each syllable has an independent meaning. These were presented to the child who was then requested to repeat the word, omitting one syllable. ("*Say keyhole without saying key*"). This was followed by ten phoneme deletion tasks in which the child was asked to delete a phoneme from a monosyllabic word, beginning with the first phoneme of the word ("*Say meat without the /m/ sound*"), followed by the end phoneme ("*Say please without the /z/ sound*") and finally the most difficult task, deleting a phoneme which is part of a consonant blend ("*Say smack without the /m/ sound*"). To respond correctly, the child must search for the given phoneme sound in the word, delete it, and say what is left ("*eat", "plea", "sack").* The maximum score possible is 15. The Cronbach coefficient alpha calculated for RTAA was found to be α = 0.79 in the sample in the current study, that is South African children (mean chronological age 86,68 months), as compared to α = 0.84 (Cockcroft, 2002a) on a South African English-speaking sample of Grade 0, Grade1 and Grade 2 children.

AWMA (2004)

The AWMA is a computerised tool, developed to assess the four components of working memory (that is, verbal and visuo-spatial working memory and verbal and visuo-spatial short-term memory) in children aged 4 to 11 years. One benefit of the

AWMA is that it is designed to provide a practical and convenient way for non-expert assessors, such as teachers, to screen for significant working memory problems with a user-friendly interface.

Children's performance on working memory assessment measures do not reflect what they have or have not learned prior to the tests, as the test material is designed to be equally unfamiliar to all participants, and is independent of general background factors such as socio-economic status and preschool educations (Alloway, Gathercole, Adams & Willis, 2005). Thus, it is working memory capacity that constrains performance on these measures. The AWMA was presented on a laptop computer, and the automated presentation and scoring of tasks provided consistency in presentation of stimuli across participants, thus reducing experimenter error.

The test consists of twelve subtests, six of which measure working memory, or central executive function (three verbal and three visuo-spatial measures, involving simultaneous storage and processing of information) and six of which measure short-term memory (three verbal and three visuo-spatial measures, involving only the storage of information), thus measuring both active and passive working memory. The multiple assessments of each memory component are made up of the following tests.

The following three measures are administered to assess verbal working memory, or verbal central executive function. In the *Listening Recall* task, the child is presented with a series of spoken sentences, has to verify the sentence by stating 'true' or 'false' and recalls the final word for each sentence in sequence. Test trials begin with one sentence, and continue with additional sentences in each block until the child is unable to recall three correct trials at a block. In the *Counting Recall* task the child is presented with a visual array of red circles and blue triangles. The child is required to count the number of circles in an array and then recall the tallies of circles in the arrays that were presented. The test trial begins with one visual array, and increases by an additional visual array in each block, until the child is unable to correctly recall four trials. Each visual array stays on the computer screen until the child indicates that he has completed counting all the circles. If the child makes an error in counting the circles and recalls this incorrect sum, he is not penalised. In the *Backwards Digit* recall task, the child is required to recall a sequence of spoken digits in the reverse order. The test trials begin with two numbers, and increases by one number in each block, until the child is unable to recall four correct trials at a particular block. The number of correct trials is scored for each child.

Three measures are administered to assess verbal short-term memory. In the *Digit Recall* task, the child hears a sequence of digits and has to recall each sequence in the correct order. In the W*ord Recall* task, the child hears a sequence of words and has to recall each sequence in the correct order. In the *Nonword Recall* task, the child hears a sequence of nonwords and has to recall each sequence in the correct order.

Three measures are administered to assess visuo-spatial working memory, or visuo-spatial central executive function. In the first task, the *Odd-one-out,* the child views three shapes, each in a box presented in a row, and identifies the odd-one-out shape. At the end of each trial, the child recalls the location of each odd-one-out shape, in the correct order, by tapping the correct box on the screen. Each array is presented on the computer screen for two seconds. The *Mr. X* task consists of fictitious cartoon figures, designed to be unfamiliar yet likeable to children. The child is presented with a picture of two Mr. X figures, and then identifies whether the Mr. X with the blue hat is holding the ball in the same hand as the Mr. X with the yellow hat. The Mr. X with the blue hat may also be rotated. At the end of each trial, the child has to recall the location of each ball in Mr. X's hand in sequence, by pointing to a picture with six compass points. Both the Mr. X figures and the compass points stay on the computer screen until the child provides a response. In the *Spatial Span* task, the child views a picture of two arbitrary shapes where the shape on the right has a red dot on it. The child identifies whether the shape on the right is the same or opposite of the shape on the left. The shape with the red dot may also be rotated. At the end of each trial, the child has to recall the location of each red dot on the shape in sequence, by pointing to a picture with three compass points. Both the shapes and the compass points remain on the computer screen until the child provides a response.

Three measures are administered to assess visuo-spatial short-term memory. In the *Dot Matrix* task, the child is shown the position of a red dot in a series of four-by-four matrices and has to recall this position by tapping the square on the computer screen. The position of each dot in the matrix is held on the computer for two seconds. The sequences are random with no location being highlighted more than once within a trial. In the *Mazes Memory* task, the child views a maze with a red path drawn through it for three seconds. He then has to trace in the same path on a blank maze presented on the computer screen. In the *Block Recall* task, the child views a video of a series of blocks being tapped, and reproduces the sequence in the correct order by tapping on a picture of the blocks.

A computerised report provides a summary of the performance of the child, which includes raw scores, standardised scores, composite scores and percentiles, a graph, and a learning profile. The standardised scores are based on a British population, and for this reason, considering the bilingual status of approximately half of the participants in this study raw scores will be used in the analysis of this data.

One possible disadvantage to the computerised version of this test, is that only the total score for each task is provided, and it is thus not possible to calculate the reliability of the measure on a South African population. The test-retest reliabilities based on a subset (n=105) of the British norm sample aged between 54 months and 137 months (Alloway, et al., 2006), ranged from 0.64 to 0.84. Test-retest reliability coefficients are presented in Table 3.

Table 3

Task reliabilities for AWMA tests

Measure	Reliability
Verbal short-term memory (v-STM)	
Digit recall	0.84
Word recall	0.76
Nonword recall	0.64
Verbal working memory (v-WM)	
Listening recall	0.81
Counting recall	0.79
Backward digit recall	0.64
Visuo-spatial short-term memory (VS-STM)	
Dot matrix	0.83
Mazes memory	0.81
Block recall	0.83
Visuo-spatial working memory (VS-WM)	
Odd-one-out	0.81
Mr X	0.77
Spatial span	0.82

From Alloway, Gatherole & Pickering (2006) Verbal and Visuospatial Short-Term and Working Memory in Children: Are They Separable? *Child Development 77* (6), 1702-1703.

2.6 Threats to Validity

It is important to note that generalisability or external validity of the research results may be compromised by two factors, namely the sample size and the children's ability to comprehend the instructions for the instruments.

Firstly the relatively small sample (n=79) is less accurate as an estimation of the population than a larger sample would be. This is compounded by the second factor, namely convenience sampling. A purposive, non-probability sampling method, as utilised in this study, cannot guarantee that the sample is representative of the whole [heterogeneous] population (Babbie, 2004) and results of this study are thus not generalisable to the whole population. In an attempt to hold socioeconomic status constant respondents were drawn from four different schools of similar socio-economic status, and results will thus be generalisable to this population, from which the sample was drawn.

Analysis of the data, more specifically the selection of the most appropriate analysis procedures, may also be restricted by the size of the sample. As non-normal distribution patterns were identified for a number of variables, non-parametric tests were utilised in some of the analyses. Had the sample been larger, parametric analyses could have been conducted throughout, which according to Fife-Schaw (2000) should be chosen in preference to non-parametric tests since they tend to be more powerful and are thus better able to detect effects. An additional threat, in terms of the sample, relates to possible univariate outliers in terms of age in the EL2 group. The upper range, which is 106 months, is in excess of three standard deviations from the mean, and it may have been beneficial to exclude these data prior to analysis, however this would have served to further reduce the sample size.

The initial assumption that all of the children who participated in the study would share a level of proficiency in English was not the case. A number of concepts and words included in the tests were unfamiliar to some of the children, which placed them at a disadvantage during testing, despite additional time being spent familiarising them with the requirements of the tests prior to administration. The measure that was most problematic was Bradley and Bryant’s Sound Categorisation Task, as many children were unaware of the phonological composition of words, and had difficulty separating the words into their component parts. This task relates to Adams (1990) second level of phonological development, and focuses attention on the sound components of words, which requires the child to compare and contrast the sounds of words for rime or alliteration. (Oakhill and Kyle, 2000, found that performance on these tasks had a higher verbal working memory demand than verbal short-term memory demand.) However, after elaboration by the researcher, and repeated practice sessions, most children were able to identify the first sound of words (the alliteration component), but experienced greater difficulty with the remaining two tasks, namely identifying the end and middle sounds (the rime component) of words. Identification of the middle sound was found to be the most difficult aspect.

In terms of the AWMA, the Listening Recall test requires the child to listen to a series of individual sentences and judge if each sentence is true or false, after which the child recalls the final word of each sentence, in the correct order. The inclusion of words such as “fur”, an unfamiliar word for many of the participants from the EL2 sample, interrupted the first part of the task, and thus was likely to have negatively impacted on the recall process. Despite these difficulties and although the range in age (32 months) was fairly large, all participants were enrolled in their first year of schooling, and thus it was assumed that they were at an approximately equivalent educational and cognitive developmental level.

The next chapter presents the results of the analyses in relation to the hypotheses of this research, as detailed in chapter 1.

CHAPTER 3.   RESULTS

3.1 Introduction

This chapter deals with the analyses conducted, and the statistical results obtained, in order to address the research questions.

Some elaboration on the composition of the scores obtained from the various instruments is necessary at this point, prior to presentation of the results. As mentioned in chapter 2, the AWMA measures four aspects of working memory, namely verbal working memory (v-WM), visuo-spatial working memory (VS-WM), verbal short-term memory (v-STM), and visuo-spatial short-term memory (VS-STM). In addition to the above scores, the scores on the two working memory tests were combined to give one composite score for working memory (WM), and likewise the scores on the two short-term memory tests were combined to give a composite score for short-term memory (STM). The working memory (WM) and short-term memory (STM) scores were then combined to provide a memory composite score (MC). From these results, a composite verbal score for verbal short-term memory and verbal working memory (v-STM and v-WM) and a composite visuo-spatial score for visuo-spatial short-term memory and visuo-spatial working memory (VS-STM and VS-WM) were calculated, in order to address specific aspects relating to verbal and visuo-spatial memory. However, these two aspects were not included as variables in the analysis.

In terms of the scores yielded from the phonological awareness measures, the Bradley and Bryant Sound Categorisation Task comprises three separate assessments, namely first sound categorisation (BBF), middle sound categorisation (BBM) and end sound categorisation (BBE). These three scores were also combined into a composite score, Bradley and Bryant Sound Categorisation Task overall (BBSC). Rosner's Test of Auditory Analysis Skills

(RTAA) is a single test, comprising a syllable awareness task and a phoneme deletion task, which produced a single score. No composite score for phonological awareness, that is Bradley and Bryant's Sound Categorisation Task and Rosner's Test of Auditory Analysis Skills, was calculated as these tests assess different aspects of phonological awareness.

The non-verbal intelligence test, Raven's Coloured Progressive Matrices (RCPM), although consisting of three sections, provided only a single score.

Data analyses were conducted using SAS version 9.1. Only raw scores were included for analysis.

3.2 Distribution of Data

One of the criteria for the use of parametric techniques in data analysis is a normal distribution of scores obtained on each dependent variable. Two of the techniques which can be used to determine normality are the Kolmogorov-Smirnov test of normality and histograms (Bohrnstedt & Knoke, 1988). The results of the Kolmogorov-Smirnov test on the variables for the current study are presented in Table 4, for each language group.

Table 4

Kolmogorov-Smirnov Test of Normality for all measures for the EL1 and EL2 groups

Variable	EL1		EL2	
	Statistic D	p-Value	Statistic D	p-Value
RCPM	0.15	p=0.28	0.12	p>0.15
RTAA	0.18	p<0.01	0.20	p<0.01
BBF	0.29	p<0.01	0.17	p<0.01
BBM	0.17	p<0.01	0.14	p=0.09
BBE	0.20	p<0.01	0.16	p=0.02
BBSC	0.17	p<0.01	0.13	p=0.14
v-STM	0.12	p>0.15	0.10	p>0.15
VS-STM	0.10	p>0.15	0.11	p>0.15
STM	0.10	p>0.15	0.06	p>0.15
v-WM	0.10	p>0.15	0.15	p=0.03
VS-WM	0.11	p>0.15	0.08	p>0.15
WM	0.11	p>0.15	0.08	p>0.15
MC	0.09	p>0.15	0.06	p>0.15

Key to the abbreviations: RCPM = Raven's Coloured Progressive Matrices; RTAA = Rosner's Test of Auditory Analysis Skills; BBF = Bradley and Bryant Sound Categorisation Task, first sound; BBM = Bradley and Bryant Sound Categorisation Task, middle sound; BBE = Bradley and Bryant Sound Categorisation Task, end sound; BBSC = Bradley and Bryant Sound Categorisation Task, overall score; v-STM = AWMA verbal short-term memory; VS-STM = AWMA visuo-spatial short-term memory; STM = composite short-term memory score; v-WM = AWMA verbal working memory; VS-WM = AWMA visuo-spatial working memory; WM = composite working memory score; MC = memory composite.

The p-values on the various tests were examined, and where they were significant, it was concluded that the data on that particular variable were not normally distributed (Howell, 1997). Thus, the variables RTAA, BBF, BBM, BBE and BBSC were not normally distributed for the EL1 sample, and RTAA and BBF were not normally distributed for the EL2 sample.

Examination of the histograms for the EL1 and EL2 groups confirmed deviations from the normal distribution pattern for some variables. In terms of the EL1 group, the distribution for the RTAA, BBF and BBSC scores was negatively skewed, which indicated that the participants performed very well on these tests, all of which are phonological awareness tests. The v-STM histogram was positively skewed, indicating that the EL1 children did not perform well on this task. In terms of the EL2 group, the distributions for the RTAA, BBF, BBM and BBE scores were negatively skewed, and indicated that the participants performed very well on these phonological awareness tests.

It was accepted that homogeneity of variance, random independent sampling and additive means could be assumed, and all tests met the criterion of an interval scale of measure (Howell, 1997). However, since the requirements for normal distribution of data were not met in terms of all variables, both parametric and non-parametric analysis was conducted. This will be discussed in detail following the presentation of the descriptive statistics (Table 5).

3.3 Data Analysis

Data for the dependent variables (non-verbal intelligence, working memory and phonological awareness) were obtained from the relevant tests. The means and standard deviations of all the measures used in the study are presented in Table 5, separately for the EL1 and EL2 groups.

