EXPLORING THE RELATIONSHIPS BETWEEN WORKING MEMORY CAPACITY, ACADEMIC READING, AND ACADEMIC ACHIEVEMENT IN ONLINE DISTANCE E-LEARNING FIRST-YEAR STUDENTS

by

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I declare that the above thesis is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I submitted the thesis to originality checking software and that it falls within the accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at Unisa for another qualification or at any other higher education institution.

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ABSTRACT

Working memory (WM) is a neural system that plays a role in all complex thinking processes, including academic reading and learning. Research exploring the relationships between WM, academic reading, and academic achievement within online higher education is, however, limited. These relationships are particularly under-researched within the South African context. This study thus used a non-experimental ex post facto cross-sectional design to quantitatively investigate whether WM is associated with the academic reading and academic achievement of online distance e-learning first-year tertiary students attending the University of South Africa, and to evaluate the use of two open-source web-based WM tasks. One hundred and thirty-six young adult participants completed a demographic and background information survey, an academic reading test, the Reading Span, and the Operation Span. The latter two tasks were developed by the researcher and served as measures of working memory capacity (WMC). Participants' final end-of-course grades were requested from the university, and the results showed that WMC was significantly correlated with both academic reading and academic achievement. Findings furthermore illustrated the acceptable performance of both WMC tasks, providing a crucial resource in South African WM research. Findings are interpreted in relation to existing scholarship regarding cognitive functioning, academic reading, and academic achievement. Implications for higher education institutions and future research are discussed.

Keywords: academic reading, computerised cognitive testing, first-year students, open source, operation span, reading span, South Africa, Tatool, working memory capacity, working memory

IQOQA

I-Working memory (i-WM) iwuhlelo lwezodluliswa kwemiyalezo eya nebuya engqondweni olubamba iqhaza kuzo zonke izinqubo ezinzulu zokucabanga, okubandakanya ukufunda okubhaliwe nokufunda okwenziwayo ngokwenqubo yezemfundo. Ucwaningo oluhlola ubudlelwano phakathi kwe-WM, ukufunda okubhaliwe ngokwenqubo yezemfundo, kanye nempumelelo kwezemfundo emfundweni esezingeni eliphakeme oluqhutshwa nge-inthanethi, alulunigi. Aluluningi ucwaningo olwenziwe ngalobu budlelwano esimweni saseNingizimu Afrika. Ngenxa yalokho, lolu cwaningo lumiswe ngokohlelo olucubungula imininingwane eseyaqoqwa ebantwini abaningi ukuze kuhlolwe ngokocwaningo lwekhwantithethivu ukuthi ingabe i-WM iyahambisana na nokufunda okubhaliwe ngokwenqubo yezemfundo kanye nempumelelo kwezemfundo kubafundi abafundela ekhaya abafunda ngokohlelo lwe-inthanethi abasonyakeni wokuqala esikhungweni semfundo ephakeme abafunda eNyuvesi yaseNingizimu Afrika, kanye nokuhlola ukusetshenziswa kwemisebenzi ye-WM emibili yesoftiwe yamahhala esebenza nge-inthanethi. Ababambiqhaza abayikhulu namashumi amathathu nesithupha bagcwalisa ucwaningo lwemininingwane eqondene nabo siqu kanye nolwazi oluyisendlalelo, isivivinyo sokufunda okubhaliwe ngokwenqubo yezemfundo, Isikhathi Sokufunda Okubhaliwe, kanye Nesikhathi Sokusebenza. Le misebenzi emibili yasungulwa wumcwaningi futhi yasebenza njengezindlela yokukala ubungako be-working memory (i-WMC). Amazinga ababambiqhaza okugcina ekupheleni kohlelo acelwa enyuvesi, bese imiphumela yaveze ukuthi i-WMC beyihambisana kakhulu nokufunda okubhaliwe ngokwenqubo yezemfundo kanye nemiphumela yezemfundo. Imiphumela iqhubeke yaveza ukusebenza okwamukelekayo kwemisebenzi ye-WMC yomibili, okuhlinzeke ngomthombo obaluleke kakhulu ocwaningweni lwe-WM lwaseNingizimu Afrika. Imiphumela ifundwa ngokuqhathaniswa nemibhalo yabacwaningi ekhona mayelana nokusebenza komqondo,

ukufunda okubhaliwe ngokwenqubo yezemfundo, kanye nemiphumela kwezemfundo. Kudingidwa imithelela ezikhungweni zemfundo ephakeme kanye nocwaningo lwangomuso.

Amagama asemqoka: ukufunda okubhaliwe ngokwenqubo yezemfundo, ukuhlola isimo sengqondo ngekhompyutha, abafundi abasonyakeni wokuqala, isoftiwe yamahhala, isikhathi sokusebenza, isikhathi sokufunda okubhaliwe, iNingizimu Afrika, i-Tatool, ubungakho be-working memory, i-working memory

ABSTRAK

Werksgeheue (working memory, WM) is ’n neurale stelsel wat ’n rol in alle komplekse denkprosesse, insluitend akademiese lees en leer, speel. Navorsing wat die verwantskappe tussen WM, akademiese lees en akademiese prestasie in aanlyn hoër onderwys ondersoek, is egter beperk. Daar is veral in die Suid-Afrikaanse konteks min navorsing oor hierdie verwantskappe gedoen. Hierdie studie het gevolglik ’n nie-eksperimentele ex post facto dwarssnitontwerp gebruik om kwantitatief te ondersoek of WM verband hou met die akademiese lees en akademiese prestasie van die aanlyn afstands-e-leer van eerstejaar- tersiêre studente wat by die Universiteit van Suid-Afrika ingeskryf is, en om die gebruik van twee oopbron-, webgebaseerde WM-take te evalueer. Een honderd ses-en-dertig jong volwasse deelnemers het ’n demografiese en agtergrondinligtingsopname, ’n akademieseleestoets, die leesspan (reading span), en die verwerkingspan (operation span) voltooi. Laasgenoemde twee take is deur die navorser ontwikkel en het gedien om die werksgeheuekapasiteit (working memory capacity, WMC) te meet. Deelnemers se finale punte aan die einde van die kursus is van die universiteit af aangevra en die resultate het getoon dat WMC ’n beduidende korrelasie met akademiese lees sowel as akademiese prestasie toon. Bevindings het voorts die aanvaarbare prestasie van albei WMC-take geïllustreer, en verskaf ’n noodsaaklike hulpbron in Suid-Afrikaanse navorsing oor WM. Bevindings is met betrekking tot bestaande vakkundige kennis oor kognitiewe funksionering, akademiese lees en akademiese prestasie vertolk. Implikasies vir hoëronderwysinstellings en toekomstige navorsing word bespreek.

Sleutelwoorde: akademiese lees, gerekenariseerde kognitiewe toetsing, eerstejaarstudente, oop bron, verwerkingspan, leesspan, Suid-Afrika, Tatool, werksgeheuekapasiteit, werksgeheue

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
AWM Lab	Attention and Working Memory Lab
CI	Confidence interval
Covid-19	Coronavirus disease 2019
DBE	Department of Basic Education
DCCD	Department of Counselling and Career Development
DHET	Department of Higher Education and Training
DI	Discrimination index
ICELDA	Inter-institutional Centre for Language Development and Assessment
ICT	Information and communications technology
ISAL	Indigenous South African languages
JRE	Java Runtime Environment
L1	First language
L2	Second language
LiEP	Language in Education Policy (1997)
LTM	Long-term memory
MoI	Medium of instruction
NWU	North-West University
ODL	Open distance learning
ODeL	Open distance e-learning
OSPAN	Operation span
PEBL	Psychology Experiment Building Language
PM	Phonological memory

POPI	Protection of Personal Information Act (2013)
P-value	Proportion value
Q-Q	Quantile-quantile
RSPAN	Reading span
SES	Socio-economic status
SHRIDC	Senate for Higher Research and Innovation Directorate Committee
SPSS v27.0	Statistical Package for the Social Sciences, version 27.0
Stats SA	Statistics South Africa
STM	Short-term memory
SU	Stellenbosch University
S-W	Shapiro-Wilk’s W test
TALL	Test of Academic Literacy Levels
Tatool	Training and Testing Tool
Unisa	University of South Africa
UP	University of Pretoria
WM	Working memory
WMC	Working memory capacity

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CHAPTER 1: INTRODUCTION

"Language exerts hidden power, like the moon on the tides" (Brown, 1988, p. 73).

1.1. Introduction

Human memory is an essential skill for learning and comprises three types of memory: long-term, short-term, and working memory (Cowan, 2008). Long-term memory (LTM) refers to a vast store of information that is retained for minutes or up to decades. Short-term memory (STM) denotes a limited store of information that is kept for seconds or minutes (Cowan, 2008; Gazzaniga et al., 2019). This study focuses on working memory (WM), which was first conceptualised by Miller, Galanter, and Pribram (1960) (as cited in Baddeley, 2010). WM stores and manipulates information, for several seconds or minutes, and is used to plan and carry out behaviour (Cowan, 2008; Eriksson et al., 2015; R. G. Morrison, 2005[1]; Ruiz et al., 2019). WM has long been a topic of some interest, particularly in the cognitive psychology sphere, where studies have noted its role in all complex thinking processes (R. G. Morrison, 2005). These processes include both reading and learning, which are crucial for academic achievement. This study focuses on the relationships between WM, academic reading, and academic achievement in South African tertiary students.

The first objective of this chapter is to briefly introduce and define both WM and academic reading. The unique context of South Africa is then illustrated as the setting of the current study. A broad perspective is first provided by describing how South African tertiary students are not equally prepared for their post-school studies. This is related to the impact of the

[1] The *American Psychological Association Publication Manual* (7th ed.) notes that in cases where the first authors of multiple references share the same surname, their initials must be included in all in-text citations. This applies even where the year of publication differs (American Psychological Association, 2020). This rule is followed throughout the current thesis.

apartheid legacy on education and on the development of reading ability. A more focused perspective is then provided by describing the University of South Africa (Unisa) and its typical student demographic. Taking insight from this contextual narrative, the chapter then highlights in more detail the purpose of the thesis, which is to explore the relationships between WM, academic reading, and academic achievement in South African tertiary students. In addition, the chapter provides a synopsis of the research aims, research questions, and hypotheses, research design and procedures, and data analysis procedures. The scope and limitations of the study as well as the central terms are presented. Finally, the structure and outline of the thesis is noted to conclude the chapter.

1.2. Definitions of working memory and academic reading

WM is a well-known concept in many fields of research including psychology, cognitive neuroscience, and neurobiology. WM has a central role in all complex thinking processes, such as fluid reasoning, learning, language comprehension, and problem-solving (Just & Carpenter, 1992; McVay & Kane, 2012; Ruiz et al., 2019; Yuan et al., 2006). It is defined as a neural system required to mentally store a limited amount of information for a short period of time so that it can be manipulated in mental tasks, while ignoring concurrent processing, distraction, and/or attention shifts (Aben et al., 2012; Baddeley, 2003; Carretti et al., 2013; Engel de Abreu, 2011; Klingberg, 2010; Peng et al., 2018; Unsworth & McMillan, 2013). An important note here is that WM is limited in capacity. It is furthermore the ability to ***simultaneously*** store and process information, resulting in a trade-off situation for the limited capacity, which differentiates this memory system. This ability is also the basis for the theoretical relationship between WM and reading which will be outlined in the next chapter. While there are several types of reading which all contribute to learning, for example extensive reading (Boakye, 2017), this thesis focuses on academic reading.

Many terms have been used in discussions of literacy and reading and literacy skills, such as ‘critical reading’, ‘reading comprehension’, and ‘reading proficiency’. These terms are conceptually similar in that they all refer to foundational cognitive processes related to reading, such as decoding, obtaining information from text, and using focused attention (Gorzycki et al., 2016). Academic reading encompasses these processes but “is complex, purposeful, and critical, and it routinely requires readers to interpret and synthesize dense text that addresses discrete subjects in depth” (Gorzycki et al., 2016, p. 144). Academic reading requires reading with a purpose as well as with metacognitive awareness. Regarding the latter, the reader must monitor their own understanding of the logic of the text, the parts of the text and how each relate to its composition, problems within the text, the text’s context, genres, and the strategies they should use to comprehend and evaluate the text (Gorzycki et al., 2016, 2019). It is the foundation of all academic activities and fundamental to academic success (Boakye, 2017; Boakye et al., 2014; Gorzycki et al., 2016). The term ‘academic reading’ is used in this thesis to indicate the type of reading explored in this study, that is reading for academic purposes as opposed to reading for pleasure. Bearing this in mind, the foundational cognitive processes are common to both academic reading and general reading, and these two terms are thus used synonymously.

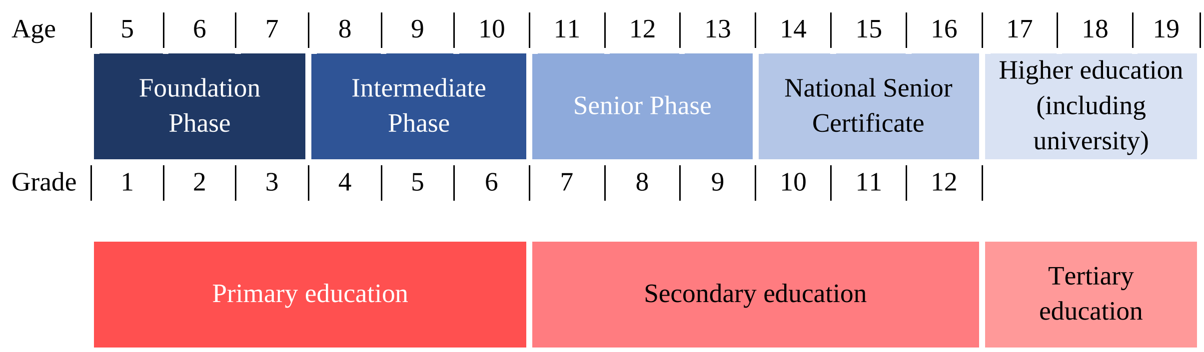
To provide additional background to the purpose of this study, and later to interpretation of the results, the educational context of South Africa is now presented.

1.3. South African educational context

The South African education system is currently undergoing substantial transformation. The aim is to develop an inclusive rather than segregated system where equal opportunities and quality education are provided to all. However, many South African learners are still struggling to read, no matter at what grade level or in which language they are assessed (Pretorius, 2010). This renders learners ill-prepared when moving from secondary education into tertiary education, as they cannot read and write at school-exit level (Bharuthram & Clarence, 2015; Boakye, 2017). Previous research has shown that South African tertiary students are indeed unable to read and write at the level expected of them (Boakye et al., 2014; Cliff, 2015). Explanatory factors have been related to contextual differences and the level of preparedness provided by previous education. The level of preparedness is herewith discussed in terms of the quality of basic and secondary education (see Figure 1) as well as the language used for instruction.

Figure 1:

Structure of the South African education system.



1.3.1. Quality of basic and secondary education

Post-1994, after election of the democratic government, it has been difficult for basic and secondary education to improve access to and participation in quality education. Firstly, the learner population is much larger than the student population at tertiary level, and there are not enough historically White schools to accommodate all historically disadvantaged learners. Secondly, apartheid spatial planning continues to make transport a barrier, as high-quality schools are in far urban areas (Mlachila & Moeletsi, 2019). There is thus a two-nation education system:

1. A poorly resourced sector providing education to the poor and largely Black African population (75-80% of learners), and
2. A set of well-funded private and semi-private institutions providing education to the wealthy and mostly White population (20-25% of learners) (Badat & Sayed, 2014; Mlachila & Moeletsi, 2019).

This bifurcation continues to perpetuate the historic systemic and structural education inequalities (Badat & Sayed, 2014; Letseka, 2015). There remains differentiated access to different institutions, where the impact of 'race'[2] on equal opportunity and outcomes has simply been joined by social class and geography (Badat & Sayed, 2014; Janks, 2014). In this way, basic and secondary education fail to provide many learners, particularly Black African learners, with the requisite educational foundation for tertiary education (Mlachila & Moeletsi, 2019; Sehoole & Adeyemo, 2016): "Learning deficits acquired at the lower levels of education make the jump to university too high for many of South Africa's students" (Mlachila & Moeletsi, 2019, p. 25). This is compounded by the language in which instruction is provided.

1.3.2. Language used for instruction in basic and secondary education

The Constitution includes nine African languages as official languages in addition to English and Afrikaans (Brock-Utne & Holmarsdottir, 2004; Broom, 2004; Hornberger, 2002; Hunter, 2015; Pluddemann, 1999). Consequently, the principle of the Language in Education Policy (LiEP) of 1997 promotes additive bilingualism, where all learners are taught their first language

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[2] It is noted that 'race' is a social construct, without biological meaning, which was used for a purpose by the apartheid government.

(L1) and a second language (L2) (Department of Basic Education [DBE], 2010). However, implementation of this policy remains problematic. Despite the constitutional and policy revisions, several authors have critiqued the continued prestige of English and the lack of active promotion of African languages (Bangeni & Kapp, 2007; Hunter, 2015). Many schools continue to use an English medium of instruction (MoI) in all grades or from Grade 4 onwards, indicating that learners who are not L1 English speakers receive their education in a second or third language (Heugh, 2009; Janks, 2014; Thomas & Collier, 2001; Wildsmith-Cromarty & Gordon, 2009). Non-equivalence between learners' home language(s) and the language(s) in which they receive their education negatively impacts learning (Prinsloo et al., 2018; Prinsloo & Harvey, 2020). Drawing together with the previous point, it is largely Black African learners who: a) are taught in their second or third language; b) have low economic and cultural capital; and c) receive a lower quality of education at poorly resourced schools (Janks, 2014).

While South Africa has one of the "best tertiary education systems in the developing world" (Mlachila & Moeletsi, 2019, p. 25), it remains characterised by dualistic outcomes as a result of spatial planning carried out under apartheid (Cummins, 2015; Mlachila & Moeletsi, 2019). South African tertiary students exhibit a wide range of reading competencies due to differences in socio-economic status (SES) background, primary and secondary education provision, and language background, among other factors (Boakye, 2017; Millin, 2015; Sehoole & Adeyemo, 2016). They are often overwhelmed by the quantity and level of reading required of them during their academic studies (Boakye, 2017; Boakye et al., 2014). This study aims to add to our understanding of academic reading by exploring WM as an additional factor. The target population were first-year tertiary students completing their studies through an online South African university.

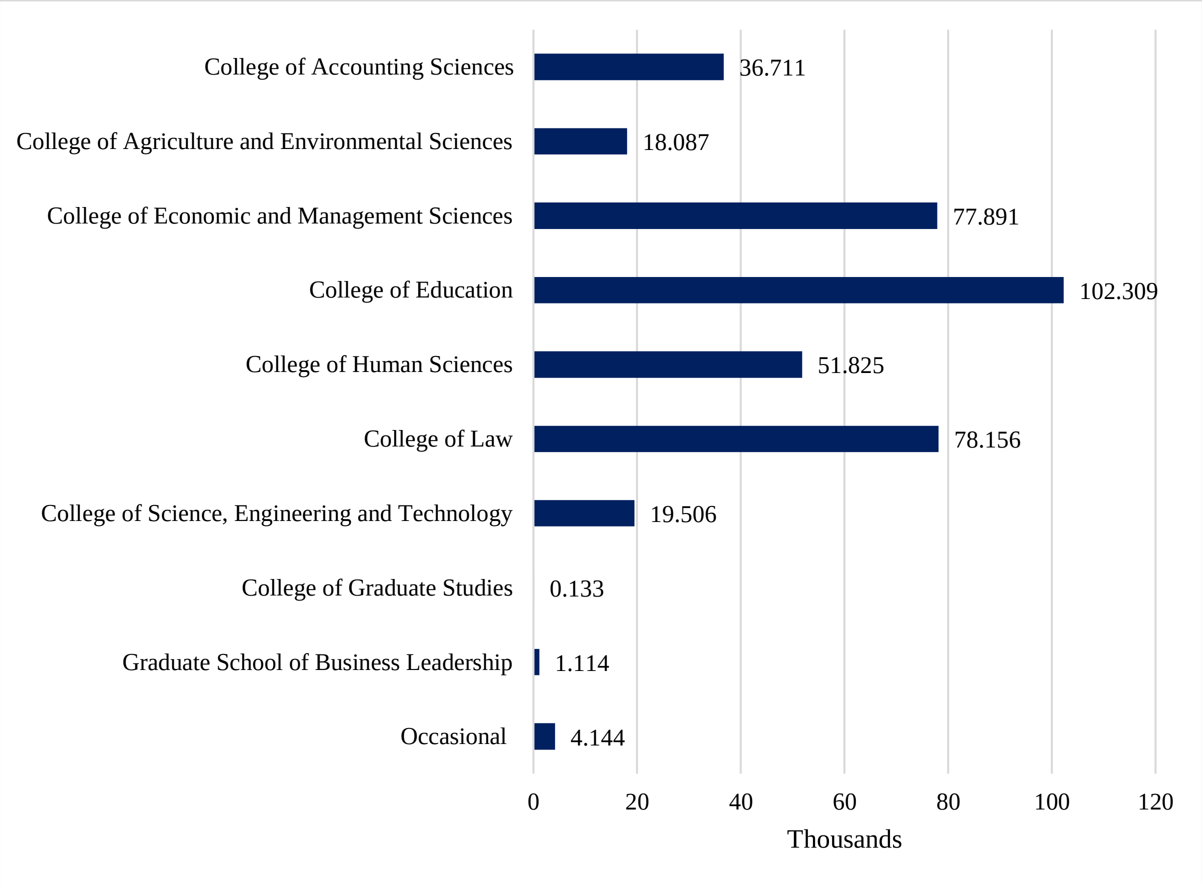
1.3.3. University of South Africa

The context for the current research project is the University of South Africa (Unisa). Beginning in 1873 as the University of the Cape of Good Hope, Unisa has a long history and has seen much change (Ngengebule, n.d.). With regard to socio-political influences, during the 1980s Unisa was controlled by the House of Assembly in the tricameral parliament and was a historically White institution. However, given that its students were off-campus, Unisa was unaffected by the permit system and could therefore enrol any applicant who qualified for admission (Bunting, 2006). It was "the university for more than half of all Black South African college students" who made up ten percent of the student body (Silk, 1974, p. 15). Nevertheless, up until 1994 Unisa was governed by supporters of the apartheid government and the institution was thus more closely aligned to Afrikaans-medium than historically English-medium universities, including its intellectual agenda. Little or no research took place, and it had few international associations (Bunting, 2006). Most Black African lecturers, referred to as 'professional assistants' and paid two-thirds the salary of White lecturers, were in the departments of African languages (Silk, 1974). Post-1994 Unisa has undertaken several initiatives towards transformation. For example, during 1994 Unisa implemented the 'Equity and Excellence' programme, which allowed a particular number of academic positions to be reserved annually for Black applicants only. Implementation saw an increase in Black African academic staff, from 6% to 10% over the 1994–1996 period (Hugo, 1998). A full review of institutional transformation is not provided here.

