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Master's Research Report

Evidence for a Bi(Multi)lingual Advantage on Working Memory Performance in South African University Students

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Abstract

Due to linguistic diversity within South Africa, multilingualism is becoming increasingly prominent. Since South Africa is host to 11 official languages, it is the norm rather than the exception that South Africans are exposed to more than one language. This has social, educational and cognitive implications. Specifically, research indicates that the acquisition of additional languages to an individual's mother tongue has a positive effect on working memory – the short-term storage and manipulation of information during the performance of cognitive tasks – which may confer a 'bi(multi)lingual advantage' and could improve academic performance. Consequently, the aim of this study was to determine whether working memory ability differs significantly between students who are monolingual or multilingual, while statistically controlling for intellectual ability and socio-economic status between these groups. Participants were 78 undergraduate students, comprising English first- (monolingual, $M_{age} = 20.06$ years, $SD = .88$) and second- or additional-language (multilingual, $M_{age} = 20.03$ years, $SD = 1.03$) speakers, matched for age, gender and socio-economic status. Language groups were compared on the Automated Working Memory Assessment (Alloway, 2007) and subtests of the Wechsler Adult Intelligence Scale – Third Edition (Wechsler, 1997). One-way between-group ANCOVAs showed that (a) the multilingual group outperformed the monolingual group across five of six non-verbal subtests, namely Mazes Memory and Block Recall (non-verbal simple span), and Odd One Out, Mister X and Spatial Recall (non-verbal complex span), (b) the multilingual group outperformed the monolingual group on two verbal subtests, namely Digit Recall (verbal simple span) and Listening Recall (verbal complex span), (c) the language groups performed equivalently on verbal simple and complex tasks of Word Recall, Non-word Recall, Counting Recall and Backwards Digit Recall. The findings contribute to the extant literature confirming a 'bi(multi)lingual advantage' in executive functioning. Theoretical and practical implications are discussed in light of academic performance.

Keywords: working memory, monolingualism, multilingualism, bi(multi)lingual advantage, South Africa

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Declaration

I, Mandy Wigdorowitz, declare that this research report is my own, unaided work. It is submitted for the degree of Master of Arts in Social and Psychological Research by Coursework and Research Report at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination at this or any other university.

Sign: ______________________

Date: ______________________

For Marisa, Evan and Leon

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Chapter One: Introduction

Due to linguistic diversity within South Africa, multilingualism is becoming increasingly prominent (Foxcroft, 2004). Since there are 11 official languages, it is the norm rather than the exception that South Africans are exposed to – and consequently speak – more than one language (Louw & de Wet, 2007; Niesler, Louw, & Roux, 2005). With the increasing prevalence of multilingualism, both in South Africa and globally, there is a need to enrich existing knowledge and gain new insight into differing linguistic profiles.

Over the past few years, there has been an increased focus on multilingualism in psychological and linguistic research (see, e.g., Bialystok, 2009; Cenoz, 2001, 2013; Gollan & Ferreira, 2009; Jessner, 1999, 2008). This research has primarily focused on the social, educational and cognitive implications of multilingualism. Specifically, the acquisition of additional languages has been shown to have an effect on executive and linguistic tasks. There is contention as to whether multilingualism is a hindrance or an advantage on a variety of tasks which assess both verbal and non-verbal cognitive domains (for a review, see Bialystok, Craik, & Luk, 2008; Costa & Sebastián-Gallés, 2014; Mindt, et al., 2008). The reasons for these differing findings remain unclear. However, various proposals and trends have been noted in relation to task specification (verbal or non-verbal) and type of executive function being assessed (i.e. inhibition, working memory, lexical selection and so forth; Hilchey & Klein, 2011). This study will specifically focus on the executive function of working memory and how linguistic variation (i.e. monolingualism versus multilingualism) affects the accomplishment of both verbal and non-verbal working memory tasks. At this point, research in this area has produced mixed results. Generally, studies investigating differences in working memory performance between language groups have observed several outcomes; (a) cognitive benefits evident in bi(multi)lingual performance are contingent upon non-verbal tasks of executive functioning, and (b) bi(multi)linguals tend to perform worse than monolinguals on tasks tapping verbal resources and linguistic processing. Attempts at replicating these results have not always been successful, however (see Anton et al., 2014; Kousaie

& Phillips, 2012a). As such, it is important to identify if, and where, working memory differences exist between monolingual and multilingual groups, as it has been found that working memory capacity plays a significant role in first language[1] (L1), second language (L2) and additional language (L3, L4 etc.) acquisition (Ellis & Sinclair, 1996; Engel de Abreu, Gathercole, & Martin, 2011; Gathercole & Baddeley 1989; Gathercole, Service, Hitch, Adams, & Martin, 1999; Service, 2006).

Alloway and Alloway (2010) acknowledge that working memory ability is largely subject to individual difference, specifically in relation to learning outcomes. Positive effects have been noted in bi(multi)lingual individuals, where they have been shown to outperform monolingual counterparts on working memory tasks (e.g., Grosjean & Miller, 1994). Consequently, the aim of this study was to determine whether working memory ability differs significantly between young adult university students who are monolingual or multilingual, while statistically controlling for verbal intellectual ability and socio-economic status (SES) between these groups. While there are many theoretical approaches to working memory, Baddeley's (2003) multi-component model of working memory has been chosen and will theoretically guide this study.

The majority of research in the area of linguistic cognition and its effect on working memory has focused on school children (e.g., Antoniou, Grohmann, Kambanaros, & Katsos, 2016; Blom, Küntay, Messer, Verhagen, & Leseman, 2014; Engel de Abreu, 2011; Engel de Abreu et al., 2011; Lambert & Tucker, 1972; Lee, Ning, & Goh, 2014), the elderly (for a review, see Hedden & Gabrieli, 2004), and groups with cognitive impairments (e.g., Belleville, Chertkow, & Gauthier, 2007; Saunders & Summers, 2010), leaving a gap in the research of younger adult populations. An investigation into these individuals could address questions of whether the effects of multilingualism on working memory manifest as a result of competency in language prior to natural aging effects on the brain, or in the elderly, where there is natural decline on working memory

[1] For the remainder of this paper, the order of languages spoken by an individual will be referred to as L1 (first language/ mother tongue), L2 (second language), L3 (third language) and so forth.

tasks. Performance on memory tasks reflect fairly consistent outcomes, where a substantial increase in performance has been noted in childhood and adolescence, followed by a peak in young adulthood, and a steady decline with proceeding age (Fandakova, Sander, Werkle-Bergner, & Shing, 2014). This study investigates working memory performance in individuals classified as young adults, who should be at their optimal level of working memory performance. Thus far, attempts to bridge this research gap have produced varied conclusions. The literature review that follows will address research assessing the effect of language differences on working memory performance, with specific reference to contradictive conclusions.

Chapter Two: Literature and Theoretical Review

The aim of this study was to determine whether there is a significant difference in working memory performance between young adult, non-clinical, university students who are either English first-language speakers (monolinguals) or English second- or additional-language speakers (multilinguals). In doing so, verbal components of intelligence and SES were controlled for when assessing working memory performance between the language groups. In this chapter, an emphasis is placed on linguistic debates either disputing or substantiating a 'bi(multi)lingual advantage'[2], based primarily on task modality (verbal vs. non-verbal), while taking the language milieu of South Africa into account. The following points will comprise the body of discussion, theorisation and arguments:

Given that multilingualism is commonplace in South Africa, an overview of the implications of this for secondary and tertiary education and cognition will be highlighted. Following this, monolingualism and multilingualism will be conceptualised in light of existing literature and in relation to the present study. This will be followed by addressing the 'bi(multi)lingual advantage' in tasks tapping executive functioning. Leading on from this, research investigating working memory and language differences will be elaborated on, wherein the literature will be guided by debates regarding the 'bi(multi)lingual advantage'. An overview of Baddeley's (2003) multi-component model of working memory will be discussed in order to contextualise working memory, both broadly and in relation to its components. An emphasis will be placed on the phonological loop and its specific role in the performance of working memory tasks. Additionally, the relationship between intelligence and working memory, and SES and working memory will be outlined, suggesting that both intelligence and SES be controlled for when investigating working memory. Lastly, the research aims and research questions for the present study will be presented.

[2] For the remainder of this paper, the 'bilingual advantage' will be referred to as the 'bi(multi)lingual advantage' since multilingualism accommodates bilinguals and the sample of this study is classified as multilingual.

The South African Context: An Overview of Education and Language

As the world is getting smaller through access to globalisation, technology and travel, so the integration of languages is increasing (Aronin & Singleton, 2008). People have more access to multiple languages now than ever before, and, as such, multilingualism is a common phenomenon (Cenoz, 2013). South Africa depicts a unique context of language fusion (Desai, 2001). The country is host to 11 official languages, as well as an equally diverse array of foreign dialects; each comprising unique syntactic characteristics, and grammatical and semantic properties (see Ardila, Rosselli, Ostrosky-Solís, Marcos, Granda, & Soto, 2000; Haspelmath, 2007; Mesthrie, 2007; Naidoo, van der Merwe, Groenewald, & Naudé, 2005; Niesler et al., 2005; Sternberg & Sternberg, 2012). Given this linguistic amalgamation, South Africa is considered a multilingual society, where English is recognised as the *lingua franca*. The 2011 Census indicated that of the South African household population of 50 961 443 people, isiZulu was the most frequent language spoken (spoken by 22.7% of the population), followed by isiXhosa (16.0%), Afrikaans (13.5%), English (9.6%), Sepedi (9.1%), Setswana (8.0%), Sesotho (7.6%), Xitsonga (4.5%), siSwati (2.6%), Tshivenda (2.4%), isiNdebele (2.1%), other (1.6%) and sign language (0.5%; Statistics South Africa, 2012). It is unclear as to the exact extent the South African population speaks more than one language. Nevertheless, given the aims of the national language-in-education policy[3], the government is highly promotive of multilingual competence through second language education (Department of Basic Education, 1997, 2009; Plüddemann, 2015). Accordingly, the national language-in-education policy requires that each secondary learner must select two official South African languages as a minimum matriculation requirement, with one language at the Home Language level, and a second language at either Home or First Additional Language level (Department of Basic Education, 2009).

[3] The national language-in-education policy was developed to promote multilingualism in the South Africa educational context, as it acknowledges sociolinguistic diversity. Its mandate is to incite communication across racial, linguistic and religious groups in an attempt to unite South Africans by fostering awareness, acceptance and education of multiple languages, including official languages, South African Sign Language and any language appearing in the South African Constitution. Additionally, the policy aims to offset potential disparity that may result from an incongruity between home and school language (for the full six aims of the policy, see Department of Basic Education, 1997).

Diversifying the medium of instruction for higher education is at a critical juncture in South Africa, as the majority of universities use English as the language of instruction (Council on Higher Education, 2001). This is a poignant initiative for the government because of the discernible linguistic variation that exists in schools and in the home environment (Hornberger, 2014). Because good quality education plays a significant role in cognitive functions – where evidence suggests a particular effect on working memory and intelligence (e.g., Ackerman, Beier, & Boyle, 2005; Alloway & Alloway, 2010; Alloway, Gathercole, Kirkwood, & Elliott, 2008; Amod, 2013; Purpura & Ganley, 2014; Shuttleworth-Edwards, Kemp, Rust, Muirhead, Hartman, & Radloff, 2004a; St Clair-Thompson & Gathercole, 2006; Swanson & Beebe-Frankenberger, 2004), it is important that learners are proficient in the language of classroom instruction. Speaking English in South Africa gives an individual a social advantage, but research suggests that proficiency in more than one language could confer a 'bi(multi)lingual advantage' (see Bialystok & Viswanathan, 2009). Linguistic proficiency – in one versus multiple languages – may, therefore, impact academic performance (Stephen, Welman, & Jordaan, 2004). This idea will theoretically and empirically guide the ensuing discussion, with an emphasis placed on the impact of monolingualism versus multilingualism on working memory performance.

Conceptualising Monolingualism and Multilingualism

Within the extant literature, definitions of mono- bi- and multilingualism lack consensus, and oftentimes overlap or interchange (Higby, Kim, & Obler, 2013). Therefore, it is necessary that a clear working definition of these terms be provided. Table 1 highlights various 'lingualism' definition that have been proposed.

Table 1
Definitions of monolingualism and multilingualism

Language term	Definition	Representative citation
Monolingualism	The use of only one language in all contexts	Cenoz (2013)
	A monolingual is "a person who has an active knowledge of only one language, though perhaps a passive knowledge of others"	Richards & Schmidt (2010, p. 374)
Multilingualism	Referring to the use of two or more languages, which includes bilingualism	Cenoz (2013)
	"…as the acquisition and use of two or more languages – so that bilingualism is treated here as a particular instance of multilingualism"	Aronin & Singleton (2008, p. 2)
	"Multilinguals speak at least two and possibly more languages"	Sternberg & Sternberg (2012, p. 412)

For the purpose of this paper, Richards and Schmidt's (2010) definition of monolingualism is useful in the South African context, where knowledge of additional languages to an individual's L1 does not involve active engagement, but is merely passive in nature, used primarily as an educational obligation rather than a purposeful learning objective. Likewise, Ellis (2006) concedes a continuum of monolingual communication, "ranging from someone who can say 'guten Tag ' or 'selamat pagi' up to someone who has studied one or more languages but falls short of being able to communicate in them" (p. 176). In relation to language use in the South African pedagogical context, Desai (2001) proclaims that

> there is a world of difference between those who are learning an additional language voluntarily to expand their linguistic repertoire and those who are forced to learn an additional language in order to gain access to education and participation in the wider society (p. 325).

Therefore, monolinguals in this study have only passive knowledge of additional reported languages, primarily contingent upon an educational context, and do not possess the linguistic competence allotting them a classification as a multilingual. In turn, multilinguals are individuals with adequate linguistic competency to actively engage in communication, thought processing, and comprehension in more than one language.

The ‘Bi(Multi)lingual Advantage’ in Executive Functioning

As noted, multilingualism, classified as the systematic use of two or more languages, is a global phenomenon. This is especially relevant in South Africa, where linguistic diversity is pronounced. This fusion of languages has social, educational and cognitive implications. On the one hand, multilingualism promotes broader communicative opportunities, while on the other hand, there is mixed evidence for multilingualism as a hindrance or an advantage on a variety of cognitive tasks, especially those tapping executive functioning. Executive functioning consists of a set of cognitive mechanisms that aid in higher-order processing. Tasks involving attentional and inhibitory control, directing, flexibility, planning, reasoning, problem-solving, working memory, abstraction, self-monitoring and behavioural assessment are categorised as executive functions (Strauss, Sherman, & Spreen, 2006; Zillmer, Spiers, & Culbertson, 2008). Undoubtedly, executive functioning is an essential aspect of task accomplishment and higher-order, goal-directed behaviour and interaction. During novel, unfamiliar or complex situations, executive functions are recruited, whereby an individual has to develop momentary strategies, while simultaneously monitoring their effectiveness (Shallice, 1990). Given the importance of executive functioning in everyday task accomplishment, along with a global emergence of multilingualism, a series of studies have sought to investigate whether links exist between multiple language acquisition and superior executive functioning (e.g., Costa et al., 2008; Luo, Luk, & Bialystok, 2010). Research in this area is fairly contradictory. Disputes regarding the superior cognitive performance in the accomplishment of executive tasks in multilinguals compared to monolinguals will therefore be explored.

What has predominantly emerged in the literature proposes that executive function accomplishment is primarily dependent upon task specification (tasks involving executive functioning versus tasks involving components of linguistic processing), and ultimately the cognitive demands needed to perform executive assessments (Bialystok, Poarch, Luo, & Craik, 2014). In tasks assessing executive function, where, for example, the employment of conflict resolution, switching, inhibition, attentional control and rule maintenance are principle cognitive resources needed, bilinguals have been shown to perform better in comparison to their monolingual counterparts.

Extensive findings suggest that monolinguals outperform multilinguals in executive tasks that utilise verbal mechanisms (e.g., lexical retrieval, naming, phonetic and semantic fluency), while the opposite has been found, where multilinguals outperform monolinguals, in tasks that employ non-verbal mechanisms (e.g., response conflict, executive control, switching, inhibitory control and flexibility, see Bialystok, 2009; Prior & MacWhinney, 2010; Sandoval, Gollan, Ferreira, & Salmon, 2010). It has been argued by Bailystok and her colleagues that successful maintenance of language switching in multilinguals can be accomplished with the employment of non-linguistic cognitive mechanisms when performing an executive task. For example, to determine if language context (the immediate cognitive linguistic framework in a given interaction) has an effect on bilingual performance, Wu and Thierry (2013) tested a group of bilingual Welsh-English participants (M_{age} = 20.4 years, SD = 2.1 years) on a non-verbal measure of executive function, namely a conflict resolution task, by manipulating the language context by intermittently presenting words in English, Welsh or both languages. It was concluded that the participants' resolution of interference was enhanced when exposed to a mixed context (both languages) compared with a single language context, suggesting that working memory, in terms of fast changing language context (i.e. shifting) as opposed to language exposure, improved executive control in bilinguals ($F(1, 17) = 23.22$; $p < .001$).

Depending on the processing demands needed to complete a particular task, one language group will outperform another, based primarily on the modality or type of presented representation (such as verbal versus non-verbal tasks; Shah & Miyake, 1996). In line with the literature, multilingual individuals with a processing advantage in non-verbal (visuo-spatial) modalities should possess fewer attentional resources – as compared to their monolingual counterparts – when completing verbal tasks, but more resources when a task is embedded within a non-verbal framework (Feldman Barrett, Tugade, & Engle, 2004).

Support for the 'bi(multi)lingual advantage'.

Multiple language use has systematic consequences for executive performance. Several explanations for the apparent 'bi(multi)lingual advantage' in executive tasks have been proposed. The main reason is due to multilinguals' ability to task switch between languages with greater ease compared to their monolingual counterparts (Abutalebi & Green, 2007). For multilinguals, all their languages are simultaneously activated and available for use[4] (for a review, see Bialystok, 2009; Kroll & Bialystok, 2013; Kroll, Dussias, Bogulski, & Valdes-Kroff, 2012). This is more likely when an individual is a 'balanced multilingual[5]' and has acquired linguistic proficiency in all spoken languages before the age of six (Flege, Yeni-Komishian, & Liu, 1999; Portocarrero, Burright, & Donovick, 2007). The multilinguals' languages, therefore compete with one another. In order to efficiently facilitate this competitive process, there is a need for an executive control mechanism to mediate appropriate selection, and avoid the surfacing of additional, unnecessary languages (Bialystok et al., 2014; Sandoval et al., 2010). A multilingual will need to correctly select the target language over the alternative, competing language when faced with an executive task presented in a specific language. The increased use of the repertoire of available languages will result in the enhancement of the control mechanism, strengthening its function beyond merely language control (Bialystok et al., 2014).

This advantage is, therefore, a result of the analogous cognitive mechanisms required when performing language selection processes and selective attentional tasks (Abutalebi & Green, 2007; Bialystok, 2009; Tse & Altarriba, 2012). When an individual learns an alternative language, his/her

[4] Simultaneous activation of languages in multilinguals, when only one is being utilised, has been extensively documented (for example, see de Bruijn, Dijkstra, Chwilla, & Schriefers, 2001; Kerkhofs, Dijkstra, Chwilla, & de Bruijn, 2006; Marian, Spivey, & Hirsch, 2003; van Heuven, Schriefers, Dijkstra, & Hagoort, 2008) and contested (Kroll, Bobb, & Wodniecka, 2006).

[5] Cenoz (2013) speaks of balanced and unbalanced multilingualism, where the former suggests that an individual has attained equal fluency in at least two languages, while the latter refers to an incomparable mastery of spoken languages by an individual.

representation of L2 progresses from a common cognitive store into two separate cognitive stores[6] (Núñez Cruz, 1991). Initially, the comprehension of L2 is achieved through “association” or “direct translation”, but an increase in language proficiency becomes associated with symbolic meaning (Núñez Cruz, 1991, p. 18). In accordance, Canagarajah (2007) claims, that “rather than knowledge of form, multilingual competence features an array of interactional strategies that can create meaning out of shifting contexts” (p. 932).

Disputing the ‘bi(multi)lingual advantage’.

In contrast to the abovementioned discussion, monolinguals have also been shown to have outperformed multilinguals on verbal tasks assessing aspects of linguistic processing (Jared & Kroll, 2001). Various studies have concluded that, in comparison to monolinguals, multilinguals identify more words in total when taking their knowledge of two languages into account, but their vocabulary in each language is significantly smaller than that of monolinguals (Bialystok & Luk, 2012; Bialystok et al., 2014; Gollan & Acenas, 2004; Gollan & Brown, 2006; Portocarrero et al., 2007). Gollan and colleagues have produced a series of studies demonstrating a monolingual advantage on tasks of verbal processing. Specifically, multilinguals have been found to have reduced verbal fluency in comparison to their monolingual peers (Gollan, Montoya, & Werner, 2002; Rosselli et al., 2000), they name fewer pictures on the Boston Naming Test (Gollan, Fennema-Notestine, Montoya, & Jernigan, 2007; Roberts, Garcia, Desrochers, & Hernandez, 2002), and they recall the names of pictures slower than monolinguals (Gollan, Montoya, Fennema-Notestine, & Morris, 2005). In addition to this, multilinguals exhibit less fluency in all their languages when compared to monolinguals (Gollan, Bonanni, & Montoya, 2005; Ivanova & Costa, 2008).

[6] This can be explained by the dual-system hypothesis, which proposes separate systems in the brain for each language acquired by an individual (Feldman Barrett et al., 2004). However, this idea has been widely debated, where the single-system hypothesis advocates a common brain location or system for multiple languages (Hernandez, Dapretto, Mazziotta, & Bookheimer, 2001). Results from studies assessing brain damaged individuals lean more towards the dual-system hypothesis, however (see Meinzer, Obleser, Flaisch, Eulitz, & Rockstroh, 2007).

There is considerable evidence for superior performance in monolinguals compared to multilinguals in tasks utilising verbal, as opposed to non-verbal cognitive resources. For example, in a study conducted by Bialystok and Feng (2009) on both lexical retrieval (verbal Peabody Picture Vocabulary Test III-A) and cognitive control (non-verbal Proactive Interference task) in bilinguals (M_{age} = 21.1 years, *SD* = 2.3, *n* = 55) compared to English monolinguals (M_{age} = 21.9 years, *SD* = 3.1, *n* = 54), it was concluded that monolinguals performed better on the verbal task ($F(1,107) = 11.94$, $p < .0008$), while no difference or interaction was found in the non-verbal task between the language groups. Likewise, a study was conducted by Rosselli, Ardila, Salvatierra, Marquez, Matos, and Weekes (2002) comparing verbal fluency differences in 45 English monolinguals, 18 Spanish monolinguals and 19 Spanish-English bilinguals on their performance and productivity strategies on two verbal fluency tests, namely a phonemic category and a semantic category. Participants were given three one-minute oral fluency trials where they had to use the letters “F”, “A” and “S” to recall as many words as they could think of (phonemic category), as well as one-minute oral fluency trials where they were asked to recall as many *animals* as they could think of (semantic category). Differences were only found for the semantic fluency test, where English monolinguals produced significantly more words than the bilingual group. This result has subsequently been replicated (see Gollan et al., 2002; Sandoval et al., 2010). Results suggest a monolingual advantage in tasks tapping into verbal components of executive functioning. Multilingualism introduces processing costs when verbal tasks need to be accomplished.