Table 5

Descriptive statistics for the tests per group (raw scores)

Variable		EL1 (N=42)	EL2 (N=37)
RCPM	M	22.40	16.32
	SD	3.64	4.84
RTAA	M	11.88	11.81
	SD	2.65	2.84
BBF	M	9.14	7.76
	SD	1.07	2.11
BBM	M	7.21	5.92
	SD	1.77	2.44
BBE	M	8.14	6.95
	SD	1.93	2.25
BBSC	M	24.50	20.62
	SD	3.83	5.68
v-STM	M	58.98	56.43
	SD	8.37	7.94
VS-STM	M	53.31	41.95
	SD	9.60	..9.98
STM	M	112.29	98.38
	SD	13.50	14.77
v-WM	M	37.55	27.35
	SD	7.87	8.31
VS-WM	M	36.74	27.22
	SD	8.92	8.19
WM	M	74.29	54.57
	SD	14.91	14.45
MC	M	186.57	152.95
	SD	24.00	26.57

Key to the abbreviations: RCPM = Raven's Coloured Progressive Matrices; RTAA = Rosner's Test of Auditory Analysis Skills; BBF = Bradley and Bryant Sound Categorisation Task, first sound; BBM = Bradley and Bryant Sound Categorisation Task, middle sound; BBE = Bradley and Bryant Sound Categorisation Task, end sound; BBSC = Bradley and Bryant Sound Categorisation Task, overall score; v-STM = AWMA verbal short-term memory; VS-STM = AWMA visuo-spatial short-term memory; STM = composite short-term memory score; v-WM = AWMA verbal working memory; VS-WM = AWMA visuo-spatial working memory; WM = composite working memory score; MC = memory composite.

A visual inspection of the mean scores in Table 5 shows that all thirteen scores in the EL1 group were higher than in the EL2 group, and the standard deviations suggest generally greater variability among the scores in the EL2 group.

Prior to addressing the hypotheses, as outlined in chapter 1, the selection of analysis tools, that is, parametric and non-parametric tests, is briefly discussed. As discussed (refer to Table 4), not all data were found to be normally distributed, and it is therefore relevant to substantiate the choice of statistical tests used. The normal distribution of non-verbal intelligence data and working memory data justified the use of an ANOVA in order to determine whether the performance by the EL1 group was significantly different to the performance by the EL2 group on these measures. In the case of the phonological awareness measures, data were not normally distributed, necessitating the use of the non-parametric Wilcoxon rank-sum test to determine possible differences in their performance.

Due to the non-normal distribution of some data, non-parametric analysis was conducted in order to explore the relationship between working memory and phonological awareness. Spearman rank-order correlation coefficients between working memory measures, phonological awareness measures and non-verbal intelligence were thus explored for the EL1 and EL2 groups. The multivariate correlation matrix for all variables, for both the EL1 group and the EL2 group, is presented in Table 6.

Despite the non-normal distribution of data, it was decided to also calculate Pearson product-moment correlations (r) between the variables, after which both the significant and non-significant correlations were compared with the previously calculated Spearman rank-order correlation coefficients (r_s) (refer to Table 6, in which both Spearman rank-order correlation coefficients and Pearson product-moment correlation coefficients are presented to facilitate a comparison between the two sets of analyses).

The two sets of correlation coefficients yielded comparable results, thus allowing for the parametric Fisher-z transformation and hypothesis test to be included in the analysis of the data. The Fisher-z transformation and hypothesis scores are designed to determine the significance of differences between correlations for two groups, and were included in the current study in order to identify whether or not significant differences existed between the correlations for the EL1 and EL2 groups (refer to Table 7).

Table 6 *Parametric and non-parametric correlation coefficients between working memory, phonological awareness and non-verbal intelligence for EL1 and EL2* Spearman Rank-Order Correlation coefficients (r_s) between all measures Pearson Product-Moment Correlation coefficients (r) between all measures

	RCPM	RTAA	BBF	BBM	BBE	BBSC	v-STM	VS-STM	STM	v-WM	VS-WM	WM	MC
RCPM		-0.09 -0.06	0.10 0.15	0.03 0.07	0.17 0.08	0.11 0.12	0.02 0.15	0.44 ** 0.45**	0.30 0.41**	0.40 ** 0.47**	0.32 * 0.41**	0.40 ** 0.50**	0.43 ** 0.54**
RTAA	0.42 ** 0.42**		0.38 * 0.49**	0.47 ** 0.47**	0.52** 0.54**	0.57 *** 0.63***	0.08 0.13	-0.02 0.06	0.07 0.12	0.07 0.14	-0.21 -0.13	-0.09 -0.01	0.04 0.07
BBF	0.10 0.15	0.63 *** 0.70***		0.32 * 0.34*	0.40 ** 0.45**	0.59 *** 0.66***	0.06 0.09	0.15 0.22	0.13 0.21	0.23 0.26	0.17 0.22	0.22 0.26	0.23 0.28
BBM	0.07 0.06	0.52 ** 0.56**	0.51 ** 0.62***		0.58 *** 0.51**	0.82 *** 0.81***	0.10 0.17	-0.08 -0.01	-0.02 0.10	0.38 * 0.38*	0.01 0.04	0.19 0.23	0.13 0.20
BBE	0.37* 0.38*	0.67*** 0.70***	0.66 *** 0.65***	0.35 * 0.38*		0.89 *** 0.87***	0.20 0.21	0.02 0.00	0.08 0.13	0.29 0.26	0.20 0.11	0.25 0.21	0.22 0.21
BBSC	0.23 0.23	0.74 *** 0.78***	0.85 *** 0.90***	0.74 *** 0.81***	0.82 *** 0.80***		0.17 0.21	-0.02 0.06	0.03 0.17	0.38 * 0.38*	0.15 0.14	0.26 0.28	0.22 0.27
v-STM	0.28 0.31	0.48 ** 0.51**	0.54 ** 0.56**	0.41 * 0.43**	0.39 * 0.37*	0.53 ** 0.54**		0.06 0.13	0.61 *** 0.71***	0.13 0.26	-0.09 0.01	0.00 0.14	0.34 * 0.49**
VS-STM	0.43 ** 0.49**	0.34 * 0.42*	0.08 0.19	0.17 0.20	0.21 0.24	0.16 0.25	0.28 0.35*		0.78 *** 0.79***	0.46 ** 0.44**	0.45 ** 0.41**	0.54 ** 0.48**	0.79 *** 0.74***
STM	0.44 ** 0.50**	0.51 ** 0.55**	0.33 * 0.42**	0.35 * 0.37*	0.33 * 0.36*	0.39 * 0.46**	0.77 *** 0.77***	0.80 *** 0.86***		0.40 ** 0.47**	0.29 0.30	0.39 ** 0.43**	0.81 *** 0.83***
v-WM	0.52 ** 0.54**	0.47 ** 0.50**	0.40 * 0.41*	0.36 * 0.35*	0.37 * 0.39*	0.44 ** 0.46**	0.51 ** 0.56**	0.62 *** 0.55**	0.74 *** 0.67***		0.50 ** 0.58***	0.83 *** 0.87***	0.75 *** 0.81***
VS-WM	0.44 ** 0.51**	0.41 * 0.48**	0.39 * 0.41*	0.17 0.23	0.55 ** 0.57**	0.47 ** 0.48**	0.08 0.14	0.58 ** 0.59**	0.41 * 0.47**	0.56 ** 0.53**		0.87 *** 0.90***	0.68 *** 0.73***
WM	0.54 ** 0.60***	0.52 ** 0.56**	0.48 * 0.47**	0.30 0.34	0.54 ** 0.54**	0.54 ** 0.53**	0.37 * 0.40*	0.60 *** 0.65***	0.63 *** 0.65***	0.86 *** 0.88***	0.86 *** 0.87***		0.83 *** 0.86***
MC	0.55 ** 0.60***	0.55 ** 0.61***	0.44 * 0.49**	0.36 * 0.38*	0.46 ** 0.50**	0.50 ** 0.55**	0.62 *** 0.65***	0.79 *** 0.83***	0.90 *** 0.91***	0.88 *** 0.85***	0.71 *** 0.74***	0.90 *** 0.91***	

Correlations for the EL1 children are reported above the diagonal and correlations for the EL2 children are reported below the diagonal.

Key to the abbreviations: RCPM = Raven's Coloured Progressive Matrices; RTAA = Rosner's Test of Auditory Analysis Skills; BBF = Bradley and Bryant Sound Categorisation Task, first sound; BBM = Bradley and Bryant Sound Categorisation Task, middle sound; BBE = Bradley and Bryant Sound Categorisation Task, end sound; BBSC = Bradley and Bryant Sound Categorisation Task, overall score; v-STM = AWMA verbal short-term memory; VS-STM = AWMA visuo-spatial short-term memory; STM = composite short-term memory score; v-WM = AWMA verbal working memory; VS-WM = AWMA visuo-spatial working memory; WM = composite working memory score; MC = memory composite. * $p < 0.05$ ** $p < 0.01$ *** $p < 0.0001$

The Fisher-z transformation and hypothesis test transforms the Pearson product-moment correlation coefficient (r) into a z-score, which enabled the significance of the differences between the correlations for the EL1 group and the correlations for the EL2 group to be determined (Rosenthal & Rosnow, 1991).

Table 7

Fisher-z Transformation and Hypothesis Test

Measures	EL1 r	EL2 r	z
RTAA – RCPM	-0.06	0.42	-2.16*
RTAA – STM	0.12	0.55	-2.12*
RTAA – VS-WM	-0.13	0.48	-2.77**
RTAA – WM	-0.01	0.56	-2.74**
RTAA – MC	0.07	0.61	-2.72**
BBF – BBSC	0.66	0.90	-2.90**
BBF – v-STM	0.09	0.56	-2.32*
BBE – VS-WM	0.12	0.57	-2.25*

Key to the abbreviations: RCPM = Raven's Coloured Progressive Matrices; RTAA = Rosner's Test of Auditory Analysis Skills; BBM = Bradley and Bryant Sound Categorisation Task, middle sound; BBE = Bradley and Bryant Sound Categorisation Task, end sound; BBSC = Bradley and Bryant Sound Categorisation Task, overall score; v-STM = AWMA verbal short-term memory; STM = composite short-term memory score; VS-WM = AWMA visuo-spatial working memory; WM = composite working memory score; MC = memory composite.

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

As can be seen in Table 7 the z- scores indicate that a significant difference was identified between the correlation in the EL1 group and the correlation in the EL2 group in terms of each relationship as detailed in this table. In terms of the EL1 group, all correlations were non-significant, with the exception of that between BBF and BBSC, and in terms of EL2 all correlations were significant (refer to Table 6 for significance levels). The negative z-scores indicate that the correlations were significantly stronger in the EL2 group than in the EL1 group. All other correlational differences not documented in the table were non-significant. In terms of reporting these results, significant differences between both individual measures and composite scores are included. However, in terms of the discussion to follow in chapter 4, only those differences relating to performance on individual tasks, namely RTAA - RCPM, RTAA – VS–WM, BBF - v-STM and BBE - VS-WM, and not to the composite scores (as the composite scores comprise the individual task scores), will be included.

Results based on the above data are now presented in relation to the research hypotheses.

Hypothesis 1: Performance on the Raven's Coloured Progressive Matrices (RCPM)

The first hypothesis states that in terms of performance on the non-verbal intelligence task there would be no significant difference between the EL1 and EL2 children.

The RCPM, as a relatively culture-fair measure of non-verbal intelligence (Raven et. al., 1998), was deemed important in this study, as intellectual ability may have impacted on the groups' performance on the other measures. The first hypothesis stated that there would be no difference between the EL1 and EL2 groups in terms of performance on the RCPM, and in order to explore this hypothesis, the performance of the two language groups on this measure was compared. Since the scores on the RCPM test, when examined, were judged to be normally distributed, a parametric, independent t-test was calculated (Howell, 1989). These results are presented in Table 8.

Table 8

t-test for two independent samples (EL1 and EL2) on the RCPM (df=77)

Language	Mean	t
EL1	22.40	
EL2	16.32	
Diff	6.08	6.36***

*** p<0.0001

The results in Table 8 indicate that the EL1 group performed significantly better on the RCPM than the EL2 group. The implications of these results are discussed in the next chapter.

Hypothesis 2a: Performance on the working memory measures and on the phonological awareness measures.

Hypothesis 2b: Relationship between working memory, phonological awareness and non-verbal intelligence for the EL1 and EL2 samples and possible differences in these relationships

The second hypothesis states firstly, that, in terms of performance on the working memory and phonological awareness measures there would be no significant difference between the EL1 children and the EL2 children; and secondly, that working memory, phonological awareness and non-verbal intelligence will be significantly correlated with one another for the EL1 and EL2 groups, and that there will be no significant difference between the correlations for the two groups.

Working memory measures for the EL1 and EL2 groups

In order to determine whether the EL1 group performed significantly better than the EL2 group on the working memory tests, an independent pairs t-test was applied using the means of the two groups on the RCPM (Howell, 1989). These results are presented in Table 9.

Table 9

t-test for two independent samples (EL1 and EL2) on working memory measures (df=77)

Measure	EL1	EL2	Diff	t
v-STM	58.98	56.43	2.54	1.38
VS-STM	53.31	41.95	11.36	5.16***
STM	112.29	98.38	13.91	4.37***
v-WM	37.55	27.35	10.20	5.60***
VS-WM	36.74	27.22	9.52	4.92***
WM	74.29	54.57	19.72	5.95***
MC	180.65	163.40	17.25	5.91***

Key to the abbreviations: v-STM = AWMA verbal short-term memory; VS-STM = AWMA visuo-spatial short-term memory; STM = composite short-term memory score; v-WM = AWMA verbal working memory; VS-WM = AWMA visuo-spatial working memory; WM = composite working memory score; MC = memory composite.
*** $p<0.0001$

The results in Table 9 indicate that the EL1 group performed significantly better on the majority of working memory measures than the EL2 group. There was no significant difference between the language groups on v-STM. Thus, performance on the working memory tasks was significantly different for the language groups, unlike the correlations between the working memory tasks, as detailed in Figure 1, for which no significant differences were found, suggesting that the relationship was similar for each group.

In order to simplify the presentation of the correlations between the working memory variables for the EL1 and EL2 groups, a visual representation of the significant relationships is presented in Figure 1.