Unisa has a notable headcount, with a total enrolment of 381 483 students across nine colleges (Figure 2) (Unisa, 2021). Unisa is the only dedicated distance education institution in South Africa (Van Schoor, 2010). Reflecting its long history, its model of delivery has changed substantially.

Figure 2:

Number of students enrolled at Unisa in 2020 by college



Note. Adapted from *Student Enrolments*, by Unisa, 2021 (https://www.unisa.ac.za/sites/corporate/default/About/Facts-&-figures/Student-enrolments). In the public domain.

Traditional higher education refers to full-time, contact, and campus-based courses (Letseka, 2015). In contrast, distance education connotes courses where the lecturer and student are separated by geographical and/or temporal factors (Moore et al., 2011). Distance education, or distance learning, changed greatly as it transitioned through the first, second, and third correspondence models (Buerck et al., 2003; Ngubane-Mokiwa, 2017; Tait, 2000). In these three models the only constant link between the student and the learning environment was the lecturer (Ngubane-Mokiwa, 2017). This changed with the advent of open distance learning (ODL), which was made possible through the development of information and communications technology (ICT) and the marketisation of education (Buerck et al., 2003; Ngubane-Mokiwa, 2017; Tait, 2000). In this fourth model, communication between lecturer and student was supplemented with other technologies, including face-to-face central lectures, course notes, telephone, fax, mail, email, video conferencing systems, and Internet-based modes of communication (Buerck et al., 2003; Tait, 2000). ODL therefore uses these modern Web 2.0 technologies to facilitate institution-student, lecturer-student, and student-student interactions (Letseka, 2015; Ngubane-Mokiwa, 2017). Through these tools, ODL is able to widen access and increase participation in higher education.

Over the past 15 years ODL has accounted for almost a third of all higher education enrolments (Letseka, 2015). Given the focus on accessibility, ODL has been identified within South Africa as a means of transformation to an inclusive rather than exclusive education system, and has greatly assisted in increasing higher education access (Letseka, 2015; Simpson, 2013). Therefore this learning model was used at Unisa to "bridge the time, geographical, economic, social, education and communication" distances (Letseka, 2015, p. 131). However, in response to the labour market need for graduates proficient in ICT, Unisa has recently transitioned from an ODL model to an open distance e-learning (ODeL) approach (Baijnath, 2014; Letseka, 2015). The main similarities and differences between ODL and ODeL are now discussed, with a summary provided in Table 1 (Letseka, 2015; Ngubane-Mokiwa, 2017).

Both ODL and ODeL have the same main benefit: the reduction of barriers to higher education. Firstly, ODL and ODeL are not subject to constraints of time or space. Additionally, they provide the opportunity to avoid travel or relocation and/or retain employment (Buerck et al., 2003; Ngubane-Mokiwa, 2017; O'Shea et al., 2015). Thus, ODL and ODeL students are typically non-traditional rather than traditional students (Ngubane-Mokiwa, 2017; Rovai, 2003). Traditional students are most often individuals who complete their secondary education and immediately enrol for tertiary education, where they attend full-time until graduation (Rovai, 2003). Non-traditional students are generally viewed as being older, part-time students in full-time employment (Buerck et al., 2003; Rovai, 2003). The reasons for non-traditional students returning to their studies are numerous but include pursuit of an advanced degree, completion of a previously begun degree, or to stay up to date and competitive within their field (Buerck et al., 2003; Miller & Lu, 2003). There are, however, two important differences between ODL and ODeL which impact course design and student support initiatives.

There are two main assumptions when using an ODeL model which differ from the ODL approach: 1) an increased focus on optimal use of electronic technologies, and 2) a shift from teacher-centred to student-centred learning (Letseka, 2015). With regard to the first, it is expected in the ODeL model that all students have access to and are adept in using modern electronic technologies and other digital services to access their learning material and take part in the various interactions (Ngubane-Mokiwa, 2017). Additionally, this first assumption presumes that the relevant courses are adequately designed with an ODeL approach in mind (Ngubane-Mokiwa, 2017). Specific technologies, such as video conferencing, online discussion forums, blogs, podcasts, and peer-to-peer assessment, should be used to facilitate dialogue and bridge spatial distance (Ngubane-Mokiwa, 2017). In the second assumption, ODeL is student-centred so as to consider the impact of students' background and academic journey (Letseka, 2015; Ngubane-Mokiwa, 2017). Both assumptions thus motivate that academic reading is particularly important for South African students enrolled in online programmes. To enhance our understanding of academic reading within this population, the current study explores the role of WM in academic reading and academic achievement in ODeL first-year tertiary students enrolled in a Unisa course.

Table 1

A comparison of the open distance learning and open distance e-learning models

Key features	Distance education or learning model	
	Open distance learning	Open distance e-learning
Typical student	Mature, non-traditional, working student	Mature, non-traditional, working student
Interaction	Institution-student, lecturer-student, and student-student interaction	Institution-student, lecturer-student, and student-student interaction
Synchronicity	Asynchronous	Asynchronous and synchronous
Educational theory basis	Teacher-centred learning – 'teaching by telling'	Student-centred learning

1.4. Purpose of the research project

ODeL is able to overcome several barriers and thus widen access, but the accompanying high academic reading and writing load of an online course can be exigent (Buerck et al., 2003; O'Shea et al., 2015). As noted, the medium of instruction (MoI) in South Africa is associated with historic disparity based on the previous dispensation. This has left structural differences in society, with one consequence being that students are not equally proficient in the MoI used in higher education (English) (Bharuthram, 2012; Gous & Roberts, 2016; Pretorius, 2000). Linked to MoI proficiency, scholarship has noted the poor reading ability of Unisa students and how this can act as a barrier to academic success (for example, see Bohlmann & Pretorius, 2002; Pretorius, 2000; Van Schoor, 2010). However, academic reading is crucial for the educational setting (Unsworth & McMillan, 2013). Research must thus go beyond language proficiency and explore other relevant factors. Working memory (WM) has been purported as a crucial factor, with individual differences in its capacity being highly indicative of reading ability (Linderholm & van den Broek, 2002). This study thus aims to explore the relationships between WM, academic reading, and academic achievement of ODeL first-year tertiary students at Unisa.

Given the focus on ODeL students, the study used an online, web-based method of data collection. This involves gathering original data via the Internet which, after analysis, provides new evidence regarding a specific research question (Latkovikj & Popovska, 2019). Although not a consideration during the proposal development of this project, the coronavirus disease 2019 (Covid-19) pandemic highlighted the need for such a method: institutions closed their physical spaces, which forced all data collection to be conducted online. Online research has both advantages and disadvantages. Regarding benefits, online research is convenient, it can be more flexible for participants, it is useful to researchers as they do not necessarily need a laboratory or costly equipment, and it can provide large, diverse datasets as well as open-source measures (Latkovikj & Popovska, 2019; Leidheiser et al., 2015). Online tasks which are open source, such as those used within this study, additionally offer exceptional value for furthering research as they can be used across contexts and in large-scale studies. Furthermore, studies have shown that data gathered from online and lab-based experiments is comparable (for example, see Hauser & Schwarz, 2016; Huber & Gajos, 2020; Ruiz et al., 2019). However, negative outcomes can include reduced experimental conditions, unreliable responses, participant online connectivity issues or exclusion of individuals with limited or no technological access, pollution of the sample when participants share links, and low motivation of participants (Latkovikj & Popovska, 2019; Leidheiser et al., 2015). An additional purpose of this study is therefore to document the process of developing open-source, web-based measures of WM and the associated benefits and challenges.

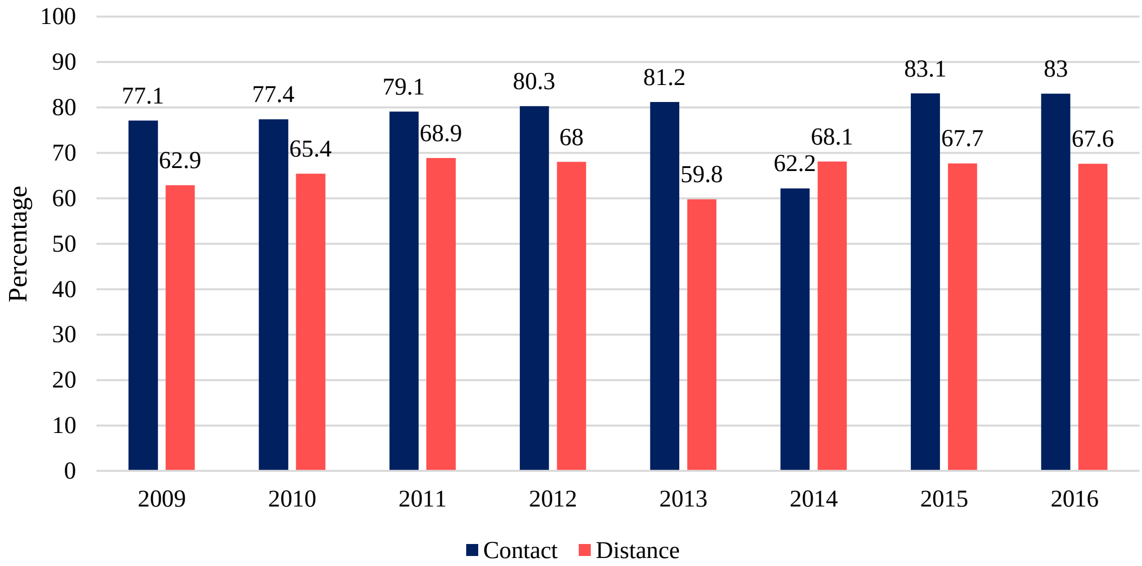
1.5. Rationale

While funding facilitates access, it is inadequate in ensuring student success (Sehoole & Adeyemo, 2016). Student dropout and throughput rate continue to be challenges associated with ODeL and non-traditional students (Gilardi & Guglielmetti, 2011; Khuluvhe et al., 2021;

Miller & Lu, 2003; Rovai, 2003; Simpson, 2013). Khuluvhe et al. (2021) report that of the 2017 first-time-entering students enrolled in a distance three-year undergraduate degree, 28% of the cohort dropped out after the first year. Persistence is thus a core element of student success (Kuh et al., 2007) and in adult education can be defined as the length of time an adult spends attending classes to achieve their learning goal (for example, graduation). Persistence rates in South Africa show a similar trend to international data (Figure 3). For example, the higher education undergraduate success rate for distance education (which includes ODeL students) in the 2015/16 financial year was reported as 68%, as opposed to the 83% reported for contact institutions (Department of Higher Education and Training [DHET], 2016; Statistics South Africa [Stats SA], 2019). Furthermore, of the distance student cohort who first registered in 2009, only 31% had graduated after 10 years (Khuluvhe et al., 2021). Low levels of persistence thus negate the key advantage of ODeL, as "access to higher education without success is meaningless" (Letseka, 2015, p. 8). High rates of student attrition are costly for both students and the higher education institution itself (Cadle, 2013; Khuluvhe et al., 2021; Van Schoor & Potgieter, 2011). When one also considers the greater system, it is beneficial to the economy of South Africa to have students who graduate and who graduate timeously (Raju & Schumacker, 2015; Tamhane et al., 2014). As reading is a factor in student dropout (van Dyk et al., 2013), it is worthwhile to explore factors related to this activity.

Figure 3:

Public South African universities undergraduate success rates, 2009–2016



Note. Adapted from *Education Series Volume V: Higher Education and Skills in South Africa, 2017*, by Stats SA, 2019 (http://www.statssa.gov.za/?page_id=1854&PPN=Report-92-01-05). Copyright 2019 by Stats SA. Adapted with permission.

Academic reading enables individuals to take part in the learning process and is fundamental to academic success (Bharuthram, 2017; Boakye, 2017; Bohn-Gettler & Kendeou, 2014; Clinton-Lisell et al., 2022; Peregoy & Boyle, 2000). A correlation has consistently been shown between reading proficiency and academic achievement. This correlation has been identified both for first language (L1) and second language (L2) readers (Pretorius, 1995). There are several ways in which reading proficiency influences academic studies. If students are unable to understand and interpret academic texts, this results in incomplete prescribed readings, incomplete or unsuccessful tests, assignments and exams, and lack of class participation (Bharuthram & Clarence, 2015). In other words, being unable to read quickly and proficiently leads to decreased task persistence, as students are frustrated and have limited time to study (Pretorius, 2000). Furthermore, when students are struggling to decipher text, they focus to the point where content and meaning is lost (Roberts & Gous, 2014). Understandably, students are unable to cope academically, resulting in high attrition and low throughput rates (Bharuthram, 2012; Bharuthram & Clarence, 2015). This study focuses on the relationships between WM, academic reading, and academic achievement as they can impact student performance and withdrawal[3]. Exploration of these relationships adds to the scholarship by incorporating the role of executive functions into these discussions. This is important, as it allows for a better understanding of the cognitive abilities of Unisa ODeL first-year tertiary students. This understanding is then useful for the development of theoretical and instrumental models of academic reading, possibly leading to strategies that will improve academic achievement and the overall academic success of students. The current study would, in essence, form the first phase of this crucial work.

Examination of these relationships in Unisa ODeL first-year tertiary students within the South African context is of further value. Although it is known that WM is necessary for both academic reading and academic achievement, the exact nature of how these abilities are inter-related is not clearly understood. The current study will add evidence from the Global South to the existing largely Global North body of literature exploring these relationships (R. Adams & Shahnazari-Dorcheh, 2014; Barreyro et al., 2019; Burin et al., 2018; M. J. Lee, 2014). It will furthermore do so with both English L1 and L2 students within a diverse, multilingual, and unequal context. These elements bring exceptional novelty to the study. Firstly, the nature of these relationships in English L2 students who are studying in English is poorly understood (R.

[3] It is noted that there is a wide variety of factors which can lead to student dropout, including demographic variables such as gender and age (Jenkins-Guarnieri et al., 2015; Jose et al., 2016), student factors such as academic background and psychological attributes (Hart, 2012; Jenkins-Guarnieri et al., 2015; Y. Lee & Choi, 2011), financial aid (Chen & DesJardins, 2008; Stewart et al., 2015), course or programme factors such as institutional support and increased communication with the lecturer (Chen, 2012; Hart, 2012; Y. Lee & Choi, 2011; Stewart et al., 2015), as well as environment factors such as work commitments and family support (Hart, 2012; Y. Lee & Choi, 2011).

Adams & Shahnazari-Dorcheh, 2014). Conducting this study in the South African context will thus add valuable information as the majority of students are English L2 students (Stats SA, 2016). Secondly, the South African context is markedly unequal with students having had disparate access to educational environments that support and stimulate development (Badat & Sayed, 2014; Janks, 2014; Mlachila & Moeletsi, 2019; Sehoole & Adeyemo, 2016). Exploring the relationships between WM, academic reading, and academic achievement within this context thus adds original insights.

The development of open-source, web-based measurements of WM will also have several benefits. Currently, most automated WM measures are costly and/or require specialised software, illustrating a gap for the advancement of cognitive ability measurements that are open source and can be administered online without any software, setup, or installation requirements. The current study thus fills an important niche, particularly given the exploration of WM in several domains of research, as it assists investigation of the WM construct as well as its associations with other factors (Stone & Towse, 2015). An additional benefit would be larger and more diverse samples who are less vulnerable to specific research biases such as researcher bias (Leidheiser et al., 2015). This will assist in furthering the research agenda regarding WM in South Africa. However, as noted above, there are challenges with using an online WM measure. The current study will therefore also be able to provide recommendations for mitigating these issues.

1.6. Research aims, questions, and hypotheses

One of the aims of the study was to further the understanding of the theoretical relationships between WM, academic reading, and academic achievement within the Global South context. The primary research aim was thus to explore the relationships between WM, academic reading, and the academic achievement of Unisa ODeL first-year tertiary students. Derived from this overall aim, the following research questions and related hypotheses guide this study:

1. What are the profiles of the student participants on psychometric measures of:
   a. English academic reading ability, as measured by the Test of Academic Literacy Levels (TALL); and
   b. WM as measured by the Reading Span (RSPAN) and Operation Span (OSPAN)?

2. Are WM scores positively correlated to academic reading as measured by the TALL?

$H_{0.1}$ There is no relationship between WM scores and academic reading.

H_1 WM scores are positively correlated to academic reading.

3. Are WM scores positively correlated to end-of-course academic performance?

$H_{0.2}$ There is no relationship between WM scores and end-of-course academic performance.

H_2 WM scores are positively correlated to end-of-course academic performance.

4. Is academic reading as measured by the TALL positively correlated to end-of-course academic performance?

$H_{0.3}$ There is no relationship between academic reading and end-of-course academic performance.

H_3 Academic reading is positively correlated to end-of-course academic performance.

5. What is the contribution of these predictors (WM and academic reading) to end-of-course academic performance?

$H_{0.4}$ WM and academic reading do not make direct, positive contributions to end-of-course academic performance.

H_4 WM and academic reading make direct, positive contributions to end-of-course academic performance.

$H_{0.5}$ WM does not indirectly influence end-of-course academic performance via academic reading.

H_5 WM indirectly influences end-of-course academic performance via academic reading.

1.7. Research design and procedure

A non-experimental ex post facto cross-sectional research design was followed. The targeted participants were ODeL first-year tertiary students enrolled at Unisa and residing in South Africa. All assessments were conducted in English, either on campus or at home. Participants were asked to complete a demographic and background information survey, an academic reading test (Test of Academic Literacy Levels (TALL)), and two working memory capacity (WMC) tasks. The latter were the reading span (RSPAN) and operation span (OSPAN). All instruments were self-administered on a computer and responses were indicated using a computer mouse and keyboard. The final end-of-course grades achieved by participants were requested from the university. Data was collected over the course of the 2020/21 academic years.

All targeted students were sent a solicitation email providing information and the participant information sheet about the study, and they were asked to indicate their interest in participating

(Appendices A and B) by completing both the informed consent and background survey (Appendix C). Following completion, the two WMC tasks were then sent to the participant via a personalised email, along with a link giving access to the research project website (https://jaquelineharvey.wixsite.com/harveyproject). Once the participant had completed the two WMC tasks, they were sent the TALL test link via email. For the first data collection (beginning 3 January 2020) students were also able to volunteer in-person on the Sunnyside campus, Gauteng, but this was halted due to the Covid-19 pandemic and subsequent campus closures. In the subsequent two data collections, participation was purely online.

1.8. Data analysis procedure

The Statistical Package for the Social Sciences (SPSS v27.0) was used to analyse the data generated in this study by means of descriptive and inferential measures, where appropriate. The data analysis was conducted in a series of steps: 1) descriptive statistics, 2) correlational statistics, and 3) mediation analysis.

1.9. Limitations of the study

Although the study made important contributions, it had several limitations related to the research design, the inadequacy of the sample, the challenges of using open-source, web-based measures of WM, and limited insight into other variables. As the research design was non-experimental and used correlational statistics, the findings cannot speak to causality. The sample of the study furthermore lacked diversity and was small in size, limiting generalisability. Related to the method followed in the study, there were also limitations associated with using online instruments as well as how the participants were asked about their parent's or guardian's occupation in the demographic survey. A final limitation was that there was limited insight into other factors having an influence on the associations between WM, academic reading, and academic achievement.

1.10. Definition of central terms

Central terms as used in this study were defined as outlined below.