Additionally, contradictory results have emerged indicating a monolingual advantage for non-verbal tasks. For instance, Paap and Sawi (2014) compared 62 monolingual and 58 bilingual university students on 13 measures of executive function from four commonly used tasks, namely Antisaccade Task, Color-Shape Switching Task, Simon Task, and Attentional Network Test. Only three of the measures found a significant difference in the language groups, in the direction of a monolingual advantage, namely Antisaccade reaction time (RT, $p = .027$), Simon global RT ($p = .006$) and the Simon effect ($p = .006$).

Moreover, conflicting results have been found in replicated studies. Specifically, in a study conducted by Costa, Hernández, and Sebastián-Gallés (2008) using an Attentional Network Task comparing 100 Catalan-Spanish bilinguals (M_{age} = 22 years) and 100 Spanish monolinguals (M_{age} = 22 years), a bilingual advantage was found for both congruent and incongruent trails. However, using the same Attentional Network Task comparing 180 Basque-Spanish bilinguals and 180 Spanish monolinguals, Anton et al. (2014) failed to come to the same conclusion.

Despite the surfeit of literature supporting a ‘bi(multi)lingual advantage’ in tasks of executive functioning, contention central to the generalisation of this cognitive enhancement is evident, as seen in the above studies. In accordance, Namazi and Thordardottir (2010) have questioned the choice of bilingual participants, suggesting that more control needs to be placed on the conceptualisation and selection of bilinguals, while Sternberg and Sternberg (2012) have proposed that contradictions in the literature are a product of differing participant populations, language groups, methodologies and experimenter biases (cf. Grosjean, 1998). In addition to methodological faults, Paap and Sawi (2014) have disputed the convergent validity of executive function tasks through cross-task correlations of indices assumed to measure the same component of executive function. They found that, at best, only a few dependent variables measuring inhibitory control or monitoring had weak associations. They concluded that “the low levels of convergent validity imply that these measures are reflecting task-specific mechanisms rather than the efficacy of general functions” (p. 14). Furthermore, de Bruin, Treccani, and Della Sala (2015) acknowledge that publication bias favouring bilingual studies with positive results (compared to studies with null conclusions) have contributed more to the available literature delineating this phenomenon. They conducted a meta-analysis of 104 conference abstracts from 1999 to 2012, either accepting or challenging (with full or partial support: 38%, 13%, 32% and 16%, respectively) the bilingual advantage on executive control tasks, on the basis of their journal publication outcomes. Of the 52 published articles from the conference abstracts, 63% reported a bilingual advantage, while 36% disputed it. A binary logistic regression found a significant difference in publication outcomes

(Wald $\chi^2(1, N = 104) = 7.36$, $p = .007$, $\eta_p^2 = .073$), suggesting that there is disparity between conference papers and publications that look at linguistic differences. It was concluded that publications should be open to the full scope of results, including null outcomes in order "to facilitate a better understanding of the actual effect of bilingualism and the boundaries of this effect" (p. 105). In Adesope, Lavin, Thompson, and Ungerleider's (2010) systematic review and meta-analysis of the cognitive correlates of bilingualism, publication bias also arose as a potential validity concern.

The 'Bi(Multi)lingual Advantage' in Working Memory and the Working Memory Model

Working memory is one component of executive functioning. Research into linguistic differences in working memory performance has increased over the past few years, but its role in the 'bi(multi)lingual advantage' phenomenon has not been as well researched as inhibitory control mechanisms. Working memory fosters the accomplishment of higher cognitive tasks of reasoning, learning, problem-solving and comprehension (Baddeley, 2003, 2007). It is a cognitive process that is involved in mental flexibility, where information is retained, stored and manipulated for a brief period of time (Baddeley & Hitch, 1974; Baddeley, 2003). Theoretical and empirical evidence proposes that working memory comprises a cohort of separate, yet interconnected components that mediate the connection of lower-level perceptual stimuli into the storage of long-term memory (Baddeley, 2003). Within this system, there are capacity limitations that determine how well or efficiently a task can be executed (Lee et al., 2014). This indicates that the amount of information accessible at a given time is limited in capacity, whereby an increase in task complexity is directly proportional to a decline in performance (Oberauer, 2005). In order to assess working memory capacity, span measures are usually utilised, in which information is cognitively stored for a brief period of time and subsequently recalled either immediately (simple span tasks), or following the completion of an overlapping, often unrelated, task (complex span tasks; Alloway, Gathercole, & Pickering, 2006; St Clair-Thompson, 2007).

Numerous models and theories have been developed to explain working memory systems (e.g., Atkinson & Shiffrin, 1968; Baddeley, 2003; Baddeley & Hitch, 1974; Cowan, 1999, 2005), and there have been extensive reviews of these memory models (see Baddeley, 2007; Miyake & Shah, 1999). However, Baddeley's (2003) modified multi-component model of working memory will theoretically guide the present study (see Appendix A) as there is extensive neuropsychological, neuroanatomical and psychometric evidence in support of this model (see Baddeley, 1996; Jonides, Lacey, & Nee, 2005; Shallice & Burgess, 1991; Vallar & Baddeley, 1984).

According to Baddeley (1996, 2003), working memory comprises distinct, yet related cognitive processes: specifically, a multifunctional attentional system called the central executive; two 'slave systems', referred to as the phonological loop and visuospatial sketchpad; and a newer component called the episodic buffer. The central executive, or 'control system', is responsible for higher cognitive facilitation, oversight, planning and integration of short-term memory information; the phonological loop is responsible for the storage and articulation of verbal information and language acquisition by providing a momentary representation of novel phenome sequences and acquiring linguistic knowledge through rehearsal; and the visuospatial sketchpad, a non-verbal presentation of working memory, is responsible for visual and spatial storage and manipulation, as well as for facilitating semantic acquisition regarding objects and stimuli within the environment (Baddeley, 1996, 2003; Baddeley & Hitch, 1974). A fourth element was added to the three-component model when concerns arose regarding the interaction with long-term memory, as well as between the phonological loop and visuospatial sketchpad (Baddeley, 2000, 2003). This fourth component is the episodic buffer, and acts as an interface to systematically address these concerns, by binding together – in a limited capacity – information to form integrated episodes, accessible to conscious awareness (Baddeley, 2000, 2003; Baars, 2002). The episodic buffer facilitates the integration of information relayed from the 'slave systems' with information from long-term memory (Baddeley & Wilson, 2002).

Working memory performance in adults has been linked to several cognitive aptitudes, such as mathematical ability (De Rammelaere, Stuyven, & Vandierendonck, 2001; Seitz & Schumann-Hengsteler, 2000) and comprehension (Friedman & Miyake, 2004). In children, performance on working memory tasks predicts reading ability (Swanson & Beebe-Frankenberger, 2004), mathematical competence (Bull & Scerif, 2001; Geary, Hoard, & Hamson, 1999) and overall academic achievement (Pickering & Gathercole, 2004). These findings further substantiate a multicomponent model of working memory, comprising a domain-general processing element – the central executive for controlled attention – along with various domain-specific storage elements – the phonological loop and visuospatial sketchpad for verbal and visuospatial storage, respectively (Alloway et al., 2006). In line with this, Kane, Hambrick, Tuholski, Wilhelm, Payne, and Engle (2004) have noted that verbal and visuo-spatial working memory are separable components in adults, but Baddeley (2003) suggests that when individuals perform a visuo-spatial task, they can recruit the phonological store to code information, while simultaneously manipulating the same information visuospatially.

Undeniably, researchers have investigated a plethora of variables that have contributed to individual differences in working memory performance (see Jurden, 1995). Perhaps one of the most significant contributors is linguistic differences – that of monolinguals compared to multilinguals (e.g., Hernández, Costa, & Humphreys, 2012; Luo, Craik, Moreno, & Bialystok, 2013; van den Noort, Bosch, & Hugdahl, 2006). The phonological loop plays a significant role in working memory and language differences and the visuospatial sketchpad is necessary in non-verbal working memory accomplishment. However, there has been substantially less research investigating the integration of the visuospatial sketchpad. Literature exploring the phonological loop will be discussed further.

The phonological loop and language.

The phonological loop plays a significant role in the successful acquisition of language, regardless of whether it is a first or additional language that is being acquired (Baddeley, Gathercole, & Papagno, 1998). Baddeley (2003, p. 832) indicated that "phonological loop capacity is a good predictor of the ability of children and adults to learn a second language" because its function "is not to remember familiar words but to help learn new words" (Baddeley et al., 1998, p. 158). Two components form part of the phonological loop: (a) it contains a phonological store which is responsible for the identification and short-term retention of verbal information, as well as (b) an articulatory rehearsal mechanism, responsible for the maintenance of the content presented in the phonological store, through the process of rehearsal. During language learning, novel phonological traces are held in the phonological store for a brief period of time, whereby more permanent representations of these traces are being formed (Gathercole & Baddeley, 1989). The development of this cognitive mechanism in multilinguals is suggested to play a role in their ability to perform better than monolinguals on working memory tasks. This is supported by Masoura and Gathercole's (2005) study of Greek children (M_{age} = 11.2 years, SD = 15.0 months, n = 80) learning English at school. A significant relationship ($p < .001$) was found between phonological memory performance and familiarity of prior knowledge of a second language, using the Children's Test of Non-word Repetition and two tests of children's English vocabulary.

When bilinguals frequently engage in language exchange, neural linkages increase in areas analogous to those needed when performing working memory tasks (Nosarti, Mechelli, Green, & Price, 2010). Consequently, given that L1 and L2 (3, 4 etc.) acquisition plays a role in working memory capacity, specifically with regards to the phonological loop, and as well as in relation to an academic milieu, this study is an important contribution to existing knowledge, and more generally to the South African context of education for monolingual and multilingual individuals.

Support for the 'bi(multi)lingual advantage'.

Research investigating individual differences in working memory has gained momentum in the past few years, because it is a highly complex cognitive ability, comprising both verbal and non-verbal components (see Feldman Barrett et al., 2004). Therefore, linguistic differences in working memory performance are an important contribution, where the present study will explore the effect of language on working memory, and contributions will supplement the pool of existing literature. Thus far, research indicates that working memory performance is generally in the direction of a 'bi(multi)lingual advantage'. For instance, this 'bi(multi)lingual advantage' is evident in assessments such as the Simon task (Bialystok, 2006; Bialystok, Craik, Klein, & Viswanathan, 2004), the Attentional Network Task (Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009; Costa, et al., 2008), and the Stroop task[7] (Bialystok et al., 2014; Blumenfeld & Maria, 2011; Tse & Altarriba, 2012; Zied et al., 2004). The management of attention when completing executive functional tasks is an important aspect in bilingual performance (Bialystok et al., 2014). The effects of bilingualism appear to be most notable on the attentional executive system, of which working memory is a part (Lee et al., 2014). Similarly, according to Feldman Barrett et al. (2004), individual differences in working memory performance are determined by the capacity to control attention.

Furthermore, neuroanatomical findings support this theorisation (for a review, see Higby et al., 2013). Specifically, cerebral lateralisation plays a role in hemispheric dominance for language processing (Insua, 2001). When learning a second language, debate surrounding hemispheric dominance of additional language processing has been highlighted (see Galloway, 1982; Hull & Vaid, 2007; Krashen, 1981; Perani et al., 1998). There are several scholars who have claimed that the right hemisphere is more involved when learning a second language than when acquiring a first language, especially when the L2 acquisition or learning happens at a later age. Naturally, there are scholars who dispute this, claiming that while linguistic functioning is still believed to be lateralised to the left hemisphere in about 90% of the population (Sternberg & Sternberg, 2012), research findings show that the right hemisphere is very much involved in L2, L3, L4 etc. processing (Galloway, 1982). Even so, there is no clear evidence that linguistic functions associated with a second or additional language are lateralised to one of the hemispheres, or that one of the hemispheres dominates language processing.

[7] Refer to Strauss et al. (2006) for an overview of a compendium of neuropsychological tests that assess executive functioning, memory, attention, and language.

What has been found, though, is that as language proficiency increases, so L2 becomes incorporated into the exact pathway associated with L1 processing – albeit of weaker laterality strength in multilinguals compared to monolinguals (Park, Badzakova-Trajkov, & Waldie, 2012). Neuroimaging variations have been found to exist in association with L2 proficiency and exposure. Bialystok et al. (2005) conducted a study using magnetoencephalography to note neural differences between 10 English monolinguals, 10 French–English bilinguals, and 10 Cantonese–English bilinguals, while performing the Simon task. Different neural patterns emerged between the monolingual and bilingual groups, both for congruent and incongruent trials. During signal changes, the activation of the medial prefrontal areas seemed to be similar across all language groups, but differences were observed in the activation of the superior and middle temporal regions, the cingulate, and superior and inferior frontal regions, mainly in the left hemisphere. Using data from functional MRIs, Luk, Anderson, Craik, Grady, and Bialystok (2010) found similar results when comparing English monolinguals (M_{age} = 22 years, n = 9) to bilinguals who spoke English and a variety of other languages (M_{age} = 20 years, n = 9). These results suggest that multiple language systems significantly alter neural processing and that this may ultimately extend to executive functioning, and, consequently, working memory.

Additionally, Abutalebi and Green (2007) have demonstrated that both monolinguals and multilinguals use the same brain networks (anterior cingulate cortex, caudate, left inferior parietal lobule and anterior cingulate cortex) when executing different functions, e.g., performance on conflict resolution tasks for monolinguals, and the control of interference from unwanted languages for multilinguals. This overlap of neural activation highlights a possible explanation for advantageous control processing in multilinguals.

Disputing the ‘bi(multi)lingual advantage’.

Wodniecka, Craik, Luo, and Bialystok (2010) have failed to conclude a ‘bi(multi)lingual advantage’ in working memory assessments for young adults. Results of this study deviate from expected norms, where a bilingual advantage has repeatedly been observed. Accordingly, this section will highlight research disputing the ‘bi(multi)lingual advantage’. For instance, using a recent-probe task (a display of a list of items, followed by a recognition-probe item) which comprised both verbal (letters) and non-verbal (stickman figures) variations (Jonides & Nee, 2006), Bialystok and her colleagues (2014) conducted a study to compare the difference in proactive interference in working memory of English monolinguals (M_{age} = 21.4 years, *SD* = 3.2, *n* = 36) to bilinguals (M_{age} = 20.2 years, *SD* = 2.6, *n* = 36). In conclusion, evidence to suggest a consistent bilingual advantage were weak. For the facilitation trials (where a probe appears in both trials *n* and *n* – 1, where the correct response is a “yes”), the bilinguals and monolinguals did equally well, both outperforming the other on two trials each. For the interference trials (where no probe appears in trial *n* but does appear in trial *n* – 1, where the correct response is a “no”), the bilinguals outperformed the monolinguals on only one task, and no language differences were found for the remaining two tasks. Bialystok et al. (2014) proposed that “the combination of reduced lexical resources and the need to recruit EF[8] to resolve competition makes linguistic processing more effortful for bilinguals than for monolinguals” (p. 696) due to “competition from the other jointly activated language” (p. 697).

Furthermore, as the majority of research confirming a ‘bi(multi)lingual advantage’ has relied on behavioural measures, Kousaie and Phillips (2012b) went one step further and accessed both behavioural and electrophysiological data to investigate the phenomenon. Kousaie and Phillips (2012b) acknowledge that “the inclusion of electrophysiological measures permit the examination of bilingualism-related differences in the neural responses associated with the performance of these tasks” (p. 71). Twenty-five English monolinguals (M_{age} = 23.8 years, *SD* = 4.7) were compared to 26 French-English bilinguals (M_{age} = 24.5 years, *SD* = 3.4) on the Stroop task, Simon task and a modified Eriksen flanker task. Behavioural measures were recorded as reaction times and accuracy, while electrophysiological measures were recorded using an electroencephalograph, where event-

[8] Executive functions.

related potentials were recorded as indicators of neural activation. For behavioural measures, no language group effects were found on all three tasks ($p > .05$), thereby disputing the ‘bi(multi)lingual advantage’. In addition, electrophysiological results revealed some differences in conflict monitoring, stimulus recognition, resource allocation and error processing for the language groups, but inconsistencies were noted across tasks. For instance, for the Stroop task, bilinguals exhibited smaller N2 amplitudes (an indicator of conflict monitoring), indicating a superior ability to selectively attend to pertinent stimuli, while no language differences were observed in N2 for the Eriksen task (cf. Geyer, Holcomb, Midgley, & Grainger, 2011; Moreno, Rodríguez-Fornells, & Laine, 2008). Kousaie and Phillips (2012b) therefore concluded that it would be inaccurate to denote a bilingual advantage to the explanation of the results, but rather “that there are differences between young monolinguals and bilinguals in their brain responses to conflict at various stages of processing which do not lead to different behavioral outcomes” (p. 87).

This body of empirical evidence represents a variety of contradictory evidence, with potential extraneous variables contributing to working memory performance. Nevertheless, it is evident that the majority of the literature suggests that monolinguals perform better on verbal tasks of working memory, while multilinguals perform better on non-verbal tasks of working memory. However, it is important to interpret the results of executive function assessments with caution. In addition, Bailystok and Feng (2009) acknowledge that most cognitive processing is integrative, and therefore multilinguals and monolinguals may perform differently when exposed to verbal and non-verbal tasks. Thus, because there is no consensus regarding the legitimacy of a ‘bi(multi)lingual advantage’, this study will compare monolingual English-speakers to multilingual English second- or additional-language speakers, using both verbal and non-verbal working memory tasks to investigate whether differences exist.

Working Memory, Intelligence and Socio-Economic Status (SES)

Intelligence and SES have been found to affect working memory performance, where the relationship between working memory and intelligence has been widely explored. Fewer studies have investigated the relationship between working memory and SES, but in studies comparing monolinguals to multilinguals on cognitive tasks, Gathercole et al. (2014) have criticised previous research, in that it did not control for SES. As such, this study acknowledges this criticism by controlling for SES, in the form of a measure of living standards.

The relationship between working memory and intelligence has been investigated extensively in recent years, resulting in two opposing camps. The theoretical debate has reflected on the divisible versus inseparable properties associated with working memory and intelligence. These theoretical debates disputing whether intelligence and working memory are identical or separable cognitive abilities are based on how closely they correlate with one another. Working memory has been found to correlate significantly with measures of intelligence, such as reasoning ability (Kyllonen & Christal, 1990) and measures of comprehension (Daneman & Carpenter, 1980). Similarly, Colom, Rebollo, Palacios, Juan-Espinosa, and Kyllonen (2004) conclude that working memory and intelligence correlate almost perfectly and can therefore be considered as isomorphic entities. In addition, Conway, Cowan, Bunting, Therriault, and Minkoff (2002) suggest that working memory capacity is a good predictor of fluid intelligence, and that they share psychometric properties with one another, but due to the specific cognitive domains they encompass, working memory and intelligence remain dissociable cognitive constructs (cf. Alloway, Gathercole, Willis, & Adams, 2004). In line with this notion, Chuderski (2015) identified working memory and intelligence as separable variables, where intelligence was found to moderate the impact of anxiety on working memory. It has been noted that the maturation of executive functioning (wherein working memory is a component) lags behind the development of intelligence in children (Zillmer et al., 2008), suggesting that working memory and intelligence have separable developmental milestones and are therefore different cognitive constructs. Additionally, in a meta-analysis conducted by Ackerman et al. (2005) on 86 samples that previously related working memory to intelligence, it was found that true-score correlations were at highest .653, suggesting a maximum shared variance of 42.6%. Overall, an average shared variance of 22.9% was found when the authors corrected for unreliability of working memory and intelligence. It was therefore concluded that working memory is not the same as intelligence, and

> the claim of isomorphism between working memory and *g*[9] appears to be an example of the 'jingle fallacy' – that is, the fallacy that words that are accorded to the same meaning may not in fact refer to the same underlying constructs (p. 51).

Because there is research to suggest that intelligence is not merely a proxy for working memory, but rather that both constitute unique cognitive contributions to academic development (Alloway & Alloway, 2010), intellectual ability will be controlled for between the two language groups in this study.

Research Aim and Questions

The aim of this study was to contribute to the larger body of research to determine whether working memory ability differs significantly between young adult, non-clinical, university students who are monolingual or multilingual, while statistically controlling for variables that may influence working memory performance. This aim was operationalised as the following research questions:

1. Is there a significant difference between monolinguals and multilinguals in verbal aspects of working memory?
2. Is there a significant difference between monolinguals and multilinguals in non-verbal aspects of working memory?

[9] General intelligence.

Chapter Three: Methodology

The methods used in the current study will be outlined in this chapter. Firstly, a description of the research design is outlined, followed by a description of the sample and sampling strategy, the measurements used to collect data, the research procedure, the statistical analyses that were carried out, and lastly, ethical considerations that were taken into account. The present study formed part of a larger, existing study on working memory and language proficiency, which included some previously collected data on monolingual and multilingual participants. New data was collected from monolingual participants and supplemented the existing monolingual data.

Research Design

The design of the study was a non-experimental, ex-post facto, cross-sectional comparative study between two groups (Thomas, 2013). English first- language monolingual speakers were compared to English second- or additional-language multilingual speakers on tasks measuring working memory, intelligence, SES and language proficiency. Propensity score matching was utilised to match, as closely as possible, the scores from the multilingual group to the monolingual group, to control for the demographic covariates of age, gender and SES. This statistical technique has previously been applied in linguistic studies in a similar way (see Linck et al., 2013). This design is grounded upon a post-positivist paradigm, which will be briefly elaborated on.

Post-positivism.

In contrast to positivism[10], post-positivism acknowledges that unobservable phenomena can exist and act as explanations for observable realities (Schumacher & Gortner, 1992). Critical realism is used to explain post-positivism as it functions as a method of inquiry in the discovery of knowledge (Parker, 1999). In accordance with positivism, post-positivism implies that science relies on observation, precision, testing, evidence, validation and so forth, but it does not confine

[10] Positivism affirms that knowledge is purely based on fact, logic, and scientific validation, where what we know can only exist if it is observed or experienced (for an in-depth philosophical overview, see Lenzer, 2009).

knowledge to that which can only be directly witnessed[11] (Clark, 1998). In an effort to capture reality, post-positivism uses various methods, employing methodological triangulation in the process of discovery and theoretical confirmation. Research from both quantitative and qualitative camps are collectively added to the pool of knowledge. Although the nature of quantitative and qualitative research is fundamentally different, truths inherent within each paradigm are considered valid. Post-positivism further recognises the researcher as a contributor to knowledge because of his/her personal biases, ideology and overall involvement in shaping the process. Both the researcher and audience should be cognisant of the human involvement in the process. Additionally, generalisability of results cannot be applied universally, but rather within contextual bounds, such that inferences can only be made for demographically matched populations (Clark, 1998).