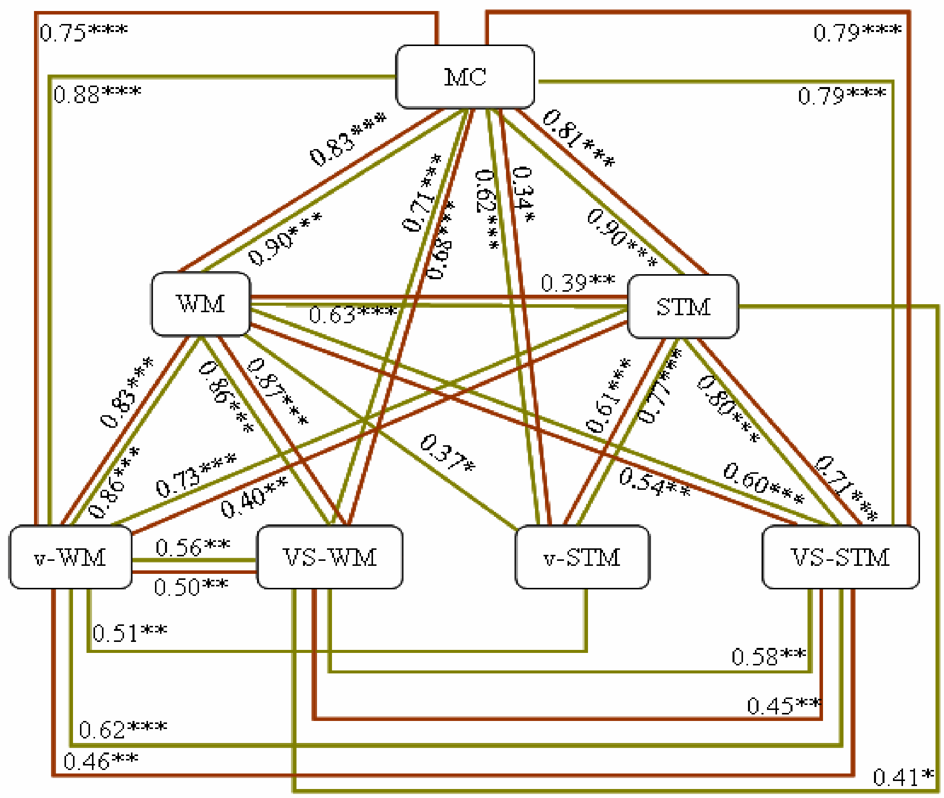

Figure 1

Significant relationships between the working memory measures for the EL1 and EL2 groups

Key to the language groups: **EL1** _____ **EL2** _____

Key to the abbreviations: v-STM = AWMA verbal short-term memory; VS-STM = AWMA visuo-spatial short-term memory; STM = composite short-term memory score; v-WM = AWMA verbal working memory; VS-WM = AWMA visuo-spatial working memory; WM = composite working memory score; MC = memory composite.

* p <0.05 ** p<0.01 *** p<0.0001

As the working memory section consists of a large number of correlations, these relationships will be presented under the following headings: the relationship between the memory composite (MC), and the short-term memory composite score and the working memory composite score; the memory composite (MC) and the four working memory tasks; the working memory composite (WM) and the four working memory tasks; the short-term memory composite (STM) and the four working memory tasks; and lastly the relationship between the four working memory tasks (v-WM, VS-WM, v-STM, VS-STM).

Correlations between memory composite (MC) and the short-term memory composite score (STM) and the working memory composite score (WM)

Since WM and STM comprise the MC score, it was not surprising that data yielded high positive significant correlations between MC and WM and between MC and STM for both language groups. In terms of differences between the language groups, working memory and short-term memory appear to be more highly correlated for the EL2 group than for the EL1 group, but the Fisher-z transformation score indicated that this difference was not statistically significant.

Correlations between memory composite (MC) and the four working memory tasks (v-STM, VS-STM, v-WM and VS-WM)

As can be seen, MC was significantly correlated with the four working memory tasks for both language groups. In terms of differences between the language groups, memory composite and the four working memory tasks again appear to be more highly correlated for the EL2 group than for the EL1 group, but as with MC, Fisher-z transformation scores indicated that this difference was not statistically significant.

Correlations between working memory composite (WM) and the four working memory tasks (v-STM, VS-STM, v-WM and VS-WM)

Working memory was correlated with all working memory tasks for both language groups, with the exception of v-STM in the EL1 group. As was to be expected, the working memory tasks were more highly correlated with WM than were the short-term memory tasks, as the working memory tasks are components of the WM score. Both short-term and working memory skills were implicated in working memory for both language groups, with the exception of verbal short-term memory in the EL1 group. This may imply that the EL2 children were drawing on both verbal short-term memory and visuo-spatial short-term memory when performing working memory tasks, suggesting that they accessed more general abilities, when performing these tasks.

Correlations between the short-term memory composite score (STM) and the four working memory tasks (v-STM, VS-STM, v-WM and VS-WM)

As was to be expected, the short-term memory tasks were more highly correlated with the STM composite score than were the working memory tasks, as the short-term memory tasks are components of the STM score. However, verbal working memory too was implicated in performance on short-term memory tasks in both language groups.

Correlations between the four working memory tasks (v-STM, VS-STM, v-WM and VS-WM)

In terms of the four working memory tasks, as can be seen, the majority of working memory tasks were significantly correlated. Verbal working memory (v-WM) was significantly correlated with VS-STM in both language groups; with VS-WM in both language groups; and with v-STM only in the EL2 group. Visuo-spatial short-term memory (VS-STM) was also significantly correlated with VS-WM in both language groups. Verbal short-term memory (v-STM) was not significantly correlated with either VS-STM or VS-WM for either of the language groups.

Based on the above results, it was decided to separate out data in relation to visuo-spatial and verbal relationships. Verbal memory, consisting of both verbal short-term and verbal working memory was assessed utilising the v-STM and v-WM tasks. A significant relationship existed between these two measures in the EL2 group but not in the EL1 group. Visuo-spatial memory, consisting of short-term and working memory, was assessed utilising the VS-STM and VS-WM tasks. A significant relationship existed between these two measures in both language groups.

In terms of differences in correlations between the language groups, those between visuo-spatial memory tasks appeared to be stronger than those between verbal memory tasks for the EL1 group, whereas the relationship between visuo-spatial memory tasks and verbal memory tasks for the EL2 group showed no noticeable differences, suggesting some disparity between the language groups. However, this was not confirmed by the Fisher-z transformation scores which revealed no significant differences between the language groups.

From the above, it can be seen that not only the correlations between components, but also the correlations between the components and the composite scores were generally higher in the EL2 group than in the EL1 group.

Phonological awareness measures for the EL1 and EL2 groups

In order to determine whether there were significant differences in the performance of the EL1 and EL2 groups on the phonological awareness measures, the Wilcoxon rank-sum test was applied. These results are presented in Table 10.

Table 10

Wilcoxon Rank-Sum Test for phonological awareness measures for the EL1 and EL2 groups (df=77)

Measure	EL1	EL2	Diff	t
BBF	47.80	31.15	16.65	-3.33**
BBM	45.58	33.66	11.92	-2.32*
BBE	45.64	33.59	12.05	-2.37*
BBSC	47.69	31.27	16.42	-3.18**
RTAA	40.10	39.87	0.23	-0.04

Key to the abbreviations: BBF = Bradley and Bryant Sound Categorisation Task, first sound; BBM = Bradley and Bryant Sound Categorisation Task, middle sound; BBE = Bradley and Bryant Sound Categorisation Task, end sound; BBSC = Bradley and Bryant Sound Categorisation Task, overall score; RTAA = Rosner's Test of Auditory Analysis Skills..
* p <0.05 ** p<0.01 *** p<0.0001 (two tailed)

The results in Table 10 indicate that the EL1 group performed significantly better (p< 0.05) on all Bradley and Bryant Sound Categorisation Tasks than the EL2 group. The two groups did not differ significantly on performance on the RTAA task, indicating that both language groups were functioning at the same level on this task.

In order to simplify the presentation of results for the correlations between the phonological awareness measures for the EL1 and EL2 groups, a visual representation of the significant relationships is presented in Figure 2.

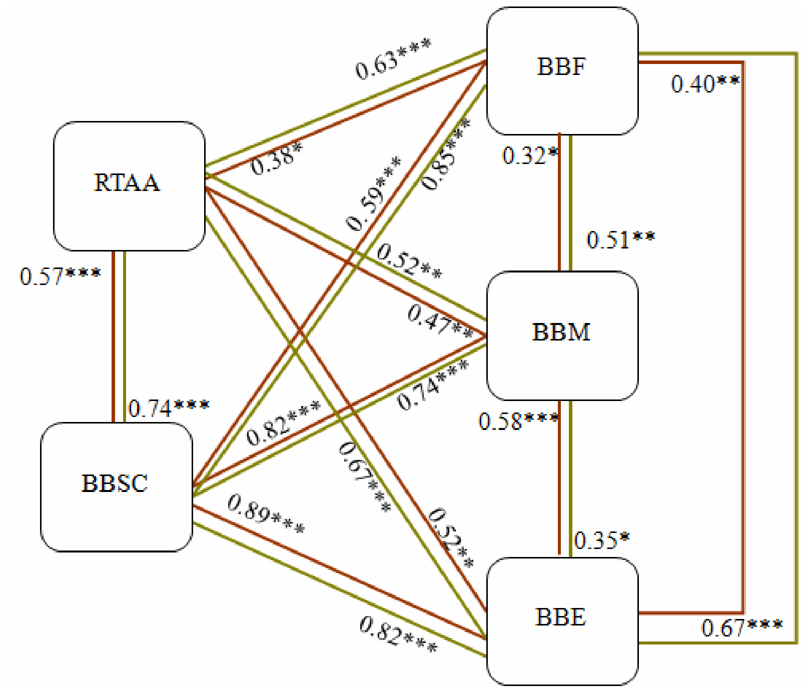

Figure 2

Significant relationships between the phonological awareness measures for the EL 1 and EL2 groups

Key to the language groups: **EL1** _____ **EL2** _____

Key to the abbreviations: RTAA, Rosner's Test of Auditory Analysis Skills; BBF, Bradley and Bryant Sound Categorisation Task, first sound; BBM, Bradley and Bryant Sound Categorisation Task, middle sound; BBE, Bradley and Bryant Sound Categorisation Task, end sound; BBSC, Bradley and Bryant Sound Categorisation Task, overall score.
* p <0.05 ** p<0.01 *** p<0.0001

Figure 2 indicates that all correlations between the phonological awareness variables were significant, and will be discussed in terms of each phonological awareness component. As can be seen, BBSC was significantly correlated with all component scores for both the EL1 and the EL2 groups, suggesting that the relationship between the three phonological awareness tasks and their composite score was similar between the language groups. The Fisher-z transformation scores confirmed this finding for all correlations, with the exception of the relationship between BBSC and BBF (r_sEL1 = 0.59; p<0.0001; r_sEL2 = 0.85; p<0.0001) (rEL1 = 0.66; p<0.0001; rEL2 = 0.90; p<0.0001; z = -2.90; p<0.05). Thus the relationship between these two variables was significantly stronger in the EL2 group than in the EL1 group.

In terms of the relationship between the three Bradley and Bryant Sound Categorisation Tasks (BBF, BBM and BBE), as seen in Table 7, all relationships between sound categorisation tasks were significant for both the EL1 and EL2 groups, suggesting that the relationship between the three sound categorisation tasks was similar between the language groups. The Fisher-z transformation scores confirmed no significant differences.

In terms of performance on the phoneme deletion task (RTAA), results suggested that the relationship between the tests of phonological awareness, namely RTAA, and BBSC and its component tasks, was similar between the language groups. The Fisher-z transformation scores confirmed no significant differences.

Thus, in terms of phonological awareness, the EL1 group generally performed significantly better on the tasks than the EL2 group, while the nature of correlations between phonological awareness variables was similar between the groups, the only exception being that the alliteration task contributed significantly more to the overall sound categorisation score for the EL2 group than for the EL1 group.

The previous section focused on the internal relationships between the working memory scores, and between the phonological awareness scores, including significant differences between the two language groups in terms of both correlations and performance on the tasks. From the above, it is seen that not only the correlations between components, but also the correlations between the components and the composite score are generally higher in the EL2 group than in the EL1 group.

Since the research question addresses the relationship between working memory and phonological awareness, the following section will report on this relationship, as well as the relationship between these variables and non-verbal intelligence. Again, significant differences in these correlations, in terms of the EL1 and EL2 groups will be included.

Correlations between working memory, phonological awareness and non-verbal intelligence for the EL1 and EL2 samples

In order to simplify the presentation of results for the correlations between the working memory, phonological awareness and non-verbal intelligence measures for the EL1 and EL2 groups, a visual representation of the significant relationships is presented in Figure 3 for the EL1 group and in Figure 4 for the EL2 group.

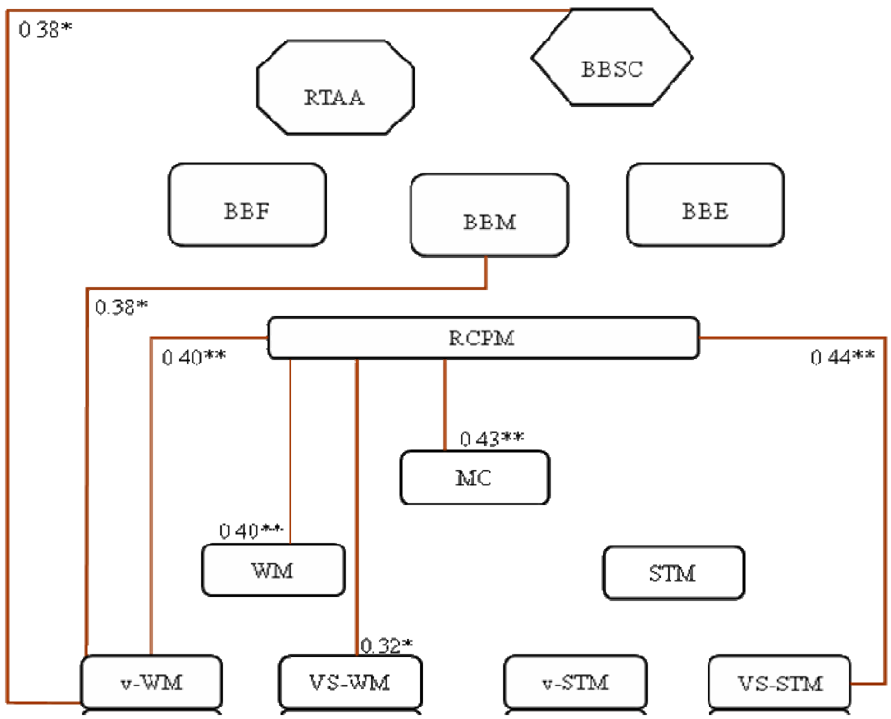

Figure 3

Significant relationships between working memory, phonological awareness and non-verbal intelligence for the EL1 group