Reading. A mental activity involving complex cognitive lower- and higher-level and linguistic processes which links a language system, a writing system, and a higher-order knowledge system to produce understanding of written text (Nassaji, 2003; Pretorius, 2010).

Academic reading. Beyond foundational cognitive and linguistic processes related to reading, academic reading interprets scholarly texts and integrates information in order to create new information (Desa et al., 2020; Gorzycki et al., 2016, 2019; Howard et al., 2018). It requires reading with a purpose as well as with metacognitive awareness (Desa et al., 2020; Gorzycki et al., 2016; Howard et al., 2018).

First language (L1). Also referred to as home language, native language, primary language, and mother tongue in the literature (Nemati & Taghizadeh, 2013; Pretorius & Stoffelsma, 2017). This is the language acquired during early childhood, before approximately three years of age (Nemati & Taghizadeh, 2013).

Second language (L2). Also referred to as First Additional Language, Additional Language, or English as a second language in the literature (Pretorius & Stoffelsma, 2017; Schaefer & Kotzé, 2019).

Working memory (WM). A neural system required to mentally store a limited amount of information for a short period of time, so that it can be manipulated in mental tasks while ignoring concurrent processing, distraction, and/or attention shifts (Aben et al., 2012; Baddeley, 2003; Carretti et al., 2013; Engel de Abreu, 2011; Klingberg, 2010; Peng et al., 2018; Unsworth & McMillan, 2013). In short, working memory is the ability to temporarily store and manipulate information while ignoring distraction (Pascual et al., 2019).

Working memory capacity (WMC). WMC is functionally defined as the trade-off between storage and active processing functions (Harrington & Sawyer, 1992). It represents the availability of WM resources for storage and processing (Camos, 2017; Gibson et al., 2012; Linderholm & van den Broek, 2002).

1.11. Conclusion and structure of the thesis

This thesis comprises six chapters, including this initial introduction. The remaining chapters of this thesis are structured in the following manner:

Chapter 2 is a literature review of the prominent theoretical perspectives and scholarship that underlies the research questions of this study. Contradictory findings as well as gaps in the knowledge around this topic are explored. This chapter furthermore provides a critical evaluation of the South African context to motivate why exploration of these questions is a crucial concern.

Chapter 3 outlines the conceptual framework that guides this study. It first provides a broad overview of WM as a construct and how the various models are differentiated, including a brief comparison across three models (continued in the appendices for interested readers). Following a justification for the choice of model, a discussion is provided of the multicomponent WM model which guides conceptualisation of WM in this study. Before describing the links between WM and academic reading, the interactive reading approach is then presented. The chapter concludes with integration of how WM is related to academic reading.

Chapter 4 is a presentation of the methods that were followed in the present study. It begins by providing the research aims, questions, and hypotheses before exploring the paradigm and its implications for the study. The research design is given before presenting the practical procedures of data collection, including instrument design. How this data is managed and statistically analysed is then described, before closing with the ethical considerations of the study.

Chapter 5 is the documentation of the statistical analyses and findings. The results of the descriptive analyses are first provided as well as evaluation of the instruments used in the study. The chapter concludes with the findings from the inferential analyses.

Chapter 6 is a critical discussion of the study findings in relation to the scholarship reviewed in the second chapter. This refers to previous studies which have or have not identified relationships between WM, academic reading, and academic achievement. The chapter also evaluates the instruments used in the study and how they performed. A discussion of the limitations of the study is given, and the chapter concludes with recommendations and suggestions for future research directions.

CHAPTER 2: LITERATURE REVIEW

"We know from research that the reading circuit is not given to human beings through a genetic blueprint like vision or language; it needs an environment to develop" (Wolf, 2018).

2.1. Introduction

The previous chapter briefly introduced working memory (WM) and its reported relationship with academic reading. WM, which is limited in capacity, has the ability to store and process information concurrently and theoretically plays a crucial role in reading (Peng et al., 2018). This chapter seeks to expand this argument through further contextualisation and critique of the existing scholarship. It comprises three parts. The first part provides the role of academic reading in academic achievement as well as the theoretical perspective of academic reading (§ 2.2 – 2.3). The chapter illustrates the importance of academic reading in academic achievement, with a focus on online distance e-learning (ODeL) first-year tertiary students. It furthermore positions how academic reading is conceptualised within this thesis regarding academic literacy, an area of ongoing debate. The generic, traditional view of academic reading and academic literacy is the focus in this study, and justification for this decision is provided.

The second part of the chapter focuses on the cognitive processes necessary for reading activity (§ 2.4) and their development in the South African context (§ 2.5). Both lower- and higher-level processes are required for reading but compete for limited mental resources. Individual differences in the capacity of these resources can thus lead to differences in reading comprehension (Kendeou et al., 2014). This is a crucial aspect of the overall argument being made since discussed in the third part of the chapter, these processes take place in WM and are thus competing for limited WM resources. In addition, inefficient lower-level processes require more of the available resources, which can negatively impact overall reading comprehension.

The author relates this to the South African context, where it is argued that many Unisa ODeL first-year tertiary students may have inefficient lower-level processes for English reading. This provides much-needed context for reading research within this population group. Review of this literature also illustrates the importance of exploring neural constructs in relation to reading processes within South Africa.

The third part of the chapter first presents WM, its definition, structure, and purpose (§ 2.6). WM is a limited-capacity neural system with both storage and processing functions (Barreyro et al., 2019). A relationship between WM and academic reading has been proposed, as both these functions are necessary in the reading process: products of previous mental operations must be stored and integrated with successive processing products as the text is read (Barreyro et al., 2019). Section 2.7 discusses studies which have found such a relationship, as well as those which have not, with overall support being indicated. Following establishment of the relationship between WM and reading, the limited capacity of WM is discussed as the mechanism through which this construct influences reading. It is at this juncture that the preceding information on lower- and higher-level processes as well as the South African context are linked. This chapter then briefly discusses the proposed link between WM and academic achievement.

The chapter concludes by uniting the preceding information to provide a comprehensive account of the proposed relationships between working memory capacity (WMC), academic reading, and academic achievement in this thesis. It is argued that WMC is associated with academic reading, with higher capacity enabling higher academic reading. Regarding Unisa ODeL first-year tertiary students, it was argued that South African contextual factors impact reading cognitive process development and provide additional support for the role of WMC in academic reading. Given the importance of academic reading in academic achievement, it is furthermore proposed that both WMC and academic reading will be positively linked to academic achievement.

2.2. Academic reading as a requirement for ODeL education

Academic reading is the foundation of ODeL education (Desa et al., 2020; Howard et al., 2018; X. Liu & Read, 2020; Roberts & Gous, 2014). Students who are enrolled in a purely online higher education course utilise academic reading as the main – if not only – tool with which to engage with the academic material (Bharuthram, 2012). Reading, together with writing, serves this engagement through three main avenues. Firstly, academic reading enables students to implicitly learn the genres and conventions of the medium of instruction and academic discipline (Center & Niestepski, 2014; Desa et al., 2020; Howard et al., 2018). This is a particularly crucial point for entering both the academic English and discipline-specific discourses, discussed below under academic literacy. Secondly, reading exposes students to ideas and data that inspire their thinking and writing. Writing, in turn, helps to improve students' reading and specifically their comprehension of the text (Bharuthram & Clarence, 2015; Center & Niestepski, 2014; Graham & Hebert, 2010). Thirdly, being proficient in reading and writing also allows for effective communication with peers, tutors, and lecturers through online discussion or email (Dabbagh, 2007). ODeL students must be able to navigate the Internet and institutional websites. This can be more difficult for English second language (L2) students, or any students who struggle with this medium, as it necessitates both language and technological fluency (Dabbagh, 2007). Therefore, the reading and writing activities play a key role in ODeL tertiary education. Focusing on reading, the aim is to understand what has been read. Deriving meaning from text allows "analysis, critique, evaluation and synthesis of information from various sources" (Bharuthram, 2012, p. 205; Bharuthram & Clarence, 2015;

Nel & Adam, 2014; Roberts & Gous, 2014; Scott & Saaiman, 2016). Being unable to do so can negatively impact academic achievement.

The need for academic reading is clear throughout the learning process and is a core component of academic literacy in higher education. Pretorius (2000) examined the influence of reading ability on academic achievement of psychology undergraduate students (n = 1 113) at Unisa. The author measured reading inference ability, as it is a key reading process in constructing meaning, that is comprehending what has been read. The inferencing ability of the sample was low, with a mean score of 53%, which indicated that these students were reading with a low level of comprehension. Furthermore, a one-way analysis of variance (ANOVA), $F(4, 1128) = 74.73$, $p < .00$, indicated that there was a significant effect of inferencing score on academic performance. The lower the inferencing score, the poorer the student performed academically. A linear regression model was run, including the following variables: student living conditions; Grade 12 (matric) results; study habits; attitude to content work; perceived value of coursework; motivation level; locus of control; and reading inference score. The results indicated that reading inference score was the highest predictor of academic achievement, accounting for 24% of the variance. Pretorius (2000) therefore concluded that students who can read fluently are able to construct meaning from their text and thus derive benefit from their studies. However, students who are unable to do so are unable to understand their readings, which manifests in poor academic achievement (Pretorius, 2000). Academic reading in tertiary education is most often discussed in terms of its contribution to academic literacy.

2.3. Academic reading as a critical component of academic literacy

The development of academic literacy is an important aspect of tertiary education. Measurement of academic literacy indicates the level of competence in using language within the academic community, that is ability in academic discourse and its conventions (van der Slik & Weideman, 2007). More specifically, van Dyk and van de Poel (2013, p. 56) define academic literacy as “being able to use, manipulate, and control language and cognitive abilities for specific purposes and in specific contexts.” The cognitive tasks of academic reading are clearly visible in academic literacy when considering these definitions. This is made even more evident in the discrete, skills-based, functional definition which underlies the Test of Academic Literacy Levels (TALL) (Nizonkiza & van Dyk, 2015). This definition was provided by Weideman (2018, p. vi), and states that academic literacy is “the ability to

- understand a range of academic vocabulary in context;
- interpret the use of metaphor and idiom in academic usage, perceive connotation, word play and ambiguity;
- understand relations between different parts of a text, be aware of the logical development of an academic text, via introductions to conclusions, and know how to use language that serves to make the different parts of a text hang together;
- interpret different kinds of text type (genre), and have a sensitivity for the meaning that they convey, and the audience at which they are aimed;
- interpret, use and produce information presented in graphic or visual format;
- make distinctions between essential and non-essential information, fact and opinion, propositions and arguments; distinguish between cause and effect, classify, categorise and handle data that make comparisons;
- see sequence and order, do simple numerical estimations and computations that are relevant to academic information, that allow comparisons to be made, and can be applied for the purposes of an argument;

- know what counts as evidence for an argument, extrapolate from information by making inferences, and apply the information or its implications to other cases than the one at hand;
- understand the communicative function of various ways of expression in academic language (such as defining, providing examples, arguing); and
- make meaning (e.g., of an academic text) beyond the level of the sentence."

Being able to do any of the above rests on being able to read academic texts with comprehension: the prevalence of academic reading in the TALL is evidence of its foundational role in academic literacy (Fouché, 2009). Therefore, as was done by Boakye (2012, p. 109) in her doctoral thesis, "reading proficiency or literacy level were determined by the TALL". At this juncture it is necessary to discuss the perspective from which academic reading and academic literacy are viewed, as this has theoretical implications. The next section briefly discusses the differences between two perspectives of academic literacy: traditional (or autonomous) and ideological. The section furthermore argues that, in line with Pretorius (2010), both views have value. While this study largely utilises the traditional approach, given the focus on the cognitive-linguistic aspects of reading, it acknowledges the context in which the study takes place.

2.3.1. Generic or context-specific reading skills?

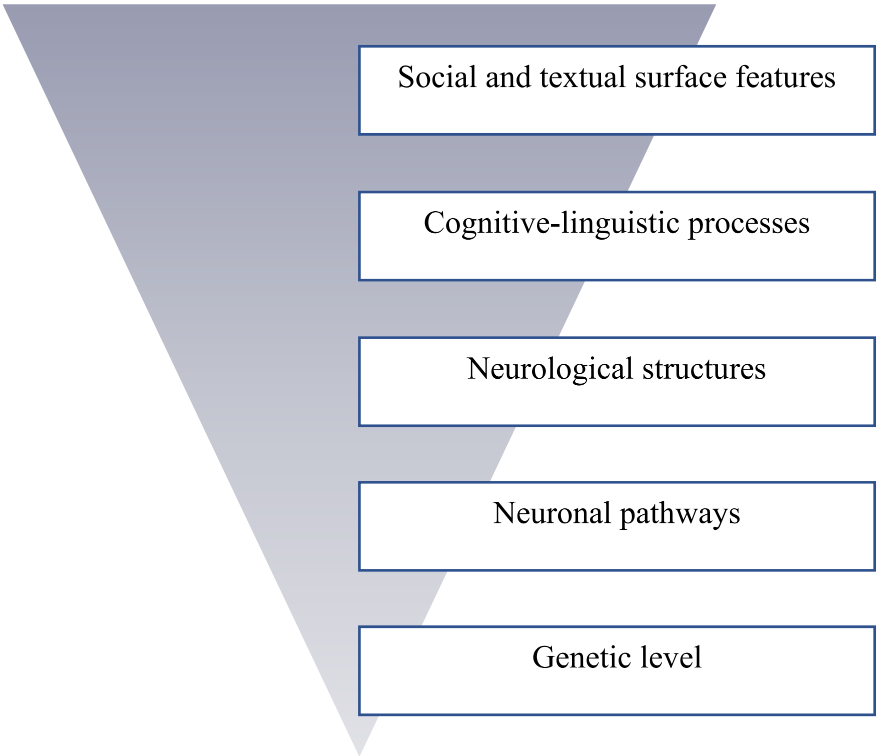
Academic texts have historically been seen as a set of established generic conventions (Duff, 2007). A shift has recently taken place, which posits academic texts as "social construction(s) by individuals based on their own histories and social contexts, their learning communities and power relations within them, and their audiences and goals" (Duff, 2007, p. 1.3). Furthermore, these social constructions are subject to change as the discipline, genres, and individuals change. Given this shift, there are two well-known models of academic literacy at either end of a continuum: traditional (or autonomous) and ideological. The traditional model perceives academic literacy as a neutral, generic, context-independent set of skills (Boughey, 2002; Gorzycki et al., 2016; Henderson & Hirst, 2007; Pretorius, 2010). This view of reading is aligned with componential views of reading. In the latter, each reading capability can be isolated, but together create meaning (Pretorius, 2010). The focus is on how readers process texts in terms of "phonemes, words, clauses, sentences and larger chunks such as paragraphs or whole texts" (Pretorius, 2010, p. 342). This focus on meaning-making furthermore considers theories of learning: how knowledge is gained and used. This approach also looks at text-based factors which relate to cognition, such as the structure and genre as well as input and experience (Pretorius, 2010). This research is typically situated within cognitivist epistemologies, where reading is explored as an aspect of human cognition using quantitative methods. Researchers therefore look at the organisation of the human mind and its processes as well as the role of cognitive structures such as memory and attention (Pretorius, 2010). The ideological model differs quite substantially.

In the pluralistic model, typically from a socio-constructivist approach, academic literacy is viewed as different sets of social practices rather than decontextualised, discrete cognitive skills (Baker et al., 2019; Boughey, 2002; Janks, 2014). This allows for acceptance of diversity wherein the manner in which each student learns to participate and make meaning within the academic context is considered. The ways in which students make meaning are "valued by the cultures, traditions or academic disciplines with which they are associated" (Henderson & Hirst, 2007, p. 26). Learning is a socio-cultural, collaborative event in a specific context and time, and determined by the power relations of the social and political context (Baker et al., 2019; Pretorius, 2010). Reading is socially and culturally embedded, with different literacy practices ratified by the different communities within the differing power dynamics (Pretorius, 2010). There is thus a wide variety of sets of practices that students can learn, which further means that no single set of these practices can be said to equal academic literacy (Henderson & Hirst, 2007). Academic literacy is dependent on the knowledge of the reader as well as their literacy skills, as it takes into account individual student differences (Baker et al., 2019; Boughey, 2002; Janks, 2014). These approaches typically make use of a socially constructed epistemology and qualitative methods (Pretorius, 2010).

Although clearly different, both the traditional and ideological views of academic literacy have value in reading research. While the first focuses on the human individual and their distinct competencies, the other looks at social phenomena and power dynamics between people. This is in line with Pretorius (2010), who argues that reading is both an individual cognitive-linguistic accomplishment as well as a socially constructed practice. Seeing these perspectives as complementary allows exploration into both the multiple processes involved in reading as well as the role of the external environment. The focus of the research therefore dictates the perspective of academic reading and academic literacy which is used. The different foci can easily be understood through the inverted 'pyramid of reading' (Figure 4) (Pretorius, 2010; Wolf, 2007). The first two levels are relevant to this study: social and textual surface features as well as cognitive-linguistic processes.

Figure 4:

Inverted pyramid of reading



Note. From "Issues of complexity in reading: Putting Occam's razor aside for now," by E. Pretorius, 2010, *Southern African Linguistics and Applied Language Studies*, *28*(4), p. 345. Copyright 2010 by Taylor and Francis. Reprinted with permission.

The first level of the pyramid is what can be observed, such as the different ways in which individuals become literate or how features of a text influence the reading process. Socially constructed perspectives of reading are typically concerned with this level of the inverted reading pyramid. This study acknowledges the role of context in the development of reading processes, but it is not the core focus. The research questions instead strongly align with the second level, which refers to the linguistic, cognitive, and reading processes which take place within the mind. The componential processes of reading are crucial at this level and are aligned to the traditional view of reading: the second level includes the many perceptual, conceptual, linguistic, and attentional processes necessary for the reading activity. There are both lower-and higher-level processes, where the former enable the latter (Pretorius, 2010). Critically, the more automatic a lower-order process, the greater the amount of WM that is freed up to devote to higher-level meaning-making processes (Ntim, 2015; Pretorius, 2010). These processes and their relationship with WM are at the heart of the current thesis. Thus, the traditional approach to academic literacy is taken, with a focus on the cognitive-linguistic processes of academic reading.

This chapter has thus far established that academic reading is integral to the learning process. Without being able to understand what is being read, there can be no learning from texts. This poses a clear challenge for ODeL tertiary students, who must largely rely on this form of learning. The chapter has also provided justification for the use of the traditional perspective of academic literacy with a focus on the componential processes of academic reading. Both this perspective and the current thesis focus on the cognitive-linguistic processes involved in academic reading. These processes involve both lower- and higher-level processes which compete for limited WMC. The next section discusses these reading processes and their relationship to one another.

2.4. Academic reading as a result of complex cognitive processes

Reading is reliant on the successful execution and integration of several cognitive processes (Bohn-Gettler & Kendeou, 2014; Ntim, 2015). In order to achieve comprehension, the reader constructs meaning within each sentence unit, between adjacent sentences, as well as across the larger text units so that the meaning of the text is understood as a whole (Pretorius, 2002). Briefly, the reader must visually process the words, match them to their phonological, orthographic, and semantic representations stored in long-term memory (LTM), and then combine these representations with context into a mental construction for understanding (Peng et al., 2018). Reading is therefore “a process that combines information from text with the reader’s prior knowledge” (Bader, 2016, p. 89). This complicated and rapid process relies on using the correct cognitive process at the right time (Kendeou et al., 2014).

Reading depends on the execution and integration of lower- and higher-level processes (Kendeou et al., 2014; X. Liu & Read, 2020; Ntim, 2015). These processes are executed in parallel while the reader simultaneously stores the intermediate product of each operation until a final mental representation is made (Kendeou et al., 2014; Prat et al., 2015; Prat & Just, 2011; Shin et al., 2018). Updating the representation as the reader proceeds ensures coherence as new information is processed (Fontanini & Tomitch, 2009; Kendeou et al., 2014; Schlaggar & McCandliss, 2007). Reading comprehension is therefore possible through intricate, fast, and large cognitive-linguistic processes and neuronal activity developed through human interaction and socialisation (Kendeou et al., 2014; Pretorius, 2010).