Based on the premise of post-positivism, latent constructs of working memory and intelligence were investigated using the Automated Working Memory Assessment (AWMA; Alloway, 2007) and subtests of the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III; Wechsler, 1997). Participants' self-reported language proficiency was measured on the Language Experience and Proficiency Questionnaire (LEAP-Q; Marian et al., 2007). While qualitative measures were included in this study (LEAP-Q, Living Standards Measure [LSM] and demographic questionnaire), the LEAP-Q and LSM were reduced to a numerical score and therefore the interpretation was statistical and thus quantitative in nature.

Sample and Sampling

This study utilised a non-probabilistic method of convenience and snowball sampling (Laher & Botha, 2012). The total sample size consisted of 78 participants, of which 39 (50%) were monolingual, English first-language speakers, and 39 (50%) were multilingual, English second- or additional- language speakers. At the time of the study, all participants were completing an

[11] However, like positivism, post-positivism is criticised for being overly concerned with reducing complex facets of human existence into measurable units of prediction, association and causation (Clark, 1998).

undergraduate degree at the University of the Witwatersrand, where English is the medium of instruction.

Half of the data concerning the monolingual group was collected by the present researcher and added to the pool of pre-existing data on monolingual participants. The data for the multilingual group was collected by the supervisor of this project as part of another study. The pre-existing data was collected from 110 multilingual participants in 2013. In order to match the monolingual and multilingual groups as closely as possible, propensity score matching was used, which controlled for the demographic covariates that may influence working memory.

Table 2 indicates the educational indices of the sample, comprising current degree being completed, faculty of registration, attainment of previous degree, year of undergraduate study, school failure and preschool attendance. The majority of the monolingual participants were completing a Bachelor of Arts degree (92.3%), while the majority of the multilingual participants were completing a Bachelor of Science degree (64.1%). Participants ranged from first years to third years, with the majority in second year, for both monolinguals (48.7%) and multilinguals (56.4%). Of the total sample, two of the monolingual participants had previously attained a degree, and one multilingual participant reported to have failed grade two. All but one monolingual participant attended preschool, whereas 11 multilinguals did not.

Table 2
Education indices by language group

	Monolingual participants (*N* = 39)	Multilingual participants (*N* = 39)
	n (%)	n (%)
Degree		
BA	36 (92.3)	4 (10.3)
BSc	2 (5.1)	25 (64.1)
LLB		1 (2.6)
BEd		4 (10.3)
BaccSci	1 (2.6)	1 (2.6)
BCom		3 (7.7)
MBBCh		1 (2.6)

(continued)

Table 2. *Education indices by language group (continued)*

	Monolingual participants (*N* = 39)	Multilingual participants (*N* = 39)
	n (%)	n (%)
Faculty		
Humanities	36 (92.3)	7 (17.9)
Science	2 (5.1)	6 (15.4)
Engineering		19 (48.7)
Health Science		2 (5.1)
Commerce	1 (2.6)	5 (12.8)
Previous degree		
Yes	2 (5.1)	
No	37 (94.9)	39 (100)
Year of undergraduate study		
1	17 (43.6)	9 (23.1)
2	19 (48.7)	22 (56.4)
3	3 (7.7)	8 (20.5)
Grade failure		
Yes		1 (2.6)
No	39 (100)	38 (97.4)
Preschool attendance		
Yes	38 (97.4)	28 (71.8)
No	1 (2.6)	11 (28.2)

Note. BA = Bachelor of Arts, BSc = Bachelor of Science, LLB = Bachelor of Law, BEd = Bachelor of Education, BaccSci = Bachelor of Accounting Science, BCom = Bachelor of Commerce, MBBCh = Bachelor of Medicine.

The mean age of the total sample was 20.05 years (*SD* = .95). As expected, the multilingual group reported speaking more languages on average than the monolingual group, with a mean number of 3.74 (*SD* = .993) and 2.10 (*SD* = .821) languages spoken by each group, respectively ($t(76) = -7.958$, $p = .000$, $d = 1.80$).

Monolingual sample.

South Africans are routinely exposed to many languages, and because a requirement to matriculate necessitates that learners be formally trained in at least two languages (Department of Education, 1997), there is no guarantee of absolutely monolingual participants. Thus, for the purpose of this study, monolinguals were conceptualised as individuals who classified themselves as English monolinguals, and rated themselves on the Language Experience and Proficiency Questionnaire (LEAP-Q) with an average score of 5 or less out of 10 for proficiency in any additional languages in the categories of speaking, understanding and reading (this is elaborated on in the Measures section on p. 31). Being able to speak a few words in another language was not regarded as constituting fluency or multilingualism in accordance with Cenoz (2013) and Richards and Schmidt's (2010) definitions of monolingualism (see Table 1 on p. 7). Participants who failed to meet these criteria were excluded from the monolingual sample. Thus the term 'monolingual' is not used in its strict sense in this study.

A total of 39 monolinguals participated in this study, of which 30 (76.9%) were female. The monolingual participants ranged in age from 18 to 22 years (M_{age} = 20.06 years, SD = .88). All but one of the monolingual participants acquired English as a first language, with one of the participants acquiring Italian, but subsequently losing it within a few years. All reported that English was their dominant language. The monolingual participants reported to have been exposed to speaking between one and three languages, where 12 (30.8%) spoke only English, 12 (30.8%) spoke English and one additional language, and 15 (38.5%) spoke English and two additional languages. The exposure to speaking more than one language is a consequence of three predominant factors: (a) in the South African schooling system it is required that at least two languages are formally taught (Department of Basic Education, 2009), (b) religious affiliation to languages, such as Hebrew, Arabic or Guajarati are common practice, and (c) children are often exposed to the language of parental heritage in the family (Ellis, 2006). On average, the monolingual participants reported speaking 2.10 (SD = .821) languages, which is predominantly a result of exposure to an additional language at school (Department of Basic Education, 2009). Within the monolingual group, exposure to 10 different languages was reported, namely English, Afrikaans, isiZulu, Arabic, French, German, Portuguese, Spanish and Italian. It is possible that such exposure may have affected the results and this is elaborated on in the Discussion chapter.

Figure 1 indicates the mean percentage of time monolingual participants were exposed to each of their languages, the mean percentage of time they chose to read a text in each of their languages, and the mean percentage of time they chose to speak with a person equally fluent in each of their languages. It is clear that English (L1) dominates in all these activities for monolinguals, with mean scores on the LEAP-Q of 94.13% (*SD* = 8.60), 97.56% (*SD* = 7.42) and 96.28% (*SD* = 8.22) for exposure, speaking and reading in English, respectively. Languages two and three comprised Afrikaans and isiZulu (optional languages taught at school), Hebrew and Arabic (religious languages), and French, German, Portuguese, Spanish and Italian (heritage languages). However, the limited exposure to these additional languages for this group was insufficient to classify the participants as being fluent in them. Consequently, the participants in this group were classified as English monolinguals, for the purposes of this study.

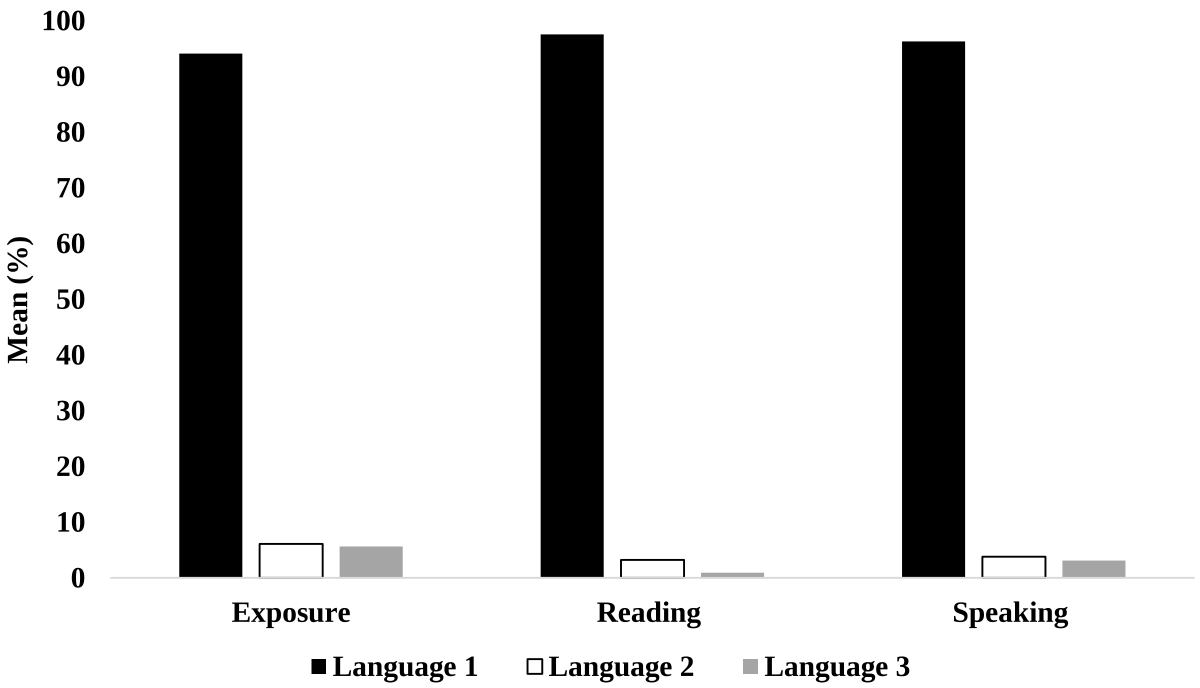

Figure 1. Mean percentage of time monolingual participants were exposed to, read in and spoke in their first, second and third languages.

Multilingual sample.

Multilinguals comprised 38 participants of which 30 (76.9%) were female. They ranged in age from 18 to 23 years (M_{age} = 20.03 years, *SD* = 1.03). All of the multilingual participants spoke between two and five languages, with English acquisition reported as being a second (76.9%), third (17.9%) or fourth (5.1%) language. The mean number of languages spoken by this group was 3.74 (*SD* = .993). Within the multilingual sample, exposure to 11 languages was reported, namely Afrikaans, English, isiNdebele, Sepedi, Sesotho, SiSwati, Xitsonga, Setswana, Tshivenda, isiXhosa, and isiZulu. The reported languages spoken by this group comprise the official South African languages.

Figure 2 indicates the mean percentage of time multilingual participants were exposed to each of their languages, the mean percentage of time they would choose to read a text in each of their languages, and the mean percentage of time they would choose to speak with a person equally fluent in each of their languages. In comparison to the monolingual sample, the multilinguals have exposure to a broader range of languages.

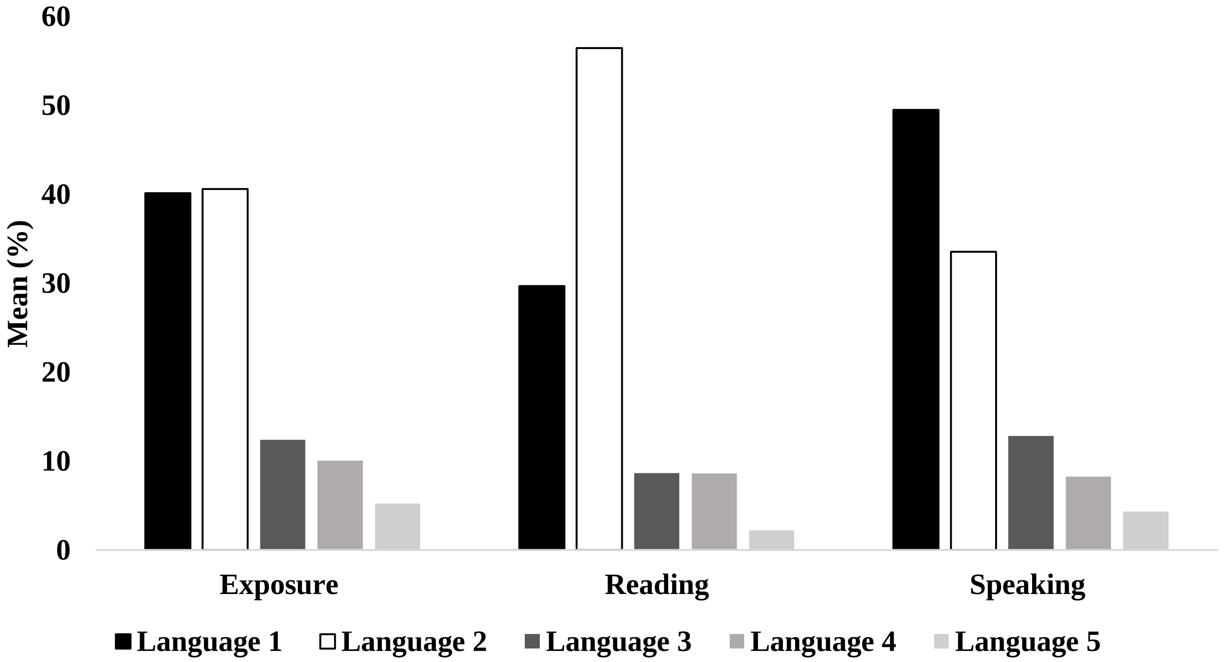

Figure 2. Mean percentage of time multilingual participants were exposed to, read in and spoke in their first, second, third, fourth and fifth languages.

The requirement for acceptance into the University of the Witwatersrand is a minimum of 50-59% for English as an additional language in matric. Therefore, university students were selected for this study because they are test-wise and sufficiently proficient in English to complete the assessments at a level of linguistic competency. It has been noted that a holistic approach to multilingualism can explain the effects of education when multiple languages are taught (Cenoz, 2013). Cenoz (2013) notes that a “holistic approach aims at integrating the curricula of the different languages to activate the resources of multilingual speakers. In this way multilingual students could use their resources cross-linguistically and become more efficient language learners than when languages are taught separately” (p. 13). This is especially the case where English is the language of instruction.

Measures

The following section presents an overview of the measures used in this study. The psychometric properties of each measure are outlined, along with indicators of reliability and validity where applicable.

Demographic questionnaire.

Each participant completed a demographic questionnaire (see Appendix B). Demographic variables of age, gender, languages spoken, education, and caregiver information were captured for descriptive purposes. Further demographic information included the highest level of parental (or primary caregiver) education which was indexed as: (0) no schooling, (1) less than primary school completed, (2) primary school completed, (3) secondary school not completed, (4) secondary school completed, (5) tertiary education completed, and (6) other.

Living Standards Measure (LSM; South African Audience Research Foundation, 2001).

The LSM is a measurement of societal change and development based on a set of marketing differentiators that group people according to their living standards and is commonly used as an index of SES (South African Audience Research Foundation, 2001). Participants answered 29 items by marking either true or false to a presented statement assessing living standard, degree of urbanisation, and ownership of a motor vehicle and major appliances. Scoring of the LSM is done manually using a weighting system, whereby each question is weighted differently according to economic trends in South Africa at any given year. Each weighted score reflects a final LSM score. Individuals can attain a score of 1 to 10, with higher scores indicating a higher living standard, and a higher SES.

Language Experience and Proficiency Questionnaire (LEAP-Q; Marian et al., 2007).

In the current study, the LEAP-Q was used to assess the degree of self-reported language proficiency of the monolingual and multilingual samples. The revised version of the LEAP-Q, developed by Marian et al., (2007) is a research-focused questionnaire of "bilingual language status with predictable relationships between self-reported and behavioural measures" (p. 940; see Appendix C). The LEAP-Q was developed to account for the distinction between self-reported measures and actual presentation of language proficiency in bilingual and multilingual individuals (Hyltenstam & Abrahamsson, 2003). The LEAP-Q measures some common indicators of linguistic proficiency, such as language competence, age and modes of language acquisition, contexts of language acquisition, previous language exposure, current language use, and self-reported proficiency ratings (Flege, MacKay, & Piske, 2002; Flege, Yeni-Komishian, & Liu, 1999; Marian et al., 2007; Vaid & Menon, 2002). These indicators are assessed across three domains of language use, namely speaking, understanding and reading. The LEAP-Q is intended for use with healthy adult samples from diverse linguistic and cultural backgrounds, who possess at least a high school level of literacy. The revisions and administration of the LEAP-Q were developed and conducted in English, thus some degree of English comprehension is necessary to complete the questionnaire. Both groups in the current study met these criteria.

The LEAP-Q consists of 31 language-related items, coded according to percentile rankings (0 to 100), which are based on standardised measures. The first section of the questionnaire determines: the number of languages spoken by an individual; the order of dominance and acquisition of each language spoken; the percentage of time an individual is currently and on average exposed to each of their specified languages; the percentage of time an individual chooses to read a text in each of their specified languages; the percentage of time an individual chooses to speak to a person equally fluent in each of their specified languages; the cultures with which an individual identifies, measured on a Likert scale ranging from 0 (*no identification*) to 10 (*complete identification*); the number of years of formal education and highest education level; and whether an individual has a vision problem, hearing impairment, language disability and/or learning disability. For the purpose of this study, questions pertaining to immigration to the USA and degree of identified accent were omitted in the analyses because these question are specific to an American context.

The second section of the LEAP-Q is answered according to each specified language that the participant has exposure to i.e. if an individual reported acquiring English (L1) and isiZulu (L2), questions pertaining to both languages are answered separately in this section. For each language an individual is exposed to, this section of the LEAP-Q determines: the age of acquisition, fluency, start of reading, and reading fluency of a language; the number of years a language is spoken in a specific country, with an individual's family and at the school attended by an individual; the proficiency in speaking, understanding and reading the language, measured on a Likert scale ranging from 0 (*none*) to 10 (*perfect*); the contributions to learning the language, such as interacting with friends and listening to the radio, which are measured on a Likert scale ranging from 0 (*not a contributor*) to 10 (*most important contributor*); and the extent of language exposure in specific contexts such as interacting with friends or watching TV, measured on a Likert scale ranging from 0 (*never*) to 10 (*always*). The questionnaire took approximately 20 to 25 minutes to complete and an average score of 5 or less (out of 10) for speaking, understanding and reading for any reported additional language, classified an individual as a monolingual English speaker.

The internal validity of the LEAP-Q was established by Marian and colleagues (2007). They analysed the responses of a linguistically diverse sample of 52 multilinguals (M_{age} = 27.29 years, *SD* = 5.92; 29 females) using factor analysis and multiple regression. Thirty-four languages were reportedly spoken by these participants, where only one (English) of the 11 official languages spoken in South Africa was reported. The researchers concluded that the LEAP-Q is an internally valid tool. To assess criterion-based validity, Marian and colleagues (2007) employed multiple regression and correlation analyses. Fifty bilingual English and Spanish participants (M_{age} = 26.7 years, *SD* = 10.4; 31 females) were recruited and it was concluded that from these studies, self-reported measures of language status are reliable indicators of bilinguals' linguistic performance (for a review, see Marian et al., 2007). Therefore, the LEAP-Q appears to be a reliable and valid tool for assessing multiple languages in diverse samples of neurologically normal adult populations in research settings.

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

The AWMA is a standardised, computer-based cognitive battery, developed by Alloway (2007). It is used to assess verbal and visuo-spatial working memory and short-term memory skills in individuals between the ages of four and 22 years – this was appropriate for the sample of the current study. The AWMA is a culturally fair tool, which is administered in English. It is based on the theoretical premise of Baddeley's (2003) multi-component model of working memory. It comprises the assessment of both simple (phonological loop) and complex (central executive) verbal and visuo-spatial short-term memory, and verbal and visuo-spatial working memory. Verbal and visuo-spatial working memory tasks require simultaneous storage and processing resources, whereas short-term memory tasks merely assessed storage resources (see Alloway, 2007; Alloway et al., 2006). The 12 tests of the AWMA, divided into their respective memory components are as follows:

Verbal short-term memory.

This cognitive domain is measured using three tests, namely Digit Recall, Word Recall, and Non-word Recall. Digits (e.g. 291537), words (e.g. drink, table, bus) and non-words (e.g. nop, jitch, garm) are stated in a sequence and each participant is asked to recall what they have heard in the correct order. The practice trials for each test consist of one-, two- and three-digit, word and non-word sequences, and the test trials start with a block of one number sequence and increase to a block consisting of nine, seven and six sequences, respectively.

Verbal working memory.

Listening Recall, Counting Recall and Backwards Digit Recall are tests used to assess verbal working memory. In the Listening Recall test, a participant judges the legitimacy of a heard sentence by noting it as ‘true’ or ‘false’. On completion of each trial, the participant must then recall, in the correct order, the final word of each sentence. Test trials start with a block of one sentence and increase to six sentences. For Counting Recall, an array of shapes are presented, and a participant must count and report the red circles, and then attempt to recall the frequency of red circles in the correct order. Test trials begin with a block of one and increase to seven arrays. The Backwards Digit Recall requires a participant to reverse the order of a sequence of heard digits. Test trials increase from two digits to a block of seven digits.

Visuo-spatial short-term memory.

Dot Matrix, Mazes Memory and Block Recall are used to assess this cognitive domain. For the Dot Matrix, participants are given four-by-four matrices and have to identify the location of a red dot previously shown, by tapping on the correct square on the computer screen. Test trials involve the recollection of one red dot, and this increases to a block of nine red dots. For the Mazes Memory test, each participant is shown a maze with a red pathway drawn through its course and, three seconds later, they need to manually trace this path on a blank maze presented on the computer screen. Trials start with small mazes that increase in size as the level of difficulty increases. In the Block Recall test, participants are shown images of a series of blocks being tapped. They need to reproduce the same sequence by tapping on each block. Test trials begin with a block of one image and this increases to a block of nine.

Visuo-spatial working memory.

Odd One Out, Mister X and Spatial Recall tests are used to measure visuo-spatial working memory. The Odd One Out test comprises images of three shapes, each presented in a box in a row, where participants are asked to detect the odd-one-out shape. At the end of each trial, participants must tap on the screen to recall the location of each odd-one-out shape in the correct order presented. Test trials start with one practice shape and this increases to blocks of seven sets of shapes in the test trials. Mister X refers to a test whereby pictures of two Mister X characters, each wearing different coloured hats, each holding a red ball and each positioned in different orientations, are shown to the participants. Participants are asked to identify whether "the Mister X with the blue hat is holding the ball in the same hand as the Mister X with the yellow hat" (Alloway, 2007, p. 35). At the end of each trial, participants must recall, in the correct order, the position of each red ball, by pointing to optional points. Test trials start with one set of Mister X and increase to seven sets of Mister X. The Spatial Recall test shows two objects (right image contains a red dot above it) and a participant must identify whether the right object is identical or opposite to the left object. The red dot is recalled at the end of each trial by pointing to it. One set of objects is used in the beginning, and this increases to blocks of seven sets of objects in the test trials.