Key to the abbreviations: RCPM = Raven's Coloured Progressive Matrices; RTAA = Rosner's Test of Auditory Analysis Skills; BBF = Bradley and Bryant Sound Categorisation Task, first sound; BBM = Bradley and Bryant Sound Categorisation Task, middle sound; BBE = Bradley and Bryant Sound Categorisation Task, end sound; BBSC = Bradley and Bryant Sound Categorisation Task, overall score; v-STM = AWMA verbal short-term memory; VS-STM = AWMA visuo-spatial short-term memory; STM = composite short-term memory score; v-WM = AWMA verbal working memory; VS-WM = AWMA visuo-spatial working memory; WM = composite working memory score; MC = memory composite.
* p <0.05 ** p<0.01 *** p<0.0001

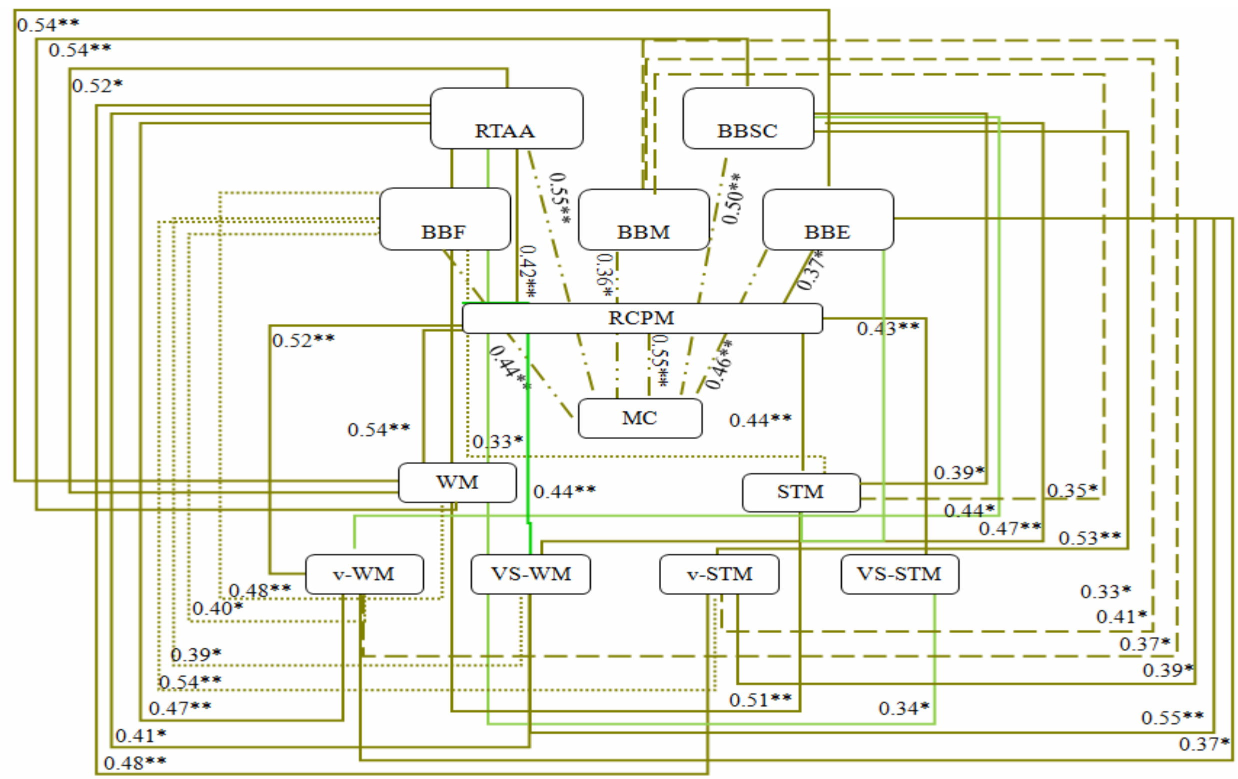

Figure 4
Significant relationships between working memory, phonological awareness and non-verbal intelligence for the EL2 group

Key to the abbreviations: RCPM = Raven's Coloured Progressive Matrices; RTAA = Rosner's Test of Auditory Analysis Skills; BBF = Bradley and Bryant Sound Categorisation Task, first sound; BBM = Bradley and Bryant Sound Categorisation Task, middle sound; BBE = Bradley and Bryant Sound Categorisation Task, end sound; BBSC = Bradley and Bryant Sound Categorisation Task, overall score; v-STM = AWMA verbal short-term memory; VS-STM = AWMA visuo-spatial short-term memory; STM = composite short-term memory score; v-WM = AWMA verbal working memory; VS-WM = AWMA visuo-spatial working memory; WM = composite working memory score; MC = memory composite.

* p <0.05 ** p<0.01 *** p<0.0001

The relationships as discussed under the previous sections between working memory measures (Figure 1) and between phonological awareness measures (Figure 2) have been excluded from Figures 3 and 4. Thus, these figures only present the significant correlations between working memory, phonological awareness and non-verbal intelligence for the EL1 and EL2 groups.

In terms of MC which is a composite score, the relationship with RCPM was significant for both the EL1 and EL2 group. The Fisher-z transformations identified a significant difference in the strength of the relationship between MC and RTAA for the two language groups ($z = -2.72$; $p>0.01$), indicating that the relationship between these two variables was significantly stronger for the EL2 group. In relation to the phonological awareness tasks, no correlations emerged between MC and any of the tasks in the EL1 group, whereas in terms of the EL2 group, MC was significantly correlated with all phonological awareness tasks, with the exception of BBM. This may be due to the EL2 children accessing a broader range of skills, including non-verbal intelligence, when conducting working memory tasks.

In terms of WM, also a composite score, the relationship with RCPM was significant for both the EL1 and EL2 groups. In relation to the phonological awareness tasks, Fisher-z transformations identified a significant difference in the strength of the relationship between WM and RTAA for the two language groups ($z = -2.74$; $p<0.05$), indicating that working memory is implicated in RTAA tasks significantly more for the EL2 group than for the EL1 group

In terms of STM, a composite score, results for the EL1 group indicated that STM was not significantly correlated with any other scores. STM was significantly correlated with RCPM and with all phonological awareness tasks for the EL2 group. Fisher-z transformations identified a significant difference in the strength of the relationship between STM and RTAA for the two language groups ($z = -2.12$; $p<0.01$), indicating that short-term memory is implicated in RTAA tasks significantly more for the EL2 group than for the EL1 group.

In terms of the first short-term memory task, namely v-STM, the relationship with RCPM was not significant for either language group. In relation to the phonological awareness tasks, within the EL1 group there were no significant correlations between v-STM and any of the tasks, whereas within the EL2 group v-STM was significantly correlated with all phonological awareness tasks. Fisher-z transformations identified a significant difference in the strength of the relationship between v-STM and BBF for the two language groups ($z = -2.32$; $p<0.05$), indicating that the EL2 group draws on verbal short-term memory to perform first sound categorisation tasks significantly more than the EL1 group, suggesting that the EL2 group accesses passive, verbal rehearsal skills to perform this phonological awareness task.

In terms of the second short-term memory task, namely VS-STM, the relationship with RCPM was significant in both language groups. In relation to phonological awareness, none of the tasks was significantly correlated with VS-STM in either language group with the exception of RTAA in the EL2 group, indicating that the EL2 group accesses passive visuo-spatial storage skills when performing the auditory analysis tasks, but not when performing the sound categorisation tasks.

In terms of the first working memory task, namely v-WM, the relationship with RCPM was significant in both language groups, which due to the non-verbal nature of the RCPM is surprising. In relation to the phonological awareness tasks data yielded significant correlations between v-WM and BBM; and between v-WM and BBSC for both language groups. Correlations between v-WM and BBF; v-WM and BBE; and v-WM and RTAA were significant for only the EL2 group. These results suggest that v-WM may have been more strongly implicated in both the sound categorisation tasks and the auditory analysis tasks, in the EL2 group.

In terms of the second working memory task, namely VS-WM, the relationship with RCPM was significant for both language groups which, due to the non-verbal nature of the test, was to be expected. In relation to phonological awareness, no tasks were significantly correlated with VS-WM in the EL1 group, whereas in the EL2 group, all tasks, with the exception of BBM, were significantly correlated with VS-WM. These results indicate that non-verbal intelligence was implicated in VS-WM for both language groups, but that only the EL2 group accessed active, or processing, visuo-spatial skills to conduct most of the phonological awareness tasks. This applied particularly to the relationships with the end sound categorisation task ($z = -2.25$; $p<0.05$) and the auditory analysis skills task ($z = -2.77$; $p<0.01$), which were significantly stronger in the EL2 group than in the EL1 group.

In terms of RCPM and phonological awareness, the relationship was not significant for these tasks in the EL1 group, but was significant for BBE and RTAA in the EL2 group. Fisher-z transformations confirmed that the correlation between RCPM and RTAA was significantly stronger in the EL2 group ($z = -2.16$; $p<0.05$), indicating that these children accessed non-verbal intelligence significantly more than the EL1 group when performing auditory analysis tasks.

In summary of the relationship between working memory and phonological awareness tasks, far more significant relationships, as discussed above, were identified within the EL2 group than within the EL1 group, indicating that these children accessed a cluster of more general skills in order to conduct the tasks, which may relate to their level of development, in terms of both working memory and phonological awareness.

Prior to addressing Hypotheses 3 to 5, it is necessary to briefly discuss another statistical tool, namely Stepwise multiple regression analysis.

Stepwise Multiple Regression Analysis

The correlations, as reported in the previous section, provided the basis for exploring the predictive ability of these variables utilising multiple regression analysis. One of the assumptions necessary for multiple regression analysis is a normal distribution of data, but not all data in this study were normally distributed. However, since only small and possibly insignificant differences had previously been found when comparing the Pearson product-moment correlation coefficients (r) with the Spearman rank-order correlation coefficients (r_s) (refer to Table 6), it was decided to run multiple regression analyses in the investigation of the predictive power in this set of variables.

The Stepwise multiple regression model was deemed to be the most suitable method for this study, for two reasons. Firstly, it is recommended as the best compromise between finding an optimal equation for predicting future randomly selected data sets from the same population and finding an equation that predicts the maximum variance for the particular data set under consideration, and is most appropriate for use in direct prediction, as opposed to theoretical research. Secondly, as significant correlations between many variables in both the EL1 and EL2 groups were found to be fairly high, ranging between 0.32 and 0.58 for the EL1 group, and between 0.33 and 0.66 for the EL2 group, it was expected that multi-collinearity may present in the results. An acceptable way of taking care of this problem is Stepwise multiple regression analysis as it significantly reduces the occurrence of multi-collinearity, or the intercorrelation between predictor variables, in comparison to other regression models (Draper & Smith, 1981). This method is essentially a combination of forward selection and backward elimination. The first step of the regression analysis consists of selecting the variable with the largest variance, from all selected predictor variables. Following this, the significance of the remaining variables is recalculated and the next largest variable is selected, as with the forward selection method. With each addition of a variable, a backward elimination process is considered to assess whether variables entered earlier might now be removed from the analysis because they no longer contribute significantly to the model (Der & Everitt, 2002). This process continues until all variables that are able to make a significant contribution have been included and those that do not are excluded from the analysis. The significance levels were set to 0.01 for entry and 0.05 for removal.

Hypothesis 3: Performance on working memory measures will predict performance on phonological awareness measures.

The third hypothesis states that the working memory tasks and non-verbal intelligence (RCPM) will predict performance on the phonological awareness tasks (that is, Rosner's Test of Auditory Analysis Skills, and Bradley and Bryant's Sound Categorisation Task, and its component measures) for the EL1 and EL2 groups.

Firstly, Rosner's Test of Auditory Analysis Skills score was entered as the dependent variable, and non-verbal intelligence, verbal working memory, visuo-spatial working memory, verbal short-term memory and visuo-spatial short-term memory as the predictor variables. Due to the different patterns of correlations between the two language groups, this analysis was run separately for the EL1 and EL2 groups.

Secondly, the Bradley and Bryant overall score and the three Bradley and Bryant tests were each entered as the dependent variable, and non-verbal intelligence, verbal working memory, visuo-spatial working memory, verbal short-term memory and visuo-spatial short-term memory as the predictor variables. Once again, as the patterns of correlations between the two language groups differed, these analyses were run separately for the EL1 and EL2 groups. The first and second sets of results for the regression analysis run in order to determine which variables were significant predictors of phonological awareness, are shown in Table 11.

Table 11

Stepwise Multiple Regression Analysis exploring working memory tasks and non-verbal intelligence as predictors of RTAA, BBSC and Bradley and Bryant Sound Categorisation Tasks for the EL1 and EL2 groups

EL1 group

Dependent Variable	Predictor Variable	Δ R^2	F
BBSC	v-WM	0.14	6.64*
BBM	v-WM	0.14	6.73*

EL2 group

Dependent Variable	Predictor Variable	Δ R^2	R^2	F
RTAA	v-STM	0.26	0.26	12.04**
	VS-WM	0.17	0.43	10.37**
BBSC	v-STM	0.30	0.30	14.47**
	VS-WM	0.16	0.46	10.28**
BBF	v-STM	0.30	0.30	15.96**
	VS-WM	0.12	0.42	6.53*
BBM	v-STM	0.19		8.02**
BBE	VS-WM	0.32		16.65**

Key to the abbreviations: RCPM = Raven's Coloured Progressive Matrices; RTAA = Rosner's Test of Auditory Analysis Skills; BBF = Bradley and Bryant Sound Categorisation Task, first sound; BBM = Bradley and Bryant Sound Categorisation Task, middle sound; BBE = Bradley and Bryant Sound Categorisation Task, end sound; BBSC = Bradley and Bryant Sound Categorisation Task, overall score; v-STM = AWMA verbal short-term memory; VS-STM = AWMA visuo-spatial short-term memory; STM = composite short-term memory score; v-WM = AWMA verbal working memory; VS-WM = AWMA visuo-spatial working memory; WM = composite working memory score; MC = memory composite.
* $p < 0.05$ ** $p < 0.01$ *** $p < 0.0001$

The first aim of the regression analysis was to identify the working memory predictors of the phonological awareness tasks. Since significant differences were found in the performance of the EL1 and EL2 groups on the RCPM task, it was decided to include RCPM as a predictor variable in the regression analysis. Results indicated that RCPM did not predict performance on any of the phonological awareness tasks for either language group, which, in terms of the EL2 group, is surprising as RCPM was significantly correlated with RTAA. A possible reason for this may be multi-collinearity, as RCPM was highly correlated with all working memory measures with the exception of v-STM, and may not have been separable, in terms of the regression, notwithstanding that Stepwise multiple regression analysis is the most suitable regression analysis for use in cases of possible multi-collinearity (Draper & Smith, 1981).

Verbal working memory was the only working memory predictor identified in the EL1 group, and was found to predict performance on BBSC accounting for 14% of the variance. The remaining working memory predictors that emerged relate only to the EL2 group, as reported here. In terms of the EL2 group, verbal short-term memory and visuo-spatial working memory together accounted for 43% of the variance in the auditory analysis task (RTAA). In terms of sound categorisation skills overall (BBSC), verbal short-term memory (30%), and visuo-spatial working memory (16%) accounted for 46% of the variance in the sound categorisation tasks.