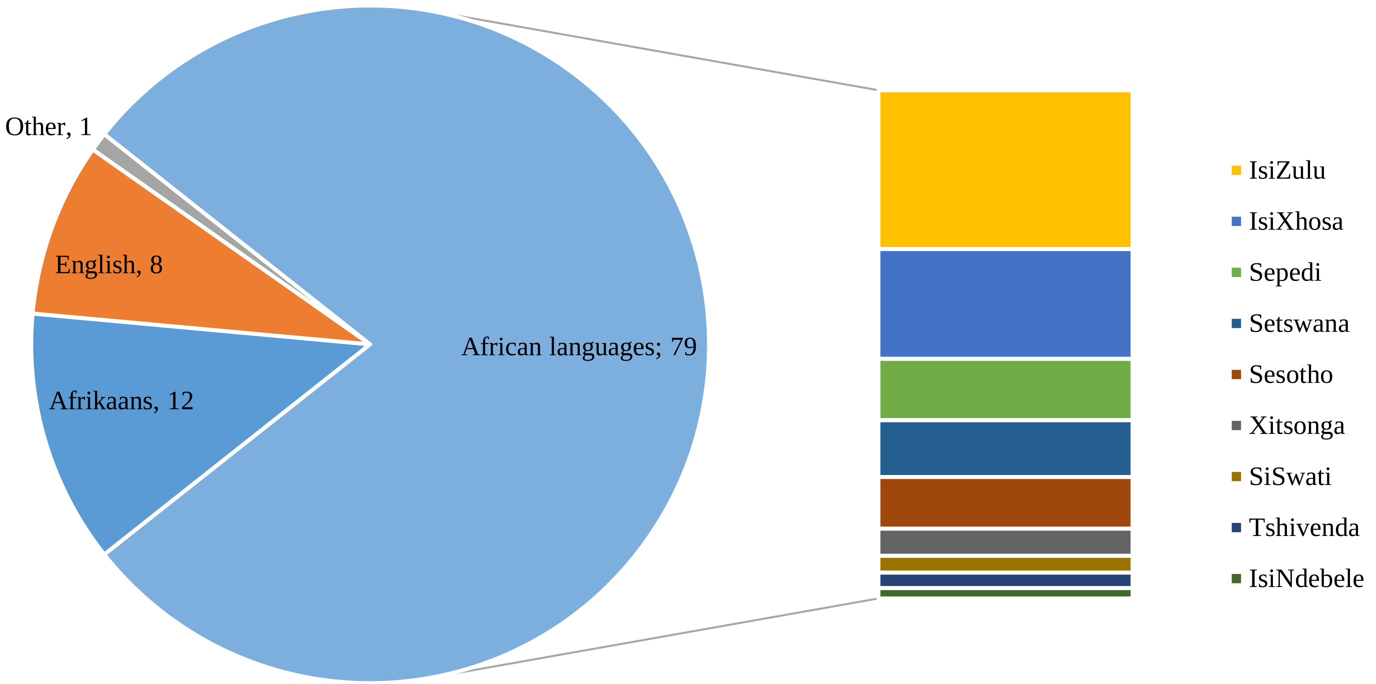
Lower-level processes require the oculomotor, perceptual, and parsing or analysing aspects of reading (McKee, 2012; Pretorius, 2002). They focus on translating the written symbols into meaningful units of language (Kendeou et al., 2014) and are usually the processes required for decoding and word recognition, such as letter identification and vocabulary size (Grabe, 2014; Jiang, 2017). These processes are developed during early childhood and are generally automated during the first years of formal education (Kendeou et al., 2014; Verhoeven et al., 2011). Automisation allows for more of the available mental resources, such as attention and WM, to be allocated to higher-level processes (Kendeou et al., 2014). Higher-level processes combine the generated units of language into mental representations to allow the reader to understand the meaning of the text (Kendeou et al., 2014; Verhoeven et al., 2011). This mental representation is the basis of comprehension; it is a model which semantically connects ideas shown and implied by the text (Kopatich et al., 2019). Higher-level processes require attentional and WM resources as they are not automated (Kendeou et al., 2014). The interactive and compensatory nature of reading means that deficiency in some processes can be compensated for by other processes. However, it is broadly considered that the generation of higher-level mental representations is reliant on efficient lower-level processes (X. Liu & Read, 2020). It is thus plausible that if lower-level processes require more of the mental resources, higher-level processes will be negatively impacted. The development of reading processes is now discussed in relation to South African contextual factors.

2.5. Academic reading development in the South African context

The majority of South African students are from African home language backgrounds, as seen in Figure 5 (Stats SA, 2016). However, the Medium of Instruction (MoI) tends to be English for the majority or for all of the education system (Howie et al., 2012; Spaull et al., 2016; S. van der Berg et al., 2011). Most South African students are thus English L2 readers. Furthermore, as illustrated in the first chapter, the sociocultural and political practices of South Africa have led to a bifurcated society and education system. Due to this, learners with an African home language are more likely to come from a low socioeconomic background and to have attended poorly resourced schools. It is generally accepted that academic reading is developmental across an individual's education (Gorzycki et al., 2019). It is thus argued that these contextual factors could influence development of lower- and higher-level reading processes even into tertiary education.

Figure 5:

Distribution of languages in South Africa (%)

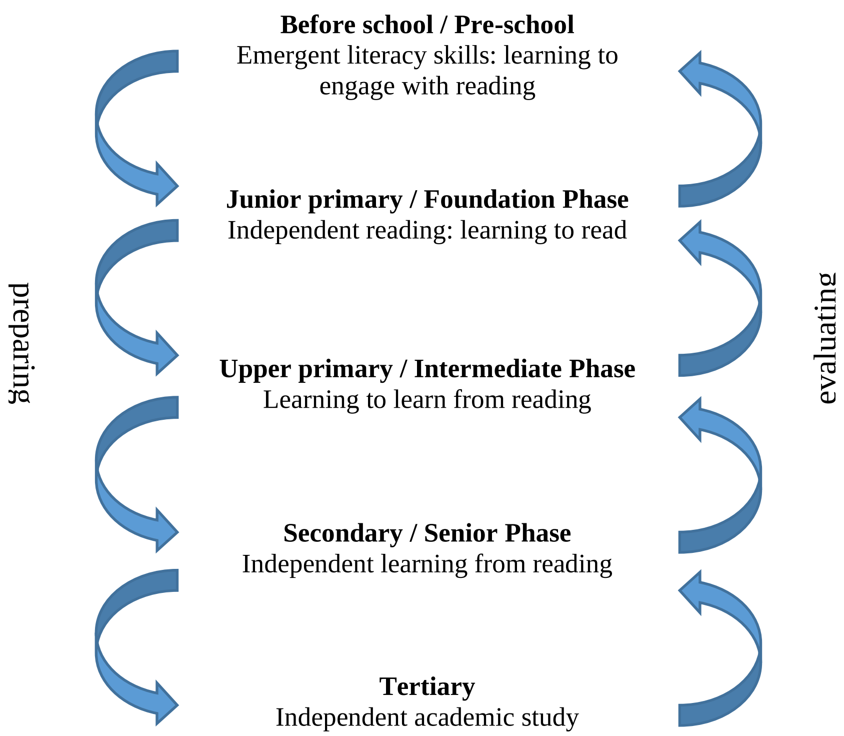


Note. Percentages were calculated using the distribution of individuals by language spoken most often in the household. Adapted from *Community Survey 2016 in Brief*, by Stats SA, 2016, (https://cs2016.statssa.gov.za/wp-content/uploads/2017/07/CS-in-brief-14-07-2017-with-cover_1.pdf). Copyright 2016 by Stats SA. Adapted with permission.

Rose (2005, 2007) reports a reading development sequence to detail reading skills that should be acquired at each stage of the school curriculum (Figure 6). Using this sequence as a basis, the discussion is structured according to five periods[4]: Pre-school; Junior Primary/Foundation Phase (Grades 1–3); Upper Primary/Intermediate Phase (Grades 4–6); Senior Primary/Senior Phase (Grades 7–9); Further Education and Training band (Grades 10–12); and tertiary education.

Figure 6:

Reading development sequence from before school to tertiary education



Note. Adapted from "A reading based model of schooling," by D. Rose, 2007, *Pesquisas em Discurso Pedagógico*, *4*(2), p. 6. Adapted with permission.

[4] Rose (2005, 2007) is situated within the Australian context, and thus the names of both the Australian and the South African stages are given for each period.

2.5.1. Pre-school

From birth, children develop emergent literacy skills. Through socialisation, parents scaffold orientations – values, attitudes, skills and knowledge – to written language as well as literacy behaviours (Matjila & Pretorius, 2004; Pretorius et al., 2016; Pretorius & Stoffelsma, 2017). The socio-economic status (SES) of the community also plays a role. Pre-schoolers from middle- and upper-SES environments tend to perform better on measurements of emergent literacy skills than their low-SES peers (Neumann, 2014). Pre-school experiences therefore influence readiness to learn to read. In addition, many learners will begin Grade 1 or Grade 4 in their second language (L2; English), which has added challenges (Janks, 2014; Wilsenach, 2015).

2.5.2. Junior Primary/Foundation Phase (Grades 1–3)

'*Learning to read*' in the Foundation Phase initially focuses on developing decoding (Pretorius, 1995, 2013, 2014). This process requires alphabetic knowledge, phonological awareness, print knowledge, and word recognition, as well as fluency (Pretorius, 2013). In other words, the lower-level reading processes which translate print symbols into language (Pretorius, 2014). In Grades 2 and 3 decoding skills are strengthened, and by the end of this period it is assumed that reading will be automatic, accurate, and fluent (Pretorius, 2013). However, a smooth transition from decoding to comprehension does not occur for all learners (Pretorius, 1995; Pretorius & Ribbens, 2005). This can be for several reasons, but a large role is played by the resources available to the school as well as teaching practices (Cummins, 2015; Heugh, 2009; Matier Moore & Hart, 2007; Pretorius & Currin, 2010; Centre for Development and Enterprise, 2015). It is likely that only learners from literate backgrounds being taught in their home language will be able to achieve independent reading in the first three years of formal education (Matier Moore & Hart, 2007). Hence it is the reality for many South African learners that they cannot read fluently and with comprehension **in any language** by the end of Grade 3, forcing them into a state of perpetual catch up (Pretorius et al., 2016).

2.5.3. Upper Primary/Intermediate Phase (Grades 4–6)

At this stage, it is assumed that learners are independent readers. The focus thus changes from '*learning to read*' to '*reading to learn*' (Pretorius, 2013, 2014). It is also from Grade 4 onwards that learners are introduced to subject textbooks which feature expository texts. These are remarkably different from the primarily short narrative texts with which they are familiar. Expository texts form the basis of learning and learners are expected to draw understanding from them while they read (Ntim, 2015; Pretorius, 1995, 2014). This involves understanding a wide range of vocabulary and various syntactic structures. Furthermore, learners must begin learning the registers specific to each academic subject (Pretorius, 2014). The ability to access meaning from text quickly and accurately is a requirement for academic reading. As the dependency on reading to learn increases throughout this stage, so does the disadvantage of learners without independent reading levels (Pretorius, 2013). This challenge is exacerbated for English L2 learners, as the majority of schools change to English as the instructional language from Grade 4 onwards (Heugh, 2009). L2 learners are typically ill-prepared to read in their additional language by the fourth grade (Pretorius & Currin, 2010), while texts become increasingly complex through this stage and learners fall more and more behind (Pretorius, 1995; Pretorius & Currin, 2010).

2.5.4. Senior Primary/Senior Phase (Grades 7–9) and the Further Education and Training Band (Grades 9–12)

Learners should be able to learn independently from reading at this point. They need to use Grades 4–9 effectively for expanding their language, knowledge, and vocabulary. During

Grades 10–12 learners should be able to read from and integrate a wide variety of texts with different perspectives. For skilled readers, their reading comprehension is now better than their listening comprehension – but it is vice versa for poor readers (Matjila & Pretorius, 2004; Pretorius & Ribbens, 2005). Research indicates that South African learners are not reaching the expected literacy levels of this stage (Matjila & Pretorius, 2004). South African learners have not been given the tools to succeed in tertiary education.

2.5.5. Tertiary education (post-Grade 12)

At the post-school phase, tertiary students' reading should be rapid and efficient. When reading, students should be able to "integrate, synthesise and critically evaluate information from a variety of sources and acquire new knowledge from reading" (Pretorius & Ribbens, 2005, p. 140). It is assumed that decoding skills are automatised (Bohlmann & Pretorius, 2002). Tertiary students should thus predominantly engage in *reading to learn* which goes beyond the basic lower-level reading processes, with a greater reliance on higher-level reading processes (Bharuthram & Clarence, 2015; van Dyk et al., 2013). However, research has suggested that in South Africa undergraduate students are not able to read and write at the school-exit level (Bharuthram & Clarence, 2015). This has been indicated for both English first language (L1) and L2 South African tertiary students (Nel & Adam, 2014; Zulu, 2005).

Nel and Adam (2014) explored the academic reading profiles of Afrikaans, English, and Setswana L1 first-year tertiary students (n = 343). Participants were divided into three proficiency groups, based on their performance in the South African National Benchmark Test. All participants, regardless of proficiency, were unable to reach the faculty requirements when tested on word-decoding efficiency, spelling, and vocabulary. Only the proficient group reached the requirements for reading comprehension (Nel & Adam, 2014). These results suggest that South African tertiary students are more likely to be preoccupied with the lower-level cognitive processes of reading, such as decoding, which have not been automatised (Ntim, 2015). Although Nel and Adam (2014) did not differentiate based on student background, this preoccupation may be even more the case for South African students who have less endowed backgrounds, with insufficient exposure to expository texts, and who have received the majority of their education in their second or third language. As noted, inefficient lower-level processes require more of the available mental resources, with a negative impact on overall reading comprehension. WM is the proposed limited-capacity cognitive structure in which reading processes occur.

WM has been highlighted as a significant predictor of reading comprehension in both L1 and L2 reading (Abu-Rabia, 2003; Alptekin et al., 2014; Bailer et al., 2013; Linck et al., 2014; Linck & Weiss, 2015; Mann et al., 2013; Sagarra & Herschensohn, 2010; Varol & Erçetin, 2016). Furthermore, previous research has indicated that all reading processes occur in WM (Fontanini & Tomitch, 2009). Therefore, this construct could be instrumental in the academic reading and academic achievement of ODeL undergraduate students. The final section of the chapter discusses WM and its role in academic reading in more depth.

2.6. Working memory

WM is a well-known concept in many fields of research, including psychology, cognitive neuroscience, and neurobiology. This concept has a central role in all complex thinking processes, such as fluid reasoning, problem solving, and learning (Just & Carpenter, 1992; McVay & Kane, 2012; Upahi & Ramnarain, 2020; Wen, 2021; Yuan et al., 2006), and WM has been significantly associated with many important skills, such as note-taking, writing skills, emotion regulation, and others. It is through WM that we are, for example, able to solve mathematical equations within our minds or remember a series of instructions. Despite its ubiquity, it has been difficult to adequately circumscribe this concept. Theoretical syntheses have nevertheless allowed for a definition of its basic role and features:

> The theoretical construct that has come to be used in cognitive psychology to refer to the system or mechanisms underlying the maintenance of task-relevant information during the performance of a cognitive task. (Miyake & Shah, 1999, p. 1)

WM is a limited-capacity neural system required to mentally store a limited amount of information for a short period of time so that it can be manipulated in mental tasks, while ignoring concurrent processing, distraction, and/or attention shifts (Aben et al., 2012; Baddeley, 2003; Carretti et al., 2013; Engel de Abreu, 2011; Klingberg, 2010; Peng et al., 2018; Unsworth & McMillan, 2013). The period of time for which information is stored can be from several seconds to minutes (Eriksson et al., 2015). In terms of features, WM is a multi-domain workspace comprising several modules which undertake both storage and processing operations (Newman et al., 2013; Wen, 2021). It is the combined storage and processing functions which differentiate WM from short-term memory (STM), as the latter is a storage system only (Baddeley, 2012; Berninger & Richards, 2002; Peng et al., 2018). The simultaneous functions are furthermore the proposed link to reading, as this ability demands both storage and processing (Peng et al., 2018). The models of working memory are discussed in the following chapter.

2.7. Working memory and academic reading

As stated previously, reading requires that lower- and higher-level processes are executed in parallel, with each output being stored for a short period to update mental representations of the text as it is being read (Osaka et al., 2002; Prat et al., 2015). All lower- and higher-level reading processes take place in WM (Grabe, 2014; Ntim, 2015): WM keeps information from previous reading cycles active and connects it to new reading cycles, and activates readers' background knowledge to connect it to the mental representation under construction (Barreyro et al., 2012; Shin et al., 2018; Slattery et al., 2021). It is the dual WM functions of transient storage and symbolic computation (processing of information) that allow the reader to generate intermediate and final products (Daneman & Carpenter, 1980; Just & Carpenter, 1992; Prat et al., 2015). Figure 7 presents the detailed roles of WM in reading (Daneman & Carpenter, 1980; Grabe & Stoller, 2013; Just & Carpenter, 1992; Peng et al., 2018; Shibasaki et al., 2015).

Figure 7:

The proposed role of working memory in reading

1	Reader visually processes letters and recognises words.	WM keeps relevant information in STM including lexical, syntactic, pragmatic, and semantic information; overall theme of the text; and continuous representation of what is being read.
2	Reader matches words to phonological, orthographic, and semantic representations in LTM (mental lexicon).	WM performs symbolic manipulations, retrieves the required information from LTM, and stores intermediate products.
3	Reader combines representations with context to create understanding.	WM integrates all sources of information into a mental representation.

Attention is also an important factor in the role of WM, particularly in the academic reading process. When reading for learning, as is the case with tertiary students, individuals must selectively attend to and respond to specific information. This focused attention often involves strategic reading, which is metacognitive in nature and includes inferencing, comprehension monitoring, and goal setting (Grabe, 2014), necessary processes for academic reading. The control of attention is represented in WM as executive control processing (Georgiou & Das, 2016; Grabe, 2014). The proposed role of WM in reading is thus summarised as retaining previously read information while at the same time integrating new information and background knowledge as the text is read with focused attention (Alptekin et al., 2014; Barreyro et al., 2012; Just & Carpenter, 1992; Peng et al., 2018; Peng & Fuchs, 2017). This theoretical relationship between WM and reading has been well supported in the scholarship.

In terms of support from cross-sectional studies with L1 readers, a meta-analysis was conducted by Peng et al. (2018) to determine WM-reading relations. Peng et al. (2018) analysed 197 studies which involved 260 independent samples, 29,629 participants, and 2,026 WM-reading correlations. The authors determined that the relation between WM and reading was moderate and significant (r = .29, p = .05). More recent research has provided additional support, such as the study by Barreyro et al. (2019). In a sample of 114 college students, the authors showed that two WM measures were significantly associated with performance on an expository text comprehension test (r = .34, $p < .01$, and r = .43, $p < .01$). Barreyro et al. (2019) furthermore used a computerised WM test battery which showed good reliability indices and evidence of construct validity, indicating that their tasks and mode were appropriate. The relationship between WM and reading has also been extended to digital texts and graphics. Burin et al. (2018) examined the role of Internet skills, previous knowledge, and WM in comprehension of digital texts embedded as lessons in an e-learning course. In a sample of 105 students, text comprehension was only significantly associated with WM (B = 0.214, 95% CI [0.012, 0.415]), and Internet navigational skills (B = 0.345, 95% CI [-0.625, -0.064]). Previous research has thus not only illustrated the relationship between WM and reading using standard and computerised modes of testing, but also that it is a crucial relationship for readers of digital texts and graphics. Previous research and two meta-analyses focusing on L2 readers have also supported this association.

Linck et al. (2014) performed a meta-analysis using data from 79 samples involving 3 707 participants and 748 effect sizes. A significant population effect of .255 (95% CI = [.219, .291]) was identified with regard to the relationship between WM and L2 processing and proficiency outcomes (Linck et al., 2014). This has since been updated in a recent and more targeted meta-analysis conducted by Shin (2020), which included data from studies exploring the relationship between WM, as measured by the reading span task, and L2 reading comprehension. Data from 25 studies involving 37 samples and 2,682 participants showed a moderate and significant association (*r* = .30, 95% CI [.24, .35]). It can therefore reasonably be put forward that WM is associated with reading comprehension in both L1 and L2 participants. Relevant to the target sample group of the current study, research has been conducted with L2 participants with varying L2 proficiency.

In the available literature, the influence of L2 proficiency on the relationship between WM and L2 reading is somewhat contradictory. The meta-analysis by Linck et al. (2014) identified similar correlations between WM and L2 outcomes for both low- and high-proficiency bilingual adults. However, M. J. Lee (2014) provided conflicting results. This author examined the role of WM, L2 vocabulary knowledge, and L2 grammatical knowledge in two groups of Korean university students: low-proficiency (*n* = 38) and high-proficiency (*n* = 40) L2 English readers. The results indicated that while WM contributed to L2 reading comprehension in both groups, it was the strongest predictor only for the high-proficiency group. L2 vocabulary knowledge was by far the highest contributor to L2 reading comprehension for the low-proficiency group (M. J. Lee, 2014). However, this contradiction may be due to administering the WM task in the L2 rather than the L1 of the participants, which conflates WM and L2 proficiency (R. Adams & Shahnazari-Dorcheh, 2014). M. J. Lee (2014) noted that this may have introduced bias, where the more proficient participants were able to benefit. Using a WM task in the participants' L1, but also contradicting Linck et al. (2014), R. Adams and Shahnazari-Dorcheh (2014) showed that the significant relationship between WM and reading comprehension in L2 English readers disappeared as L2 proficiency increased. The authors proposed that the reading tasks were less of a burden for L2 proficient readers, as they had less automaticity in language processing (R. Adams & Shahnazari-Dorcheh, 2014). Relating this to the current study, it is more likely that a relationship will be identified since – given the contextual information provided in this chapter – South African students may still not have achieved the desired English proficiency and automaticity. There have also been other studies which did not identify a relationship between WM and reading comprehension, but this may be related to the WM task used (e.g. Hummel, 2009).