Although the AWMA can be used as a screening tool to assess individual working memory deficits, this was not the focus of the current study, which sought to explain group trends in working memory performance, specifically by comparing monolingual and multilingual groups. The long form of the AWMA battery was administered to each participant, which consists of the full 12 subtests in the test battery. Table 3 outlines the subtests that test each memory component, along with the span type[12] and order in which the subtest appears in the AWMA. The sequence of tests is

[12] The working memory categories (verbal short-term memory, verbal working memory, visuo-spatial short-term memory, and visuo-spatial working memory) and span types (verbal simple span, verbal complex span, non-verbal simple span, and non-verbal complex span, respectively) will be used interchangeably throughout this paper.

automated in the computer program to account for variability among task demands and to moderate fatigue.

Table 3

Memory categories, span types and subtests comprising the AWMA

Memory category	Span type	Subtests	Sequence of subtest
Verbal short-term memory	Verbal simple span	Digit Recall	1
		Word Recall	5
		Non-word Recall	9
Verbal working memory	Verbal complex span	Listening Recall	3
		Counting Recall	7
		Backwards Digit Recall	11
Visuo-spatial short-term memory	Non-verbal simple span	Dot Matrix	2
		Mazes Memory	6
		Block Recall	10
Visuo-spatial working memory	Non-verbal complex span	Odd One Out	4
		Mister X	8
		Spatial Recall	12

Each test starts with a series of practice trials, immediately followed by test trials. Audio recorded feedback is provided for practice trials, where the computer program gives the correct answer following a participant's response. There is no feedback given for test trials. Test trials are presented in blocks with each block consisting of six trials. In each case, the participant is required to remember a piece of information and then recall it back immediately, using either storage-only resources (short-term memory tests or simple span tasks) or storage-plus-processing resources (working memory tests or complex span tasks). Testing took approximately 45 to 60 minutes.

Scoring was performed by the researcher pushing a button on the computer in response to either a correct (right arrow key) or incorrect (left arrow key) answer. Raw scores were automatically generated and summed by the computer program, with participants receiving a score of 0 (incorrect) or 1 (correct) for each response, totalling the number of trials a participant correctly recalled for each test[13]. Built-in rules are applied to move on or terminate each trial. If a participant

[13] As such, reliability for the present study could not be calculated because the researcher does not have access to item scores.

is able to attain the correct answer for the first four trials, they will automatically advance to the next block with due credit. Trials are automatically terminated if a participant obtains three errors within a block. In this way, experimenter error is reduced (Alloway et al., 2006). The raw scores are converted into standardised (or scaled) scores, which indicate an individual's performance with respect to the performance of others in the same age bracket. Average performance is indicated by a mean standard score of 100 and a standard deviation of 15.

To test the reliability of the AWMA, Alloway (2007) randomly selected a sample of 128 first-language English speakers between the ages of 4.1 and 22.5 years (M_{age} = 10.4 years, *SD* = 5.0), and tested them over two periods spanning a four week interim. Test-retest reliability of the AWMA was found to be at lowest .69 (Non-word Recall) and at highest .90 (Block Recall), with the majority of tests scoring between a range of .80 and .89. Alloway and colleagues (2006, 2008) reported on the validity of the AWMA. In conclusion, the AWMA was found to be a reliable and valid assessment of working memory performance.

Selected subtests of the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III; Wechsler, 1997).

The WAIS-III[14] is an individually administered intelligence test for individuals between the ages of 16 and 89 years (Wechsler, 1997). It was developed and standardised on 2 450 English-speaking, North American individuals (Strauss et al., 2006). It has been extensively used in South Africa (e.g. Shuttleworth-Edwards et al., 2004a; Shuttleworth-Edwards, Martin, Donnelly, & Radloff, 2004b; Shuttleworth-Edwards, Gaylard, & Radloff, 2013) and has also been normed on a South African population (see Claassen, Krynauw, Paterson & Mathe, 2001; Shuttleworth-Edwards, 2002; Nell, 1999). The South African version was used in this study.

[14] Although there is a fourth edition of the WAIS (i.e. WAIS-IV-SA), the third edition was used in this study because data collected from the multilingual sample was done so prior to the release of the fourth edition. Therefore, in order to uphold testing equivalence and appropriate comparison between the language groups, the WAIS-III was used.

For the purpose of this study, because working memory and intelligence are interconnected, it was included, in order to statistically control for possible differences in intelligence between the monolingual and multilingual groups. Four of the 14 subtests were used to assess intelligence, namely Vocabulary, Similarities, Block Design and Matrix Reasoning – administered in this order. The WAIS-III comprises both Verbal (Vocabulary and Similarities) and Performance (Block Design and Matric Reasoning) scales. Additionally, verbal comprehension and perceptual organisation indices can be observed from these subtests, whereby Vocabulary and Similarities are grouped into the former index, while Block Design and Matrix Reasoning are grouped into the latter index (Strauss et al., 2006). Because the WAIS-III necessitates face-to-face administration and manual scoring, both were conducted with adherence to the standardised procedures outlined in the testing manual. A participant can be awarded 0 to 7 points per item depending on the scoring criteria for each subtest, where high scores indicate higher levels of intellectual functioning. If a participant failed to answer correctly after a certain consecutive number of items, the subtest was discontinued, and only the score up to that point was tallied. Raw scores from the WAIS-III subtest were calculated and converted into standard scores with a mean of 10 and a standard deviation of 3 (Strauss et al., 2006). Standard scores for all subtests of the WAIS-III scaled scores are between 0 and 19, with higher scores indicating better performance in the specific cognitive task. The four subsets of the WAIS-III are explained below:

Vocabulary subtest.

Participants are presented, both verbally and visually, with a series of 33 vocabulary words that are printed on cards. They are instructed to provide oral definitions of each word, which need to be recorded verbatim and scored accordingly. The maximum points awarded for each item is 2 and a total of 66 points can be attained.

Similarities subtest.

Participants are orally presented with pairs of words (e.g. fork and spoon) and they are asked to explain the similarities associated with each pair. There are 19 items and participants can score a maximum of 1 point in items 1 to 5 and 2 points in the remaining items. The maximum points awarded for this subtest are 33.

Block Design subtest.

Participants use two-coloured blocks (each with two white, two red, and two half-red-half-white sides) to replicate images of two-dimensional designs, which increase in difficulty from simple two-block designs to complex nine-block designs. There is a time limit given for each design which increases along with the difficulty of the task. There are 14 designs and participants can earn a maximum of 68 points – up to 2 points for designs 1 to 6, and up to 7 points for designs 7 to 14.

Matrix Reasoning subtest.

This subtest comprises four types of non-verbal reasoning: pattern completion, classification, analogy, and serial reasoning. Participants are instructed to complete a series of incomplete gridded patterns by selecting the correct response from five possible options. There are three sample items and 26 test items, whereby 1 point is awarded for each correct item response. A maximum of 26 points can be awarded.

Good reliability and validity for the WAIS-III have been established (The Psychological Corporation, 2002). According to The Psychological Corporation (2002), reliability and validity for the WAIS-III were thoroughly addressed using a sample of 394 participants tested twice over an interim of two to 12 weeks, where reliability coefficients ranged from .88 to .97. Additionally, concurrent validity was established using correlational analyses between the WAIS-III and the WAIS-R, WISC-III, WIAT, the *Stanford-Binet Intelligence Scale – Fourth Edition,* and the *Standard Progressive Matrices* (The Psychological Corporation, 2002). Furthermore, construct validity was established by administering the WAIS-III to individuals with neuropsychological deficits, psychiatric disorders, mental retardation, learning disabilities and hearing impairments. The WAIS-III was found to have high construct validity (The Psychological Corporation, 2002).

Procedure

Ethical clearance was obtained from the Human Research Ethics Committee (HREC Non-Medical) from the University of the Witwatersrand before any research was conducted: protocol number MPSYC/15/001 IH. Upon ethical approval, permission was requested from the appropriate persons (e.g., course coordinators, lecturers and tutors) in order to address the undergraduate psychology students. Once permission was granted, participant recruitment was conducted by (a) posting advertisements (see Appendix D) around various locations at the university, (b) utilising an electronic version of the advertisement (see Appendix E), as well as information sheets (see Appendix F and G) which were uploaded onto the online university portal, and (c) by approaching undergraduate psychology classes during their lessons or tutorials.

If a student wanted to participate, he/she emailed the present researcher, and a suitable date and time was then allocated for data collection. Upon agreeing to participate, each participant was given an information sheet which outlined the study aims, the duration of testing, the voluntary and confidential nature of the research, the right to refuse to participate or to withdraw at any point in the study, as well as the researcher's and supervisor's contact details. First-year psychology students were informed that they would receive 1% course credit upon completion of participation. No other group of participants was provided with an incentive.

Each participant was assessed individually. The duration of participation was approximately two to two-and-a-half hours, and participants needed to commit to this period over one testing session. By consenting to participate, it was declared by each participant that they have not suffered a head injury or concussion, they were not taking drugs or alcohol, they had not been formally diagnosed with a psychological disorder and/or were not taking prescribed medication, they had not been diagnosed with a learning or language disorder and had had no previous exposure to the assessments involved in this study.

On the day prior to testing, each participant was sent a reminder email about the time and venue of testing. Prior to assessment administration, each participant was required to sign a consent form (see Appendix H). All of the paperwork and assessments were administered in English. Testing was conducted by the same researcher in a quiet venue in the Emthonjeni Centre at the University of the Witwatersrand on a face-to-face basis. Each participant first completed a demographic questionnaire, followed by the LSM and LEAP-Q. Upon completing the LEAP-Q, the researcher noted each participant's level of monolingualism, and if it was found that the participant was proficient in an additional language to English, he/she was excluded from further participation. The administration of the AWMA and the WAIS-III were randomly alternated between each participant to control for order effects and fatigability (Stangor, 2011). The examiner was seated across from each participant for the administration of the WAIS-III and on the right side of each participant facing the computer for the administration of the AWMA (in accordance with the outlined testing procedures).

Testing and scoring of the WAIS-III and LEAP-Q were conducted manually, while the AWMA was administered and scored on a computer, overseen by the researcher. Each assessment was conducted with adherence to the standardised conditions and scoring criteria. The outlined procedure was identical to that followed for the multilingual sample. To uphold confidentiality and anonymity for analysis of the data, numerical codes were noted on each participant's completed instrument, so as to group an individual's demographic information and corresponding data together. To ensure that course credit was provided, each participant needed to provide his/her student number and course codes by filling in the credit slip (see Appendix I). To maintain confidentiality and anonymity of results, no further identifiable information is provided and only those who wished to obtain credit consented to do so.

Overview of Data Analysis

The purpose of this study was to assess whether working memory differed between monolingual English first-language speakers and multilingual English second- or additional-language speakers, while controlling for intellectual ability and SES between the language groups. In light of the posed research questions and the type of research design, the most appropriate statistical procedures were descriptive statistics, frequencies, Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA). The analyses of all data were performed with IBM SPSS, version 22.0.0. Propensity score matching was used to match participants from the multilingual sample to the monolingual sample, by selecting the demographic variables of gender, age and SES scores with respect to the distribution of observed covariates (Rosenbaum & Rubin, 1985). Matching was performed using a nearest-neighbour matching approach (Linck et al., 2013), where each individual in the smaller monolingual sample (n = 39) was matched with an individual from the bigger multilingual sample (n = 110) with the closest propensity score. No individual could be matched to another individual more than once. This resulted in a sample of 39 monolingual participants matched to 39 multilingual participants. The scoring of the WAIS-III and AWMA was conducted by the researcher under the supervision of Prof. Kate Cockcroft, and no discrepancies were found. Raw scores of the WAIS-III and AWMA were converted into scaled scores for the purpose of analysis.

Descriptive statistics were used to describe features of the sample, and means and standard deviations were reported for demographic interval variables, while frequencies assisted in comprising a summary of how frequently conditions occurred within the data set. For the inferential analyses, parametric assumptions were addressed in order to assess whether the data was normally distributed. It was found that the data was normally distributed allowing for parametric statistics to be conducted. The statistical analyses were conducted over two-phases. Initially, independent sample t tests were run for interval demographic variables, and simple one-way between subjects ANOVAs (phase one) were run for four subtests of the WAIS-III (Vocabulary, Similarities, Block Design and Matrix Reasoning) and all AWMA subtests, in order to assess whether a difference existed between the language groups on any measures of intelligence. If any of these variables were found to differ significantly between the monolingual and multilingual groups, they would be treated as covariates and controlled for in an ANCOVA (phase two), to test for differences in working memory performance. Covariates that differed significantly between the groups included two verbal subtests from the WAIS-III, Vocabulary and Similarities, as well as the LSM score measuring SES. Consequently, ANCOVAs were run controlling for these variables. Cohen's *d* analyses and partial eta squared analyses reported effect sizes (Cohen, 1992). Alpha was set at .05 for all statistical tests in order to establish significance of results.

Ethical Considerations

When working with human subjects it is essential to consider ethical issues that may arise during the course of the research process. In light of this, specific ethical standards were upheld to ensure the well-being of each participant. Prior to participation, each participant who volunteered to take part in this study received an information sheet detailing the aims and rationale of the study, the data gathering procedure, the voluntary and confidential nature involved in participation, as well as the researcher and supervisor's contact information. Additionally, each participant was made aware of their right to refuse to participate in this study or to withdraw at any point without any negative academic or social consequences.

After participants received information concerning this study, those who wished to participate were asked to sign a consent form agreeing to volunteer to participate in the research. Because all participants were above the age of 18 years, they were legally allowed to consent to participate without additional approval required from a parent or guardian (National Health Act, 2004). The voluntary and confidential nature of the study was additionally stipulated in the consent form. The consent form also stated that there would be no risks or benefits arising from participation in this study. Any concerns or questions that were raised by the participants before, during or after the assessment, were addressed thoroughly.

Due to the face-to-face nature of the testing procedure and the awarding of course credit[15], complete anonymity could not be guaranteed. However, no identification of individual results or

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[15] Incentivising participation has been criticised in the literature, but it is the university's policy that first year Psychology students may be awarded credit when participating in research studies. Therefore, the awarding of credit was in line with the university's policy and was not regarded as an unusual, cooping plan to attract participants. Further, of the monolingual and multilingual samples, only 43.6% and 23.1% were first year students, respectively (see Table 2 on p. 26).

data was possible as each participant was assigned a numerical code which was noted on each completed set of tests. Consequently, there is no way to trace any assessment or questionnaire back to an individual. As individual feedback on performance was not provided, anonymity was guaranteed in the data analyses, reports, theses, conference presentations and/or publications arising from this study by removing participants' identifying information and coding the data anonymously immediately after assessment. Confidentiality of results is ensured as only the researcher and supervisor have access to the data, which is stored electronically on password-protected computers, and in a locked cupboard at the university.

Chapter Four: Results

The primary purpose of this study was to assess whether differences exist in working memory performance between monolingual and multilingual South African, non-clinical, young adult, university students, while controlling for verbal intelligence and SES between the groups. Working memory (dependent variable) was assessed using the AWMA – the data of which was interval in nature. Language group (independent variable) was operationalised as monolingualism and multilingualism based on self-reports using the LEAP-Q. This variable was a combination of nominal and interval scales of measure. Three covariates were identified, namely Vocabulary, Similarities (verbal intelligence) and SES. Data was attained for these variables using the WAIS-III and LSM, respectively, and was interval in nature. In this chapter, the various descriptive and inferential statistical analyses that were performed are described. The results are discussed below.

Demographic Synopsis of the Sample

The total sample consisted of 78 participants, of which 39 (50%) were monolingual. Propensity score matching was used to get an equal number of monolingual and multilingual participants as closely matched as possible. Since the multilingual group comprised 110 participants, the 39 closest matches to the monolingual sample were used in this study. Figure 3

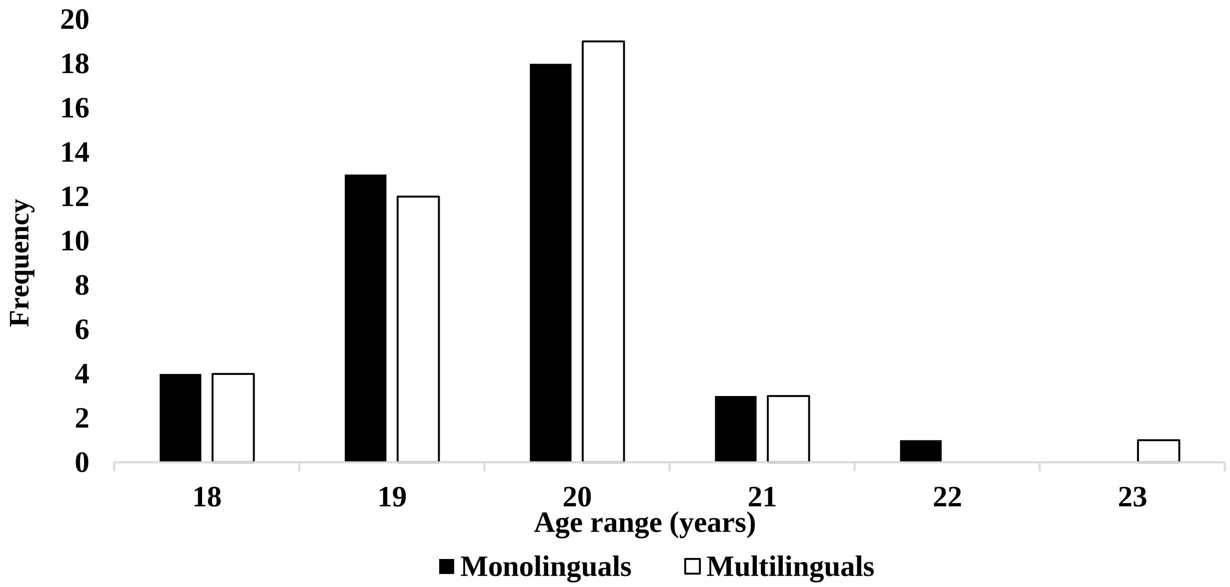

Figure 3. Age distribution of monolingual and multilingual participants.

shows the frequency of monolingual and multilingual participants between the ages of 18 and 23 years. The mean age of the total sample was 20.05 years (*SD* = .95), with the monolingual sample having a mean age of 20.06 years (*SD* = .88), and the multilingual sample having a mean age of 20.03 years (*SD* = 1.03). In terms of sample characteristics, it was found that there was no statistically significant age difference between the language groups (*t*(76) = .119; *p* = .906, *d* = .03), as shown in Table 4. There was a statistically significant difference in LSM scores between the

Table 4
Demographic descriptive statistics and t tests by language group

	Monolinguals (N = 39)			Multilinguals (N = 39)			*t* test		
	M	*SD*	Range	*M*	*SD*	Range	*t* (df)	*p*	*d*
Age in years	20.06	.88	18–22	20.03	1.03	18–23	.119 (76)	.906	.03
LSM	10.00	.00	10	6.89	1.89	2–10	10.294 (38)	.000**	2.33
Maternal education	4.41	.68	3–5	3.92	1.20	1–5	2.203 (58.261)	.032*	.50
Paternal education	4.50	.65	2–5	4.04	1.18	1–6	2.010 (62)	.049*	.48
Number of languages spoken	2.10	.82	1–3	3.74	.99	2–5	-7.958 (76)	.000**	1.80

Note. LSM = Living Standards Measure. *d* = Cohen's *d* effect size. * = *p* < .05, ** = *p* < .01.

language groups (*t*(38) = 10.294; *p* = .000, *d* = 2.33), with monolingual participants scoring higher on the LSM (*M* = 10.00; *SD* = .00) compared to multilingual participants (*M* = 6.89; *SD* = 1.89). Maternal and paternal highest level of education was found to differ significantly between the language groups (*t*(58.261) = 2.203; *p* = .032, *d* = .50 and *t*(62) = 2.010; *p* = .049, *d* = .48, respectively), but these differences approached the 5% level of significance. In terms of linguistic differences, as anticipated, a statistically significant difference was found in the number of languages spoken by the groups (*t*(76) = -7.958, *p* = .000, *d* = 1.80), with the multilingual group speaking more languages on average than the monolingual group, with a mean number of 3.74 (*SD* = .993) and 2.10 (*SD* = .821) languages spoken by each group, respectively.

Language Characteristics of Participants

Monolingual sample.

Collectively, the majority of monolingual participants spoke between one and two languages (30.8% and 30.8%, respectively), and 38.5% reported speaking three languages. Because South African schooling syllabi stipulate that at least two languages be taught (Department of Basic Education, 2009), the exposure to second and third languages in this group is predominantly a result of educational requirements. It should be noted that monolingual participants reported that they could only speak English and used English as a predominant language with a high level of proficiency, and had limited understanding and proficiency in the additional languages they reported to know. Sandoval et al. (2010) made a similar inference in their study, where a few monolingual participants reported to have learned a second language as a school requirement, where participants reported having limited proficiency in an additional language.

Linguistic proficiency is a useful measure to assess an individual’s language knowledge. This construct was measured using the LEAP-Q. Specifically, information regarding language dominance and acquisition was obtained from the LEAP-Q, where participants were instructed to list all the languages they knew in relation to these measures. Table 5 indicates the languages reported by the monolingual participants in order of dominance. English was reported to be the dominant first language for all monolingual participants, followed by Afrikaans as a second language (59.0%) and a variety of languages reported as third languages. Across the monolingual participants, exposure to 10 languages was reported.

The order of language acquisition by the monolingual participants is indicated in Table 6. All but one participant reported acquiring English as a first language. However, the individual who acquired Italian as a first language subsequently lost it within a few years. In accordance with the

Table 5
Language dominance for the monolingual sample

	L1 Dominance	L2 Dominance	L3 Dominance
	n (%)	n (%)	n (%)
English	39 (100.0)		
Afrikaans		23 (59.0)	2 (5.1)
isiZulu		2 (5.1)	2 (5.1)
Hebrew		1 (2.6)	2 (5.1)
French		1 (2.6)	1 (2.6)
German			1 (2.6)
Portuguese			3 (7.7)
Spanish			1 (2.6)
Italian			2 (5.1)
Arabic			1 (2.6)

reported language dominance, Afrikaans was reported as the second language of acquisition by the majority of the monolingual sample (56.4%), and a variety of languages was acquired by the participants as third languages. The linguistic profile suggests that all of these participants regarded English as their dominant language.

Table 6
Language acquisition for the monolingual sample

	L1 Acquisition	L2 Acquisition	L3 Acquisition
	n (%)	n (%)	n (%)
English	38 (97.4)	1 (2.6)	
Afrikaans		22 (56.4)	2 (5.1)
isiZulu		2 (5.1)	2 (5.1)
Hebrew		1 (2.6)	2 (5.1)
French			2 (5.1)
German			1 (2.6)
Portuguese			3 (7.7)
Spanish			1 (2.6)
Italian	1 (2.6)		1 (2.6)
Arabic			1 (2.6)

For each dominant and acquired language reported by the monolingual participants, further questions in the LEAP-Q assessed self-reported language history and proficiency. These results are shown in Table 7.