In order to refine the investigation, the predictive value of working memory tasks on each Bradley and Bryant Sound Categorisation Task was explored. In terms of the EL1 group v-WM accounted for 14% of the variance in BBM. In terms of the EL2 group, v-STM (30%) and VS-WM (12%) together accounted for 42% of the

variance in BBF. This result is not surprising, as the BBF task presented as the most difficult task of the three, and it may be that the EL2 children accessed a broader resource pool in their attempt to complete this task. In terms of the middle and end sound categorisation tasks, 19% of the variance for BBM, and 32% of the variance for BBE was accounted for by VS-WM in this group of children.
From the above it is clear that it is the sound categorisation tasks that were more demanding of working memory than the auditory analysis tasks, particularly for the EL2 group. Short-term memory was implicated in the first and middle sound categorisation tasks, which may be as a result of the tasks requiring the children to hold the words in mind for a short time, whilst simultaneously completing the processing aspect of the task.

Hypothesis 4: BBSC will predict performance on RTAA

The fourth hypothesis states that BBSC (Bradley and Bryant's Sound Categorisation Task overall score), and its component tasks (BBF, BBM and BBE) will predict performance on RTAA (Rosner's Test of Auditory Analysis Skills) for both the EL1 and EL2 children.

Developmentally, it has been suggested that sound categorisation tasks precede auditory analysis tasks in the hierarchic development of phonological awareness (Adams, 1990). The third regression analysis was thus computed with RTAA as the dependent variable and BBSC as the predictor variable in order to determine the power of the sound categorisation skills in predicting performance on the auditory analysis task. Due to the different patterns of correlations between the two language groups, this analysis was run separately for the EL1 and EL2 groups. The third set of results for the regression analysis, run in order to determine whether sound categorisation skills predict auditory analysis skills, is shown in Table 12.

Table 12

Stepwise Multiple Regression Analysis exploring sound categorisation skills (BBSC) as predictors of auditory analysis skills (RTAA) for the EL1 and EL2 groups

EL1 group

Dependent Variable	Predictor Variable	ΔR^2	F
RTAA	BBSC	0.39	25.96***

EL2 group

Dependent Variable	Predictor Variable	ΔR^2	F
RTAA	BBSC	0.60	52.98***

Key to the abbreviations: RTAA = Rosner's Test of Auditory Analysis Skills; BBSC = Bradley and Bryant Sound Categorisation Task overall score.
*** $p < 0.0001$

Sound categorisation skills (BBSC) emerged as a significant predictor of auditory analysis skills (RTAA) for both language groups, (accounting for 60% of the variance in the EL2 group, and for 39% of the variance in the EL1 group). This result was to be expected, and supports the hierarchic development of phonological awareness skills in which BBSC and RTAA are assessing slightly different aspects of phonological awareness at different levels of analysis, namely sound categorisation and phoneme deletion.

The fourth regression analysis was computed with Rosner's Test of Auditory Analysis Skills as the dependent variable and the three Bradley and Bryant Sound

Categorisation Tasks as the predictor variables in order to determine the power of the individual sound categorisation tasks in predicting the phoneme deletion skills for the EL and EL2 groups, as presented in Table 13. This analysis was conducted because of the different patterns of correlations between the individual sound categorisation measures and RTAA, in the two language groups, and this analysis was thus run separately for the EL1 and EL2 groups.

Table 13

Stepwise Multiple Regression Analysis exploring the three Bradley and Bryant Sound Categorisation Tasks as predictors of RTAA in the EL1 and EL2 groups

EL1 group

Dependent Variable	Predictor Variable	Δ R^2	R^2	F
RTAA	BBE	0.29	0.29	16.65**
	BBF	0.08	0.37	4.57*

EL2 group

Dependent Variable	Predictor Variable	Δ R^2	R^2	F
RTAA	BBF	0.49	0.49	33.82***
	BBE	0.10	0.59	8.58**

Key to the abbreviations: RTAA = Rosner's Test of Auditory Analysis Skills; BBF = Bradley and Bryant Sound Categorisation Task, first sound; BBE = Bradley and Bryant Sound Categorisation Task, end sound
* $p < 0.05$ ** $p < 0.01$ *** $p < 0.0001$

In order to refine the investigation, the predictive value of the three Bradley and Bryant Sound Categorisation Tasks on RTAA was explored. In terms of the EL1 group, BBE and BBF emerged as predictors of performance on RTAA, together accounting for 37% of the variance, of which BBE was the primary predictor, accounting for 29%. Similarly BBF and BBE predicted performance on RTAA in the EL2 group, together accounting for 59% of the variance, of which BBF was the primary predictor accounting for 49%. Of interest is that the BBE component (i.e. rime) is the primary predictor for the EL1 group and the BBF component (i.e. onset) for the EL2 group, which may relate to the orthographic structure of the home languages of the two groups. BBM did not predict performance on RTAA which is surprising because although both the EL1 and EL2 groups performed lowest on the BBM task, both the BBM and the BBE tasks are rime tasks.

Hypothesis 5: RCPM will predict working memory

The fifth hypothesis states that performance on the RCPM (non-verbal intelligence) will predict performance on MC (memory composite score), and on the individual working memory tasks (v-STM, VS-STM, V-WM and VS-WM). The fifth regression analysis was computed with the memory composite score as the dependent variable and the non-verbal intelligence score as the predictor variable in order to determine the power of non-verbal intelligence in predicting working memory skills. Due to the different patterns of correlations between the two language groups, this analysis was run separately for EL1 and EL2 groups. The set of results for the above regression analysis, run in order to determine whether non-verbal intelligence predicts working memory skills, is shown in Table 14.

Table 14

Stepwise Multiple Regression Analysis exploring non-verbal intelligence as a predictor of working memory skills for the EL1 and EL2 groups

EL1 group

Dependent Variable	Independent Variable	Δ R^2	F
MC	RCPM	0.29	16.63**

EL2 group

Dependent Variable	Independent Variable	Δ R^2	F
MC	RCPM	0.36	19.70***

Key to the abbreviations: RCPM = Raven's Coloured Progressive Matrices; MC = memory composite.
* $p < 0.05$ ** $p < 0.01$ *** $p < 0.0001$

RCPM emerged as a significant predictor of working memory (MC) for both language groups, with the predictive value in the EL2 group accounting for 36% of the variance, in comparison to the EL1 group, where it accounted for only 29%**.** As RCPM was found to be a significant predictor of MC, it was decided to calculate the predictive value of RCPM on each of the four individual working memory measures. The set of results for the above regression analysis, run in order to determine whether non-verbal intelligence predicts performance on each of the four working memory skills, is shown in Table 15.

Table 15

Stepwise Multiple Regression Analysis exploring non-verbal intelligence as a predictor of v-STM, VS-STM, v-WM and VS-WM for the EL1 and EL2 groups

EL1 group

Dependent Variable	Predictor Variable	ΔR^2	F
VS-STM	RCPM	0.20	10.28**
v-WM	RCPM	0.22	11.58**
VS-WM	RCPM	0.17	8.27**

EL2 group

Dependent Variable	Predictor Variable	ΔR^2	F
VS-STM	RCPM	0.24	11.01**
v-WM	RCPM	0.29	14.38**
VS-WM	RCPM	0.26	12.00**

Key to the abbreviations: RCPM = Raven's Coloured Progressive Matrices; v-STM = AWMA verbal short-term memory; VS-STM = AWMA visuo-spatial short-term memory; v-WM = AWMA verbal working memory; VS-WM = AWMA visuo-spatial working memory.
** $p < 0.01$

In order to refine the investigation, the predictive value of RCPM on the four working memory measures was explored. In terms of the EL1 group, RCPM emerged as a predictor of performance on VS-STM accounting for 20% of the variance, on v-WM accounting for 22% of the variance, and on VS-WM accounting for 17% of the variance. Similarly in terms of the EL2 group, RCPM emerged as a predictor of performance on VS-STM accounting for 24% of the variance, on v-WM accounting for 29% of the variance, and on VS-WM accounting for 26% of the variance. It is unsurprising that RCPM, which provides an indication of non-verbal intelligence, did not predict performance on v-STM, which is supported by the non-significant correlation between the two variables.

This section has detailed the correlations between variables; identified significant differences in these correlations between the EL1 and EL2 groups; and reported the predictive value of working memory and RCPM on phonological awareness tasks, as well as various variables on working memory and phonological awareness tasks. The pattern that emerged for the EL2 children in this study is thus rather different from what has been observed in previous studies involving children of this age group (e.g. Alloway, et al., 2006; Oakhill & Kyle, 2000). The implications of these findings and how they relate to the literature covered in the Literature Review, is discussed in the next chapter.

CHAPTER 4. DISCUSSION

Introduction

This research aimed to determine the relationship between working memory and phonological awareness in young South African children. A key feature of the present study is that it drew a comparison between two language groups, that is, between children who have English as their home language, and those who have an indigenous South African language as their home language. It was hypothesised that there would be no difference between speakers of the opaque English language and speakers of the transparent African languages in the relationship between working memory and phonological awareness. In particular, measurement focused on the recently developed computer-based working memory test, the Automated Working Memory Assessment (AWMA), Bradley and Bryant's Sound Categorisation Task (BBSC) and Rosner's Test of Auditory Analysis Skills (RTAA). The relationship between these measures and non-verbal intelligence (RCPM) was also assessed, since the two samples differed significantly from one another on this measure. Results will be discussed in this chapter within the context of the existing literature.

In terms of significance levels, the alpha criterion for significance was set to $\alpha = 0.05$ for presentation of the results in the previous chapter. However, in order to minimise the number of spuriously significant correlations arising from the inclusion of all thirteen measures in the correlation matrix, the alpha criterion for significance was set to $\alpha = 0.01$ in terms of Spearman rank-order correlations, for discussion purposes in this chapter. Significance levels were held at $\alpha = 0.05$ in terms of Fisher-z transformations and Stepwise multiple regression analysis, for both presentation (chapter 3) and discussion (chapter 4) purposes. Similarly, results for the four working memory tasks, and the four phonological awareness tasks, as well as their composite scores were reported in the previous chapter, but in the current chapter the composite scores for the working memory measures, that is WM, STM, and MC will be excluded from the discussion, in an attempt to prevent duplication of results. Thus, only v-STM, VS-STM, v-WM, VS-WM, BBF, BBM, BBE, BBSC, RTAA and RCPM are discussed.

RCPM

The RCPM was included in this study as a control variable in order to provide a baseline measure to determine whether the two language groups were comparable in this respect. Performance by the EL1 and EL2 groups on the RCPM yielded unexpected results in that a significant difference was found between the RCPM mean raw scores for the two language groups, where the EL1 group performed significantly better than the EL2 group. Despite the significant difference in performance, correlations between RCPM and working memory measures were similar for the two language groups, but less similar in terms of the phonological awareness measures. This will be discussed later in this chapter.

Relationship between working memory measures, phonological awareness measures and non-verbal intelligence

As mentioned in chapter 3, the overall working memory score (MC) is a composite of the four working memory task scores, each of which assesses a different aspect of working memory. Firstly, the four tasks will be considered in isolation, starting with the short-term memory tasks followed by the working memory tasks, and their relationship with phonological awareness and non-verbal intelligence. From chapter 1, the reader will recall that within the working memory construct, the visuo-spatial component consists of a short-term memory component, for those tasks which require only storage of information, and a working memory component for those tasks which require both storage and processing. The verbal component too, consists of two components, namely a short-term component, which is used for the storage of verbal information within the phonological loop, and is utilized only for those tasks that require no processing; and a working memory component which is used for storage and processing of verbal information, within the central executive (Gathercole & Pickering, 2000). It was thus expected that verbal memory, that is verbal short-term memory and verbal working memory, would be significantly associated with the phonological awareness measures, and this will therefore lead this discussion. Results also implicated one of the visuo-spatial components, namely visuo-spatial working memory, in one of the phonological awareness tasks, namely BBE, and this aspect will thus be included in the discussion. VS-STM was neither correlated with, nor predicted performance on any phonological awareness measures, but a brief discussion will address the EL1 and EL2 groups' performance on the task, and its relationship with RCPM.

The first task, verbal short-term memory (v-STM), is the only one of the four memory tasks on which the EL1 group did not perform significantly better than the EL2 group, suggesting that the two groups enjoy equivalent ability in terms of this task, which was not unexpected. Although the EL1 group performed significantly better on the RCPM task, the correlation between non-verbal intelligence and verbal short-term memory was not significant for either language group, and thus the difference in performance on RCPM did not reflect in the performance on v-STM. However, the remaining working memory tasks were significantly correlated with RCPM, and thus significant differences in performance on these tasks were anticipated.

In relation to the first phonological awareness task, the Bradley and Bryant Sound Categorisation Task, the findings revealed that v-STM was significantly correlated with BBF in the EL2 group, but not in the EL1 group. The finding for the EL1 group is supported by Oakhill and Kyle's (2000) results from a study conducted on 58 children, aged 7 and 8 years old, which showed no significant relationship between v-STM and an adaptation of Bradley and Bryant's (1983) Sound Categorisation Task by Cain, Oakhill and Bryant (2000). The EL2 finding is supported by results from the Alloway et al. (2004) study, in which the age of the sample was slightly younger (4 to 6 years old) than that of the current study, where a moderate correlation between verbal short-term memory tasks, namely digit recall and word recall, and sound categorisation tasks, namely rime detection and initial consonant detection was found. Thus, current results indicate that it was only the EL2 group which accessed verbal short-term memory when performing the sound categorisation tasks, particularly the alliteration task, on which performance by the EL2 group depended significantly more on v-STM than the EL1 group. In terms of the relative contribution of v-STM to performance on the sound categorisation tasks, v-STM predicted 31% of the variance in performance on BBF, and 19% of the variance in performance on BBM in the EL2 group. The findings yielded in terms of the EL2 group are supported by those of Oakhill and Kyle (2000), that wordspan, an aspect of verbal short-term memory, predicted performance on the sound categorisation task as adapted from Bradley and Bryant's Sound Categorisation Task (1983) by Cain, Oakhill and Bryant (2000) .

The findings yielded in terms of the correlations between the variables in the EL1 group are supported by Oakhill and Kyle's (2000) findings for the 7- to 8-year-old sample. Results for the EL2 group are supported by Alloway et al.'s (2004) findings in a younger sample, aged 4 to 6 years olds. Thus, findings in terms of the EL1 group are supported by those shown in older children, and the EL2 group by those shown in younger children, suggesting that, in terms of the relationship between v-STM and phonological awareness, the two language groups may be functioning at different developmental levels. Of significance is the relationship between v-STM and Bradley and Bryant's first sound task, namely the alliteration task. Findings for the EL1 group are supported by Bradley and Bryant's (1985) findings which indicate that verbal short-term memory is not implicated in performance on the alliteration task, but which differ to findings for the EL2 group which used verbal short-term memory significantly more than the EL1 children, to conduct alliteration tasks.