Some studies did not report a significant relationship between WM and reading comprehension. This may have been due to the use of a WM measure that assessed storage only, rather than both storage and processing. Hummel (2009) examined the association between phonological memory (PM) and L2 proficiency. PM is one aspect of WM and is theoretically related to verbal information, and thus often explored in studies regarding L2 proficiency. Important to the current thesis, Hummel (2009) used a sample of non-novice adult English L2 tertiary students ($N = 77$). Her participants were native French speakers who had completed at least seven years of English study, had attained a relatively advanced level on an L2 proficiency test, and were completing almost all of their academic course work in English. Her results showed that PM was significantly correlated to L2 proficiency ($r = .35$, $p < .01$), vocabulary ($r = .36$, $p < .01$), and grammar ($r = .33$, $p < .01$), extending results identified previously in children. However, PM did not correlate significantly with L2 reading comprehension (Hummel, 2009). PM was measured using a simple span task, the non-word repetition task, which reflects the storage component of WM only (Hummel, 2009; M. J. Lee, 2014; Yoo & Kaushanskaya, 2012). In contrast, complex span tasks reflect both the storage and processing components of WM, and have been shown to have stronger associations with L2 processing and proficiency outcomes (M. J. Lee, 2014; Linck et al., 2014). As reading is a complex cognitive skill which requires both storage and processing, this may be why a relationship was not identified in Hummel's (2009) study, as opposed to studies using a complex span task (Barreyro et al., 2019; M. J. Lee, 2014; Linck et al., 2014; Peng et al., 2018, p. 201). The task used to evaluate reading comprehension may also be a factor.

Some studies have not identified a significant relationship between WM and reading, but this may relate to the way in which the latter was conceptualised. Using a sample of Turkish university students who spoke English as L2 (N = 173), Demir and Ercetin (2020) did not find a significant association between WM and reading comprehension. The authors proposed that the reading comprehension test used in their study was not sufficiently challenging to identify an association.

It is therefore concluded that there is support for the role of WM in both L1 and L2 academic reading. Now focusing on how WM is assessed, individual differences in WM are explored using measures of its capacity. As stated, WM is theorised to be a limited capacity system with available resources differing from individual to individual (Daneman & Merickle, 1996; Fontanini & Tomitch, 2009; Keijzer, 2013). Availability of WM resources for storage and processing is referred to as working memory capacity (WMC), and individuals with higher WMC perform better on a range of cognitive tasks (Camos, 2017; Demir & Ercetin, 2020; Gibson et al., 2012; Heriyawati et al., 2018; Linderholm & van den Broek, 2002). Individual differences in WMC are thus able to predict performance on cognitive tasks. With regard to the task of reading, the influence of individual differences in WMC is visible from early childhood and even up to tertiary education (Georgiou & Das, 2016; Prat et al., 2015). There is substantial evidence that WMC can enable or constrain reading (Calvo, 2001; Fontanini & Tomitch, 2009; Heriyawati et al., 2018; Linderholm & van den Broek, 2002; Prat et al., 2015). Furthermore, this relationship becomes stronger during more challenging tasks, such as academic reading (Linderholm & van den Broek, 2002) or L2 reading (Fontanini & Tomitch, 2009). Higher WMC is thus associated with greater skill in reading.

Readers possessing a higher WMC have more resources for storage and integration of selected information from text and background knowledge into a working mental model (Daneman & Merickle, 1996; Harrington & Sawyer, 1992; McVay & Kane, 2012; Prat et al., 2015). In addition, relative efficiency of lower-level processes, such as decoding and word recognition, reduce cognitive load to allow for a focus on storage and higher-level reading processes (Harrington & Sawyer, 1992; Jenkins et al., 2003; Pretorius, 2010; Prince & Gifford, 2016). That is, automatic reading processes require less resources as they do not require attentional control (Jenkins et al., 2003; Nouwens et al., 2020). However, inefficiency will require more of the available resources and fewer resources can then be allocated to storage of partial products of the reading activity as well as to the higher processes needed for integration and comprehension (Harrington & Sawyer, 1992; Nouwens et al., 2020; Ntim, 2015). There is thus plausible reasoning for how individual WMC can impact academic reading ability: limited capacity can interfere with academic reading (Prince & Gifford, 2016). This has implications for the expected results of the current study.

It is expected that individual differences in WMC will be shown to influence the academic reading ability of Unisa ODeL undergraduate first-year students. Firstly, this relationship has been identified in several publications in different types and modes of reading, as well as with both L1 and L2 readers. Secondly, it is argued that the impact of individual differences in WMC on academic reading ability will be identified, given the development of reading in the South African context. As noted previously (§ 2.5), many South African students may not have well-developed lower-level reading processes. Inefficient processes lead to fewer WM resources available for storage and higher-level processing, and thus lower academic reading ability. It is also expected that WM is associated with academic achievement.

2.8. Working memory and academic achievement

WMC is the best predictor of academic success and plays a significant role in learning (Alloway & Alloway, 2010; Fenesi et al., 2015). Learning processes comprise the following: (1) inhibition of unrelated information; (2) maintenance of new information; and (3) conscious retrieval of LTM information. The majority of information which must be learned and remembered passes through WM, making the capacity and functioning of this system a determining factor in the rate and extent of learning. Thus, learning and ultimately academic achievement are heavily WM dependent and become less successful when this construct is overloaded (Demir & Ercetin, 2020; Fenesi et al., 2015). In addition to reading, studies have shown an association between WMC and written language (Vanderberg & Swanson, 2007), L2 learning (Jackson, 2020), and mathematics (Allen et al., 2019; Berkowitz et al., 2022). Ramos-Galarza et al. (2020) explored the role of WM in academic achievement, using each student's average overall grade, in 175 university students enrolled in a wide range of courses. Their study identified a significant negative correlation between WM difficulties and academic performance ($r = -.30$, $p < 0.001$). Furthermore, WM was a significant predictor of academic achievement (Ramos-Galarza et al., 2020). There is thus evidence that WM can act as a constrainer of academic performance, with difficulties in WM being associated with lower attainment. The current study thus aims to explore the role of WMC in academic reading and academic achievement in South African ODeL undergraduate students.

The focus on these relationships in Unisa ODeL first-year tertiary students within the South African context is important for several reasons. Previous research with both English L1 and L2 students has shown that WM is necessary for both academic reading (e.g. Linck et al., 2014; Peng et al., 2018) and academic achievement (e.g. Demir & Ercetin, 2020; Fenesi et al., 2015; Ramos-Galarza et al., 2020). However, the exact nature of how these abilities inter-relate is not fully understood. The current study will add evidence from the Global South to the existing largely Global North of literature examining these relationships. A South African sample will furthermore provide novel insights related to language and inequality. The majority of South African students are English L2 students (Stats SA, 2016), a population within which these relationships between WM, academic reading and academic achievement are poorly understood (R. Adams & Shahnazari-Dorcheh, 2014). The South African context is furthermore unequal with students having had differing educational experiences that could have impacted their development (Badat & Sayed, 2014; Janks, 2014; Mlachila & Moeletsi, 2019; Sehoole & Adeyemo, 2016). Exploring the relationships between WM, academic reading, and academic achievement within this context thus adds original insights.

2.9. Conclusion

The ability to read and understand what has been read is crucial for success in the academic sphere. This chapter reported that WM is extensively involved in the activity of reading as the mental space where the cognitive processes take place. In terms of constraints on reading ability, previous literature has noted that readers with low WMC may evince lower scores on tests which measure reading comprehension. In addition, inefficient lower-level processes require more of the available WM resources and thus reduce reading comprehension. There has been ample scholarship indicating a role for WMC in academic reading, which would also impact academic achievement. This research project thus aims to explore the role of WMC in academic reading and academic achievement in Unisa ODeL first-year tertiary students. The theoretical basis for the research project is discussed in the next chapter.

CHAPTER 3: CONCEPTUAL FRAMEWORK

“Reading or written language is a cultural invention that necessitated totally new connections among structures in the human brain underlying language, perception, cognition, and, over time, our emotions” (Wolf, 2016).

3.1. Introduction

Learning is influenced through both biological and cognitive phenomena specific to the individual. Biological brain processes are intricately bound to cognitive abilities, although they are considered as two different concepts. The biology of the brain influences personality, values, as well as the recall of learnt knowledge and experiences. In turn, cognition influences brain development. Both monism and dualism are thus rejected when contemplating the brain and the mind; consideration of the mind-brain relationship allows biological evidence to support behavioural evidence and vice versa (Howard-Jones, 2008). When considering the theoretical basis for this research project, it was therefore not a simple matter of deliberating the possible relationship between WM and reading – the context, or backgrounds of the students, must be contemplated. As portrayed in the previous chapters, the development of reading among South African tertiary students cannot be isolated from the context and language use within the education system. The current research project is thus cognisant of the mind-brain relationship and works within the broad framework of cognitivism.

Cognitivism focuses on students’ learning processes, their coding and structuring of knowledge in internal mental structures, as well as their learning outcomes. In this perspective both environmental and student factors are foci (Ertmer & Newby, 2013). The cognitivist approach defines learning as an internal process involving “memory, thinking, reflection, abstraction, motivation, and metacognition” (Anderson, 2008, p. 21). Information is initially taken in by the senses to the sensory store, and must then be transferred to WM or it is lost (Anderson, 2008). How much sensory information is sent to WM is reliant on the attention paid and existing cognitive structures. In WM the information is processed and sent to LTM, with deeper processing linked to more associations in memory. Assimilation in LTM means that the new information is changed to fit the existing cognitive structures. Accommodation in LTM indicates that the new information is incorporated through changing the existing cognitive structures (Anderson, 2008). This broad summary of the cognitive learning process is aligned with the aims of the current research project, as it considers the influence of diverse cultural and linguistic backgrounds in terms of existing cognitive structures (mind) and development of efficient cognitive processes (brain).

Situated within this understanding of learning from a cognitivist perspective, this chapter presents the conceptual framework linking WM and academic reading. There are multiple theoretical accounts of both WM and reading. Selection of a WM model has implications for the extent to which storage and processing factors each influence task performance (i.e. multiple resource or resource sharing), whether WM is considered domain specific or domain general, and the role of attention. The significance of this and the rationale for the WM model ultimately selected for this study – the multicomponent WM model – is provided. This presents WM as a limited capacity neural system in which reading processes take place. The chapter then provides a description of the interactive reading approach which was introduced in the previous chapter. For both first language (L1) and second language (L2) readers, this serves to illustrate the relationships between lower- and higher-level reading processes, students' background knowledge, and compensatory mechanisms. How the limited capacity of WM constrains or enables reading comprehension is then illustrated using the constrained capacity model. The chapter ultimately draws together information from the multicomponent WM model, the interactive reading approach, and the constrained capacity model to present the theoretical account of how working memory capacity (WMC) is related to academic reading.

3.2. Working memory: What is it and how is it measured?

The term 'working memory' was coined in the seminal text *Plans and the Structure of Behavior* by Miller, Galanter, and Pribram (1960) (as cited in Baddeley, 2010). This concept received much interest during the 1960s, particularly from an information-processing approach to psychology which was later termed cognitive psychology (Baddeley, 2010; Cowan, 2014). Reflecting the complexity of this structure and decades of research since, there are over a dozen models of WM from the cognitive psychology field. Although there is substantial variation in theoretical definitions of WM, it is largely agreed that WM is *the ability to hold a limited amount of information in mind and manipulate it for short periods while ignoring distraction* (Baddeley, 2003; Cowan, 2008; Oberauer, 2019). There are thus two key characteristics of this construct: firstly, it has a limited capacity, and secondly, it provides a space for simultaneous storage and executive processing of information, that is, it is a *working* memory.

The *storage* component reflects the maximum amount of information that can be held in an active stage for a short period (Aeschlimann et al., 2017). This is also referred to as short-term memory (STM) and is measured by simple span tasks (Aeschlimann et al., 2017; Bayliss et al., 2003; Fenesi et al., 2015; Ruiz et al., 2019). The *executive processing* component is known by several terms, for example executive attention, executive control, control of attention, cognitive control, or controlled processing (Aeschlimann et al., 2017). Rather than review each term, this study uses the typical operationalisation used by Aeschlimann et al. (2017, p. 2): "Executive processing is defined as the residual variance left in WM after variance of storage has been controlled for." In this way, executive processing refers to all mental operations which go beyond passive storage. This includes attention and cognitive control processes (Aeschlimann et al., 2017). Executive processing is measured indirectly by complex span tasks (Aeschlimann et al., 2017; Ruiz et al., 2019). Complex span tasks are based on the dual task paradigm and were designed from the perspective of Baddeley and Hitch's (1974) WM model (Baddeley & Hitch, 1974; Bayliss et al., 2003; Conway et al., 2005; Fenesi et al., 2015). They require that participants store information for subsequent recall, that is, to-be-remembered target stimuli such as digits or words, and simultaneously engage in some form of mental information processing, for example comprehending sentences or verifying equations (Bayliss et al., 2003; Conway et al., 2005; Draheim et al., 2022; Fenesi et al., 2015; Stone & Towse, 2015). Complex span tasks thus measure concurrent storage and processing and provide an indication of WMC (Bayliss et al., 2003; Conway et al., 2005; Fenesi et al., 2015). WMC is therefore an individual differences construct which indicates the capacity of an individual's WM (Wilhelm et al., 2013).

It is thus agreed by most researchers that WM refers to a hypothetical cognitive system that is limited in capacity and has both storage and executive processing aspects (Aeschlimann et al., 2017; Bayliss et al., 2003; Fenesi et al., 2015; Wilhelm et al., 2013). Furthermore, simple span and complex span measures are often used to assess the WM components. Beyond these similarities, the cognitive architecture of WM is hotly debated (Tulsky et al., 2013), as is the role of attention (Oberauer, 2019). The opposing perspectives related to architecture and attention are discussed in the next section. Following this, an in-depth discussion of the model used to guide conceptualisation of WM in this study is provided.

3.3. Working memory models: How are they differentiated?

There are two main factors where models of WM deviate: 1) the degree of modularity, and 2) the role of attention. The degree of modularity indicates how the structure of WM is conceived by the model, that is, how many modules (components) it has, where a module is an independent functioning part of the system dedicated to one domain (E. J. Adams et al., 2018; Baddeley, 2017). Modules are differentiated either by how long they retain information or by the type of information they store, maintain, or process (E. J. Adams et al., 2018). WM models with multiple modules are also known as multiple-resource models[5], while those without are termed resource-sharing models (Bayliss et al., 2003). Indicated by these labels, the degree of modularity has implications for how the models view cognitive resources underlying WM performance. Multiple-resource models assume that several subsystems support task performance: when one module is at capacity, there are other modules which can still actively store or process information (E. J. Adams et al., 2018; Bayliss et al., 2003). Each subsystem is dedicated to a specific domain or process, and multiple-resource models are therefore domain specific (Bayliss et al., 2003). In contrast, resource-sharing models assume that storage and processing operations compete against one another for a limited pool of WM resources; when WM is at capacity, no other information can be stored or processed (E. J. Adams et al., 2018; Bayliss et al., 2003). Resource-sharing models are domain general (Bayliss et al., 2003). Models are also differentiated based on how they view the relationship between WM and attention.

WM and attention are closely linked (Oberauer, 2019). However, how WM and attention are related is influenced by the definition of attention, that is, as a resource or as a selection

[5] These models are also termed componential models (Rowe et al., 2019).

mechanism (Oberauer, 2019). *Attention as a resource* assumes that the cognitive system has a limited resource to be used for carrying out attention-demanding processes. Relating this to WM, as the cognitive system, it is therefore assumed that the limited capacity of WM reflects the limited capacity of a resource that undertakes functions commonly ascribed to attention. This perspective can be further divided into three versions, based on the functions undertaken by the attentional resource: 1) a resource for storage and processing of information; 2) a shared resource for perceptual attention and memory maintenance; and 3) a resource for the control of attention (Oberauer, 2019). *Attention as selection* defines attention as a mechanism for selecting and highlighting representations. Here attention is not related to the capacity of WM; instead, WM can be considered as attention on specific mental representations to hold them in mind and make them available for mental operations (Oberauer, 2019). Attention is thus intricately related to WM, but this relationship is conceptualised in several ways across theories.

The degree of modality and the role of attention are thus two common ways to differentiate WM models, although there are other differences (E. J. Adams et al., 2018). It is likely that these differences across theories and models of WM are the result of theorists' focus on certain aspects of the literature (E. J. Adams et al., 2018). However, convergence is beginning to take place. For example, the multicomponent model of WM and the embedded-processes model are beginning to converge, "in both a reconciliation between modularity and attention and a reconciliation between nomothetic and ideographic purposes" (E. J. Adams et al., 2018, p. 350). These two models, as well as the attention control model, are prominent WM models and were considered as a guiding framework for the current study. Table 2 provides a comparative summary of their main points (E. J. Adams et al., 2018; Alshahrani, 2018; Fenesi et al., 2015;

Redick et al., 2012; St Clair-Thompson & Holmes, 2008). These differences are briefly discussed here with Appendix D providing further depth.

The multicomponent WM model, the embedded-processes model, and the attention control model can be differentiated based on modularity, the role of attention, and the relationship between WM and LTM. The multicomponent model posits multiple modules: including a domain-general attention system, termed the central executive, and domain-specific storage systems. Regarding the role of attention, the central executive uses attentional resources to coordinate processing within the subsystems and integrate information (Alshahrani, 2018; Cowan, 2014; Fenesi et al., 2015; Ozimič, 2020). The multicomponent model views WM and LTM as functionally distinct, although connected, as information in the domain-specific storage systems is temporarily linked to similar information in LTM (Fenesi et al., 2015). The embedded-processes model exhibits less modularity by focusing on hierarchical levels of activation within a unitary model (Alshahrani, 2018; Cowan, 2014). The first level is comprised of LTM representations where several can be activated at any given moment. Within these activated representations there is the second level termed the focus of attention (Fenesi et al., 2015; Ozimič, 2020). Representations held in the focus of attention are limited in number (1-4) with activation occurring through attentional processes (Baddeley, 2017; Fenesi et al., 2015; Gruszka & Orzechowski, 2016; Jackson, 2016). WM is thus viewed as part of LTM in this model (Jackson, 2016). The attention control model has no modularity and is non-hierarchical (Alshahrani, 2018; Cowan, 2014). This model also posits temporary activation of LTM representations, similarly viewing WM as part of LTM (Engle, 2010), but it is limited by individual differences in attention rather than the number of items that can be stored (Fenesi et al., 2015).

Table 2

A comparison of three working memory models

Key features	Theoretical frameworks		
	Multicomponent model	Attention control model	Embedded-processes model
Degree of modularity	Four modules: central executive, two slave systems, and episodic buffer.	Non-hierarchical.	Two nested mechanisms: One homogenous memory system with two hierarchically embedded levels.
Domain generality (attention)	The central executive uses attention to coordinate resource allocation between two slave systems and integrate information.	Attentional control drives the active maintenance of goal-relevant information, particularly during interference or distraction.	Focused attention drives both storage and processing: activation and maintenance of mental representations, attention switching, and inhibition.
Domain specificity	Visuospatial sketchpad and phonological loop are domain-specific systems which store information.	Acknowledges that there are domain-specific stores, but instead emphasises the domain-general attentional control rather than the domain-specific stores.	Acknowledges domain-specific stores but emphasises the role of focused attention on activated mental representations.
Capacity limitation (individual differences)	WMC indicates limitation of domain-specific stores and domain-general central executive needed for processing.	WMC indicates domain-general executive attention in the face of interference or distraction.	WMC is the limited but flexible domain-general focus of attention.
LTM integration	LTM is a functionally distinct system which integrates active representations via the episodic buffer.	Very close connection between WM and LTM.	WM is an activated subset of LTM.

Baddeley's multicomponent model of WM is a well-tested model that is the dominant perspective of the structure of WM (Alshahrani, 2018; Barreyro et al., 2019; Chai et al., 2018). Since its introduction in 1974 (Baddeley & Hitch, 1974), however, the model has been critiqued on several aspects as it was unable to explain certain experimental results, with its structure consequently being revised (for a fuller understanding of this model and how it came to conceptualise WM, the reader is directed to its historical development, presented in Appendix E). It has also been considered too simplistic or vague. For example, it is unclear whether its capacity refers to limited attentional resources or a fixed workspace in which storage and processing demands compete (Chiappe et al., 2002). The current study, however, did not seek to explore the structure or mechanisms of WM, only its relationships with academic reading and academic achievement. In addition, complex span tasks were used which were based on the perspective of the multicomponent WM model. The study thus found the multicomponent model to be acceptable. In the next section, the current characteristics of the multicomponent WM model are discussed.