Table 7
Monolinguals' language history and proficiency scores (N = 39)

	L1			L2			L3		
	M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Self-Reported Proficiency[a]									
Speaking	9.21	.80	7–10	3.14	1.53	1–5	2.13	2.60	1–6
Understanding	9.28	.79	7–10	3.79	1.45	1–7	2.60	1.06	1–5
Reading	9.21	.89	7–10	3.71	1.88	0–8	2.60	2.44	0–8
Age Milestones (years)									
Started Learning	1.56	.87	1–4	9.07	2.63	5–15	12.00	5.90	0–19
Attained Fluency*	4.67	1.94	1–9	14.86[A]	1.95	12–18	15.00[D]		15
Started Reading*	6.03	1.16	3–9	10.62[B]	2.74	6–19	13.21[E]	4.84	5–19
Attained Reading Fluency*	7.79	1.67	5–13	14.22[C]	2.49	10–18	12.00[F]	2.65	10–15
Contribution to Language Learning[b]									
Friends	8.79	1.84	1–10	1.50	2.41	0–9	1.13	1.55	0–5
Family	9.72	.65	7–10	1.39	1.73	0–5	.80	2.57	0–10
Reading	9.46	.97	5–10	2.61	3.07	0–10	2.27	2.84	0–9
TV	8.56	2.05	3–10	1.82	2.50	0–8	1.80	2.27	0–6
Radio	7.44	2.66	0–10	.96	1.04	0–4	1.47	1.64	0–5
Independent Study	4.33	4.39	0–10	1.50	2.53	0–9	3.07	2.92	0–9
Extent of Language Exposure[c]									
Interacting with Friends	8.56	1.80	3–10	2.04	2.59	0–10	1.73	2.31	0–6
Interacting with Family	9.51	1.00	5–10	2.21	2.83	0–9	.87	2.56	0–10
Reading	9.19	1.12	6–10	3.18	2.51	0–10	3.33	3.06	0–10
Watching TV	8.13	2.15	2–10	2.25	2.52	0–8	1.60	1.96	0–6
Listening to the Radio	7.46	2.81	0–10	.96	1.29	0–5	.93	1.34	0–4
Language Tape/ Self-Instruction	4.76	3.96	0–10	2.00	2.26	0–7	4.20	3.28	0–10

Note. [a]Range = 0 (*none*) to 10 (*perfect*). [b]Range = 0 (*not a contributor*) to 10 (*most important contributor*). [c]Range = 0 (*never*) to 10 (*always*). * = Numerical values could not be assigned for responses of still not achieved, therefore only reported numerical values are presented in the table. A = 20 monolinguals rated this achievement as still not met. B = 1 monolingual rated this achievement as still not met. C = 18 monolinguals rated this achievement as still not met. D = 14 monolinguals rated this achievement as still not met. E = 1 monolingual rated this achievement as still not met. F = 12 monolinguals rated this achievement as still not met.

The monolingual participants all started learning English as a first language from birth to the age four (M_{age} = 1.56 years, *SD* = .870) and attained fluency in English between the ages of one and nine years (M_{age} = 4.67 years, *SD* = 1.94). These participants started to read in English between the ages of three and nine years (M_{age} = 6.03 years, *SD* = 1.16), and attained reading fluency between five and 13 years of age (M_{age} = 7.79 years, *SD* = 1.67). For L2 and L3 age of acquisition, age of language fluency, age of reading and reading fluency age, some monolingual participants reported that they had still not reached fluency. Consequently, Table 7 only indicates mean and standard deviation scores for numerical responses given, and does not indicate cases where fluency had not been achieved. The mean age of acquisition for both L2 and L3 reported by the monolingual participants was older compared to that reported for the acquisition of English (M_{age} = 9.07 years, *SD* = 2.63 and M_{age} = 12.00 years, *SD* = 5.90, respectively). Of the 27 (69.2%) monolinguals who reported exposure to a second language, 20 (74.1%) were still not fluent in that language. Similarly, of the 15 (38.5%) monolinguals who reported to be exposed to a third language, 14 (93.3%) reported that they were still not fluent in that language.

When asked to report proficiency in speaking, understanding and reading in L2 or L3, these participants' mean scores were below 5 (suggesting low proficiency): ranging from 3.14 (*SD* = 1.53, speaking) to 3.79 (*SD* = 1.45, understanding) for their L2, and 2.13 (*SD* = 2.60, speaking) to 2.60 (*SD* = 1.06, understanding and *SD* = 2.44, reading) for their L3. However, when reporting their English proficiency in speaking, understanding and reading, monolingual participants had mean scores of 9.21 (*SD* = .80), 9.28 (*SD* =.79) and 9.21 (*SD* =.89), respectively, further suggesting that the use of English dominated in communication for this group.

These participants reported being exposed to their L1 mostly in the context of family, followed by reading, interacting with friends, watching TV, listening to the radio and independent language study. This differed for L2 and L3, whereby the context of exposure to L2 was highest for reading, followed by TV, family, friends, independent language study and radio, and for L3 the order was independent language study, reading, friends, TV, radio and family. When asked to report how different factors contributed to language learning, participants reported that learning L1 relied mostly on family, followed by reading, friends, TV, radio and self-instruction, whereas L2 relied mostly on reading, then TV, joint friends and self-instruction, family and radio. Given this group's low proficiency rating in L2 and L3 and the dominance of their L1, together with their high levels of self-reported proficiency, they were assigned to the monolingual group – although the name of this group is a bit of a misnomer, it is used for ease of reference.

Multilingual sample.

Propensity score matching was used to match a sample of 39 multilingual participants to the 39 monolingual participants. The number of languages spoken by the multilingual group ranged between two and five, with the majority speaking four languages (38.5%), and a small portion speaking only two languages (7.7%). Across the multilingual sample, all 11 official South African languages were reported to be spoken, with varying degrees of dominance. Table 8 indicates the languages reported by the multilingual participants in order of dominance. The multilinguals reported a variety of languages as being dominant, with Sepedi reported by the majority of participants as the dominant first language (20.5%), followed by Tshivenda (17.9%) and

Table 8
Language dominance for the multilingual sample

	L1 Dominance	L2 Dominance	L3 Dominance	L4 Dominance	L5 Dominance
	n (%)	n (%)	n (%)	n (%)	n (%)
English	4 (10.3)	31 (79.5)	2 (5.1)	2 (5.1)	
Sesotho	2 (5.1)	2 (5.1)	3 (7.7)	3 (7.7)	2 (5.1)
IsiZulu	6 (15.4)	3 (7.7)	11 (28.2)	6 (15.4)	2 (5.1)
IsiXhosa	3 (7.7)		6 (15.4)		1 (2.6)
Sepedi	8 (20.5)	1 (2.6)	6 (15.4)	5 (12.8)	1 (2.6)
SiSwati	1 (2.6)				
Xitsonga	4 (10.3)		3 (7.7)	1 (2.6)	
Setswana	4 (10.3)	1 (2.6)	3 (7.7)	5 (12.8)	1 (2.6)
Tshivenda	7 (17.9)			1 (2.6)	3 (7.7)
Afrikaans		1 (2.6)	1 (2.6)	1 (2.6)	
IsiNdebele				1 (2.6)	

isiZulu (15.4%). English was the dominant second language for the majority of the multilinguals (79.5%), followed by isiZulu (7.7%) and Sesotho (5.1%). Only one participant reported speaking isiNdebele (2.6%) as their fourth dominant language, and Tshivenda was reported by three participants as a fifth dominant language (7.7%). Overall, the multilingual sample reported speaking a range of indigenous South African languages with varying degrees of dominance.

Table 9 refers to the order of language acquisition reported by the multilingual sample. Compared to some participants from the monolingual sample, who acquired a maximum of three languages, participants from the multilingual sample acquired a maximum of five languages. Twenty-five (64.1%) of the 39 multilingual participants reported acquiring four languages, and 10 (25.6%) participants reported acquiring five languages. None of the multilingual participants acquired English as a first language, but it was reported as the second (76.9%), third (17.9%) or fourth (5.1%) language. IsiZulu was acquired as a first language by the majority of participants (23.1%), which was followed by Sepedi (acquired by 20.5% of the sample) and Tshivenda (acquired by 17.9% of the sample). SiSwati and isiNdebele were acquired by one participant each as a first and third language, respectively.

Table 9
Language acquisition for the multilingual sample

	L1 Acquisition	L2 Acquisition	L3 Acquisition	L4 Acquisition	L5 Acquisition
	n (%)	n (%)	n (%)	n (%)	n (%)
English		30 (76.9)	7 (17.9)	2 (5.1)	
Sesotho	3 (7.7)	2 (5.1)	2 (5.1)	3 (7.7)	2 (5.1)
IsiZulu	9 (23.1)	2 (5.1)	9 (23.1)	4 (10.3)	4 (10.3)
IsiXhosa	3 (7.7)	4 (10.3)	1 (2.6)	1 (2.6)	1 (2.6)
Sepedi	8 (20.5)		6 (15.4)	5 (12.8)	2 (5.1)
SiSwati	1 (2.6)				
Xitsonga	4 (10.3)		3 (7.7)	1 (2.6)	
Setswana	4 (10.3)	1 (2.6)	3 (7.7)	6 (15.4)	
Tshivenda	7 (17.9)		1 (2.6)	2 (5.1)	1 (2.6)
Afrikaans			2 (5.1)	1 (2.6)	
IsiNdebele			1 (2.6)		

The multilinguals' self-reported language history and proficiency measures are shown in Table 10. Across the multilingual sample, exposure to up to five languages was reported. Some participants from the multilingual sample started learning a first (33.3%), second (2.6%) and third language (7.7%) from birth, while others started learning a fourth and fifth language at the age of four. L1 fluency was attained between the ages of two and 11 years (M_{age} = 5.36 years, *SD* = 2.46), L2 fluency from five to 17 years (M_{age} = 10.74 years, *SD* = 3.24), L3 fluency from four to 19 years (M_{age} = 12.33 years, *SD* = 5.13), L4 fluency from nine to 21 years (M_{age} = 16.00 years, *SD* = 3.93) and L5 form six to 19 years (M_{age} = 15.63 years, *SD* = 4.84). The mean age of additional language acquisition increased with each subsequent additional language (with the exception of L4 and L5 acquisition). One multilingual participant reported that she had still not attained fluency in L2, while for L3 (n = 31), there were four (12.9%) multilinguals and for L4 (n = 22), there were also four (18.2%) multilinguals who reported a lack of fluency attainment in each language.

When asked to report on their proficiency in speaking, understanding and reading in each language, participants obtained average scores above 5 for all five languages across both proficiency indicators of speaking and understanding. Mean scores fell just below 5 for L3 (*M* = 4.84, *SD* = 3.34), L4 (*M* = 4.78, *SD* = 3.23) and L5 (*M* = 4.00, *SD* = 4.28) for reading proficiency. Each proficiency score decreased with each corresponding additional language reported by the participants (except for reading at L1 and L2, which differed by only .13 points). Participants reported the highest proficiency for understanding in the L1 (*M* = 9.13, *SD* = 1.24), L3 (*M* = 7.23, *SD* = 1.59), L4 (*M* = 6.96, *SD* = 2.21) and the L5 (*M* = 6.63, *SD* = 1.77), while reading proficiency was reported as highest for the L2 (*M* = 8.69, *SD* = 1.64). These results suggest that speaking, understanding, and reading proficiency decrease with the acquisition of an additional language (L3, L4, or L5, as reading proficiency was rated as highest in L2). Additionally, the high levels of proficiency in speaking, understanding and reading in multiple languages in this group indicates that these individuals are competent multilinguals. The requirement for assignment to this group was proficiency ratings of above 5 on the LEAP-Q in two or more languages.

Table 10

Multilinguals' language history and proficiency scores (N = 39)

	L1			L2			L3			L4			L5		
	M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Self-Reported Proficiency[a]															
Speaking	9.10	1.29	5–10	8.44	1.39	4–10	6.68	1.42	4–10	6.48	1.93	3–10	5.25	2.32	3–9
Understanding	9.13	1.24	6–10	8.59	1.35	4–10	7.23	1.59	4–10	6.96	2.21	2–9	6.63	1.77	4–10
Reading	8.56	1.93	3–10	8.69	1.64	2–10	4.84	3.34	0–10	4.78	3.23	0–10	4.00	4.28	0–10
Age Milestones (years)															
Started Learning*	2.03	2.31	0–9	6.69	2.42	0–13	9.10	5.23	0–18	14.05	4.60	4–20	14.25	4.80	4–18
Attained Fluency*	5.36	2.46	2–11	10.74[B]	3.24	5–17	12.33[E]	5.13	4–19	16.00[H]	3.93	9–21	15.63	4.84	6–19
Started Reading*	7.64	2.61	5–16	7.78[C]	2.83	3–18	14.04[F]	4.61	6–20	15.50[I]	4.15	6–20	17.57[K]	1.40	16–20
Attained Reading Fluency*	10.61[A]	3.09	6–17	11.83[D]	2.95	7–19	14.26[G]	5.61	0–20	15.77[J]	6.18	0–20	19.00[L]	1.41	17–21
Contribution to Language Learning[b]															
Interacting with Friends	6.92	2.58	3–10	7.82	2.29	2–10	6.94	2.86	0–10	6.87	3.31	0–10	8.00	2.00	4–10
Interacting with Family	8.23	2.31	0–10	3.54	2.37	0–8	3.55	3.04	0–10	1.77	2.51	0–8	.50	1.07	0–3
Reading	4.05	3.26	0–10	8.36	3.02	0–10	2.84	3.20	0–10	3.00	3.28	0–10	.63	1.41	0–4
Watching TV	3.46	3.23	0–10	7.21	3.11	0–10	4.00	3.28	0–10	4.48	3.36	0–10	4.38	2.93	0–10

(continued)

Table 10. *Multilinguals' language history and proficiency scores (continued)*

	L1			L2			L3			L4			L5		
	M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Listening to the Radio	3.67	3.17	0–10	6.03	3.41	0–10	2.90	3.12	0–10	3.57	3.25	0–10	4.50	3.25	0–10
Language Tape/ Self-Instruction	1.56	2.06	0–9	3.82	3.79	0–10	1.74	2.72	0–10	1.39	2.55	0–10	1.38	2.67	0–7
Extent of Language Exposure[c]															
Friends	8.03	2.08	3–10	7.15	2.69	0–10	6.63	2.68	0–10	7.35	3.38	0–10	7.13	3.04	2–10
Family	8.87	2.14	1–10	4.28	2.87	0–10	4.58	3.41	0–10	2.17	3.13	0–10	1.38	2.56	0–6
Reading	7.67	2.59	2–10	8.79	1.99	1–10	3.39	3.15	0–10	3.09	2.83	0–10	1.00	1.51	0–4
TV	4.39	2.86	0–10	8.08	2.74	0–10	4.40	3.09	0–10	5.30	3.13	0–10	5.50	2.67	3–10
Radio	5.26	3.13	0–10	6.67	3.18	0–10	3.65	3.34	0–10	3.52	3.04	0–10	3.88	3.68	0–10
Independent Study	3.38	2.92	0–9	4.72	3.85	0–10	2.45	3.24	0–10	2.17	3.01	0–10	.88	1.64	0–4

Note. [a]Range = 0 (*none*) to 10 (*high*). [b]Range = 0 (*not a contributor*) to 10 (*most important contributor*). [c]Range = 0 (*not at all*) to 10 (*always*). * = Numerical values could not be assigned for responses of still not achieved, therefore only reported numerical values are presented in the table. A = 1 multilingual rated this achievement as still not met. B = 1 multilingual rated this achievement as still not met. C = 2 multilinguals rated this achievement as still not met. D = 3 multilinguals rated this achievement as still not met. E = 4 multilinguals rated this achievement as still not met. F = 6 multilinguals rated this achievement as still not met. G =12 multilinguals rated this achievement as still not met. H = 4 multilinguals rated this achievement as still not met. I = 6 multilinguals rated this achievement as still not met. J = 9 multilinguals rated this achievement as still not met. K = 1 multilingual rated this achievement as still not met. L = 2 multilinguals rated this achievement as still not met.

Multilingual participants reported being exposed to L1 mostly in the context of family, followed by friends, reading, radio, TV and lastly through independent language study. For each subsequent reported language, this pattern of exposure differed. For L2, the context of language exposure was from reading, followed by TV, friends, radio, independent language study and lastly family. In the context of learning a third, fourth or fifth language, the multilinguals reported that the most important contributor was interacting with friends. Exposure to TV and radio played an additional role in contributing to language learning, while interacting with family, as well as studying independently contributed less to learning an additional language.

In addition to rating the role of various contexts in promoting language learning, participants were asked to report on the extent to which different factors contributed to learning their reported languages. Multilinguals reported that learning their L1 relied mostly on interacting with family, followed by interacting with friends, reading, listening to the radio, watching TV and self-instruction, whereas learning their L2 relied mostly on reading, followed by friends, TV, radio, self-instruction and family. Interacting with friends was the biggest contributor to learning a third, fourth and fifth language, followed by watching TV. The remaining order of listening to the radio, reading, interacting with family and self-instruction varied for learning a third, fourth or fifth language, with family and self-instruction being the least contributing factors.

Mean Differences between Language Groups

The data derived from the AWMA scores were subjected to the following analyses:

1. Means and standard deviations were calculated for descriptive purposes.
2. Assessment of normality was investigated.
3. One-way ANOVAs were used as a means to investigate the effect of demographic indicators (such as living standards) on monolingual versus multilingual language groups.
4. One-way ANOVAs were used as a means to investigate the effect of verbal and non-verbal components of intelligence on monolingual and multilingual language groups.

5. Pearson correlation coefficients were calculated between covariates and AWMA measures.
6. One-way ANCOVAs were used as a means to investigate the effect of working memory on monolingual and multilingual language groups, while controlling for verbal components of intelligence (Vocabulary and Similarities), as well as a measure of living standards.

Statistical analyses of the data assessed each of the 12 subtests of the AWMA, as well as four memory components investigated in the AWMA (verbal short-term memory, verbal working memory, visuo-spatial short-term memory and visuo-spatial working memory).

Tests for normality.

Prior to running parametric statistics, assumptions of normality need to be met. Parametric techniques make a number of assumptions about the population from which the sample has been drawn and the nature of the data (Pallant, 2011). Both ANOVA and ANCOVA techniques have outlined assumptions, but the latter requires additional assumptions. In this study, the data is normally distributed and does satisfy the majority of the necessary assumptions. These will be outlined with reference to the particular criteria that need to be satisfied:

Scale of measurement.

The dependent variable needs to be continuous and at least an interval scale of measure. This is true for the dependent variable of this study (working memory), which was determined using the AWMA. This is a psychological test and therefore scores are considered to be at least interval. The independent variable is discrete – participants were either monolingual or multilingual.

Random sampling.

The next assumption indicates that there needs to be random sampling. This assumption indicates that the scores obtained from the study need to be done using a random sample from the population. This assumption is not satisfied in this study because a non-probabilistic sampling technique was used. However, Pallant (2011) acknowledges that obtaining a random sample is often not possible in real-life research.

Independence of observations.

This assumption suggests that the observations making up the data need to be independent of one another; that is, each observation or measurement must not be influenced by any other observation or measurement. For the present study, this assumption was satisfied because each participant was assessed following the same standardised procedure, whereby the measurement of one participant did not influence the next.

Normal distribution.

In order to use the parametric techniques of ANOVA and ANCOVA, it is assumed that the populations from which the samples are taken are normally distributed. This "theorem and its generalizations imply that the sum of several random influences on some measurement suggests that the measurement has an approximate normal distribution" (Hogg & Tanis, 2014, p. 181). There are various methods that indicate normality, including the Central Limit Theorem (CLT), Skewness and Kurtosis coefficients, the Kolmogarov-Smirnov test and the Shapiro-Wilk test. The CLT is defined as a theorem that specifies the nature of the sampling distribution of the mean (Howell, 2011). According to the CLT, the sample size needs to be at least 30 participants in order to approximate a normal distribution (Howell, 2011). In this case, the total sample size is 78 participants, of which 39 belong to each language group. Therefore, the assumption to satisfy the CLT is met.

Skewness and Kurtosis are values that indicate the spread of the distribution. The former specifies the symmetry of the distribution, while the latter provides information regarding the 'peakedness' of the distribution. In order for the distribution to be classified as normal, Skewness and Kurtosis values need to fall within a range of -1 to 1 (with 0 indicating a perfectly normal distribution; Pallant, 2011). Appendix J provides a summary of indicators assessing whether the data is normally distributed. For the WAIS-III scores, all Skewness values for the scaled scores lie within the normal range, with the exception of the Matrix Reasoning subtest for the monolingual group, which was slightly above the normal range (Skewness coefficient = 1.053). For the monolingual data, Kurtosis values were within normal range for the Vocabulary and Similarities subtests, but not for the Block Design and Matrix Reasoning subtests. The Kurtosis values of the multilingual group fell within range for the Similarities and Matrix Reasoning subtests, but were out of range for the Vocabulary and Block Design subtests. Overall, though, it can be concluded that the data is generally normally distributed with reasonable Skewness and Kurtosis values.

The majority of the AWMA subtests met the criteria for univariate normality, with the exception of the distribution for the Digit Recall scores in the monolingual group, the Word Recall scores in the multilingual group, and Backwards Digit Recall scores for both language groups. All four memory components of the AWMA fell within the normal Skewness and Kurtosis ranges. Overall, Skewness and Kurtosis for the AWMA met the criteria for univariate normality.

The Kolmogorov-Smirnov and Shapiro-Wilk statistics assess the normality of the distribution of scores. For normality to be met, the result of these tests must be non-significant. Results for the Kolmogorov-Smirnov and Shapiro-Wilk tests are found in Appendix J. The majority of results were found to be non-significant, with minor non-normal cases. This further suggests that the data is normally distributed and that parametric techniques are suitable for the analyses.

Homogeneity of variance.

Parametric techniques assume that samples are obtained from populations with equal variances, which means that the variability of scores for each of the groups is similar. For normality to be met, the result of tests of equal variances must be non-significant. For the demographic indicators, the assumption of homogeneity of variance was satisfied for age (F(1,76) = .074, p = .786), paternal education (F(1,62) = 3.098, p = .083) and number of languages spoken by the participants (F(1,75) = .047, p = .829). However, this assumption was violated for LSM scores (F(1,76) = 68.809, p = .000) and maternal education (F(1,75) = 12.409, p = .001). Homogeneity of variance was met for all four subtests of the WAIS-III: Vocabulary (F(1,76) = .124, p = .725), Similarities ($F(1,76) = 1.451$, $p = .232$), Block Design ($F(1,76) = 1.771$, $p = .187$) and Matrix Reasoning ($F(1,76) = .169$, $p = .682$). Homogeneity of variance was met for three of the four memory categories of the AWMA: verbal working memory ($F(1,76) = 1.007$, $p = .319$), verbal short-term memory ($F(1,76) = .135$, $p = .714$) and visuo-spatial short-term memory ($F(1,76) = 2.040$, $p = .157$). However, this was not met for the visuo-spatial working memory combined score ($F(1,76) = 5.417$, $p = .023$). Additionally, ten subtests of the AWMA met this assumption, with the exception of the Odd One Out ($F(1,76) = 5.453$, $p = .022$) and Spatial Recall ($F(1,76) = 4.924$, $p = .029$). Because ANOVA is a robust statistical technique (Pearson, 1931) and the majority of the scores meets the criteria for homogeneity of variance, one-way ANOVAs and ANCOVAs were deemed suitable statistical tests to use.