In terms of the second phonological awareness task, Rosner's Test of Auditory Analysis Skills (RTAA) was not significantly correlated with v-STM in the EL1 group, but was moderately significantly correlated in the EL2 group, showing a similar pattern to that with the sound categorisation tasks, discussed above.

Oakhill and Kyle (2000) found that, in terms of short-term memory, verbal short-term memory was weakly correlated with a phoneme deletion task, which involved the deletion of a single phoneme from a consonant cluster, and was deemed to be at a suitable level of difficulty for the 7- and 8-year old sample. Verbal short-term memory also accounted for a small proportion of the variance in predicting performance on this task. In the current study, v-STM accounted for 26% of the variance in predicting performance on RTAA in the EL2 group, but, as was to be expected, had no predictive value in the EL1 group.

It has been suggested that short-term memory tasks are one way of tapping underlying phonological skills (McDougall et al., 1994), and as mentioned, Oakhill and Kyle (2000) found that verbal short-term memory correlated significantly with the phoneme deletion task, although weakly, and with the overall sound categorisation score in a sample of 7- to 8-year-old children in the United Kingdom. This supports the current findings in terms of the EL2 group, but not the EL1 group, for whom no significant relationship existed between verbal short-term memory and the phonological awareness tasks. The findings in terms of the EL1 group are supported by those of earlier research (e.g. Alloway, Gathercole, Adams, Willis, Eaglen & Lamont, 2005; Gathercole et. al., 1991) in which a distinction between the two constructs, namely phonological awareness and short-term memory, was identified, suggesting that although both these measures are subject to the effectiveness of phonological processing, they reflect distinct cognitive processes.

The second short-term memory component is visuo-spatial short-term memory (VS-STM), for which a significant difference was found between the mean raw scores for the EL1 and EL2 groups, indicating that the EL1 group performed significantly better on this task. Both the EL1 and EL2 group accessed non-verbal intelligence to perform the VS-STM tasks, and consequently RCPM was found to predict performance on VS-STM, and accounted for 20% of the variance in the EL1 group, and for 24% of the variance in the EL2 group, suggesting that this relationship was similar for the groups. In terms of the relationship between the two variables, no significant difference was observed between the EL1 and EL2 groups. Thus, correlations between VS-STM and RCPM were similar between the two language groups.

In addition to the short-term memory tests which assess the storage component of working memory, the AWMA includes two working memory tests that assess the processing component. Until fairly recently, a single test was utilised to assess working memory in young children, in line with the tripartite structure as proposed by Baddeley (1986, 2000) and Gathercole et al. (2000). Due to the verbal nature of the earlier visuo-spatial working memory test utilized in the assessment of older children and adults, it was deemed not suitable for use with young children. However, an age-appropriate, non-verbal test has recently been developed, and is included in the AWMA. Thus, verbal working memory and visuo-spatial working memory have been assessed, and will be discussed separately in this study.

The third of the four memory measures, and first working memory component, is verbal working memory (v-WM). The EL1 group performed significantly better on this task than the EL2 group. No significant differences were found between the correlations between v-WM and phonological awareness measures, and between v-WM and non-verbal intelligence for the two language groups. Further, non-verbal intelligence was both implicated in, and predicted performance on, verbal working memory tasks in both the EL1 and EL2 groups.

Verbal working memory was not significantly correlated with any of the three individual sound categorisation tasks for either the EL1 or EL2 group, but a significant relationship existed with the overall sound categorisation score for the EL2 children only. The finding for the EL2 group is supported by those of Alloway et al. (2004) and Oakhill and Kyle (2000), who found a significant relationship between v-WM and sound categorisation tasks, that is rime and alliteration tasks and oddity detection tasks. In the current study, regression analysis identified v-WM as a significant predictor of BBM (accounting for 14% of the variance), and of BBSC (also accounting for 14% of the variance) in the

EL1 group, which supports Oakhill and Kyle's findings which identified verbal working memory as a predictor of overall sound categorisation in the 7- to 8-year old sample. Although the correlation was significant, results yielded for the EL2 group indicated no predictive relationship between v
-WM and the sound categorisation tasks. Thus, earlier research supports the correlational association between v-WM and BBSC in the EL2 group (Alloway et al.; Oakhill & Kyle), and supports the predictive value of v-WM on BBM and BBSC in the EL1 group (Oakhill & Kyle).

As was the case with the sound categorisation tasks, the relationship between v-WM and the second phonological awareness task (RTAA), was significant only for the EL2 group, indicating that the EL2 children may depend more on working memory skills than the EL1 children when performing the auditory analysis tasks. In support of the findings for the EL2 group, Oakhill and Kyle (2000) also observed a significant correlation between verbal working memory and RTAA. The current research, in which verbal working memory did not predict performance on RTAA for either the EL1 or EL2 group despite the significant correlation in the EL2 group, was contradictory to Oakhill and Kyle's findings in which verbal working memory predicted variance in performance on the phoneme deletion task. This difference may be attributable to the fact that the Oakhill and Kyle sample, although the same age as the sample in the current study, had started school at a younger age and thus had been exposed to literacy instruction, which is an essential component in the development of phonological awareness, for a longer period.

The inclusion of the visuo-spatial working memory test (Alloway et al., 2006), which assesses the second component of working memory, has enabled the current study to examine the relationship between VS-WM, phonological awareness and non-verbal intelligence in young children, independently of either visuo-spatial short-term memory or verbal working memory. The VS-WM task assesses non-verbal, combined storage and processing abilities, and has been found to contribute to the identification of developmental changes in the structure of working memory in children, which has relevance for the current study. In addition, the current study yielded data which supports the inclusion of VS-WM in the assessment of working memory. This will be addressed following the general discussion.

Data from the current study yielded the following results in terms of VS-WM. The EL1 group performed significantly better on the VS-WM task than the EL2 group. RCPM was correlated with, and predicted performance on VS-WM for both language groups.

As with the short-term memory tasks, the EL2 group appears to have depended significantly more on visuo-spatial working memory than the EL1 group when performing the sound categorisation tasks, which was substantiated by the significant differences in strength of correlations between VS-WM and BBE, and between VS-WM and RTAA when the language groups were compared. The difference in terms of BBE may indicate a difference in rime awareness, since BBE is the end sound categorisation task, and may be linked to familiarity with nursery rhymes and rhyming words in the EL1 group. While the Nguni and Sotho language group (EL2) have a strong oral tradition in terms of story telling, rhymes are not a typical part of that tradition and the EL2 group may not have encountered rhymes prior to entering Grade 1 (Cockcroft, 2002a).

In terms of VS-WM and RTAA, a non-significant negative correlation existed for the EL1 group, which, due to the verbal nature of the RTAA task, and the fact that it accesses short-term memory skills, was to be expected. A positive correlation ($p < 0.05$) existed for the EL2 group. In light of the current findings, this was also to be expected, as there appears to be less dissociation between verbal working memory and visuo-spatial working memory in the latter group, as indicated by the strong correlation between the two variables. Normally the above correlation, which was not significant at $p < 0.01$, would have been excluded from this discussion, however, a significant difference in correlations was found to exist between the language groups, and it will thus be included. This finding indicates that the EL2 group, in performing the auditory analysis task, relied significantly more on VS-WM than the EL1 group ($z = -2.77$; $p<0.01$), which did not appear to access this skill when performing this task. In addition, regression analysis identified VS-WM as a predictor of performance on the RTAA task in the EL2 group, but not in the EL1 group, supporting this difference.

Both Oakhill and Kyle (2000) and results yielded by the current research data for the EL2 group support the view that the sound categorisation tasks (BBF, BBM, BBE) are more demanding of working memory than is the phoneme deletion task (RTAA), as the tasks assess slightly different aspects of phonological awareness, at different levels of analysis. Thus, the relationship between working memory and phonological awareness appears to be dependent on the depth of analysis of phonological awareness, which determines the level of demand made on working memory. The phoneme deletion task assesses the level of phonemes which relates to Adams' (1990) fifth level and appears to implicate fewer working memory skills, while the sound categorisation task assesses phonological awareness at the level of onset and rime, which relates to Adams' second level, and places a higher demand on working memory. This may relate to the size of the phonological units to be retained in working memory, as phonemes are smaller than onsets and rimes, and would thus determine the level of demand made on working memory. This was relevant for only the EL2 group, as no significant correlations were identified between the working memory components and phonological awareness measures for the EL1 group, suggesting that they accessed skills, or resources, not assessed in this study, when performing the phonological awareness tasks.

In terms of the role of home language in the relationship between working memory and phonological awareness, the most noticeable difference relates to the number of significant associations between variables. In terms of the EL2 group, numerous significant correlations were identified between the variables, suggesting that the EL2 group accessed a cluster of more general, related skills in order to conduct the various tasks, and that the same skills seem to be implicated in performance on a variety of tasks. This may relate to a relatively integrated working memory structure, and may be an indication of the level of cognitive development in this group, which is comparable to that of younger British children (Alloway, et al., 2004). Results for the EL1 group showed fewer significant relationships between the variables, and suggest that different elements may have been involved in their performance on the working memory and phonological awareness tasks. The auditory analysis task and the sound categorisation task appear to be entirely independent of working memory skills in the EL1 group. These children appear to be using skills not tapped by the measures included in this study, as phonological awareness was also not related to RCPM.

The separate visuo-spatial working memory measure provided data relating to the structure of working memory, and has also allowed for developmental changes during childhood to be monitored (Alloway et al., 2006).

The structural validity of the working memory model (Gathercole & Pickering, 2000), as adopted in the current study, is supported by results yielded by the current study. Earlier studies (e.g. Jarvis & Gathercole, 2003, as cited in Alloway et al., 2006) confirm the relative independence of verbal and visuo-spatial short-term memory from a more domain-general working memory component in young children. More recent data (e.g. Alloway et al., 2006) has shown that, notwithstanding the domain-general working memory model, verbal working memory and visuo-spatial working memory may be dissociated. The association between the short-term memory measures, that is visuo-spatial short-term and verbal short-term memory was not significant at $p < 0.01$ in the current study, and supports the relative independence of these structures within the domain-general tripartite structure. The stronger association between visuo-spatial and verbal working memory measures (r_sEL1 = 0.50; $p<0.01$; r_sEL2 = 0.56; $p<0.01$) indicated that the EL2 group showed a differentiated, yet slightly more integrated working memory component, with less partition between these components than the EL1 group. This may explain the results yielded by their performance on the phonological awareness and working memory tasks, particularly the unexpected implication of VS-WM in phonological awareness tasks.

Developmental changes during childhood (Alloway et al., 2006) are pertinent to this study as it involves children. The current data revealed that the link between the domain specific visuo-spatial storage construct, namely visuo-spatial short-term memory (as assessed by tasks which measure the ability to hold information in mind for a brief period of time, such as the Dot Matrix and Block Recall tasks of the AWMA) and the domain-general visuo-spatial processing construct, namely visuo-spatial working memory (as assessed by tasks that measure the capacity to hold in mind and manipulate information over a brief period of time, such as Mr X and Spatial Span), although not significant, differed between the groups (r_sEL1 = 0.45; $p<0.01$; r_sEL2 = 0.58; $p<0.01$). These findings are supported by those of Alloway et al. (2006) who found that developmental patterns for the visuo-spatial domain differed across age groups, and that younger British children (4- to 6-year-olds) tended to draw more on executive resources when performing visuo-spatial short-term memory tasks, thus showing greater intercorrelations among tasks of processing and storage. The relationship between VS-STM and VS-WM was found to be significantly stronger in the 4- to 6-year-old sample, when compared with children aged 7 to 11 years old (Alloway, et al.), and performance by the EL2 group appears to be very similar to that of the 4- to 6-year-old sample in Alloway et al.'s study in relation to correlations between these memory tasks. This also supports the findings in the current study, in that the relationship in the EL1 group was weaker when compared with the relationship in the EL2 group. This suggests developmental differences in working memory which appear to be related to home language, and thus the EL2 group may be functioning at a different developmental level to the EL1 group in terms of working memory. It appears that, as the children mature, the central executive and short-term storage components of working memory become less highly correlated. However, this would need to be confirmed in the South African context by a larger sample. It should be noted that Alloway et al.'s findings relate only to the visuo-spatial component of working memory, and do not extend to verbal working memory, as their data yielded no evidence of developmental change in the relationship between the verbal storage and processing components of the latter across different age groups.

As discussed, performance on most working memory, phonological awareness and non-verbal intelligence tasks was significantly higher in the EL1 group than in the EL2 group. In an attempt to gain some clarity on this disparity between the two language groups, a study by Alloway, Gathercole, Adams, Willis, Eaglen, et al., (2005) was consulted. The investigation reported on working memory and phonological awareness as predictors of academic progress in a sample of 194 British children (mean chronological age 61.1 months). Working memory measures were taken from the WMTB-C (Pickering & Gathercole, 2001) which is an earlier version of the AWMA; and the phonological awareness measures included a rime detection task, similar to the BBE task, and an initial consonant detection task, similar to the BBF task. Alloway et al.'s results were very similar to those found in the current study in terms of the relationship between verbal working memory, verbal short-term memory, phonological awareness and non-verbal intelligence in the EL2 group. As indicated above, the age of Alloway et al.'s sample was younger than that of the current study (EL1 - mean chronological age 87.1 months; EL2 - mean chronological age 86.1 months), but may be comparable in terms of all three groups being registered at school for their first year of formal education. Correlations for the EL1 and EL2 groups in the current study and Alloway et al.'s younger group of children are detailed below. In order to enable a comparison to be drawn between the three groups, both significant and non-significant correlations are reported.

Verbal working memory (v-WM) was correlated with verbal short-term memory (v-STM) (r_sEL1 = 0.13; $p>0.01$; r_sEL2 = 0.51; $p<0.01$; r Gathercole = 0.57; $p<0.01$); with phonological awareness (r_sEL1 = 0.38 [BBSC]; $p>0.01$ and 0.07 [RTAA]; $p>0.01$; r_sEL2 = 0.44 [BBSC]; $p<0.01$; and 0.47 [RTAA]; $p<0.01$; r Gathercole = 0.50; $p<0.01$); and with non-verbal intelligence (r_sEL1 = 0.40; $p<0.01$; r_sEL2 = 0.52; $p<0.01$; r Gathercole = 0.48; $p<0.01$). Verbal short-term memory was further correlated with phonological awareness (r_sEL1 = 0.17 [BBSC]; $p>0.01$; and 0.08 [RTAA]; $p>0.01$; r_sEL2 = 0.53 [BBSC]; $p<0.01$; and 0.48 [RTAA]; $p<0.01$; r Gathercole = 0.57; $p<0.01$); and with non-verbal intelligence (r_sEL1 = 0.02; $p>0.01$; r_sEL2 = 0.28; $p>0.01$; r Gathercole = 0.33;

p<0.01). In addition, phonological awareness was correlated with non-verbal intelligence (r_sEL1 = 0.11 [BBSC], p>0.01 and -0.09 [RTAA], p>0.01; r_sEL2 = 0.23 [BBSC], p>0.01; and 0.42 [RTAA], p>0.01; r Gathercole = 0.29; p<0.01).