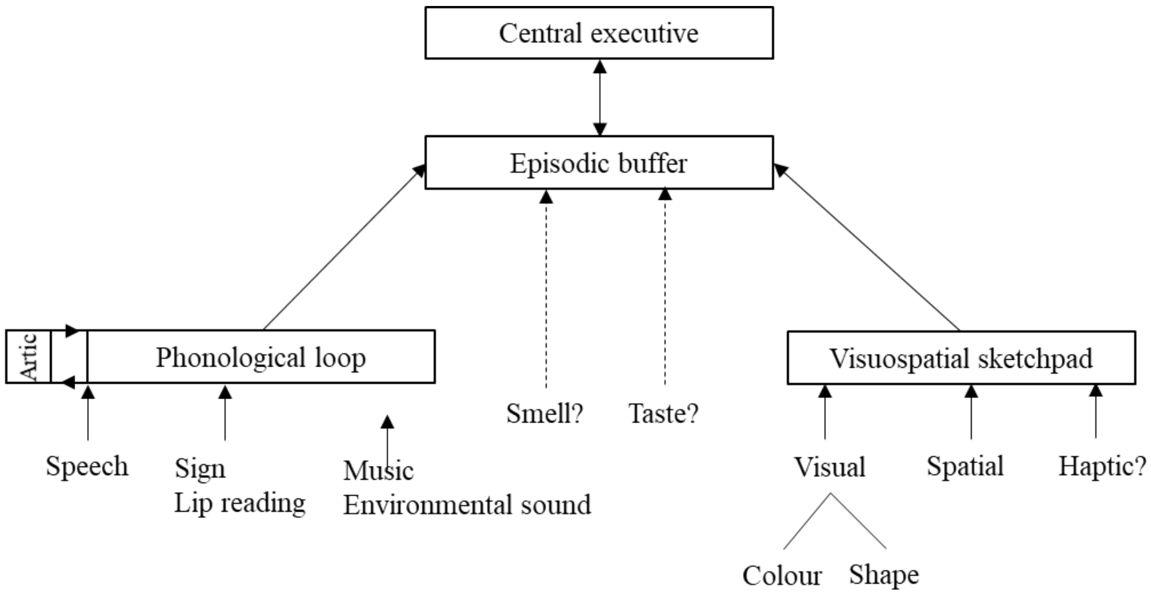
3.4. Baddeley's multicomponent working memory model

In terms of the degree of modularity, the multicomponent model structure is arguably one of the most modular WM models (Baddeley, 2017). The current multicomponent WM model proposes a structure of four key subcomponents or modules: the phonological loop, the visuospatial sketchpad, the episodic buffer, and the central executive (Figure 8) (Baddeley, 2012; Barreyro et al., 2019; Jackson, 2016; St Clair-Thompson & Holmes, 2008). The phonological loop and the visuospatial sketchpad are the **domain-specific**, storage-based, slave systems and are analogous to short-term memory (Baddeley, 2003; Linck et al., 2014; St Clair-Thompson & Holmes, 2008). The phonological loop is concerned with auditory and verbal information while the visuospatial sketchpad is concerned with spatial, visual, and possibly kinesthetic information (Baddeley, 2003; St Clair-Thompson & Holmes, 2008). Differentiation between these two components has provided a further differentiation: *verbal* WM and *visuo-spatial* working memory. The two slave systems are governed by the central executive, the heart of the model (Baddeley, 2003; Dent, 2013; St Clair-Thompson & Holmes, 2008). This is a **domain-general**, limited capacity attentional system which directs the flow of information, updating, and behaviour (Baddeley, 2003, 2017; Dent, 2013; Hubber et al., 2019; St Clair-Thompson & Holmes, 2008). The central executive thus has several functions and, in essence, conducts executive functions (Miyake et al., 2000; St Clair-Thompson & Gathercole, 2006). These functions process and manipulate information and include integration of information from the slave systems, task switching, inhibition, and activation of information held in LTM (Draheim et al., 2022; R. G. Morrison, 2005). In terms of the preceding two points, the model is hierarchical in that the central executive is domain-general while the two slave systems are domain-specific. The episodic buffer is a recently added component which binds information from diverse sources into multidimensional integrated episodes (Baddeley, 2003, 2017).

The structure presented in Figure 8 indicates the flow of information within the verbal and visual domains, from perception to working memory. For example, auditory-verbal information can be united with non-auditory language-related information (such as sign language) within the phonological loop, combining with semantic and syntactic information stored in LTM (Baddeley, 2017). A similar stream takes place within the visuospatial sketchpad whereby visual, spatial, and tactile information is bound into visuo-spatial representations (Baddeley, 2017). Both the phonological and visual domains influence conscious awareness through the episodic buffer (Baddeley, 2017). The episodic buffer is also able to use this information to provide feedback and control perceptual input. This component furthermore combines the phonological and visual representations with information from LTM to plan, control, and execute future action (Baddeley, 2017). There is thus a flow of information which utilises both domain-specific and domain-general structures. This is also reflected in the tasks used to assess WM.

Figure 8:

The current elaboration of the multicomponent model



Note. From "Modularity, working memory and language acquisition," by A. D. Baddeley, 2017, *Second Language Research*, *33*(3), p. 307. Copyright 2017 by SAGE. Reprinted with permission.

As noted, STM is assessed using simple span tasks. An example of this within the framework of the multicomponent WM model is the digit span task. This task presents participants with a series of digits and asks them to recall them in the same order, measuring the storage capacity of the phonological loop (St Clair-Thompson & Holmes, 2008). WMC is measured using complex span tasks. Within the multicomponent WM model, complex span tasks require the domain-specific storage systems but primarily assess the domain-general executive processing central executive (Conway et al., 2005; Sanchez et al., 2010; St Clair-Thompson & Holmes, 2008).

In sum, the multicomponent WM model was used to guide the current project and defines WM as a limited-capacity cognitive system for the maintenance and manipulation of information. WM has been shown to be related to many complex cognitive functions, including reading. To examine this relationship, it is first essential to discuss the interactive reading approach as a conceptualisation of reading. Following this, the theoretical relationship between WM and reading as presented in the constrained capacity model is described.

3.5. Rumelhart's interactive approach to reading

Together with a higher-order knowledge system, reading requires both lower- and higher-level processes. The importance of these processes in attaining reading comprehension has been widely debated. Over several decades of reading research, some researchers have emphasized lower-level processes, others higher-level processes, and some have argued for the equal importance of both (Nassaji, 2003). During this debate, both metaphorical and specific models of reading have been proposed. The metaphorical models include the bottom-up, top-down, and interactive approaches. Each of these approaches has their proponents and specific models of reading within them with most recent research focusing on the interactive reading approach which was used in this thesis. The latter was first proposed as a model by Rumelhart (Rumelhart & McClelland, 1981) and attempted to overcome the criticisms of the bottom-up and top-down approaches (S. Liu, 2014; Nassaji, 2003). All three models are briefly described here. In sum, their differences lie in the degree of emphasis they place on either text-based or reading-based variables (Lally, 1998).

3.5.1. Bottom-up approach to reading

In a bottom-up approach, reading proceeds from part to whole where raw input undergoes increasingly sophisticated analyses in discrete stages. Reading is sequential in this perspective, from letter to sound, to words, to meaning (F. Liu, 2010; Stanovich, 1980; Verhoeven et al., 2011). Thus, from this perspective, reading relies on lower order processes and is largely a text-based decoding process ultimately resulting in word recognition (Lally, 1998; Ngabut, 2015;

Verhoeven et al., 2011). The weakness of this approach is that it views the process of reading in only one direction. This argues that higher level information such as the reader's role and background information does not have an influence (Ahmadi et al., 2013; F. Liu, 2010; Stanovich, 1980). Modification or changes to the lower-level analysis does, however, take place. For example, higher level semantic and syntactic processing can be crucial to identification of an unknown word (F. Liu, 2010). The next approach to reading focused on these processes in response.

3.5.2. Top-down approach to reading

Top-down, or concept-driven, approaches take the perspective that reading proceeds from whole to part. This process relies on the reader making predictions of what upcoming words will be and thereafter identifying the fewest and most informative cues necessary to confirm word identity (F. Liu, 2010). It is the previous experiences and language of the knowledge that allows the reader to do so; they have semantic and syntactic information as well as the actual letters of the text (F. Liu, 2010). Theoretically, readers do not need the precise perception and identification of each element in a word. Instead, they form and test hypotheses regarding the identity of upcoming words using meaning (Lally, 1998; F. Liu, 2010; Stanovich, 1980). In this way, higher order processes guide the choice of, and flow of information through, lower order processes (Stanovich, 1980; Verhoeven et al., 2011). A major criticism of these types of models is that it is implausible that it is quicker to generate a hypothesis based on syntactic and semantic reasoning than it is to visually recognise a word (Stanovich, 1980). The reality is that both poor and good readers do rely on graphic information as it is more efficient than trying to predict words from context and language structure (F. Liu, 2010). Thus, neither bottom-down nor top-down approaches alone are able to account for the process of reading.

3.5.3. Interactive approach to reading

Rumelhart (1977) proposed a synthesis of the bottom-down and top-down approaches where orthographic, lexical, syntactic, semantic, and pragmatic knowledge together allow word identification (as cited in Rumelhart & McClelland, 1981). Although the higher-level processes influence lower-level processes, they themselves are also constrained by lower-level analyses (Stanovich, 1980). Thus, the reading process is cyclical with both text-based and reader-based variables influencing comprehension (Lally, 1998; Ngabut, 2015). It is a combination of the bottom-up (perceptual) and top-down (cognitive) reading approaches which maximises the strengths of each while minimising the weaknesses (Rumelhart, 1985). For example, it acknowledges that automatic word recognition is needed for reading but also that higher-level processes such as inferencing are required. The interactive approach to reading was taken in this thesis as it accounts for relations between the lower- and higher-level processing and is applicable to both L1 and L2 reading (Nassaji, 2003).

It is a widely held view that less skilled readers are less proficient in lower-level processing, rather than in higher-level processing (Nassaji, 2003). This relates to the compensatory mechanism which was later introduced where "information at one level of processing compensates for deficiencies at other levels of processing" (Nassaji, 2003, p. 263; Ngabut, 2015; Stanovich, 1980). If there is a deficiency in word recognition, as a lower-level process, then higher-level processes can compensate. However, as they draw on the same cognitive resources, this operation is at the cost of attentional and cognitive capacity which can negatively impact overall comprehension (Jiang, 2017; Lesgold & Perfetti, 1978; Nassaji, 2003). In sum, efficient and automatic word recognition skills are noted to be essential for reading so that capacity can be allocated to higher level processes. Furthermore, compensation of inefficient word recognition results in lower overall comprehension (Gelderen et al., 2003;

Han, 2015; Harrington & Sawyer, 1992). This perspective is also echoed in L2 reading (Nassaji, 2003). Unskilled L2 readers typically focus on graphemic information, using lower-level processes, rather than higher level processing. Furthermore, even skilled L2 readers are slower in word recognition and process text at a shallower level than in their L1 readings (Harrington & Sawyer, 1992). The need for fluent word recognition skills in both L1 and L2 reading is derived from the assumption of limited WMC present in many reading models (Gelderen et al., 2003; Harrington & Sawyer, 1992). Here, if lower-level processes are inefficient, slow, and attention demanding, they will require most of WMC which hinders higher-level processes. On the other hand, when lower-level processes are efficient, fast and attention-free (automatic) then WMC can be fully devoted to higher level processes for comprehension (Gelderen et al., 2003). The role of WMC is well described in the Constrained Capacity Model (1992).

3.6. Just and Carpenter's constrained capacity model

All reading processes take place in WM (Grabe, 2014). Skilled readers need to be able to 1) hold new information in mind as they read text, 2) retrieve and store relevant information from background knowledge, as well as 3) integrate these sources of information. This occurs iteratively as the text is read with focused attention (Shahnazari & Dabaghi, 2014). The constrained capacity model is able to integrate the dual functions of WM, storage and processing, with language comprehension. This model is particularly appropriate for the current study as Zhou et al. (2017) reported that it was able to account for both L1 and L2 processing.

Just and Carpenter (1992) proposed the constrained capacity model which integrated the dual functions of WM in relation to language comprehension. The authors proposed that both storage and processing were enabled through activation, with WMC theorised as the maximum amount of activation available to undertake storage and/or computation. Thus, the cognitive capacity of this system constrained these two functions as they compete for limited resources (Daneman & Carpenter, 1980; Just & Carpenter, 1992; Nouwens et al., 2020; Zhou et al., 2017). The authors motivated that capacity constrains language comprehension with greater limitations for some individuals. The manner in which this occurs is now unpacked in more detail.

Pieces of information, or elements, are held in WM through activation; each element has an associated activation level which must be above the threshold to become part of WM(Daneman & Carpenter, 1980; Just & Carpenter, 1992). An element refers to a number of informational sources such as "a word, phrase, proposition, grammatical structure, thematic structure, object in the externa world, and so on" (Just & Carpenter, 1992, p. 123). Information from reading becomes encoded in WM through one of three avenues of activation: 1) perceptually encoded from text; 2) retrieved from LTM; or 3) generated by a computation process (Daneman & Carpenter, 1980; Just & Carpenter, 1992). With regards to the last avenue, activation not only allows for maintenance (or storage) of the information. It allows for operations which produce intermediate products which are then also maintained (Just & Carpenter, 1992). Thus, both storage and processing functions require activation resources. If the task demands exceed available resources, both storage and processing functions are degraded (Just & Carpenter, 1992).

Once the maximum WMC has been reached, information is lost through either decay or displacement (Daneman & Carpenter, 1980; Just & Carpenter, 1992). Decay is time dependent where information is lost if its activation subsides to subthreshold over time (Daneman &

Carpenter, 1980). Displacement takes place as additional elements are encoded, activated, or constructed until WMC is exceeded (Daneman & Carpenter, 1980). The resource requirements for each process impact whether other information will be decayed or displaced (Daneman & Carpenter, 1980). Individual differences in reading were therefore related to individual capacities. An individual with a large WMC would have a greater amount of activation available for meeting the storage and processing demands of language comprehension (Abu-Rabia, 2003; Just & Carpenter, 1992). Furthermore, automatic reading comprehension processes do not require attentional control and thus need fewer cognitive resources. This reduces cognitive load on the individual and frees resources for reading comprehension, illustrating the trade-off between WMC storage and processing functions (Nouwens et al., 2020; Yang, 2015). The next section discusses the model of WM used in the current research project, the multicomponent WM model, and its relationship with lower- and higher-reading processes.

3.7. Explanations of the role of working memory capacity in academic reading

As discussed in the previous chapter, a good reader is able to construct and constantly update mental models which incorporate "elaborated text based information" with prior knowledge structures (Woolley, 2010). Thus, information from both STM and LTM is required. WM, as the construct coordinating the allocation of resources and LTM activation, is crucial in this process (Woolley, 2010). WM is used to store, process, and integrate information (St Clair-Thompson & Holmes, 2008). Its efficiency in these endeavours is thus a fairly large determinant of reading ability (Woolley, 2010). Using the multicomponent WM model, this can be explained as follows.

Firstly, the central executive coordinates attentional resources between the storage and processing functions. The central executive is also responsible for temporarily activating information from LTM (Woolley, 2010). This includes syntactic, semantic, and text-specific information (Chiappe et al., 2002). Secondly, the capacity-limited slave systems temporarily store information: the phonological loop holds auditory information while the visuospatial sketchpad retains visual information as spatial representations (Woolley, 2010). The phonological loop stores words, phrases, and sentences and requires attentional resources in the form of sub-vocal rehearsal to prevent decay (Chiappe et al., 2002; Woolley, 2010). The efficiency of the slave systems depends on disregarding irrelevant information as well as the quality of information retained (Woolley, 2010). Individuals with high WMC are better able to suppress irrelevant information so that applicable information can remain active (Shin et al., 2018). Finally, the episodic buffer binds and stores chunks of material. Each chunk is an amalgamation of well-linked, in order to be retrievable, representations from LTM and the two slave systems. Furthermore, each is held as a mental representation which includes elements of time and space and is a conscious experience. The episodic buffer is also capacity limited regarding the number of chunks of material which can be held concurrently (Woolley, 2010). With regards to reading, readers who do not have automatic word recognition need to perform letter-by-letter decoding. This is attention demanding and requires more active, or more conscious, chunking (Woolley, 2010). Without automisation, fewer cognitive resources can be devoted to understanding the meaning of the text and thus to *reading for learning* (Verhoeven et al., 2011). It also reduces reading speed (Maluch & Sachse, 2020). The involvement of WM in reading is thus extensive. It is furthermore plausible that its capacity can constrain or enable reading (Burin et al., 2018).

The above roles of WM in reading highlight the need for high WMC and for efficient co-ordination of lower- and higher-level processes. It furthermore indicates that a lack of automatisation of certain skills, as may be the case for South African ODeL tertiary students, can interrupt academic reading by reducing the amount of cognitive resources available for higher-level processes. Lastly, the above perspective shows the importance of representations from LTM.

3.8. Conclusion

This chapter has presented the conceptual framework for the study which links WM and academic reading. In sum, WM is understood, from the perspective of Baddeley's multicomponent WM model, as a limited capacity neural system in which both lower- and higher-level reading processes take place. Due to the extensive role of WM in reading, the capacity of this system acts as a constrainer or enabler. The following chapter explains the method of the study.

CHAPTER 4: METHOD

"We need to cultivate a new kind of brain: a "bi-literate" reading brain capable of the deepest forms of thought in either digital or traditional mediums" (Wolf, 2018).

4.1. Introduction

The current study aimed to explore the roles of WM and academic reading in the academic achievement of Unisa first-year undergraduate students. The independent variables explored were WM and English academic reading, while the dependent variable was academic performance in higher education. It was hypothesised that WM would be positively and significantly correlated with academic reading, while both WM and academic reading would have positive, significant associations with academic achievement. It was also postulated that WM would make an indirect contribution to academic achievement via reading level, as it is the latent variable that governs its attainment. These aims and their hypotheses are provided in the ensuing section. The chapter then provides a rationale for the research paradigm (positivist quantitative research), research design (non-experimental ex post facto cross-sectional), research methods (sampling design, questionnaire, and instruments), and data analysis (descriptive, correlation, and regression or mediation analysis) that furnished the framework for exploring these relationships. It furthermore discusses the ethical considerations and their implications for this study.

4.2. Research aims, questions, and hypotheses

The current study aimed to explore the contributions of WM and areas of reading, as measured by the Test of Academic Literacy Levels (TALL), on the academic achievement of Unisa first-year undergraduate students. Derived from this overall aim, the following research questions and related hypotheses were made:

1. What are the profiles of the student participants on psychometric measures of:
    a. English academic reading ability as measured by the TALL; and
    b. WM as measured by the Reading Span (RSPAN) and Operation Span (OSPAN)?

2. Are WM scores positively correlated to academic reading as measured by the TALL?

$H_{0.1}$ There is no relationship between WM scores and academic reading.

H_1 WM scores are positively correlated to academic reading.

3. Are WM scores positively correlated to end-of-course academic performance?

$H_{0.2}$ There is no relationship between WM scores and end-of-course academic performance.

H_2 WM scores are positively correlated to end-of-course academic performance.

4. Is academic reading as measured by the TALL positively correlated to end-of-course academic performance?

$H_{0.3}$ There is no relationship between academic reading and end-of-course academic performance.

H_3 Academic reading is positively correlated to end-of-course academic performance.

5. What is the contribution of these predictors (WM and academic reading) to end-of-course academic performance?

$H_{0.4}$ WM and academic reading do not make direct, positive contributions to end-of-course academic performance.

H_4 WM and academic reading make direct, positive contributions to end-of-course academic performance.

$H_{0.5}$ WM does not indirectly influence end-of-course academic performance via academic reading.

H_5 WM indirectly influences end-of-course academic performance via academic reading.

4.3. Positivist paradigm: Ontology, epistemology, methodology, and axiology

Positivism was created through the work of several French philosophers and the ‘Vienna Circle’ of philosophers. It was popularised by Auguste Comte (1798–1857) (Aliyu et al., 2014; Cohen et al., 2007; Hussain et al., 2013). From this position the social world is viewed as a “concrete and unchangeable reality which can be quantified objectively” (Rahman, 2017, p. 102). Positivism thus refers to positions which apply scientific methods to analysis of the social world, even when including ideational factors such as beliefs and ideas (Hussain et al., 2013; Poni, 2014). Research from this approach is viewed as “systematic, controlled, and empirical which is subject to any challenging theories or new understanding in the future” (Hussain et al., 2013, p. 2377). Its strengths include clarity, precision, rigour, standardisation and generalisability, but it has been understandably critiqued for lack of applicability to real-world settings (Hasan, 2016; Hussain et al., 2013; Poni, 2014). While a laboratory setting can be controlled, its results are more likely to approximate the real world in the natural sciences than in the humanities and social sciences (Aliyu et al., 2014). It is, however, argued that this is an appropriate paradigm for the current study as it seeks to statistically explore the relationships between quantified variables.

It is acknowledged that there are social, historical, ethical, and ethico-political aspects to education (Saari, 2016). Furthermore, language testing is a complex social phenomenon (Rahman, 2017). It would thus undoubtedly add value to have qualitative and holistic insight into participants' feelings, opinions, and experiences with language and academic literacy in the context of South Africa (Rahman, 2017). However, the main question of the current research project was to evaluate the correlations and relationships between the variables. This type of question is asking 'to what extent' and requires quantified variables whose associations can be statistically explored (Rahman, 2017). Therefore, the positivistic perspective and its quantitative methods are appropriate in the current research project. The ontology, epistemology, methodology, and axiology of the positivistic paradigm are now briefly discussed in terms of their application to this study.