Comparisons between monolingual and multilingual groups.

Preliminary analyses of variance (ANOVAs) evaluated whether there were between-group differences on the WAIS-III subtests (Vocabulary and Similarities as measures of verbal intelligence, and Block Design and Matrix Reasoning as measures of non-verbal intelligence) as well as between verbal and non-verbal working memory. If differences emerged in WAIS-III measures, these variables would subsequently be used as covariates in an analysis of covariance (ANCOVA). Significance tests of the main effect for WAIS-III scores of language groups, as well as effect sizes (Cohen's *d*), are reported in Table 11.

Table 11
WAIS-III standard scores and ANOVAs by language group

	Monolinguals (*N* = 39)			Multilinguals (*N* = 39)			ANOVA			
	M	SD	Range	*M*	SD	Range	*F*	*p*	MSE	*d*
Vocabulary	12.56	2.22	8–17	10.08	2.39	3–16	22.672	.000**	5.32	1.08
Similarities	11.64	2.69	7–19	9.00	2.10	5–13	23.335	.000**	5.83	1.09
Block Design	9.05	2.65	2–16	9.51	3.15	4–19	.492	.485	8.44	.16
Matrix Reasoning	11.21	2.05	8–18	11.62	2.18	6–16	.730	.395	4.50	.19

Note. M = mean. *SD* = standard deviation. MSE = Mean Square of Errors. *d* = Cohen's *d* effect size. ** = $p < .01$.

Standard scores for all subtests of the WAIS-III scaled scores are between 0 and 19, with higher scores indicating better performance in the specific cognitive task. Significant language differences emerged on both verbal tests of intelligence (Vocabulary: $F(1,76) = 22.672$, $p = .000$, $d = 1.08$; and Similarities $F(1,76) = 23.335$, $p = .000$, $d = 1.09$), in favour of the monolingual group. Cohen's *d* values indicate that these results have strong effect sizes, which are in line with the significance found (Cohen, 1992). There were no significant differences between the language groups on non-verbal components of intelligence (Block Design and Matrix Reasoning). In accordance with the results, effect sizes were small (Cohen, 1992). Because differences were found in both verbal components of intelligence, these will be controlled for in an ANCOVA. Additionally, SES was found to differ significantly between the language groups, with the monolingual group scoring significantly higher on this variable than the multilingual group (refer to Table 4 on p. 47), and this variable will be a third covariate in the ANCOVA.

Between group ANOVAs were additionally conducted on all 12 subtests of the AWMA, as well as four composite memory components (verbal short-term memory, verbal working memory, visuo-spatial short-term memory and visuo-spatial working memory). Significance tests of the main effect for AWMA scores of language groups, as well as effect sizes (Cohen's *d*), are reported in Table 12. Three of the four broad memory components were found to differ significantly between the language groups, namely verbal working memory ($F(1,76) = 10.242$, $p = .002$, $d = .72$), visuo-spatial short-term memory ($F(1,76) = 8.337$, $p = .005$, $d = .65$) and visuo-spatial working memory ($F(1,76) = 15.153$, $p = .000$, $d = .88$), in favour of the multilingual group. In accordance with the results, the effect sizes were large (Cohen, 1992). There was a significant difference between the language groups on the Counting Recall subtest of verbal working memory ($F(1,76) =16.221$, $p = .000$, $d = .91$), the Dot Matrix and Block Recall subtests of visuo-spatial short-term memory ($F(1,76) = 4.750$, $p = .032$, $d =.49$; and $F(1,76) = 5.724$, $p = .019$, $d = .54$, respectively) and all three subtests of visuo-spatial working memory (Odd One Out: $F(1,76) = 10.966$, $p = .001$, $d = .75$;

Table 12
AWMA standard scores and ANOVAs by language group

	Monolinguals (*N* = 39)			Multilinguals (*N* = 39)			ANOVA			
	M	*SD*	Range	*M*	*SD*	Range	*F*	*p*	MSE	*d*
Verbal short-term memory	92.69	11.95	69–121	88.87	13.23	69–127	1.792	.185	158.83	.30
Digit Recall	85.90	9.85	69–116	93.77	13.95	69–136	8.286	.005**	145.82	.65
Word Recall	89.84	13.33	66–116	85.56	12.71	66–129	2.107	.151	169.66	.33
Non-word Recall	106.63	16.18	68–136	93.84	13.43	60–127	14.434	.000**	221.17	.86
Verbal working memory	87.00	10.46	72–106	95.72	13.41	72–125	10.242	.002**	144.71	.72
Listening Recall	92.36	12.53	70–119	97.05	14.70	73–136	2.302	.133	186.54	.34
Counting Recall	88.46	12.39	57–116	101.87	16.70	57–138	16.221	.000**	216.19	.91
Backwards Digit Recall	84.97	19.09	1–126	88.92	18.91	10–126	.840	.362	360.97	.21
Visuo-spatial short-term memory	86.77	11.42	62–111	95.67	15.49	62–139	8.337	.005**	185.15	.65
Dot Matrix	92.62	13.80	63–122	99.97	15.94	63–138	4.750	.032*	222.32	.49
Mazes Memory	92.90	16.82	62–130	99.46	14.72	70–134	3.363	.071	249.81	.42
Block Recall	82.49	12.21	60–106	90.21	16.03	60–121	5.724	.019*	202.92	.54
Visuo-spatial working memory	90.38	10.84	66–112	101.87	14.90	71–132	15.153	.000**	169.81	.88
Odd One Out	91.36	9.02	77–109	100.79	15.34	74–131	10.966	.001**	158.33	.75
Mister X	95.41	13.22	68–128	103.10	16.56	64–131	5.142	.026*	224.55	.51
Spatial Recall	90.38	10.16	72–116	99.92	14.81	79–136	10.997	.001**	161.16	.75

Note. *M* = mean. *SD* = standard deviation. MSE = Mean Square of Errors. *d* = Cohen's *d* effect size. * = *p* < .05, ** = *p* < .01.

Mister X: $F(1,76) = 5.142$, $p = .026$, $d = .51$; and Spatial Recall: $F(1,76) = 10.997$, $p = .001$, $d = .75$). All differences were in favour of the multilingual group. Effect sizes ranged from moderate to large (Cohen, 1992). No significant group differences were found in Listening Recall, Backwards Digit Recall and Mazes Memory, and effect sizes for these scores were small (Cohen, 1992). Additionally, there was no significant difference between monolinguals and multilinguals on the composite verbal short-term memory scale, although significant group differences were found on two of the three subtests of this memory category (Digit Recall: $F(1,76) = 8.286$, $p = .005$, $d = .65$; and Non-word Recall: $F(1,76) = 14.434$, $p = .000$, $d = .86$) in favour of the multilinguals for Digit Recall and monolinguals for Non-word Recall. All robust tests of equality of means, specifically Welch and Brown-Forsythe yielded the same statistical results, deviating marginally in some cases.

Correlational analysis.

Pearson correlation coefficients were conducted among the covariates and all measures from the AWMA for the monolingual and multilingual sample in order to determine the relationship between these variables (see Table 13). Results were fairly similar across the language groups, with only marginal differences. Significant positive correlations were found between the verbal components of intelligence (Vocabulary and Similarities) for both the monolingual ($r = .56$, $p = .000$) and multilingual ($r = .53$, $p = .000$) samples. This relationship was moderate in strength. Because all the monolingual participants received a score of 10 on the LSM, correlations in this group were not permitted due to the lack of variance. However, in the multilingual group, LSM (as a measure of SES) did not correlate with the other covariates, but correlated positively with the verbal short-term memory composite measure ($r = .37$, $p = .019$), Word Recall ($r = .43$, $p = .007$) and Listening Recall ($r = .33$, $p = .042$). These relationships were weak to moderate in strength. As expected, all composite memory components of the AWMA (verbal short-term memory, verbal working memory, visuo-spatial short-term memory and visuo-spatial working memory) correlated positively with each of their three subtests in both the monolingual and multilingual samples.

Table 13

Pearson's correlation coefficients between the covariates and all AWMA scales and composite measures by language group

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Covariates																			
1. Vocabulary	-	.56**		.25	.21	.09	.28	-.09	-.04	-.25	-.04	.11	.12	.13	-.05	.07	-.01	.14	.01
2. Similarities	.53**	-		.03	-.07	-.19	.27	-.12	-.04	-.05	-.22	.14	-.07	.33*	-.04	-.06	.12	-21	.04
3. LSM	.31	.13	-																
AWMA																			
4. *Verbal Short-Term Memory*	.68**	.41**	.37*	-	.70**	.76**	.79**	.49**	.30	.27	.32*	.15	.05	.33*	-.14	.15	.07	.13	.15
5. Digit Recall	.53**	.32*	.25	.84**	-	.44**	.33*	.41**	.23	.09	.36*	.07	.04	.30	-.24	.14	.22	.10	.04
6. Word Recall	.64**	.39*	.43**	.90**	.77**	-	.33*	.47**	.35*	.35*	-.01	.09	.08	.08	.02	.35*	.17	.36*	.27
7. Non-word Recall	.53**	.32*	.28	.70**	.28	.44**	-	.28	.15	.18	.36*	.22	.06	.38*	-.08	-.02	-.07	-.05	.09
8. *Verbal Working Memory*	.35*	.33*	.22	.51**	.45**	.44**	.38*	-	.71**	.75**	.32*	.16	.21	.12	.00	.28	.25	.12	.36*
9. Listening Recall	.24	.30	.33*	.40*	.29	.29	.41**	.77**	-	.46**	-.09	.34*	.29	.28	.08	.29	.09	.29	.28
10. Counting Recall	.11	.19	-.12	.18	.18	.24	.01	.66**	.21	-	.09	.04	.06	.02	-.01	.17	.06	.07	.30
11. Backwards Digit Recall	.34*	.24	.17	.48**	.51**	.36*	.30	.70**	.48**	.22	-	-.04	.03	.02	-.13	-.04	.10	-.20	.09
12. *Visuo-Spatial Short-Term Memory*	.30	.14	.13	.32*	.29	.22	.30	.43**	.31	.29	.24	-	.73**	.64**	.66**	.57**	.47**	.45**	.47**
13. Dot Matrix	.27	.19	.05	.22	.19	.18	.20	.34*	.18	.30	.21	.86**	-	.10	.45**	.60**	.40*	.54**	.50**
14. Mazes Memory	.29	.16	.12	.39*	.32*	.28	.39*	.42**	.33*	.35*	.13	.80**	.64**	-	.04	.19	.22	.08	.19
15. Block Recall	.24	.04	.20	.21	.24	.13	.16	.31	.26	.06	.24	.76**	.46**	.35*	-	.42**	.38*	.35*	.30
16. *Visuo-Spatial Working Memory*	.33*	.32*	.23	.38*	.32*	.38*	.27	.49**	.46**	.22	.27	.61**	.57**	.45**	.48**	-	.74**	.84**	.82**
17. Odd One Out	.37*	.15	.16	.33*	.31	.33*	.19	.37*	.29	.12	.28	.42**	.39*	.30	.36*	.76**	-	.41*	.51**
18. Mister X	.04	.13	.30	.22	.15	.21	.19	.34*	.46**	.05	.16	.58**	.53**	.44**	.45**	.81**	.46**	-	.50**
19. Spatial Recall	.30	.41**	.06	.27	.23	.27	.18	.39*	.36*	.28	.16	.41**	.37*	.31	.35*	.74**	.27	.48**	-

Note. Monolinguals (N = 39) above the diagonal, Multilinguals (N = 39) below the diagonal in bold. All LSM scores for the monolingual sample were 10 and it was not possible to correlate these scores. LSM = Living Standards Measure. AWMA = Automated Working Memory Assessment. * = $p < .05$, ** = $p < .01$.

For the monolingual sample, the strength of these relationships was predominantly strong, with the exception of verbal working memory and Backwards Digit Recall, which was weak (r = .32). The relationship with the highest correlation was between visuo-spatial working memory and Mister X (r = .84). Likewise, for the multilingual sample, the strength of these relationships was strong, ranging from r = .66 (for verbal working memory and Counting Recall) to r = .90 (verbal short-term memory and Word Recall).

In addition to this finding, common relationships were observed in both language groups across composite memory measures. Verbal short-term memory was found to significantly correlate with verbal working memory (monolinguals: r = .49, p = .002, multilinguals: r = .51, p = .001), Backwards Digit Recall (monolinguals: r = .32, p = .049, multilinguals: r = .48, p = .002) and Mazes Memory (monolinguals: r = .33, p = .041, multilinguals: r = .39, p = .014); verbal working memory significantly correlated with Spatial Recall (monolinguals: r = .36, p = .023, multilinguals: r = .39, p = .014); and significant relationships were found between visuo-spatial short-term memory and visuo-spatial working memory (monolinguals: r = .57, p = .000, multilinguals: r = .61, p = .000), Odd One Out (monolinguals: r = .47, p = .003, multilinguals: r = .42, p = .007), Mister X (monolinguals: r = .45, p = .004, multilinguals: r = .58, p = .000), and Spatial Recall (monolinguals: r = .47, p = .002, multilinguals: r = .41, p = .009). All these relationships were positive and weak to moderate in strength.

Working memory differences between language groups while controlling for covariates.

Results from phase one (where ANOVAs were used to identify covariates) were used as base-line indices, whereby results of the ANCOVAs were assessed in light of the initial findings in order to evaluate whether the covariates have an impact on the overall nature of working memory in the two language groups. The aim of phase two of analysis was to detect whether significant group differences are still apparent when SES and verbal intelligence are statistically controlled for. The section that follows will address the results of the ANCOVAs.

Additional assumptions of normality when conducting an ANCOVA.

Prior to running an ANCOVA, and in addition to the assumptions required to conduct an ANOVA, further assumptions need to be satisfied in order to assess whether the data is normally distributed. In this study, the data was found to be normally distributed and satisfied the majority of the assumptions for conducting an ANCOVA. These will be outlined below:

Correlations among covariates.

In order to meet this assumption, two criteria need to be satisfied: (a) there should not be strong correlations among the covariates, and (b) the covariates should correlate substantially with the dependent variable (working memory; Pallant, 2011). The matrix of correlation coefficients by language group for the covariates and AWMA measures are shown in Table 13 on p. 65. In addressing the first criterion, both verbal components of intelligence (Vocabulary and Similarities) positively correlated with one another for each language group (monolinguals: $r = .56$, $p = .000$; multilingual: $r = .53$, $p = .000$). However, these correlations are moderate in strength. Pallant (2011) stipulates that strong correlations should not occur between the covariates, but because Vocabulary and Similarities are verbal components of intelligence, it is expected that some relationship should exist as they measure a similar underlying cognitive construct (Wechsler, 1997). Regarding the third covariate of living standards, no significant LSM correlations were found for Vocabulary and Similarities for the multilingual group. LSM correlations are not provided for the monolingual group because all participants received a score of 10. Because, at best, moderate relationships exist between the covariates, we can assume that this criterion is satisfied.

The following points will address the second criterion. Correlations between the covariates and memory measures were not evident in the monolingual sample, with the exception of Similarities and Mazes Memory ($r = .33$, $p = .04$). In the multilingual sample, there were substantially more significant relationships between covariates and memory measures than in the monolingual sample. However, a few memory measures failed to correlate with any covariate, namely Counting Recall, Mister X and all subtests of (and including) visuo-spatial short-term memory. Thus, it cannot be concluded that this assumption was met with confidence. However, because no non-parametric version of an ANCOVA exists, and because the test is robust to non-normality, violation of this assumption is unlikely to result in a Type I error, and is useful in the present study (Pearson, 1931).

Linear relationship between working memory and covariates.

In order to run an ANCOVA, the relationship between the working memory variables and the covariates (Vocabulary, Similarities and SES) needs to be linear (Pallant, 2011). Because this study has three covariates, the assumption additionally indicates that a linear relationship needs to exist between each pair of covariates. For the most part, a linear relationship between working memory and the covariates, as well as between each pair of covariates was determined.

Homogeneity of regression slopes.

In order to satisfy this assumption, the relationship between the covariates and the working memory variables for both monolinguals and multilinguals should be the same. Thus, there should be no interaction between the covariates and the language groups. Refer to Appendix K for an outline of the homogeneity of regression slopes for language groups with covariates Vocabulary, Similarities and SES. If there is a significant interaction at an alpha level of .05, then this assumption is violated. For all 12 subtests of the AWMA, as well as the four composite language components, there were two interaction effects for Word Recall (p = .010) and verbal short-term memory (p = .019). The majority of the subtests did not show interaction effects between the covariates and the language groups (p > .05). Therefore, it can be concluded that this assumption has been met, and an ANCOVA is an appropriate statistical technique to use. Results from the ANCOVA are presented in the next section.

Working memory differences between language groups.

In order to statistically control for the possible effects of the confounding variables of verbal intelligence and SES between the language groups, a one-way between-groups ANCOVA was conducted. The independent variable was the language group (monolingual or multilingual), and the dependent variable consisted of working memory scores collected from the 12 subtests of the AWMA, as well as the four composite memory categories (verbal short-term memory, verbal working memory, visuo-spatial short-term memory and visuo-spatial working memory). In the earlier section, an ANOVA indicated that monolinguals and multilinguals differ statistically on verbal intelligence (Vocabulary and Similarities) and SES, which may influence their performance on the working memory measures. As such, it was necessary to control for these variables by statistically removing their effects, by treating them as covariates in the analysis. Preliminary checks were conducted to ensure that there were no major violations of the assumptions of normality, linearity, homogeneity of variances, and homogeneity of regression slopes. Unadjusted means and standard deviations, adjusted means and standard error scores, significance tests of the main effect of the AWMA for both language groups as well as effect sizes (partial η^2) are reported in Table 14.

The results of the ANCOVA indicated that three of the four composite memory components of the AWMA differed significantly between the language groups (verbal working memory: $F(1,76) = 11.141$, $p = .001$, $\eta_p^2 = .132$; visuo-spatial short-term memory: $F(1,76) = 7.265$, $p = .009$, $\eta_p^2 = .091$; and visuo-spatial working memory: $F(1,76) = 15.561$, $p = .000$, $\eta_p^2 = .176$) in favour of the multilingual group. In line with the significance found, effect sizes were large (Cohen, 1992). There was no significant difference in performance on verbal short-term memory between the language groups. Results concerning the composite memory categories of the AWMA are consistent in phase one and phase two, regardless of the effects of the covariates.

Table 14

One-way ANCOVA for AWMA scores by language group

	Monolinguals (*N* = 39)				Multilinguals (*N* = 39)				ANCOVA				
	M	*SD*	Estimated *M*	Standard error	*M*	*SD*	Estimated *M*	Standard error	*F*	*p*	MSE	Partial η^2	R Squared
Verbal short-term memory	92.69	11.95	87.68	2.44	88.87	13.23	93.89	2.44	2.204	.142	123.20	.029	.272
Digit Recall	85.90	9.85	82.35	2.46	93.77	13.95	97.32	2.46	12.633	.001**	124.98	.148	.258
Word Recall	89.84	13.33	84.93	2.60	85.56	12.71	90.46	2.60	1.540	.219	140.10	.021	.228
Non-word Recall	106.63	16.18	102.01	3.04	93.84	13.43	98.46	3.04	.462	.499	191.43	.006	.301
Verbal working memory	87.00	10.46	83.84	2.63	95.72	13.41	98.88	2.63	11.141	.001**	143.32	.132	.162
Listening Recall	92.36	12.53	87.48	2.95	97.05	14.70	101.93	2.95	8.194	.005**	179.77	.101	.102
Counting Recall	88.46	12.39	89.59	3.27	101.87	16.70	100.74	3.27	3.968	.050	220.98	.052	.191
Backwards Digit Recall	84.97	19.09	82.34	4.16	88.92	18.91	91.55	4.16	1.665	.201	597.09	.022	.056
Visuo-spatial short-term memory	86.77	11.42	84.35	2.97	95.67	15.49	98.08	2.97	7.265	.009**	182.88	.091	.145
Dot Matrix	92.62	13.80	91.68	3.27	99.97	15.94	100.91	3.27	2.716	.104	221.02	.036	.101
Mazes Memory	92.90	16.82	89.80	3.41	99.46	14.72	102.56	3.41	4.778	.032*	240.47	.061	.115
Block Recall	82.49	12.21	79.60	3.13	90.21	16.03	93.09	3.13	6.325	.014*	202.77	.080	.107

(continued)

Table 14. *One-way ANCOVA for AWMA scores by language group (continued)*

	Monolinguals (*N* = 39)				Multilinguals (*N* = 39)				ANCOVA				
	M	*SD*	Estimated *M*	Standard error	*M*	*SD*	Estimated *M*	Standard error	*F*	*p*	MSE	Partial η^2	R Squared
Visuo-spatial working memory	90.38	10.84	86.60	2.82	101.87	14.90	105.66	2.82	15.561	.000**	164.39	.176	.225
Odd One Out	91.36	9.02	88.44	2.74	100.79	15.34	103.71	2.74	10.611	.002**	154.88	.127	.179
Mister X	95.41	13.22	91.61	3.26	103.10	16.56	106.91	3.26	7.516	.008**	219.47	.093	.121
Spatial Recall	90.38	10.16	88.18	2.76	99.92	14.81	102.12	2.76	8.662	.004**	158.11	.106	.177

Note. *M* = mean. *SD* = standard deviation. MSE = Mean Square of Errors. η^2 = eta squared. * = $p < .05$, ** = $p < .01$.

When controlling for verbal intelligence and SES, monolinguals and multilinguals differed significantly on the AWMA tasks of Digit Recall (F(1,76) = 12.633, p = .001, η_p^2 = .148), Listening Recall (F(1,76) = 8.194, p = .005, η_p^2 = .101), Mazes Memory (F(1,76) = 4.778, p = .032, η_p^2 = .061), Block Recall (F(1,76) = 6.325, p = .014, η_p^2 = .080), Odd One Out (F(1,76) = 10.611, p = .002, η_p^2 = .127), Mister X (F(1,76) = 7.516, p = .008, η_p^2 = .093), and Spatial Recall (F(1,76) = 8.662, p = .004, η_p^2 = .106), all in favour of the multilingual group. Effect sizes for these results range from moderate to large, with the majority of results having large partial eta squares (Cohen, 1992). Differences in performance between monolinguals and multilinguals were found on all visuo-spatial working memory subtests of the AWMA (Odd One Out, Mister X and Spatial Recall), while for the memory components of verbal short-term memory, verbal working memory and visuo-spatial working memory, only one to two subtests (Digit Recall, Listening Recall, Mazes Memory and Block Recall, respectively) of the AWMA were found to differ between the language groups in each of these categories.

No differences were found between the language groups for Word Recall and Non-word Recall subtests of verbal short-term memory, Counting Recall and Backwards Digit Recall subtests of verbal working memory, and the Dot Matrix subtest of visuo-spatial short-term memory. Effect sizes for these results were weak (Cohen, 1992).

Differences in results with and without controlling for the effects of the covariates.