It is apparent that the results obtained for the EL2 group in the current study in terms of correlations, are very similar to those observed by Alloway, Gathercole, Adams, Willis, Eaglen et al. (2005) in the 4- to 5-year-old sample. The relevance of the comparison between the current study and that of Alloway et al. lies not only in the similar correlational statistics between the EL2 group and Alloway et al.'s sample, but also in the differences between these and the correlations for the EL1 group, particularly the relationships involving verbal working memory and verbal short-term memory, namely between v-WM and verbal short-term memory, between v-WM and the phonological awareness measures, between v-WM and non-verbal intelligence, between v-STM and the phonological awareness measures, and between v-STM and non-verbal intelligence.

In criticism of this comparison, it may be argued that British children are first enrolled at school between the ages of 4 and 5 years old, whereas South African children only begin their formal education between the ages of 6 and 7 years old. However, although the British sample was chronologically younger than the South African EL1 and EL2 samples, as previously mentioned, the children from all three groups were enrolled in their first year of formal education and thus it may be expected that they would be functioning at a similar academic level. It is generally accepted that the development of phonological awareness skills is strongly related to the age of learning to read as there appears to be a reciprocal causal relationship between reading and phonological awareness, in which phonological awareness accelerates and assists reading acquisition in an alphabetic language, and also develops as a consequence of having learned to read (Lopez & Greenfield, 2004; Wagner, Torgesen & Rashotte, 1994). Cockcroft (2002a) found that differences in performance between EL1 and EL2 groups of children (which were similar in terms of orthography to the EL1 and EL2 sample in the current study) on phonological awareness measures at pre-school level disappeared after exposure to reading instruction. It is possible that the EL2 group in the current study had not experienced the same exposure to the foundation skills required for the development of phonological awareness that the EL1 group may have had. It is therefore possible that the EL2 children in the current study will perform at a similar level to the EL1 children after a period of reading instruction.

Notwithstanding these limitations, data yielded from the current study suggest that the EL2 children draw on a wider range of skills in order to conduct various working memory and phonological tasks, as indicated by the appreciably larger number of correlations between them, and the significantly higher strength of the correlations observed between the variables relative to the EL1 children. These skills are important for performance on the tasks for only the EL2 group. It appears plausible to assume that the EL1 group and the EL2 group are functioning at different levels of development in terms of both working memory and phonological awareness. This distinction may be due to any of a number of factors surrounding cognitive development, depth of orthography and bilingualism.

In terms of cognitive development, this disparity between the language groups may be due to developmental fractionation (Hitch, 1990), or cognitive mechanisms developing at different rates. Pickering et al. (2001) found evidence of a developmental fractionation, which they propose results from whether tasks are presented in a static or dynamic format. The AWMA, which was used to assess working memory in the current study, includes tasks which involve both static formats, and dynamic formats such as visuo-spatial short-term memory tasks, namely perceptuo-motor tracking of dots and block in the Dot matrix and Block recall tasks which involve executive functions. A second explanation for the dependence on executive resources could simply be that the brain areas related to higher-level cognition are still developing (Nelson, 2000).

An alternative explanation relates to the orthographic structure of the opaque and transparent languages. Although performance on the sound categorisation tasks was disparate between the groups, with the EL1 group performing significantly better than the EL2 group, performance on RTAA, which assesses both syllable splitting and phoneme manipulation skills, was similar for the two language groups. This indicates that, in the EL2 group, the skills required to perform the RTAA task were more developed than those required to perform the BBSC tasks. This may be understood in terms of the orthographic structure of the languages. Larger phonological units (onsets, rimes and syllables), as assessed by the sound categorisation tasks, are more salient in the opaque English language than in the more transparent Nguni and Sotho languages, where the emphasis falls more strongly on the phoneme (Guma, 1971). The EL2 group may thus have been using their first language phonological skills and syllable structures to complete the RTAA tasks (particularly the phoneme manipulation aspect) as phonological awareness skills have been found to be transferable across languages (Abu-Rabia & Siegel, 2002). Similarly, the main emphasis of the English orthography on rimes, syllables, and particularly onsets would explain the EL1 group's superior performance on the sound categorisation tasks, particularly those involving alliteration.

In addition to the structure of language, the level of proficiency in a language may affect phonological awareness. Gorman and Gillam (2003) state that when and how a child was exposed to each language, will have significant implications for assessment, as a child's particular language experience will have a considerable impact on his or her phonological knowledge. The current findings may thus be due to the age at which the EL2 group achieved their bilingual status, as in terms of sequential bilingualism, the sample may have included children who had not yet achieved the same level of English proficiency as that of their home language. A shortcoming of the current study was that the level of bilingualism, and thus bilingual status, were not assessed.

Research suggests that bilingualism facilitates the acquisition of language-related skills (e.g. Bruck & Genesee, 1995; Lesaux & Siegel, 2003). Bruck and Genesee found that children exposed to more than one orthography are likely to have heightened levels of explicit phonological awareness than monolinguals, and as a result of their dual language exposure, the EL2 group would have been expected to have had a greater awareness of the sound structure of words and hence to have performed better on the phonological awareness tasks than the EL1 children, yet, there was no significant difference in performance between the language groups on most of the phonological awareness tasks. However, numerous significant correlations were found between the working memory and phonological awareness measures for the EL2 group as opposed to the few correlations evident within the EL1 group. This may reflect a greater awareness of the sound structure of words in the EL1 group which enabled them to perceive the phonological awareness tasks as unrelated to one another by virtue of their different demands.

The primary aim of this study was to identify the relationship between working memory, phonological awareness and non-verbal intelligence for the two language groups. Beyond the primary aim, the data yielded some interesting results with regard to differences between the language groups within each set of tasks, and the following discussion addresses these findings, firstly within the working memory tasks, and secondly within the phonological awareness tasks, and their relationship with RCPM.

Working memory

The individual working memory mean raw scores between the two language groups were significantly different, indicating that the EL1 group performed significantly better than the EL2 group on all working memory tasks, with the exception of v-STM, where there was no significant difference between the groups. A comparison of the correlations between working memory scores indicated that the associations were fairly similar for the two language groups. Examination of the data identified differences generally relating to the number and strength of associations between the individual tests, and the composite scores. These were more numerous and stronger in the EL2 group, when compared with the EL1 group. In all relationships, with the exception of the relationship between VS-STM and STM, the strength of the association was stronger in the EL2 group.

In terms of the four working memory measures, most tasks were significantly correlated for both language groups. The exceptions related to the association between v-STM and the remaining three memory tasks for the EL1 group and the correlation between v-STM and VS-STM, and between v-STM and VS-WM, for the EL2 children, none of which was significant.

Alloway et al. (2006) found several working memory correlations within the 7- to 8-year-old age band. Individual test scores were reported for each of the three subtests assessing the four components of working memory, namely v-STM, VS-STM, v-WM, and VS-WM. No composite scores were reported, and thus the range for each group of subsets is presented here. In terms of v-STM correlations ranged from 0.33 - 0.48 with v-WM; from 0.26 - 0.41 with VS-STM; and from 0.17 - 0.35 with VS-WM. In terms of v-WM, correlations ranged from 0.33 - 0.46 with VS-STM; and from 0.25 - 0.59 with VS-WM. In terms of VS-STM correlations ranged from 0.25 - 0.48 with VS-WM. Generally, these results appear to support the findings for the EL1 group in the current study, as the majority of correlations for the EL2 group fall outside the upper limit of these ranges. This supports the earlier suggestion regarding developmental differences between the EL1 and EL2 children in terms of working memory functioning.

The only notable difference, in terms of correlations between working memory variables, although not statistically significant, related to the association that emerged between the two verbal memory tasks, namely v-WM and v-STM, which was significant only in the EL2 group. The correlation between the visuo-spatial memory components, namely VS-WM and VS-STM was similar between the groups. The results indicate that in the EL1 group the relationship between the visuo-spatial memory components was stronger than that between the verbal components in the EL1 group.

Thus, in terms of the EL2 group, as observed in the relationship between working memory and phonological awareness, the components of working memory appear to be less differentiated, and accessed in more instances, than in the EL1 group.

Again, this is indicated by both the number and strength of the correlations yielded by the data.

In terms of RCPM, the relationship with MC was significant for both the EL1 and EL2 groups, which prompted an investigation into the nature of this relationship.

Colom et al. (2004) found working memory to be highly related to *g* (general intelligence), as defined by several diverse tests which included fluid intelligence. Regression analysis revealed that RCPM predicted MC for both the EL1 group (accounting for 29% of the variance) and the EL2 group (accounting for 36% of the variance), a finding which was expected, as some memory tasks in the current study, particularly the working memory tasks, were strongly correlated with non-verbal intelligence, which reflects the ability to keep a representation active in the face of interference (Engle et al., 1999). The predictive value of RCPM differed only by a relatively small margin between the language groups.

In addition to the above findings, results obtained on the phonological awareness measures also presented some interesting results, particularly in terms of performance on the individual tasks. These are discussed below.

Phonological Awareness

Unlike the RCPM scores and the majority of working memory scores, the phonological awareness mean raw scores differed significantly between the two language groups only in one case, namely BBF. The EL1 group significantly outperformed the EL2 group on this measure. Metsala (1999) stated that the more familiar a word is, the easier it is to segment into its constituent parts, and it is assumed that the unfamiliarity of some words in the sound categorisation task may have impacted on the performance of the EL2 children. In spite of the significant difference in performance on this phonological awareness measure, the nature of the correlations between all phonological awareness measures was generally similar in the two language groups. The three Bradley and Bryant Sound Categorisation Tasks were significantly correlated with one another in both the

EL1 and EL2 groups. All sound categorisation scores were also significantly correlated with RTAA in both language groups, suggesting that, not only the relationship between the three tasks, but also the relationship between the two tests of phonological awareness, was similar between the two language groups.

Some studies have shown non-verbal intelligence to be correlated with phonological awareness (e.g. Alloway, Gathercole, Adams, Willis, Engle, et al., 2005; Alloway et al., 2004). In the current study, RCPM was not significantly correlated with BBSC or its component tasks in either the EL1 or the EL2 groups, which indicates that non-verbal intelligence was not implicated in the sound categorisation tasks. In terms of RTAA, non-verbal intelligence was accessed significantly more by the EL2 group than by the EL1 group. The findings for the EL1 group are supported by those of Cockcroft (2002a) which revealed no significant correlation between RCPM and BBSC or RTAA.

As mentioned earlier, Bradley and Bryant's Sound Categorisation Tasks, which are oddity detection tasks, measure the child's onset (alliteration) and rime awareness. First sound oddity detection is a measure of onset awareness and phoneme awareness, since the first sounds are also single phonemes, and together, the middle and end sounds, constitute a word rime. The final sound oddity detection also constitutes a form of rime knowledge (Cockcroft, 2002a). The tasks require the child to remember three or four words in order to say which is the odd one out, and thus involves short-term and working memory as well as phonological skills (Bradley & Bryant, 1985).

In terms of the individual sound categorisation test scores, it may have been expected that results for the EL1 group would be supported by British findings, and that the results for the EL2 group may have differed due to their EL2 status, and structural differences in their home language to English. According to Bradley and Bryant (1985) in the three conditions, rime, as tested by the middle and end sound conditions, is much easier than alliteration, which is tested by the first sound condition. Developmentally, children recognize rime some time before alliteration, and recognition of alliteration only seems to occur some time after children go to school (Carillo, 1994).

Surprisingly, findings from the current study (refer to Table 5) indicate that both language groups obtained the highest score on the alliteration tasks, namely the first sound categorisation task, followed by the rime tasks, namely the end sound categorisation task, and finally the middle sound categorisation task which proved to be the most difficult. Cockcroft (2002a), in a study of South African Grade 1 children of the same age, found that the EL1 children scored highest on the middle sound task, followed by the first sound task, and that the end sound task was experienced as the most difficult task. Performance by the EL2 group in Cockcroft's study differed somewhat, in that the children scored highest on the first sound task, followed by the middle sound task, with the end sound task presenting as the most difficult task. This is contrary to Bradley and Bryant's (1985) finding that the first sound task was experienced as the most difficult task. The reason for the disparity between the Bradley and Bryant, the Oakhill and Kyle (2000) and the current findings is unclear, but may be explained in terms of formal education. Teaching methods may have impacted on performance on the above tasks in the form of teaching focus. In South African schools, in Grade 1, each term is devoted to focus on word sounds in a particular location in words, for example, beginning sounds, middle sounds and end sounds, and thus the focus will be on either rime or alliteration, and this focus may have impacted on the child's performance on the sound categorisation tasks, depending on the time of the school year at which testing took place.

The superior performance on the alliteration task in terms of the EL2 group may be explained by the large number of Zulu speaking children in the sample. Scores obtained on the BBF task by the EL2 group were higher than those obtained on the BBM and BBE tasks, indicating that they found the alliteration task easier than the rime tasks, which may be explained in terms of language structure. In the Zulu language, all nouns tend to begin with one of only twelve class prefixes, such as *u-, ama-, i-* (de Picciotto & Watt, 2003), and as 57% of the children in the EL2 sample spoke only Zulu as their home language, this could, in addition to teaching focus, explain their superior performance on the alliteration task.

Since the results for the sound categorisation tasks revealed a number of differences between the language groups, it was expected that examination of the data for the second phonological awareness task, RTAA would reveal similar results. Firstly, however, as a hierarchic relationship has been found to exist between BBSC and RTAA (Adams, 1990), it is pertinent to present a brief discussion addressing this relationship, prior to discussing the RTAA results.

The relationship between BBSC and RTAA was similar for the EL1 and EL2 groups. This was to be expected, as developmentally competence in sound categorisation skills precedes competence in auditory analysis skills (Adams, 1990). The predictive value of BBSC on RTAA was significant in both the EL1 and EL2 groups. In terms of the predictive value of the three individual BBSC tasks on performance on RTAA, BBE had a stronger predictive value in the EL1 group accounting for 29% of the variance, than in the EL2 group in which this rime task accounted for only 10% of the variance. BBF, the alliteration task, accounted for only 7% of the variance in the EL1 group, but accounted for 49% of the variance in the EL2 group. Thus, the alliteration task was the primary predictor of performance on RTAA in the EL2 group, whereas the rime task was the primary predictor in the EL1 group, which again, appears to relate to the orthographic structure of their home languages.