4.3.1. Ontology: Realism

Researchers working with the positivist paradigm assume that social reality exists independently of the observer and can be known as it really is. This reality can be observed, measured, and studied objectively using the scientific method without any interference from the researcher or observer (Aliyu et al., 2014; Cohen et al., 2007; Hussain et al., 2013; Kivunja & Kuyini, 2017). The researcher is therefore required to dissociate themselves from this reality to discover unbiased research findings (Poni, 2014). However, it is not plausible to claim perfect objectivity. However subtly, the perspective of the researcher influences the direction, implementation, and interpretation of the research project. For example, when developing a model, it is noted that

> … models do not build themselves any more than they interpret themselves; it is neither a predominantly mechanical nor purely deductive process. Of course, some standard

> techniques are involved; they are not starting from scratch. But choices still have to be made, and these are frequently based on intuitions, hunches and ideas of what is needed that have not yet been fully rationalized. (Greiffenhagen et al., 2016, p. 103)

This quote indicates that all individuals have biases, which will manifest as they make necessary decisions during their statistical analyses. Being aware of this, making decisions based on existing literature and accepted methods as much as possible, and exercising reflexivity was thus a part of this study. Appendix F includes the researcher's critical reflection on the project as a whole as well as the data analysis itself. While reflexivity is a cornerstone of research using a qualitative approach, it is much less common in studies utilising a quantitative approach. However, the current study involved face-to-face encounters with student participants in the early stages, as well as via email. There was thus a need to reflect on the qualities of the researcher which shaped negotiation of boundaries between researcher and participants (Ryan & Golden, 2006).

4.3.2. Epistemology: Objectivist and dualist

With regard to what can be known, the experience of the social reality above is objective and thus reveals an independent reality (Aliyu et al., 2014; Hussain et al., 2013; Kivunja & Kuyini, 2017). The researcher is limited to observer status and cannot interfere with the research process (Hussain et al., 2013). This could not be fully realised in the current research project, as neither natural observation nor laboratory experimentation was conducted due to ethical, resource, and time constrictions. The researcher took all reasonable measures to ensure objectivity. For example, it was initially necessary to hold multiple testing sessions in order to obtain as high a number of participants as possible. However, doing so could have introduced confounding variables. The researcher attempted to overcome this by presenting the same instructions to all participants at the testing sessions. Additionally, it became necessary early in the data collection period to allow students to complete the tests at home due to the spread of Covid-19. The researcher therefore sent the same text messages and emails to all students to ensure that they received exactly the same instructions. It is nevertheless noted that online multiple data collections could have introduced confounding variables, and this is noted as a limitation of the study.

4.3.3. Methodology: Empirical experimentalism

As has been noted above, positivism centres on the scientific method of investigation. Here proposed hypotheses are tested under carefully controlled conditions (Aliyu et al., 2014; Cohen et al., 2007; Hussain et al., 2013). Broadly speaking, there are two categories of positivist research enquiry: experimental and non-experimental. Experimental designs aim to establish cause and effect relationships which can be generalised (Hussain et al., 2013). They utilise control and manipulation of the independent variable (conditions) to determine if it causes changes in the dependent variable, and thus the relationship between variables (Hussain et al., 2013; Kivunja & Kuyini, 2017). Non-experimental designs do not manipulate the independent variable and thus cannot establish cause and effect, or allow generalisation, as alternative explanations are possible (Hussain et al., 2013). A non-experimental design had to be used as the independent variables of academic reading and WMC were not manipulated. Use of this design was noted as a limitation of the findings of this study.

4.3.4. Axiology: Beneficence

The researcher must maximise good outcomes for the research project, for the research participants, and for mankind in general (Kivunja & Kuyini, 2017). Additionally, the researcher must avoid or at least minimise any risks or harm that could occur (Kivunja & Kuyini, 2017).

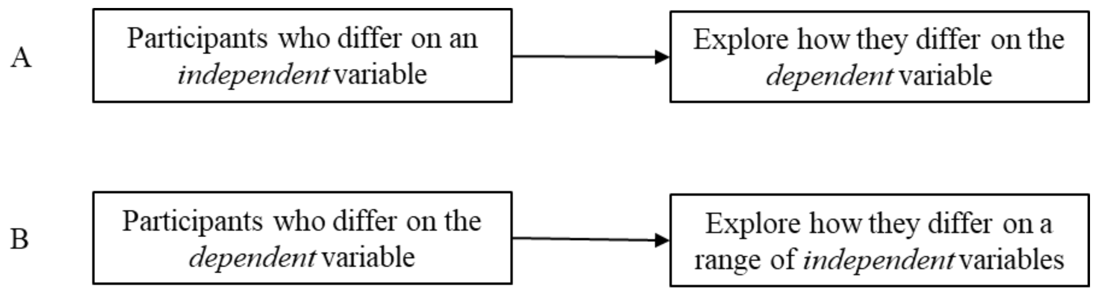
The researcher therefore conducted a comprehensive risk-harm analysis in order to plan for any possible risk to participants, which is discussed in the section on ethics. The research also ensured that all participants received comprehensive feedback on their results.

4.4. Research design

A positivist, quantitative, descriptive research orientation was taken (Rosenthal & Rosnow, 2008). The manipulation of explanatory variables or random assignment was not possible in this research project, as WMC, English academic literacy level, or academic achievement of the participants cannot be altered by the researcher (Laher et al., 2019; Silva, 2012). The research project thus used ex post facto research, which is focused on identifying possible antecedents of an existing condition which cannot be manipulated by the researcher (Cohen et al., 2007). There are two main approaches to ex post facto research, that are illustrated in Figure 9 (Cohen et al., 2007). In the first approach, the study begins with participants who differ on an *independent* variable, and the researcher then explores how the participants differ on the *dependent* variable. The second approach was used in this research project; this begins with participants who differ on the *dependent* variable (i.e. academic achievement) and then explores how they differ on a range of *independent* variables (i.e. English reading level and WMC). In this way the contributors to a particular outcome can be identified (Cohen et al., 2007). Furthermore, there was no control group in this research project, as there was no manipulation of variables or treatment group. A non-experimental ex post facto cross-sectional research design was therefore used for this research project (Bresgi et al., 2017; Laher et al., 2019; Silva, 2012).

Figure 9:

Two approaches in ex post facto research



4.5. Source and collection of data

4.5.1. Participants and setting

The targeted participants were first-year undergraduate ODeL students within South Africa enrolled at Unisa. The research project provided students with access to a website created by the researcher (https://jaquelineharvey.wixsite.com/harveyproject). The website was built and hosted on wix.com, which is a free site builder program. The electronic asynchronous communication with students included email sent both directly and through the website.

4.5.1.1. Selection criteria

Students who agreed to participate were included in the data collection if they:

1. were between the ages of 18 and 65 years;
2. were enrolled in their first-year;
3. were enrolled in an undergraduate ODeL module at Unisa;
4. had no visual impairments influencing the readability of computer screens; and
5. had no physical impairments influencing their use of a computer mouse and keyboard.

4.5.1.2. Exclusion criteria

Students were excluded from participating if they had been previously diagnosed with epilepsy, previously experienced a seizure, or had ever experienced an adverse reaction to flashing lights. This exclusion criterion was applied to protect the safety of students who may experience adverse effects from stimuli appearing in quick succession on a computer screen. These criteria were included as items in the background survey, where a confirmatory response ended the survey with a thank you message to the student. Student participants' data was also excluded from analyses, with the exception of data used to evaluate the WM complex span tasks, if there was missing or incomplete data.

Although previous studies also excluded participants based on pre-existing conditions such as a learning disability diagnosis or traumatic brain injury, the current study did not use these exclusion criteria unless the traumatic brain injury resulted in post-injury epilepsy. These criteria were also included in the background survey, but without automatic closure on confirmatory responses. The current research project seeks to explore the role of WMC for the typical student demographic at Unisa, which would include these students.

4.5.2. Target sample size and sampling procedures

Statistical power and effect size were considered to establish target sample size. Statistical power is the probability of a false null hypothesis being rejected, and guards against Type I and Type II[6] errors (VanVoorhis & Morgan, 2007). One can increase statistical power through increasing the sample size or increasing the effect size (VanVoorhis & Morgan, 2007). For the current research project, the practical reality of obtaining a very large sample of student

[6] A Type I error is a false positive where the null hypothesis is rejected although it is true. A Type II error is a false negative where the null hypothesis is accepted although it is false.

participants was tenuous and therefore effect size was considered. Effect size estimates the magnitude of the true population effect from the sample (Goulet-Pelletier & Cousineau, 2018). As the test requiring the largest sample size, the planned regression analysis was considered. In his seminal article on the number of participants required for regression analyses, Green (1991) noted some support for a sample size of $N \geq 104 + k$, where k is the number of independent variables for a medium effect size (Green, 1991; VanVoorhis & Morgan, 2007). The initial target sample was therefore 118 participants in order to perform a regression analysis. However, the disruptions caused by the Covid-19 pandemic and other challenges required further consideration of data analysis and what would be an acceptable sample size. The target sample size was thus re-examined for a) correlation analyses, and b) a mediation analysis.

As noted by Cohen et al. (2018), a sample size of 30 participants is generally considered a minimum sample size per variable for statistical analyses. For correlational research in particular, “a minimum of 30 participants is desirable” (Gall et al., 2003, p. 176). It is nevertheless recommended by Cohen et al. (2018) to include a higher number of cases, as samples of less than 30 allow the possibility of considerable standard error. To determine an adequate minimum for correlational research in the current study, two methods were employed: (1) the use of correlational tables ‘in reverse’ to determine sample size, and (2) the use of statistical calculators.

Table 3 shows that there is an inverse proportion where the larger the effect size, the smaller the required sample size. Drawing from this table, using a medium effect size, a target sample size of 66 participants is estimated at the .05 significance level and .7 power level (Gall et al., 2003; Olejnik, 1984). Lakens and Evers (2014) provide further insight and estimates based on the required stability of the effect size. The stability of the effect size denotes a scenario where the estimated effect is close to the true effect size and remains close. The 'corridor of stability' (*w*) is used to indicate this stability (Lakens & Evers, 2014). Lakens and Evers (2014) note that in the psychology field a *w* = .2 is reasonable and thus, for an effect size of .2 and to achieve the point of stability with 80% confidence and corridor widths of .2, a target sample size of 57 participants is estimated. To triangulate these estimates, calculations were also performed using power analysis to compute a target sample size.

Table 3

Minimal total sample sizes for correlation coefficient tests with alpha at either the .05 or .10 level of significance and statistical power at either the .7 or .5 level

Hypothesis test	Small effect size		Medium effect size		Large effect size	
	Statistical power		Statistical power		Statistical power	
	.7 N	.5 N	.7 N	.5 N	.7 N	.5 N
Correlation coefficient						
α = .05	616	384	66	42	23	15
α = .10	470	277	51	30	18	11
Partial correlation						
α = .05	312	195	44	29	21	14
α = .10	238	138	33	21	15	11

Note. For correlation coefficient (r) and partial correlation ($r_{vx.z}$), small, medium, and large effect sizes refer to 1%, 6%, and 13% of the explained variance in the dependent variable, respectively. Adapted from Tables 2 and 3 from "Planning educational research: Determining the necessary sample size," by S. F. Olejnik, 1984, *The Journal of Experimental Research*, *53*(1), p. 44-45. Copyright by Taylor and Francis. Adapted with permission.

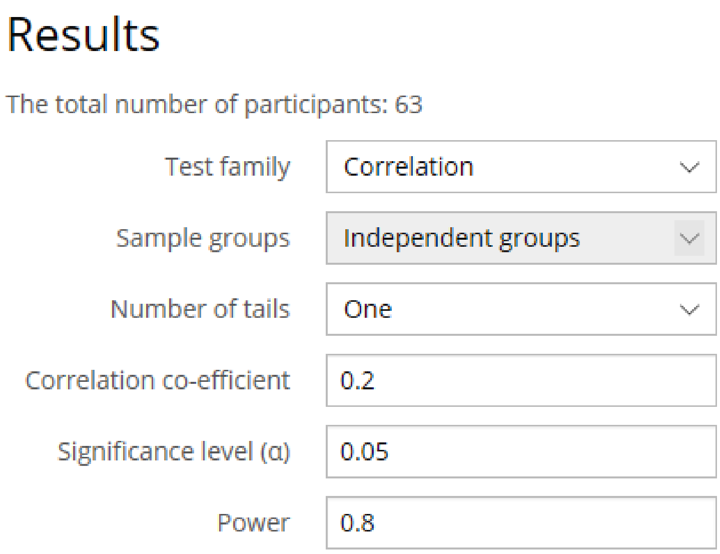
There are four main components in a statistical power analysis (Cohen et al., 2018):

1. Effect size;
2. Sample size;
3. Significance level (e.g., α=.05); and
4. Power of statistical test (i.e., acceptable β level and desired power, e.g., β=.2 and .8)

The online sample size calculator recommended by Cohen et al. (2018) was used: https://www.ai-therapy.com/psychology-statistics/sample-size-calculator. For analyses in the correlation family, one-tail, with estimated effect size of .2, α = .05 significance level, and power of .80, the statistical output indicated a target sample of 63 participants (Figure 10). Drawing from the above two references as well as this calculation, the target sample size to perform correlation analyses was between 57 and 66 participants.

Figure 10:

Statistical output indicating target sample size for a correlation analysis



As the section regarding data analysis strategies will note (§ 4.8), the freely available macro for SPSS named PROCESS, developed by Dr Andrew F. Hayes, will be used for conducting the mediation analysis. In accordance with the recommendation in his book *Introduction to Mediation, Moderation, and Conditional Process Analysis* (Hayes, 2018, p. 141), the article by Fritz and MacKinnon (2007) was consulted in order to calculate the required sample size for a mediation analysis. These authors provide a table of sample sizes needed to identify an indirect effect (Fritz & MacKinnon, 2007). Based on medium path sizes, the target sample size to perform a mediation analysis was 78 participants.

4.5.3. Administration procedures and data collection

All assessments were conducted in English, either on campus or at home. Students were asked to complete a demographic and background information survey, an online academic literacy test, and online WMC tasks. All instruments were self-administered on a computer, and their responses were indicated using a computer mouse and keyboard. The final end-of-course grades achieved by student participants were requested from the university. Given the interruptions from Covid-19 and other challenges, changes to take the assessment entirely online as well as multiple data collections were necessary. These changes assisted in obtaining as large a sample size as possible and were not considered detrimental to the study, as previous research has indicated that WM tasks administered remotely and online show similar performance as in the lab (Ruiz et al., 2019). In addition, other studies have shown that attention to task and data results are comparable between online and lab-based experiments (Casler et al., 2013; Dandurand et al., 2008; Hauser & Schwarz, 2016), even when samples are uncompensated and unsupervised (Huber & Gajos, 2020). Making use of an automated and online platform afforded the current research several benefits.

The principal advantage of using online tasks relates to time and resource efficiency (Sauter et al., 2020). It is a convenient method and can be more flexible for participants. Furthermore, researchers do not necessarily need a laboratory or costly equipment (Latkovikj & Popovska, 2019; Leidheiser et al., 2015). Remote online testing also removes the presence of the researcher, which reduces the researcher’s time spent running the experiment as well as researcher error and inconsistency (Unsworth et al., 2005). This can furthermore lessen researcher effects (Ruiz et al., 2019). Participants may also find it less stressful to complete the test instruments without the presence of the researcher. Scalability also becomes more feasible, as large samples do not require more resources or an increased workload for the researcher (Sauter et al., 2020). Online tasks can thus contribute to larger, more diverse datasets (e.g. age, gender, social status) as well as open-source measures (Latkovikj & Popovska, 2019; Leidheiser et al., 2015; Sauter et al., 2020). There were furthermore methodological advantages specifically related to an online form of WMC task administration. Firstly, automation of WMC tasks allows participants to complete them autonomously and simplifies recording and processing of their data. Secondly, it improves the method of the complex span tasks, as time limits can be placed on the processing component to prevent rehearsal of the to-be-remembered item (Đokić et al., 2018). Thirdly, the study performed by Redick et al. (2012) showed that automated complex span tasks have desirable psychometric indicators, including: 1) high test-retest reliability, 2) high internal consistency, 3) convergent and discriminant construct validity, and 4) criterion-related validity. Additionally, the study by Đokić et al. (2018) showed that group administration of the automated complex span tasks did not compromise their psychometric properties. However, these advantages, are accompanied by challenges such as ensuring that the task instructions are easily understood by all participants.

The testing procedures for online tasks need to be extremely clear and standardised, which can also assist when undertaking replication studies (Ruiz et al., 2019). Sauter et al. (2020) make several recommendations to ensure that instructions to participants are understandable:

- Providing step-by-step instructions with images;
- Keeping instructions on the screen for a reasonable time before allowing the participant to continue; and
- Including a practice run and online evaluation before participants begin the main task.

As will be described in the section on WMC instructions (§ 4.6.3), each task had clear instructions as well as practice trials to confirm that participants were familiar with what was required from them during the experiment. Participants could read through these instructions at their own pace, and were able to return to previous pages. In addition, participants received feedback following each practice trial to inform them if they had understood the task or if they needed to return to the instructions.

Other negative outcomes can include reduced experimental conditions, unreliable responses, participant online connectivity issues or exclusion of individuals with limited or no technological access, pollution of the sample when participants share links, and participant low motivation (Latkovikj & Popovska, 2019; Leidheiser et al., 2015). In the current study steps were taken to mitigate the latter two challenges. Firstly, participants were asked not to share the personalised links sent to them, and secondly, participant motivation was assisted by the feedback during the practice trials (Sauter et al., 2020).

4.5.3.1. First data collection

The first data collection took place in the first semester of 2020 and targeted first-year Unisa students living in Pretoria, Gauteng. This focus was necessary as in the first data collection students could take part either on the Sunnyside Campus, Pretoria, Gauteng, or online at home. Data collection was later changed to online only due to the Covid-19 pandemic.

The Unisa first semester began on 2 January and ended on 30 June 2020. The participants were solicited from a pool of 4 456 students living in Gauteng and who were registered for a first-year, undergraduate ODeL module at Unisa delivered through the Internet via the myUnisa platform during the 26-week semester. The research project employed a non-probability convenience sampling strategy and invited interested parties to participate in the research project voluntarily should they wish to do so (Rosenthal & Rosnow, 2008). This was completed through two processes.

In the first process, students were able to volunteer to participate in person at the Sunnyside Unisa campus and to attend the group testing session on that campus. To attract volunteers and limit attrition, it was stated that student participants would receive light refreshments and feedback on any assessments that they undertook as part of the data collection. Through this process, 154 students provided their details. At their scheduled testing session students completed the informed consent and background survey (Appendix C), the two WM tests, and the TALL. Before the disruption caused by Covid-19, a total of 25 out of 66 scheduled students came to the campus and completed their tests (6–13 March 2020). However, this process was terminated for the first semester data collection when Covid-19 spread in South Africa (effective from 16 March 2020).

The second process consisted of three steps. An initial email was sent to the pool of students providing information about the research project and the participant information sheet, and asking them to indicate their interest in participating (Appendices A and B) by completing the informed consent and background survey (Appendix C). Following completion, the two WM tests were then sent to the student via a personalised email, along with access to the research project website (https://jaquelineharvey.wixsite.com/harveyproject). Once students had completed the two complex span tests, they were sent the TALL test via email. The tests were divided in this manner as a limited number of TALL tests were purchased and they were only provided to students who had completed both WM tests.

The total survey responses (211) were first cleaned to remove incomplete responses, students who could not be contacted using their provided details, and students who had indicated that they did not accept the informed consent. A further 86 students were later excluded for the following reasons: not a first-year student (3); did not respond to WM test link email (67); outside the age limits (1); only completed RSPAN (1); only completed OSPAN (9); only completed RSPAN and OSPAN (2); academic achievement results outstanding (1); or absent from all or most final examinations (1). For the first data collection, 27 student participants completed all assessments either on campus or online.

4.5.3.2. Second data collection

The second data collection took place in the second semester of 2020, which began on 3 August 2020, and targeted all first-year undergraduate Unisa students living in South Africa. This data collection was entirely online and used the same three-step process via email as described above. After cleaning the total survey responses (1 093), as above, 521 students were further excluded for the following reasons: did not respond to WM test link email (449); only completed RSPAN (11); only completed OSPAN (28); only completed RSPAN and OSPAN (28); only completed OSPAN and TALL (1); academic achievement results outstanding (1); or absent from all or most final examinations (3). For the second data collection, 34 student participants completed all assessments. In addition, academic achievement scores of two participants who participated in the first data collection were retrieved from the university. A total of 63 students participated, either on campus or online.

At this point, after two data collections, a comparative analysis was conducted to evaluate whether the data from the 22 participants who completed the tasks on campus could be merged with those of the 41 participants who completed the tasks online. The non-parametric Mann-

Whitney test was used. The results of this analysis showed that the two groups of participants differed significantly with regard to TALL test scores, WMC test scores, as well as academic achievement, indicating that the two groups could not be collapsed. The 41 participants who had completed the tasks online had significantly higher scores for all variables. It was therefore decided to exclude the participants who had completed the tasks on campus, leaving 41 participants, and to undertake a third and final data collection in the 2021 academic year.