Controlling for the effect of verbal intelligence and SES resulted in five changes to the results. Performance on the AWMA subtests of Non-word Recall, Counting Recall and Dot Matrix were found to differ significantly between the language groups in the ANOVA, but once verbal intelligence and SES were held constant, the results of the ANCOVA indicated that there were no significant differences between the language groups on these measures. Likewise, performance on both Listening Recall and Mazes Memory were not found to differ between monolingual and multilingual groups when covariates were not accounted for; but in the ANCOVA, the effect of the covariates resulted in a significant difference on these subtests between the language groups. This indicates that verbal intelligence and living standards have an influence on working memory performance.

In terms of consistency of results across the ANOVAs and ANCOVAs, differences between the language groups remained the same prior to controlling and after controlling for verbal intelligence and SES for subtests of Digit Recall, Block Recall, Odd One Out, Mister X and Spatial Recall. Additionally, three memory composite scores differed between the language groups both before and after accounting for the covariates. These scores were verbal working memory, visuo-spatial short-term memory and visuo-spatial working memory. No differences were observed for Word Recall, Backwards Digit Recall and the composite score of verbal short-term memory both before and after controlling for verbal intelligence and SES. These results have important social, educational and cognitive implications in the multilingual society of South Africa, which will be presented in the following chapter.

Chapter Five: Discussion

This study investigated working memory performance in young adult university students comparing English first-language speakers (monolinguals) to English second- or additional-language speakers (multilinguals), while controlling for verbal intelligence and SES. This chapter presents a discussion of the key findings from the results of the ANCOVA (phase two of the study). The results are discussed in light of the research questions, followed by an overview and integration of the debates presented in the literature review. The chapter concludes with a summary of the theoretical and practical implications of the results in light of academic performance in the South African context.

Four key findings emerged from this study: (a) firstly, controlling for the effects of verbal intelligence and SES resulted in five significant changes to the preliminary results (phase one of the study), indicating that these covariates had an effect on working memory performance in addition to the number of languages spoken by participants; (b) secondly, the multilingual group performed significantly better than the monolingual group across five of six non-verbal subtests of the AWMA for simple and complex working memory, namely Mazes Memory and Block Recall (non-verbal simple span), and Odd One Out, Mister X and Spatial Recall (non-verbal complex span); (c) the multilingual group outperformed the monolingual group on two verbal subtests of the AWMA, namely Digit Recall (verbal simple span) and Listening Recall (verbal complex span); and (d) no group differences were found across the remaining verbal short-term memory (Word Recall and Non-word Recall) and working memory (Counting Recall and Backwards Digit Recall) subtests, as well as across one visuo-spatial short-term memory (Dot Matrix) subtest of the AWMA, indicating that monolinguals and multilinguals performed equally well on these tasks. These key findings will guide the succeeding discussion.

In phase one of this study, both verbal intelligence and SES were found to differ significantly between the two language groups. Thus, these variables were controlled for in phase two of the analysis (in an ANCOVA), which resulted in five significant changes across the verbal simple and complex memory spans and the non-verbal simple memory span. This indicates that these covariates had an effect on working memory performance over and above the number of languages spoken by the participants. It must be noted that even though propensity score matching was used to match the language groups on age, gender, and SES, the monolingual group still appeared socio-economically more privileged than the multilingual sample. Interpretation of the findings should be considered in light of this observation.

Specifically, in phase one of the analysis, the participants performed differently on the Non-word Recall (monolingual advantage), the Counting Recall (multilingual advantage) and the Dot Matrix (multilingual advantage) subtests of the AWMA, but once verbal intelligence and SES were held constant, the groups were found to perform equally well on these measures. Likewise, performance between the language groups on the Listening Recall and the Mazes Memory subtests indicated equivalence prior to controlling for verbal intelligence and SES, but when the covariates were accounted for, differences between the groups emerged, in the direction of a multilingual advantage. This indicates that verbal intelligence and SES have an influence on working memory performance. Similarly, there have been studies suggesting that SES impacts the findings confirming a bilingual advantage (see Gathercole et al., 2014; Paap & Liu, 2014). As such, the results of the ANCOVA will guide the following discussion.

Based on the review of the literature, this study expected to find a ‘bi(multi)lingual advantage’ for young adults on non-verbal tasks of working memory – which is a component of executive functioning (e.g., Bialystok, Craik, & Ryan, 2006a; Bialystok, Craik, & Ruocco, 2006b; Bialystok et at., 2004; Colzato et al., 2008; Bialystok et al., 2008; Costa et al., 2008; Costa & Sebastián-Gallés, 2014), and a monolingual advantage on verbal working memory tasks (e.g., Bialystok & Feng, 2009). One possible reason for these expectations are because the recruitment of executive control resources for multilingual individuals is different from that of monolingual individuals (Kroll & Bialystok, 2013). The results of the current study offer partial support for this body of literature.

The second key finding, where multilinguals outperformed monolinguals on non-verbal simple and complex tasks, was unsurprising given similar evidence from previous studies (e.g., Kroll & Bialystok, 2013; Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000). It is hypothesised that the relationship between the visuospatial sketchpad and the phonological loop could explain this finding (see Baddeley, 2003). The presence of visuo-spatial information during a working memory task will need to be retained and manipulated simultaneously. However, because visual working memory is limited in capacity – because the visual world is vivid, rapidly changing and irregular – the long-term storage of detailed visual information is superfluous. As such, only necessary visual information is retained, while more detailed features are not (Luck & Vogel, 1997; Vogel, Woodman, & Luck, 2001). Consequently, activation of the phonological loop – specifically the storage component – is also required to code and store visual information, while at the same time, the change in visual stimuli is manipulated by the activation of the visuospatial sketchpad (Baddeley, 2003). This may be the case for some individuals, while it is speculated that others can rehearse using visual mechanisms alone. Both the phonological store and articulatory rehearsal mechanisms, as well as the visuospatial sketchpad are well developed in young adult populations, even when multilinguals are assessed in their non-native language (Baddeley et al., 1998).

To successfully accomplish engaging with simultaneous tasks, working memory is the cognitive process activated, whereby attentional resources compete. Because evidence suggests that multilinguals have a processing advantage in simultaneous language activation (Kerkhofs et al., 2006; Marian et al., 2003; van Heuven, Schriefers et al., 2008), it is likely that they are able to utilise this advantage to enhance their performance in non-verbal simple and complex working memory tasks. Parallel use of numerous languages in multilinguals has been reported to impact cognitive control. To this end, the likelihood that multilinguals will experience cognitive benefits on working memory tasks in relation to their monolingual peers, suggests that their engagement in multiple language use provides the necessary environment for training and enhancing cognitive control (Emmorey, Luk, Pyers, & Bialystok, 2008). In doing so, the activation of one language system will coincide with the suppression or inhibition of another (or other) language systems, while at the same time they will need to cognitively overcome interference and intrusions from non-target languages (de Bruijn et al., 2001; Kerkhofs et al., 2006; van Heuven et al., 2008). These results support the suggestion by Oberauer (2005) that the cognitive processing advantage in the multilingual participants across non-verbal tasks may stem from the maintenance of keeping alternative languages separate which enhances selective attentional mechanisms, such that selecting goal-relevant stimuli when exposed to irrelevant distractors heightens processing beyond merely language control[16] (for a meta-analysis, see Adesope et al., 2010). This theory has been substantiated by Colzato et al. (2008), and Bialystok et al. (2006b). Research indicates that there is longitudinal sustainment of an attentional control benefit in multilinguals across the life-span, where multilingualism can act as a buffer impeding age-related cognitive decline (Bialystok, Craik, & Freedman, 2007; Bialystok et al., 2004, 2006a, 2014; Gollan & Ferreira, 2009).

Based on the third key finding, a multilingual advantage on the verbal working memory tasks was unexpected, since monolinguals have been found to outperform multilinguals on vocabulary and verbal memory tasks (e.g., Engel de Abreu, 2011). Given the results of the third key finding, where a difference was also found between language groups in the direction of a multilingual advantage on the Listening Recall task (a subtest comprising the composite verbal working memory component) and the Digit Recall task (a subtest comprising the composite verbal short-term memory component), it is likely that proponents of these tasks tap into similar cognitive resources as those necessary for the completion of non-verbal working memory tasks. Specifically, for the Listening Recall task, participants are required to judge the legitimacy of a heard sentence by noting it as ‘true’ or ‘false’. On completion of each trial, the participant must then recall, in the correct order, the final word of each sentence. The primary score given to each participant is based

[16] Although a large body of research – including the results of this study – coincide with enhanced attentional control mechanisms in multilingual individuals, there have been cases where multilingualism hinders efficient processing during working memory tasks, such that the management and maintenance of multiple languages may add greater cognitive demands during the performance of these tasks resulting in a multilingual disadvantage (see Lee, Plass, & Homer, 2006; van Merrienboer, & Sweller, 2005).

on the latter requirement. As such, the final words of each sentence can be remembered in various ways, including visually, where a participant pictures the word or a scene descriptive of some or all of the words, rather than the verbal components comprising the words themselves. In doing so, the completion of this verbal task incorporates non-verbal strategies that permit the use of non-verbal cognitive resources – analogous to those employed when performing non-verbal complex working memory tasks. This outcome has been defined by Baddeley (2003) as the *phonological similarity effect*, where the employment of sematic or visual coding strategies overtake the phonological loop, generally when error rates exceed 50%.

Although it is less obvious to delineate the Digit Recall task and its relationship to a multilingual advantage, it seems that the completion of this task may also employ non-verbal cognitive resources. Digits (e.g. 291537) are stated in a specific sequence, where participants are asked to recall what they have heard in the correct order. This verbal simple span measure may similarly recruit visual resources analogous to those needed for the completion of non-verbal simple span tasks. However, empirical evidence is necessary to identify whether there is merit to this theorisation. Research into strategy use in working memory performance could, therefore, shed light on the underlying – often qualitative – processes that occur beyond purely behavioural outcomes observed in psychological assessment. Yet, studies investigating strategy use – both quantitatively and qualitatively – in executive functioning are highly under researched.

Although literature on working memory and language has produced mixed results, this study concludes a 'bi(multi)lingual advantage' on non-verbal simple and complex memory tasks. However, no group differences were observed across verbal simple tasks of Word Recall and Non-Word Recall, verbal complex tasks of Counting Recall and Backwards Digit Recall, as well as the composite score of verbal short-term memory. These results are inconsistent with regard to previous studies suggesting a monolingual advantage in linguistic processing (e.g., Bialystok, 2009; Kaushanskaya & Marian, 2009). However, these studies have predominantly focused on verbal fluency (Bialystok et al., 2008; Gollan et al., 2000, 2005; Gollan & Acenas, 2004; Ivanova & Costa, 2008; Portocarrero et al., 2007; Rosselli et al., 2000; Sandoval et al., 2010), and picture naming (Gollan et al., 2005, 2007; Roberts et al., 2002), while this study looks specifically at verbal aspects of working memory. As such, it is likely that differences would present in results found from previous research and the research conducted in this study. Importantly, it seems that there is no language-group effect on these working memory components – impacts of which are significant for academic assessment.

In light of the present study, various proposals could account for performance equivalence across the language groups on these verbal simple and complex tasks. Of course, it is plausible that multiple explanations may concurrently affect verbal working memory performance, in which case various proposals are offered. It is worth noting that the distribution for the Digit Recall scores in the monolingual group, the Word Recall scores in the multilingual group, and Backwards Digit Recall scores for both language groups failed to meet the criteria for univariate normality. Because the ANCOVA – although robust – is a parametric technique and these subtests are non-parametric, the results of these assessments must be interpreted with caution.

Firstly, since verbal intelligence was found to significantly differ between the language groups, it was treated as a covariate and controlled for in the ANCOVA. Removing the variation of verbal intelligence in working memory performance may account for test equivalence on these verbal simple and complex tasks. Secondly, even though the multilingual participants reported English as a second, third or fourth language, their high English proficiency may account for the lack of differences in verbal memory ability. This could be because English is the *lingua franca* in South Africa and the medium of instruction at their institute of study. Also, the majority of multilinguals (79.5%) reported that English was their dominant L2. English proficiency has been identified as a factor contributing to academic success at a tertiary level of education in South Africa (Stephen et al., 2004). Research investigating the role of experience in modifying executive functioning has escalated in recent years, where neural plasticity is becoming widely accepted as a primary factor for this modification (Hilchey & Klein, 2011; Kroll & Bialystok, 2013). Support for this has been shown in jugglers (Draganski, Gaser, Busch, Schuierer, Bogdahn, & May, 2004), videogame players (Dye, Green, & Bavelier, 2009) and string players (Elbert, Pantev, Rockstroth, Taub, & Wienbruch, 1995). Furthermore, this result could be a consequence of developmental differences no longer present in young adulthood. Childhood studies have noted a monolingual advantage in standardised measures of vocabulary (Carlson & Meltzoff, 2008; Namazi & Thordardottir, 2010; Thordardottir, Rothenberg, Rivard, & Naves, 2006), but this advantage seems to dissipate with age. However, the specific tests used in these studies were not identical to those that have demonstrated group equivalence in present studies.

In addition, it is hypothesised that the AWMA subtests of Word Recall, Non-Word Recall, Counting Recall, Backwards Digit Recall and Dot Matrix may lack biasing effects between language groups since the monolingual and multilingual participants performed equally well on each of these tasks. However, it was surprising that for some (difficult to explain) reason, performance on the Digit Recall subtest was found to differ between the language groups in this study, where previous research has concluded that it ought to lack a biasing effect as well. Further research would be warranted to explain the present finding. These measures without biasing effects could, therefore, be used as tests when individuals of study comprise a heterogeneous linguistic profile, and research into working memory does not want to discriminate between language groups but some other construct. This result has been replicated across studies with child samples. For instance, Engel de Abreu (2011) failed to conclude a difference between 22 monolingual and 22 bilingual school children (M_{age} = 6 years 4 months, *SD* = 2.88 months) matched on age, gender and SES on the Counting Recall, the Backwards Digit Recall and the Digit Recall subtests of the AWMA. Likewise, in a South African study conducted by Cockcroft (2016) on 67 English monolingual (M_{age} = 6.81 years, *SD* = .61) and 53 English second- or additional-language bilingual (M_{age} = 6.64 years, *SD* = .65) school beginners, no differences emerged across verbal simple span measures (Non-word Recall and Digit Recall) and verbal complex span measures (Counting Recall and Backwards Digit Recall). These tests of verbal simple and complex working memory seem to be equitable ways of testing across different age groups, since monolingual and multilingual groups performed equivalently on these subtests at varying ages. Cockcroft (2016) concludes that multilingual's dependency on an additional language (in this case English) plays a smaller role in their performance on the Non-word Recall and the Counting Recall tests (in her study) and additionally the Word Recall, the Backwards Digit Recall and the Dot Matrix tests (in the present study), resulting in their seemingly unbiased nature.

Moreover, it has been argued that word-length recall (words, non-words and numbers) results primarily (Cowan, Baddeley, Elliott, & Norris, 2003), or even exclusively (Dosher & Ma, 1998) as a consequence of the delay during output, as opposed to the effect of rehearsal (see Baddeley, 2003). That is, these tasks rely on on-line processing rather than prior knowledge retrieved from long-term memory (Kaushanskaya & Yoo, 2013). Therefore, it has been suggested that word "repetition-type tasks can be used to index language performance" in populations with varying levels of linguistic proficiency (Kaushanskaya & Yoo, 2013, p. 1027) and SES conditions (Engel, Santos, & Gathercole, 2008). These tasks would be suitable in the South African context in relation to educational settings as there is evidence to suggest that they can be applied to fairly widespread sociocultural and sociolinguistic populations.

Strengths of the Study

This study explored whether multilingual young adults exhibit an advantage in verbal and non-verbal working memory performance when compared to their monolingual peers. Largely, research investigating the 'bi(multi)lingual advantage' has focused on inhibitory control or attentional control mechanisms (Bialystok et al., 2004, 2006a) rather than working memory as a contributor to this phenomenon. Further, most research that has looked at working memory differences has been conducted on children (e.g., Engel de Abreu, 2011; Stavrakaki, Megari, Kosmidis, Apostolidou, & Takou, 2012; St Clair-Thompson & Gathercole, 2006), leaving a gap in the literature regarding young adult populations. In accordance, this study sought to investigate young adult, undergraduate students on tasks assessing verbal and non-verbal working memory.

This study makes a significant contribution to the literature. As mentioned, few studies have looked at differences in working memory performance across young adult populations, and those that have investigated this group, have predominantly studied participants speaking European languages. This study has considered multilingual participants who speak English and one or more African languages. To the researcher's knowledge, this is the only study that has investigated language differences in young adults on the full version of the AWMA, where an African language was reported as the mother tongue of the multilingual sample. While there was methodological overlap with Cockcroft's (2016) study, her sample comprised of school beginners and assessed them on only four verbal subtest from the AWMA.

In terms of methodological rigour, participants were assessed on the LEAP-Q in order to get a sense of their proficiency in their reported language repertoire. The use of a valid instrument to classify individuals as monolingual or multilingual adds to the rigour of this study. The LEAP-Q has been used as an indicator of language proficiency in monolinguals and multilinguals in studies with varying contexts and reported language use (e.g., Kaushanskaya & Marian, 2009; Shi, 2011; Shook & Marian, 2012). As such, the language groups in this study were able to be classified as either monolingual or multilingual based on their self-reported proficiency in each spoken language, which was validated by the LEAP-Q. These groups were, therefore, comparable in terms of linguistic differences. In addition, propensity score matching is a statistical technique scarcely applied in multilingual comparative studies. It was used in this study to obtain monolingual and multilingual groups that were balanced with respect to age, gender and SES. Using it in this study allowed for the two groups to be matched on many variables that could have influenced working memory, whereby reducing the impact of extraneous variables on the outcome of results and enhancing linguistic differences as an explanation for the results. Age, gender and SES have been identified as factors, over-and-above proficiency differences, as contributing to executive performance (Linck et al., 2013).

In addition to the abovementioned points, psychological testing in South Africa has been viewed somewhat negatively because of the history of testing procedures and unethical intentions during the apartheid era (see Laher & Cockcroft, 2013; Nell, 1999; Van de Vijver & Rothmann, 2004). This study acknowledged these concerns by statistically controlling for the effect of verbal intelligence and SES between the language groups, taking into account that completing an assessment in a language different from one's mother tongue may lead to test bias – "nuisance factors that threaten the comparability of scores" (Van de Vijver & Rothmann, 2004, p. 2). In this study, SES was controlled for, where previous research in this area often failed to do so, while research that did control for SES found a significant improvement in bilingual performance exceeding the domain of language (see Ransdell, Arecco, & Levy, 2001). However, it has been acknowledged that SES is a contributor to vocabulary development (Hoff, 2003; Hoff & Tian, 2005; Walker, Greenwood, Hart, & Carta, 1994) and cognitive ability (Hoff, 2006), and so these variables are likely to be interconnected.

Limitations and Future Research

Because the acquisition of more than two languages is increasing, so research into learning multiple languages has propagated (Cenoz, 2009; Jessner, 1999; Rutgers & Evans, 2015). Given the current (and rising) prevalence of multilingualism, it is important to identify if, and where, working memory differences exist between monolingual and multilingual groups as there is no consensus regarding a 'bi(multi)lingual advantage' within the extant literature. This study is one such contribution to the pool of existing literature. Accordingly, there are limitations that need to be acknowledged along with recommendations for future research. Firstly, the multilinguals' level of multilingualism (i.e. age of additional language acquisition, parallel or consecutive language learning etc.) was not explored. Because *bilingualism* and *multilingualism* encompass a broad typology of speakers and a large range of linguistic conditions (Costa & Sebastián-Gallés, 2014), it is necessary that each classificatory criterion be established. Various conditions of multilingualism have been proposed. For instance, Ransdell et al. (2001) distinguishes between early and late multilinguals, where the former refers to individuals who acquire an L2 (3, 4 etc.) prior to 11 years of age, while the latter refers to individuals acquiring additional languages after the 'critical age period' of around 6 years old. Cenoz (2013) speaks of balanced and unbalanced multilingualism, where the former suggests that an individual has attained equal fluency in at least two languages, while the latter refers to an incomparable mastery of spoken languages by an individual. Similarly, additive and subtractive multilingualism should be distinguished between the multilingual group. The former refers to additional language acquisition in addition to a relatively well-developed L1, while the latter indicates that elements of additional languages replace elements of L1. It appears that the additive form results in increased thinking ability and the subtractive form, in decreased thinking ability (Sternberg and Sternberg, p. 412). Costa and Sebastián-Gallés (2014) note a difference between simultaneous and successive/sequential multilinguals, where an individual is classified as a simultaneous multilingual when he/she learns two (or more) languages concurrently from birth, while sequential multilinguals learn additional languages to their mother tongue later on in life, usually under formal training. Importantly, working memory and semantic fluency skills are notably better in simultaneous multilinguals (Stavrakaki et al., 2012).

Given these distinctions, future studies should explore and conceptualise the level of multilingualism with greater emphasis, so as to attain a more homogeneous multilingual sample more generalisable to the population. In this study, it was unclear whether this sample were early or late, balanced or unbalanced, simultaneous or sequential, or additive or subtractive multilinguals[17]. However, due to the nature of this study, the time constraints involved and the relatively small sample size, particularly if needing to split the multilingual participants, it was impractical to address each facet and level of multilingualism for each participant.

A further limitation from this study was that the multilingual sample were not a linguistically homogeneous group, as they spoke a range of different languages – for L1, L2 etc.

[17] Note that an individual's level of multilingualism can be classified in more than one dichotomy i.e. someone can be both a balanced and simultaneous multilingual.

Specifically, eight different first languages were reported to be acquired by this group (see Table 9 on p. 53). Although these languages were classified as official South African languages, there are notable distinctions in orthography, semantic properties and syntactic characteristics between them (see Mesthrie, 2007; Naidoo et al., 2005; Niesler et al., 2005). L1 differences in the multilingual group may have had an impact on the results. It is also worth noting that the monolingual group reported exposure to nine additional languages over-and-above English as their L1– albeit of markedly inferior proficiency. Similarly, such exposure to these languages – and the languages themselves – may have affected the results. The exact cognitive impact and how it relates to a ‘bi(multi)lingual advantage’ in tasks tapping non-verbal executive functions is unknown, and thus warrants further investigation. Further research is needed to address whether, and to what extent, different languages either diverge or converge in relation to various linguistic physiognomies. This will give a clearer indication as to the specific attributes of language processing that contribute to a ‘bi(multi)lingual advantage’ on non-verbal tasks.

At the time of this study, the majority of the monolingual participants were completing a Bachelor of Arts degree (92.3%), while the majority of the multilingual participants were completing a Bachelor of Science degree (64.1%, see Table 2 on p. 26). The core components (such as reading material, degree of mathematical exposure and evaluation methods) required to complete these degrees can have fundamental differences. For example, an undergraduate psychology assessment may include a theoretical review and critical analysis of a specified topic, while a physiology assessment could rely on more practical laboratory engagement and report generation. The employment of cognitive resources are likely to vary in accordance with exposure to each degree, but it is unclear to what extent (if any) these differences contribute to working memory performance within language-like (e.g., bilingual to bilingual) groups and between different language groups. Therefore, it would be useful to investigate if degree-type plays a role in working memory differences in young adults.