In terms of performance on RTAA, the two language groups appeared to be functioning at similar levels. RTAA is primarily an elision task that assesses the child's ability in both syllable segmentation, and phoneme manipulation which has a working memory component making this a more difficult task than phoneme segmentation (Yopp, 1988). One score was provided for both skills. However, as the current study examined the relationship between working memory and phonological awareness it may have been beneficial to separate out the syllable segmentation tasks, which involve only storage skills, from the phoneme manipulation tasks, which require both processing and storage skills, into two separate variables as the demand made on working memory would differ between the tasks.

It is not surprising that, as with BBSC, a strong association with working memory was found in the current research, particularly with those tasks requiring phoneme manipulation. It was also anticipated that results for the auditory analysis tasks would be similar to those for the BBSC tasks in terms of home language, namely that the EL2 group would access a wider range of skills when performing the task, which was found to be the case. One would have expected that phoneme deletion tasks make demands on both storage and processing, because these tasks require the child to hold the word in mind, remove one sound and work out what is left, but this applied only to the EL2 group, which, it appears, utilised aspects of working memory to perform auditory analysis tasks, whereas performance by the EL1 group appears to be independent of working memory.

In terms of the role of non-verbal intelligence in performance on the RTAA tasks, non-verbal intelligence was only implicated in performing this task in the EL2 group. Analysis of the relationship between RCPM and RTAA revealed that this difference between the language groups was significant ($z = -2.16$), which indicates yet again that the EL2 group depended on a broader range of skills, including non-verbal intelligence, in order to perform the auditory analysis task.

Since the role of non-verbal intelligence in performance on both working memory and phonological awareness tasks, as detailed in the above discussion, was in some instances dissimilar between the groups, a brief summary of these differences follows.

RCPM – non-verbal intelligence

In terms of differences between the two language groups, RCPM was significantly correlated with most working memory scores for both the EL1 and EL2 groups, and no significant difference in correlations was found between the language groups. This suggests that the relationship between non-verbal intelligence and working memory scores was fairly similar between the language groups, and may indicate that non-verbal intelligence is essential for successfully performing memory tasks, particularly working memory tasks, irrespective of home language.

RCPM was significantly correlated with BBE and RTAA for the EL2 group, but with no phonological awareness scores for the EL1 group. It appears that the EL2 group accessed non-verbal intellectual ability when performing syllable splitting, phoneme manipulation and end sound categorisation tasks, but not when performing alliteration tasks, or when performing the middle sound tasks. This suggests that the relationship between non-verbal intelligence and phonological awareness scores may differ between the language groups and this was observed in terms of the relationship between non-verbal intelligence and RTAA, but not in terms of BBSC. It would have been beneficial, in light of this finding, to have separated out the component tasks of RTAA, that is the syllable awareness tasks from the phoneme deletion tasks, in order to determine whether, and to what extent, these individual scores may have expanded on the above finding in relation to the orthographic structure of the home languages of the EL2 children.

In terms of the working memory tasks, RCPM was significantly correlated with VS-STM in both language groups, with VS-WM in both language groups, and with v-WM only in the EL2 group. Of interest is the observation that v-WM was significantly correlated with RCPM in both the EL1 and EL2 groups, and the implications of this finding, in terms of the non-verbal nature of the RCPM warrant discussion.

Although not the main focus of the research, in that it was initially only intended as a control variable in order to provide a baseline measure to determine whether the two groups were comparable in this respect, the RCPM data yielded some interesting findings. In addition to the relationship between RCPM, working memory and phonological awareness tasks as discussed, two additional findings emerged from the RCPM results.

The significant difference between the language groups in performance on the RCPM was unexpected, as the RCPM have been found to be minimally dependent on language and culture-fair (Raven et al., 1998). It was anticipated that there would be no significant difference between the two language groups as all participants were enrolled in their first year of schooling, and it was thus assumed that they were at an approximately equivalent educational level.

The difference in performance on the RCPM by the EL1 and EL2 groups may relate to the construct validity of the RCPM and the influence of home language on performance on the RCPM. The RCPM have been found to be culture-fair in a variety of situations (Raven et. al., 1998), and it was thus anticipated that there would be no significant difference between the two language groups. In order to be classified as culture-fair, a test must be deemed equally appropriate for all members of all cultures, which is typically achieved by removing the language component (Cockcroft, 2002b). The design of non-verbal forms of intelligence testing, however may not have considered the impact of cultural context on cognitive development. According to Sternberg (1996, p. 487), "Making a test culturally relevant appears to involve much more than just removing specific linguistic barriers to understanding" which was supported by Vygotsky (1956), who asserted that it is social interaction that determines the structure and patterns of internal cognition. Thus, speakers of different languages have differing cognitive systems, which in turn influence the ways in which they think about the world. This is known as the linguistic relativity hypothesis (Sternberg), which may have implications for the assessment of RCPM in the current study.

Findings in a recent South African study using the adult Raven's Advanced Progressive Matrices (RAPM) with a sample of first-year university students (Israel, 2006) support the linguistic relativity hypothesis, and indicated that a significant bias may exist with the RAPM. It was found that EL1 speakers were more likely to make incomplete correlate errors on the RAPM, namely errors that are basically correct but incomplete solutions, whereas EL2 speakers were more likely to conduct confluence of ideas errors, which relate to the inability to distinguish relevant information from irrelevant information. The difference in errors between the language groups may suggest a fundamentally different outlook on the way items are approached between the language groups (Sternberg, 1996). Israel's findings could possibly extend to the version of the test developed for use with children, the RCPM, and may thus account for the significantly better performance of the EL1 children when compared to the EL2 children.

Secondly, as a non-verbal intelligence test, the RCPM claim to be culture-fair (Raven et. al, 1998) and it is this claim to language independence on which its validity relies. The current study suggests that, in addition to non-verbal ability, the RCPM also draw on verbal ability, since a moderate relationship existed between RCPM and verbal working memory in both the EL1 and EL2 groups.

In summary of this discussion, a complex and generally different set of relationships was found to exist between the EL1 and EL2 groups in terms of working memory, phonological awareness and non-verbal intelligence. A summary is presented in the final chapter.

CHAPTER 5. CONCLUSION, LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

The present study extended the findings of previous studies both in terms of examining the relationship between working memory and phonological awareness and in terms of the South African context within which it was conducted. Systematic examination of these relationships identified possible differences between the language groups. It is apparent that, in terms of the two language groups, the relationship between working memory and phonological awareness differs, as observed in a number of cases where the concurrent correlates and predictors differed between the language groups.

The difference in performance on the RCPM between the language groups was unexpected due to the assumed non-verbal nature of the test, and the attendant expectation that the EL2 children would perform at a similar level to the EL1 children, as all were assumed to be at an approximately equivalent educational level. The possible implication of verbal skills in the RCPM may have contributed to the relatively poorer performance of the EL2 group on this measure, and questions the non-verbal nature of the test. Results indicated a relationship between non-verbal intelligence and working memory in both groups of children, but found no evidence to support a relationship between non-verbal intelligence and phonological awareness.

While only one significant difference was observed between the mean scores for performance on the phonological awareness tasks on the basis of language group, differences were significant on the majority of working memory tasks, indicating that in terms of phonological awareness, performance was similar between the EL1 and EL2 groups, but in terms of working memory, performance was more varied between the two groups.

Both the quantity and strength of correlations between the working memory measures, phonological awareness measures, and non-verbal intelligence were higher in the EL2 group than in the EL1 group, suggesting that the EL2 group draws on more skills, across the three constructs, in order to complete various tasks, and that the tasks are more related to one another. The observed relationships in the EL1 group suggest that a resource not included in this study was accessed by this group of children when performing the various tasks. This skill may relate to a verbal intelligence construct.

Significant differences between correlations in the two language groups indicated a stronger correlation within the EL2 group in all cases, and each difference implicated phonological awareness relationships. VS-WM and RCPM were significantly correlated with one another, and were both implicated in performance on the phonological awareness tasks only in the EL2 group, suggesting that skills not normally associated with phonological awareness (i.e. visuo-spatial memory and non-verbal intelligence) were accessed in order to complete the tasks in this group of children.

While working memory skills were not implicated in the prediction of either the alliteration task or the syllable awareness/phoneme deletion task in the EL1 group, verbal working memory predicted performance on rime tasks in this group. Verbal short-term memory and visuo-spatial working memory predicted performance on the majority of phonological awareness tasks in the EL2 group. It is unclear why verbal working memory was implicated in the EL1 group, but not in the EL2 group, and may suggest that skills not normally associated with phonological awareness were accessed by the EL2 group in order to complete the tasks, which appeared to access the visuo-spatial aspect of working memory in place of the verbal aspect.

In terms of language structure, the emphasis on phonemes in the Nguni and Sotho languages, and of larger phonological units in English, provides support for the finding that, although both alliteration and rime skills predicted performance on the RTAA tasks, the predictive value of the alliteration task was higher in the EL2 group, whereas the rime task was a stronger predictor of RTAA in the EL1 group.

Home language appears to impact on performance on the working memory, phonological awareness and non-verbal intelligence tasks, but less so on the phonological awareness tasks than on the others, and this may relate to orthographic differences in the home languages of the EL1 and the EL2 groups. In addition to orthographic differences, the effect of language on performance could possibly relate to the bilingual status of the EL2 group. Although the level of bilingualism was not assessed in this study, it is tentatively proposed that the bilingual status of the EL2 group may have had a strong influence on task performance. It appears that the depth of bilingualism and its concomitant socio-cultural influence may have influenced the development of both working memory and phonological awareness, and thus performance by the EL2 group on the tasks.

Limitations of the current study

Despite the value these findings may have within the South African context, a number of limitations were noted. There are several practical limitations which relate to both the instruments and the sample.

In terms of bilingual children, when and how a child was exposed to each language may have implications for their cognitive, and thus, memory development. Vygotsky (1956) states that internal cognition determines social interaction, and it is language that enables the child to participate in the social life of his or her cultural group. Thus, the possible impact of cultural context on the EL1 and EL2 children's cognitive development should be considered in this, and future studies. As English was not the home language of the EL2 group, it would have been appropriate to conduct a test of home language proficiency and English proficiency, which may have contributed to a greater understanding of the current findings. According to Gutiérrez-Clellen, Calderón and Weismer (2004), to evaluate the processing skills of bilingual children, their language proficiency should be evaluated based on language histories and spontaneous language measures, as bilinguals do not constitute a homogeneous group. This is particularly important in light of the nature of the tests conducted in this study.

In terms of the instruments, the culture-fairness of the tests for the EL2 group may be a significant limitation in this study. Limitations in this regard for the RCPM have been discussed in detail in the previous chapter. In addition, the exclusion of a verbal intelligence test presents a further limitation. The inclusion of a verbal intelligence test, in addition to the non-verbal test, may have accounted for findings in the EL1 group which were not explained by the tests administered in this study. Of further interest would be the examination of the role of verbal intelligence in terms of performance by the EL2 group on both working memory and phonological awareness tasks. The AWMA, which was developed in the United Kingdom may have not been culturally fair in terms of the performance of the EL1 group, but it can be assumed that it was not culturally fair for the EL2 group in terms of the fact that the test was administered in the children's second language, and possibly also in terms of the content of the tests. This was compounded by the presentation of the instructions in a fairly heavy British accent.

An additional limitation in terms of RTAA relates to the composite score obtained from the two tasks, on which the analysis was conducted. It may have been advantageous to the outcome of this study, to have separated the syllable awareness scores out from the phoneme deletion scores, as they measure distinctly different auditory analysis skills and may, together with Bradley and Bryant's Sound Categorisation Tasks, have contributed to identifying the level of phonological awareness at which the EL1 and EL2 groups were performing.

In terms of the sample, the relatively small sample and the method of sampling may have threatened the external validity of the findings. In an attempt to include only children from similar socio-economic backgrounds in this study, convenience sampling resulted in the entire sample being obtained from GDE schools in the

Johannesburg area, and thus the findings may be generalisable only to pupils attending urban, GDE schools. Further, in terms of the bilingual status of the EL2 group, and the heterogeneous nature of bilingualism, the results may not be generalisable to all bilinguals, irrespective of the depth of orthography of their home language. This could possibly have been controlled by determining the degree of bilingualism of each participant in terms of age of exposure to their various languages, and thus their level of bilingualism at the time of testing.

Bearing in mind these limitations, several suggestions for future research in the field can be made.

Suggestions for further research

In South Africa, the majority of children are exposed to more than one language, particularly as they enter formal education. Being educated in a second language has implications in terms of levels of working memory and phonological awareness, which may impact on reading development. This in turn could impact on the child's ability to cope in the classroom, and there may be associated emotional consequences (Gathercole & Alloway, 2004).

A difficulty in comparing the performance of the children in this study may have resulted from either the bilingual status of the EL2 children, the reciprocal nature of phonological awareness, or both. Many studies have examined balanced bilinguals, yet the majority of bilinguals are not equally proficient in both languages. As discussed, this refers to the two different levels of bilingualism, namely balanced and dominant bilinguals, and it is imperative for future research that this distinction be made. In terms of phonological awareness, with formal literacy instruction, children acquire the second level of more complex segmental awareness skills, such as sound-letter identification, blending, phoneme segmentation and manipulation, spelling and reading (LaFrance & Gottardo, 2005), and thus those children with prior literacy exposure may have been in an advantageous position.

In order to more accurately assess the influence of orthographic depth on working memory and phonological awareness, a longitudinal study of this nature, possibly a long-term follow up of this sample, in which these two factors, that is level of phonological awareness and bilingual status, could be controlled, should be conducted.

Conclusion

In conclusion, this study has relevance to the field of cognitive research. Theoretically, findings contribute toward an understanding of the relationship between working memory and phonological awareness in both first- and second-language English children. Results have identified a disparity in performance on working memory, phonological awareness and non-verbal intelligence between the EL1 and the EL2 groups. It is also possible that the status of their bilingualism may have affected the level of development in the EL2 children, and thus their performance on the tasks.

The inclusion of the recently developed working memory test, the AMWA, in this study was pioneering, and has allowed this particular test to be assessed for suitability in the South Africa context, including its use with young children whose first language is not English. On a practical level, the administration of the test presented no observable problems in assessing working memory skills in EL1 children. However, assessment of working memory skills in second-language English children should be conducted with a degree of caution, with particular attention being paid to the level of English proficiency in these children. As working memory capacity constrains performance on working memory measures, working memory assessment provides an indication of a child's potential that is independent of more general factors. For this reason, the limitations relating to the use of the AWMA in a second-language English child, or group of children, are outweighed by the potential benefit to the child or children, in identifying working memory deficits which may be addressed within the classroom. Alloway and

Gathercole (2006), for example, recommend the introduction of a learning support programme which could offer guidance for teachers on ways of reducing excessive working memory loads in classroom activities, and on developing children's own strategies for coping with memory failures.

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