In addition, strategy use in working memory performance is under explored both at a neurological level and qualitatively. Given that multilinguals have an enhanced attentional control system, where they can suppress one (or more) language(s) while concurrently engaging in another, this provides a unique advantage of cognitive strategy use. Identifying strategic mechanisms employed by monolingual and multilingual individuals while performing working memory tasks will further and enhance the understanding of working memory beyond theoretical models and provide practical explanations for education. Canagarajah (2007) suggests that "language learning and use succeed through performance strategies, situational resources, and social negotiations in fluid communicative contexts" (p. 923). Empirical evidence is the necessary component to understand the mechanisms of strategy use alongside behavioural measures assessing working memory. Furthermore, the use of imaging techniques is the next step in the process of language differences at a neurological level. However, given the lack of access to imaging machinery in South Africa, as well as the costs and expertise involved in conducting research of this kind, this study was only able to access behavioural evidence supporting a 'bi(multi)lingual advantage'.

Conclusion

To conclude, the results of this study have both theoretical and practical value. Theoretically, evidence from this study supports a 'bi(multi)lingual advantage' across non-verbal simple and complex working memory tasks, and equivalence in performance between these language groups across verbal simple and complex working memory tasks. de Bruin et al., (2015) note that "studies with mixed results are especially valuable because they can identify the circumstances under which a bilingualism effect may and may not occur" (p. 105). It appears that multilingualism enhances performance in measures involving the central executive in line with Baddeley's (2003) model, while multilinguals are not disadvantaged in tasks assessing verbal working memory. On a practical level, there are implications for academia. Governmental initiatives promoting additional language learning should continue with these conquests, starting as early as possible, as multilingualism does seem to confer an advantage in executive control. Ellis

(2006) notes that “language learning is a good thing to be encouraged by governments and education systems, and to fail to engage in it constitutes a missed opportunity” (p. 183). In addition to this, few working memory measures do not have biasing language effects and can be used at a practical level in South Africa – given the amalgamated pooling of linguistic and culturally diverse individuals. With an increase in global multilingualism, it is important that research continues to investigate cognitive trends that evolve along with increased language use.

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Appendix A: Baddeley's Model of Working Memory

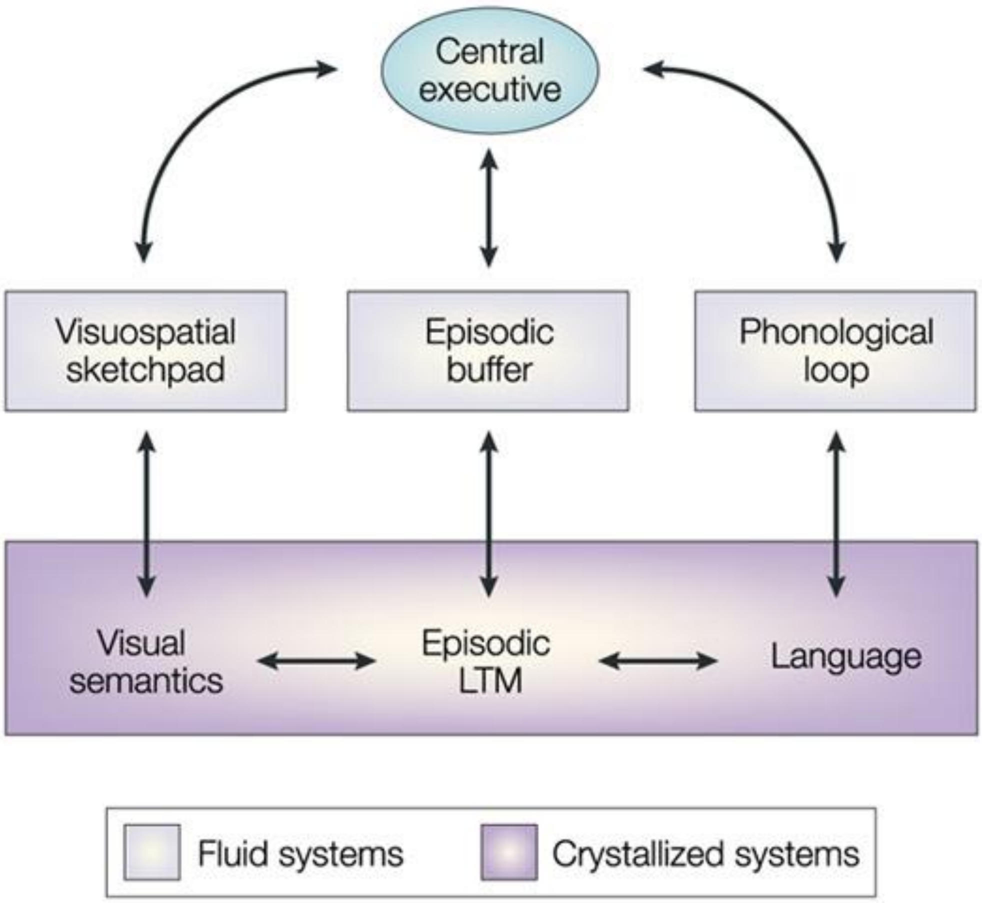

Figure 4. Baddeley's modified multi-component model of working memory adopted from "Working Memory: Looking back and looking forward" by A. D. Baddeley, 2003, *Nature Reviews Neuroscience*, *4*, 829-839.

Appendix B: Demographic Questionnaire

CODE | | | | |

Demographic Questionnaire

Gende | M | F | Date of Birth: | D | D | | M | M | | Y | Y | Y | Y |

Home Language(s): ____________________

School Language(s): ____________________

Current Degree and Faculty: ____________________

Previous degrees or qualifications: ____________________

Current year of study (1st, 2nd, 3rd): ____________________

How many years have you been at university? ____________________

Did you ever fail a grade at school? If so, which one? ____________________

Did you ever require an intervention from a language specialist? ____________________

Did you attend pre-primary school? ____________________

Living Amenities & Caregiving

Educational and occupational status of your parents or primary caregivers:

Mother: Level of Education		**Father: Level of Education**	
No schooling		No schooling	
Less than primary school completed		Less than primary school completed	
Primary school completed		Primary school completed	
Secondary school not completed		Secondary school not completed	
Secondary school completed		Secondary school completed	
Tertiary education completed		Tertiary education completed	
Other		Other	
Current occupation:		Current occupation:	

Marital status of primary caregivers:

Married	
Living together as husband and wife	
Widow/widower	
Divorced/separated	
Other	

Number of caregivers in the household in which you spend the most time (please tick):

0	
1	
2	
>2	

Living Standards Measure:

Please answer the following questions according to your circumstances while growing up, and not in your current student accommodation if these are different.

Question	**Answer**	
1. I have the following in my household:		
TV set	TRUE	FALSE
VCR	TRUE	FALSE
DVD player	TRUE	FALSE
M-Net/DStv subscription	TRUE	FALSE
Hi-fi/music centre	TRUE	FALSE
Computer / Laptop	TRUE	FALSE
Vacuum cleaner/floor polisher	TRUE	FALSE
Dishwashing machine	TRUE	FALSE
Washing machine	TRUE	FALSE
Tumble dryer	TRUE	FALSE
Home telephone (excluding a cell)	TRUE	FALSE
Deep freezer	TRUE	FALSE
Fridge/freezer (combination)	TRUE	FALSE
Electric stove	TRUE	FALSE
Microwave oven	TRUE	FALSE
Built-in kitchen sink	TRUE	FALSE
Home security service	TRUE	FALSE
3 or more cell phones in household	TRUE	FALSE
2 cell phones in household	TRUE	FALSE
Home theatre system	TRUE	FALSE
2. I have the following amenities in my home or on the plot:		
Tap water in house/on plot	TRUE	FALSE

Hot running water from a geyser	TRUE	FALSE
Flush toilet in/outside house	TRUE	FALSE
3. There is a motor vehicle in our household	TRUE	FALSE
4. I am a city dweller	TRUE	FALSE
5. I live in a house, cluster or town house	TRUE	FALSE
6. I live in a rural area outside Gauteng and the Western Cape	TRUE	FALSE
7. There are no radios, or only one radio (excluding car radios) in my household	TRUE	FALSE
8. There is no domestic workers or household helpers in household (both live-in & part time)	TRUE	FALSE

Appendix C: Language Experience and Proficiency Questionnaire (LEAP-Q)

Last Name	N/A	First Name	N/A	Today's Date	
Age		Date of Birth		Male ☐	Female ☐

(1) Please list all the languages you know **in order of dominance**:

1	**2**	**3**	**4**	**5**

(2) Please list all the languages you know **in order of acquisition** (your native language first):

1	**2**	**3**	**4**	**5**

(3) Please list what percentage of the time you are *currently* and *on average* exposed to each language.
(*Your percentages should add up to 100%*):

List language here:					
List percentage here:					

(4) When choosing to read a text available in all your languages, in what percentage of cases would you choose to read it in each of your languages? Assume that the original was written in another language, which is unknown to you.
(*Your percentages should add up to 100%*):

List language here					
List percentage here:					

(5) When choosing a language to speak with a person who is equally fluent in all your languages, what percentage of time would you choose to speak each language? Please report percent of total time.
(*Your percentages should add up to 100%*):

List language here					
List percentage here:					

Language:

This is my (please select from pull-down menu) language.

All questions below refer to your knowledge of .

(1) Age when you…:

began acquiring :	*became fluent* in :	*began reading* in :	*became fluent reading* in :

(2) Please list the number of years and months you spent in each language environment:

	Years	Months
A country where is spoken		
A family where is spoken		
A school and/or working environment where is spoken		

(3) On a scale from zero to ten, please select your *level of* ***proficiency*** in speaking, understanding, and reading from the scroll-down menus:

Speaking	(click here for scale)	Understanding spoken language	(click here for scale)	Reading	(click here for scale)

Appendix D: Sample Recruitment Advertisement

Psychology
School of Human & Community Development
University of the Witwatersrand
Private Bag 3, Wits, 2050
Tel: 011 717 4503 Fax: 011 717 4559

CALL FOR PARTICIPANTS

Is your home language **ENGLISH**?

If you are fluent in **ONLY** English i.e. **monolingual**, are completing an undergrad degree, and you would like to participate in a study about
Language and Working Memory,
please contact me!

The study will involve the completion of a demographic questionnaire and some cognitive assessments, which will take approximately 90 minutes of your time.

If you are interested, please contact
Mandy Wigdorowitz at
mandy.wigdorowitz@gmail.com or 0833051594

Please note: participation excludes individuals with previous head injuries, current drug or alcohol use, diagnoses of psychological, learning and/or language disorder/s.

Appendix E: University Portal Sample Recruitment Advertisement

Psychology
School of Human & Community Development
University of the Witwatersrand
Private Bag 3, Wits, 2050
Tel: 011 717 4503 Fax: 011 717 4559

CALL FOR PSYCHOLOGY PARTICIPANTS

Is your home language **ENGLISH**?
If you are fluent in **ONLY** English i.e. **monolingual**, are completing an undergrad degree and you would like to participate in a study about
Language and Working Memory,
please contact me!
The study will involve the completion of a demographic questionnaire and some **cognitive assessments**, which will take approximately 90 minutes of your time.
If you are interested, please contact
Mandy Wigdorowitz at
mandy.wigdorowitz@gmail.com or 0833051594

Please note: participation excludes individuals with previous head injuries, current drug or alcohol use, diagnoses of psychological, learning and/or language disorder/s.

Appendix F: Information Sheet for Psychology First Year Students

Psychology
School of Human & Community Development
University of the Witwatersrand
Private Bag 3, Wits, 2050
Tel: 011 717 4503
Fax: 011 717 4559

Dear Sir/Madam

As part of a partial fulfilment of a postgraduate Master's degree in Social and Psychological Research Psychology at the University of the Witwatersrand, I am currently conducting research examining how language proficiency affects working memory. I understand that taking part in such research requires an investment of your time, but your participation will be greatly appreciated. I would therefore like to invite you to participate in this research. Participation is entirely voluntary and choosing to participate will not advantage or disadvantage you in any way. There are no foreseeable risks or benefits involved in your participation. Please note that you have the right to refuse to participate or to withdraw from the study at any time and this will not be held against you in any way.

The assessment procedure will be conducted individually at a time suitable to you, whereby a portion of the assessments will be computer-based and recorded. Participation in the study will involve signing consent forms, completing questionnaires, and completing a compilation of cognitive assessments. This will take approximately 90 minutes in total, and you would be required to stay for the duration of the assessments. After the completion of the assessments, you will be free to leave. By consenting to participate in this study, it will be declared that you have not suffered a previous head injury or concussion, are not currently taking drugs or alcohol, have not been formally diagnosed with a psychological disorder and/or are not taking prescribed medication, have not been diagnosed with a learning or language disorder and have had no previous exposure to the assessments involved in this study.

Due to the personal nature of this study, complete anonymity is not guaranteed. Furthermore, because 1% course credit is awarded on completion of participation, your student number and course codes needs to be provided. However, this information will not be linked to any results or traced back to any individual. Anonymity will be guaranteed in resulting reports, theses and/or publications. Complete confidentiality will be guaranteed since only the researcher and supervisor have access to the questionnaires and corresponding data. The results of this research are not set out to examine individual performance, but rather group trends.

If you choose to participate, you will be consenting to the abovementioned information, and you will be giving permission for all data collected throughout the study to be used for analysis, reporting, and possible publication or conference presentation. You may receive general feedback on the outcomes of the study if requested, but given the confidential nature of the study, individual feedback is not possible.

Please see the contact details provided below if you have any further questions, concerns or you require feedback on the progress of the research. Thank you again for considering being part of this study. Please detach and keep this sheet for future reference.

Ms Mandy Wigdorowitz
mandy.wigdorowitz@gmail.com

Prof. Kate Cockcroft (Supervisor)
kate.cockcroft@wits.ac.za

Appendix G: Information Sheet for Undergraduate Students, Excluding Psychology First Years

Psychology
School of Human & Community Development
University of the Witwatersrand
Private Bag 3, Wits, 2050
Tel: 011 717 4503
Fax: 011 717 4559

Dear Sir/Madam

As part of a partial fulfilment of a postgraduate Master's degree in Social and Psychological Research Psychology at the University of the Witwatersrand, I am currently conducting research examining how language proficiency affects working memory. I understand that taking part in such research requires an investment of your time, but your participation will be greatly appreciated. I would therefore like to invite you to participate in this research. Participation is entirely voluntary and choosing to participate will not advantage or disadvantage you in any way. There are no foreseeable risks or benefits involved in your participation. Please note that you have the right to refuse to participate or to withdraw from the study at any time and this will not be held against you in any way.

The assessment procedure will be conducted individually at a time suitable to you, whereby a portion of the assessments will be computer-based and recorded. Participation in the study will involve signing consent forms, completing questionnaires, and completing a compilation of cognitive assessments. This will take approximately 90 minutes in total, and you would be required to stay for the duration of the assessments. After the completion of the assessments, you will be free to leave. By consenting to participate in this study, it will be declared that you have not suffered a previous head injury or concussion, are not currently taking drugs or alcohol, have not been formally diagnosed with a psychological disorder and/or are not taking prescribed medication, have not been diagnosed with a learning or language disorder and have had no previous exposure to the assessments involved in this study.

Due to the personal nature of this study, complete anonymity is not guaranteed. However, this information will not be linked to any results or traced back to any individual. Anonymity will be guaranteed in resulting reports, theses and/or publications. Complete confidentiality will be guaranteed since only the researcher and supervisor have access to the questionnaires and corresponding data. The results of this research are not set out to examine individual performance, but rather group trends.

If you choose to participate, you will be consenting to the abovementioned information, and you will be giving permission for all data collected throughout the study to be used for analysis, reporting, and possible publication or conference presentation. You may receive general feedback on the outcomes of the study if requested, but given the confidential nature of the study, individual feedback is not possible.

Please see the contact details provided below if you have any further questions, concerns or you require feedback on the progress of the research. Thank you again for considering being part of this study. Please detach and keep this sheet for future reference.

Ms Mandy Wigdorowitz
mandy.wigdorowitz@gmail.com

Prof. Kate Cockcroft (Supervisor)
kate.cockcroft@wits.ac.za

Appendix H: Consent Form

Psychology
School of Human & Community Development
University of the Witwatersrand
Private Bag 3, Wits, 2050
Tel: 011 717 4503
Fax: 011 717 4559

I ______________________________(*name and surname*)___________________ (*student number*) consent to participate in the research study assessing the relationship between language and working memory, conducted by Mandy Wigdorowitz and supervised by Prof. Kate Cockcroft.

I am aware that:

- Participation in this study is voluntary
- I may withdraw from participating in this study at any time
- Participation will have no negative effect on my academic results
- My details will be kept confidential
- My assessment results will be kept confidential
- I shall not be harmed or injured during the assessment
- There are no risks or benefits associated with the study
- None of my identifiable information will be included in the research report and no results can be traced back to me
- I am aware that the results of the study will be reported in the form of a research report for the partial completion of the degree, Master's in Social and Psychological Research Psychology
- The research may also be presented at a local/international conference and published in a journal and/or book chapter
- I may request general feedback from the study
- By consenting to participate in this study, I declare that I have not suffered a previous head injury or concussion, am not currently taking drugs or alcohol, have not been formally diagnosed with a psychological disorder and/or am not taking prescribed medication, have not been diagnosed with a learning or language disorder and have had no previous exposure to the assessments involved in this study

	Participant	**Researcher/Supervisor**
Signature:	______________________	______________________
Date:	______________________	______________________

Appendix I: Credit Slip

Student Number and Psychology Codes

(for Obtaining Course Credit Only)

Student Number:

Psychology Course Codes:

____

THANK YOU!

PROOF OF PARTICIPATION SLIP (RESEARCHER)

This slip hereby serves to confirm that student:

Student Number:

participated in a Master's-level study conducted by a student in the Department of Psychology at the University of the Witwatersrand and is thus eligible to receive 1% course credit for this participation.

Signed by researcher: ______________________________

Date: ______________________________

Appendix J: Parametric Indicators for the WAIS-III and AWMA Distribution

Table 15

Normality indicators for the data

	Monolinguals				Multilinguals				Overall		
	Skewness coefficient[a]	Kurtosis coefficient[b]	Kolmogarov-Smirnov test (*p*-value)	Shapiro-Wilk test (*p*-value)	Skewness coefficient	Kurtosis coefficient	Kolmogarov-Smirnov test (*p*-value)	Shapiro-Wilk test (*p*-value)	Homogeneity of variance for ANOVA (*p*-value)	Homogeneity of variance for ANCOVA (*p*-value)	Normal distribution (Y/N)
WAIS-III											
Vocabulary	-.143	-.367	.200	.310	-.413	1.665*	.021*	.145	.725	-	Y
Similarities	.550	.059	.015*	.170	-.197	-.773	.006*	.076	.232	-	Y
Block Design	.023	1.118*	.200	.562	.852	1.099*	.001*	.024*	.187	-	Y
Matrix Reasoning	1.053*	2.306*	.002*	.006*	.028	.560	.005*	.134	.682	-	N
AWMA											
Verbal short-term memory	.195	.238	.200	.753	.930	1.229*	.062	.035*	.714	.342	Y
Digit Recall	1.348*	2.867*	.001*	.001*	.699	1.026	.118	.198	.095	.101	Y
Word Recall	.161	-.905	.020*	.182	1.585*	3.344*	.000*	.000*	.222	.036*	N
Non-word Recall	-.168	-.180	.200	.545	-.229	.254	.133	.403	.236	.053	Y
Verbal working memory	.383	-.962	.052	.035*	.380	-.246	.200	.238	.319	.592	Y

(continued)

Table 15. *Normality indicators for the data (continued)*

	Monolinguals				Multilinguals				Overall		
	Skewness coefficient[a]	Kurtosis coefficient[b]	Kolmogarov-Smirnov test (*p*-value)	Shapiro-Wilk test (*p*-value)	Skewness coefficient	Kurtosis coefficient	Kolmogarov-Smirnov test (*p*-value)	Shapiro-Wilk test (*p*-value)	Homogeneity of variance for ANOVA (*p*-value)	Homogeneity of variance for ANCOVA (*p*-value)	Normal distribution (Y/N)
Listening Recall	.222	-.549	.200	.506	.569	.351	.001*	.034*	.658	.964	Y
Counting Recall	-.182	.512	.176	.567	-.220	.488	.200	.568	.059	.062	Y
Backwards Digit Recall	-1.957*	9.327*	.001*	.000*	-1.681*	7.154*	.001*	.000*	.900	.897	N
Visuo-spatial short-term memory	-.332	.345	.200	.380	.550	.868	.200	.528	.157	.198	Y
Dot Matrix	.295	-.477	.167	.266	-.149	-.166	.085	.170	.325	.280	Y
Mazes Memory	.624	.110	.002*	.031*	.649	1.182*	.000*	.000*	.246	.405	
Block Recall	-.239	-.960	.009*	.112	-.401	-.442	.011*	.044*	.295	.387	Y
Visuo-spatial working memory	.254	-.431	.200	.309	.049	-.709	.200	.725	.023*	.124	Y
Odd One Out	.237	-.929	.154	.192	-.360	-.157	.000*	.001*	.022*	.055	Y
Mister X	.406	-.310	.032*	.205	-.554	-.580	.000*	.014*	.088	.333	Y
Spatial Recall	.179	.112	.171	.367	.768	.087	.043*	.032*	.029*	.067	Y

Note. [a]Range = -1 to 1 (normal). [b]Range = -1 to 1 (normal). * = Indicates that the assumption of normality has not been met. Y = Yes. N = No.

Appendix K: Homogeneity of Regression Slopes

Table 16

Homogeneity of regression slopes for language groups with covariates Vocabulary, Similarities and SES

	F	*p*	SS	MSE	R squared
Verbal short-term memory	4.207	.019*	952.94	113.25	.349
Digit Recall	2.932	.060	696.07	118.70	.314
Word Recall	4.891	.010*	1238.41	126.61	.322
Non-word Recall	.196	.823	76.69	195.76	.305
Verbal working memory	2.604	.081	714.63	137.20	.219
Listening Recall	1.284	.283	458.17	178.38	.133
Counting Recall	1.599	.209	695.34	217.42	.226
Backwards Digit Recall	1.773	.177	1245.17	351.19	.101
Visuo-spatial short-term memory	1.367	.261	495.17	181.06	.177
Dot Matrix	2.200	.118	941.68	213.98	.154
Mazes Memory	.358	.700	175.23	244.78	.123
Block Recall	1.086	.343	439.20	202.29	.134
Visuo-spatial working memory					
Odd One Out	1.138	.326	351.17	154.29	.204
Mister X	.731	.485	323.05	221.10	.138
Spatial Recall	2.712	.073	819.25	151.02	.235

Note. SS = sum of squares. MSE = mean square of errors. * = $p < .05$ which indicates that the subtest fails to meet the assumption for homogeneity of regression slopes.