4.5.3.3. Third data collection

To combat the effects of the pandemic, Unisa had one merged semester in the 2021 academic year (from 1 April to 31 August 2021) rather than two semesters. The third data collection took part in the middle of this semester (17 May to 2 July 2021) and targeted all first-year undergraduate Unisa students living in South Africa. This data collection was also entirely online and used the same three-step process via email as described previously. After cleaning the total survey responses (3 089), as above, 1 428 students were also excluded for the following reasons: did not respond to WM test link email (1 237); outside of age limits (1); only completed RSPAN (14); only completed OSPAN (73); only completed RSPAN and OSPAN (99); academic achievement results outstanding (3); or absent from all or most final examinations (1). At this point, 100 student participants took part in the third data collection.

An additional exclusion criterion was applied. As will be explained below (§ 4.6.3.), participants were required to correctly answer 50% of the processing component of the WM tasks to be included in the study. Once this criterion was applied, a total of 136[7] student

[7] For the preliminary analysis, conducted before academic results were received for the third data collection, three of the six participants who had outstanding results were included. These three participants completed the tasks online and met the processing cut-off criterion.

participants from all three online data collections completed all tasks and were included in the current study. The table below provides the number of participants by tasks completed.

Table 4

Number of student participants

	TALL	RSPAN	OSPAN	Academic achievement	n
Comparative analysis	✓	✓	✓	✓	64
Descriptive analysis					
Demographic profile	✓	✓	✓	✓	136
Psychometric profile	✓	✓	✓	✓	136
Internal consistency reliability					
TALL	✓				149
RSPAN		✓			288
OSPAN			✓		366
TALL item analysis	✓				149
Inferential analysis					
Correlation analysis	✓	✓	✓	✓	136
Mediation analysis	✓	✓	✓	✓	136
Regression analysis	✓	✓	✓	✓	136

4.5.4. Actualised sample size

As stated above, the actualised sample size was 136 participants. While a larger sample size is always preferred, smaller and similar sized samples have been used in studies reported in journal articles, dissertations, and theses investigating working memory. With regard to journal articles, for example, Pluck et al. (2016) explored the relationship between general intelligence, five frontal lobe functions, WM, and academic achievement in higher education in a sample of 64 undergraduate psychology students. The authors utilised correlations and regression analysis to evaluate the relative contributions to variance in grade point average (GPA). Their results showed that WM was not correlated with GPA but was correlated with general intelligence. Hicks et al. (2016) explored the feasibility of online complex span measurements by contrasting them with measurements obtained in four experiments in the lab. The sample sizes of these four experiments ranged between 58 and 112 participants (Hicks et al., 2016). As a final example, Hubber et al. (2019) performed three separate experiments to compare the WM performance of mathematics students to that of humanities students. Their sample sizes ranged between 42 and 51 participants (Hubber et al., 2019). These studies show that the actualised sample for the current study is in line with those in previous studies.

4.6. Instruments

4.6.1. Demographic and background data

The following contact, demographic and background data were requested from the students through the online background survey. Table 5 lists the categories and the specific information requested (Diemer et al., 2013; Ma et al., 2017; McMillan & Western, 2000; Soyyılmaz et al., 2017). With regard to socio-economic status (SES), it was important to align the measurement of SES with the purposes of the study, with what was being studied, and with the participants' ability to report accurate information (Diemer et al., 2013). ODeL students may have gone directly into higher education, which constrains their educational level and personal SES, or they may be mature students with full- or part-time employment (McMillan & Western, 2000; Soyyılmaz et al., 2017). This research project therefore followed the suggestion of McMillan and Western (2000) to ask students for their parents' education level and occupation while the student was in secondary school. The use of these two measurements took into account the enduring effects of social origins, as well as the situation where some sampled students are employed (although perhaps not to their full earning potential, given that they are studying) and others are not (McMillan & Western, 2000). In addition, the survey requested information regarding secondary school type attended (no-fee public school, fee-paying public school, and private school).

Table 5

Information requested from students

Category	Requested information
Contact information	Student number Course name Contact number Preferred contact email address
Student demographic information	Age Gender First language Second additional language
Student background and pre-university experiences	SES: Social origins - Parents' highest achieved education - Parents' occupation Secondary school type attended

4.6.2. Reading level

The TALL was administered to all participants to indicate their reading proficiency. The TALL is a well-accepted and authoritative test, which has been used at several South African tertiary institutions: the University of Pretoria, Stellenbosch University, and North-West University (Le et al., 2011; van der Slik & Weideman, 2005). The TALL, and its Afrikaans counterpart, are the only academic literacy tests which have been designed for use in multilingual institutions (Le et al., 2011). They have not been developed as access tests but rather as placement tests, where the aim is to identify the level of academic literacy support required by the test taker (van der Slik & Weideman, 2005; Weideman, 2006). The TALL is based on a definition of academic literacy (Weideman, 2018, p. vi) "as the ability to

- understand a range of academic vocabulary in context;
- interpret the use of metaphor and idiom in academic usage, perceive connotation, word play and ambiguity;

- understand relations between different parts of a text, be aware of the logical development of an academic text, via introductions to conclusions, and know how to use language that serves to make the different parts of a text hang together;
- interpret different kinds of text type (genre), and have a sensitivity for the meaning that they convey, and the audience at which they are aimed;
- interpret, use and produce information presented in graphic or visual format;
- make distinctions between essential and non-essential information, fact and opinion, propositions and arguments; distinguish between cause and effect, classify, categorise and handle data that make comparisons;
- see sequence and order, do simple numerical estimations and computations that are relevant to academic information, that allow comparisons to be made, and can be applied for the purposes of an argument;
- know what counts as evidence for an argument, extrapolate from information by making inferences, and apply the information or its implications to other cases than the one at hand;
- understand the communicative function of various ways of expression in academic language (such as defining, providing examples, arguing); and
- make meaning (e.g. of an academic text) beyond the level of the sentence."

The TALL has been extensively evaluated and a multiplicity of evidence has shown that it meets the requirements of usefulness as defined by Bachman and Palmer (1996, p. 18):

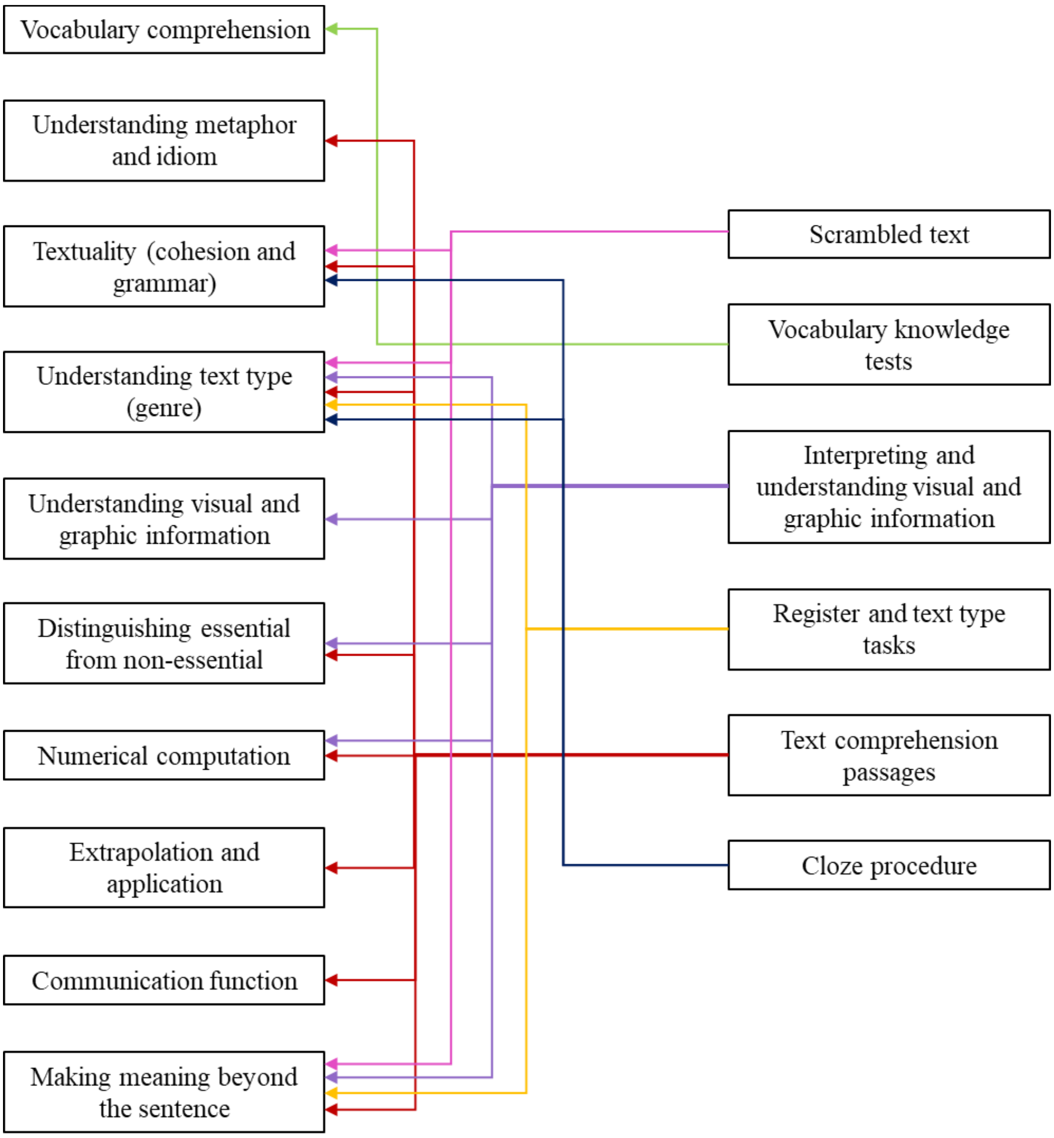
Usefulness = Reliability + Construct validity + Authenticity + Interactiveness + Impact + Practicality

Reliability. One measure of reliability is the consistency of scores from one set of tests to another (Bachman & Palmer, 1996). The TALL has shown good reliability, as test scores under different testing conditions have remained consistent (Le et al., 2011). There is no need for inter-rater reliability as the TALL does not require test-takers to write texts (Le et al., 2011). With regard to its internal consistency, the TALL has obtained a Cronbach's alpha and greatest lower bound in excess of 0.9 in South African administrations (Le et al., 2011; Weideman, 2006, 2009). Cronbach's alpha and the greatest lower bound are comparable, but the latter does not assume homogeneity and is thus generally higher (van der Slik & Weideman, 2005). Reliability is a requirement for construct validity, discussed next (Bachman & Palmer, 1996).

Construct validity requires that the definition of the construct adequately aligns with what is measured by the test, that is, *it* measures only what it sets out to measure (Le et al., 2011; Weideman, 2006). The TALL is based on the definition provided above and it measures a componential view of academic literacy using a range of typical tertiary level cognitively demanding tasks. *E*ach or several of the components of academic literacy are operationalised in the TALL as actual subtests (Le et al., 2011; Weideman, 2006, 2018). This is indicated in Figure 11, which shows the ten components on the left with the relevant task type (or subtest) on the right (Weideman, 2011). The TALL thus measures several constructs and avoids being inappropriately narrow as a measure of the complex construct that is academic literacy (Bachman & Palmer, 1996). In the study conducted by Le et al. (2011) using participants from both a South African and a Vietnamese tertiary institution, the TALL was evaluated using multiple measures. In terms of construct validity, subtest intercorrelations were between .15 and .5, indicating that none of the subtests were measuring the same construct of academic literacy (Le et al., 2011). Together with its reliability scores, the test has therefore shown high construct validity. It has, however, been noted that previous factor analyses have indicated outlying items; that is, items 1–5 of the ‘Scrambled text’ subtest and items 50–67 of the ‘Grammar and text relations’ subtest were less closely associated with measurement of a single factor (Weideman, 2009). It was argued that it was preferable to tolerate some heterogeneity, rather than exclude these subtests for technical consistency, given the complexity of the academic literacy construct (Weideman, 2009).

Figure 11:

TALL components and task type



Authenticity is defined as the extent to which the test task characteristics correspond with the features of target language use tasks in non-test scenarios (Bachman & Palmer, 1996; Le et al., 2011). It is a crucial criterion for generalisation of score interpretations, linking authenticity to construct validity (Bachman & Palmer, 1996). Furthermore, authenticity provides test takers with the feeling that the test is relevant to non-test domains, promoting both a positive affective response and performance motivation (Bachman & Palmer, 1996). The definition of academic literacy and its operationalisation in the TALL, as noted above under construct validity, meet this requirement as they are typical tertiary level cognitive tasks that students would have to undertake as part of their studies (Le et al., 2011).

Interactiveness relates to how the test taker's individual characteristics interact with performance on the test task (Bachman & Palmer, 1996). For example, test takers can differ on language ability, content knowledge, or affective schemata (Bachman & Palmer, 1996). To take interactiveness into account, the TALL asks that students draw on their relevant knowledge and make meaning of the provided text "beyond the level of the sentence" (Weideman, 2003, p. xi-xii, as cited in Le et al., 2011). In addition, the TALL content was carefully selected and is intentionally bland, to avoid evoking negative inferences or causing psychological harm to test takers (Le et al., 2011). However, it is noted by the researcher that participants may have a negative affective response to undertaking an assessment of the English literacy level, based on their personal experiences with this language. Counselling offered by the Unisa Directorate: Counselling and Career Development was therefore made available to participants, as noted under ethical considerations at the end of this chapter.

Impact refers to the impact of a test on the individual and the society and educational system in which they live (Bachman & Palmer, 1996). The TALL conceptually ensures ethical handling of test design and use, so that it is fair, caring, and compassionate (Weideman, 2019). With regard to the use of the TALL in this study, impact on the individual participant was further limited, as: (a) the TALL was not used for access nor decision purposes, and thus cannot foreseeably have a lasting negative impact on the participant, (b) the participants were familiarised with the format of the test beforehand, and (c) rich verbal descriptions were used in the feedback provided to participants on their performance to make sure that it was relevant, complete, and meaningful (Bachman & Palmer, 1996; Le et al., 2011). This is particularly important for the South African context, given the history of language in education that was discussed in previous chapters. The current purpose of the TALL in this study also limits its influence on society and the educational system, as it was not the basis for any decisions in an academic programme, for example (Bachman & Palmer, 1996). The current project does, however, use the TALL to indicate the possible role of WMC in reading. It was therefore emphasised that this research project was exploratory in nature and does not make definitive claims.

Practicality, the final consideration, is the "relationship between the resources that will be required for the design, development, and use of the test and the resources that will be available for these activities" (Bachman & Palmer, 1996, p. 36). This also includes reference to logistical constraints (Le et al., 2011). The TALL has been shown to be a fully practical way of assessing academic literacy, given its affordability, relatively short testing time (60 minutes) and multiple-choice format, precluding time-consuming marking (Le et al., 2011; Weideman, 2006).

The TALL was therefore considered an adequate instrument to assess participants' reading levels. Based on their results, participants can be categorised into one of five groups, indicating their risk of withdrawal, from extremely high risk (1); to high risk; borderline case; low risk; and low to no risk (5) (Nizonkiza & van Dyk, 2015). It consisted of 64 questions in multiple-choice format, administered online, with six subtests (Nizonkiza & van Dyk, 2015):

Section 1: Scrambled text presents a scrambled paragraph which participants must organise into the correct order (5 items).

Section 2: Interpreting graphs and visual information tests participants' ability to interpret either a graph or a diagram, as well as their quantitative literacy ability (5 items).

Section 3: Understanding texts asks participants to complete a reading comprehension test, where questions focus on "critically important aspects of the construct, such as distinguishing between essential and non-essential information, or cause and effect, as well as inferencing, sequences, defining, handling metaphor and idiom, and so forth" (Nizonkiza & van Dyk, 2015, p. 154) (24 items).

Section 4: Knowledge of academic vocabulary tests participants' academic vocabulary directly (9 items).

Section 5: Text types presents sentences and phrases extracted from various genre text types, which the participants must match with a list of sentences and phrases from the same text types (5 items).

Section 6: Grammar and text relations relies on the cloze procedure, and has three sub-sections: 1) participants must indicate the place in the text where a word has been omitted; 2) the place where a word has been omitted is given and participants must indicate the correct word; and 3) participants must indicate both place and the omitted word (16 items).

4.6.3. Working memory capacity

WM measures are suitable for non-Western, low-resource, and developing communities, as they have reduced cultural and socioeconomic bias compared to measures of intelligence or educational ability (Hicks et al., 2016; Milligan & Cockcroft, 2017). WMC consists of both storage and processing components, which can be assessed separately or together (Juffs & Harrington, 2011). WMC measures therefore include both simple span and complex span tasks: the European tradition is to employ a simple span task as a measure of WMC, while the North American tradition is to use a complex span task (Wen, 2014). To reduce the load placed on participants, the current research project uses complex span tasks only. Simple and complex span tasks are briefly discussed below to illustrate the reasoning behind this decision.

Simple span tasks measure short-term storage capacity and typically present a span of unrelated stimuli, such as digits or words, to be recalled (Bayliss et al., 2003; Juffs & Harrington, 2011; Redick et al., 2012; Unsworth & Engle, 2007). These items are generally presented in sets of ascending length size, until the maximum for the participant is reached (Juffs & Harrington, 2011). They include the digit span and Corsi blocks, where participants are asked to serially report a series of digits or tap a specific sequence of blocks presented to them (Redick et al., 2012). Simple span tasks do not tax both storage and processing and are thus insufficient measures of WMC (Bailer et al., 2013). They have also been considered insufficiently reliable and inconsistently valid as predictors of higher-level and real-world cognitive tasks (Engle, 2010). Given that the current study focuses on WMC and the complex cognitive tasks of reading, it was decided to utilise complex span tasks as a WMC measurement[8].

Complex span tasks present both the storage task of a simple span task interleaved with a processing task (Conway et al., 2005; Juffs & Harrington, 2011; Redick et al., 2012; Unsworth

[8] The simple span tasks were, however, developed and can be provided on request.

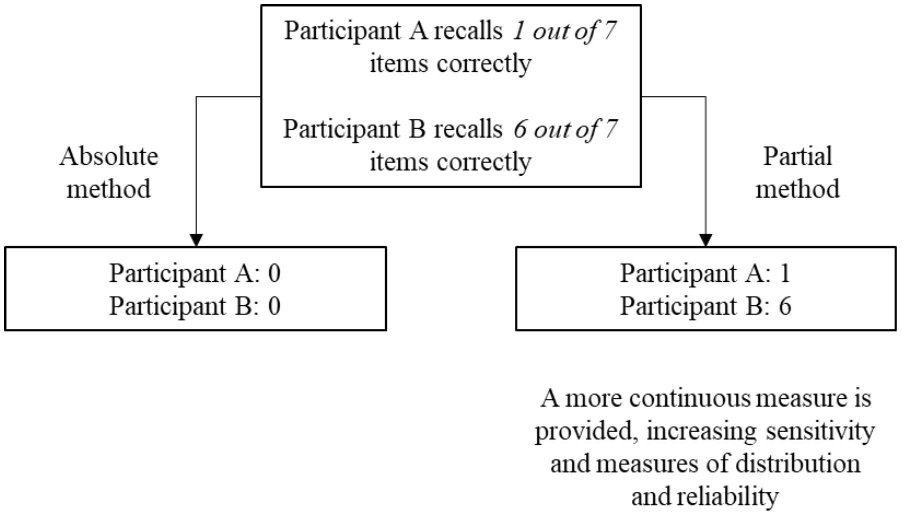
& Engle, 2007). This requires participants to engage in online processing while retaining specific aspects of the processing for later recall, thus engaging the central executive (Bayliss et al., 2003; Draheim et al., 2022). Complex span tasks thus provide a measure of a dynamic WM system comprising both storage and processing of information (Redick et al., 2012; Slattery et al., 2021). These tasks include the reading span (RSPAN) and the operation span (OSPAN) tests, discussed in the previous chapter, which have been shown to be moderately reliable (α = 0.7–0.9) and consistently valid as predictors of performance on a cognitive measure of interest such as reading comprehension, academic performance, and note-taking (Engle, 2010; Hicks et al., 2016; Redick et al., 2012; Redick & Lindsey, 2013; Unsworth et al., 2009). Language knowledge requirements are minimised in the OSPAN and therefore both the RSPAN and OSPAN were included in the current research project (Juffs & Harrington, 2011). The RSPAN reflects a task-specific view of WMC in that the latter varies according to the efficiency of the processes required by the task. In contrast, the OSPAN provides a general view of WMC which is independent of the nature of the task (Bailer et al., 2013). The general administration and scoring procedures are briefly discussed here and covered more deeply later in the chapter.

Administration procedures. For both the RSPAN and the OSPAN, participants completed three practice conditions: 1) storage task only, 2) processing task only, and 3) storage and processing tasks interleaved (Redick et al., 2012). Participants then completed the trials of storage and processing tasks interleaved. Trials were organised into five blocks of three trials each, beginning with a set size of three and ending with a set size of seven. When administering complex span tasks, previous studies have used an 85% accuracy criterion for the processing component: if less than 85% of the answers on the processing task were correct, then the participants' data was removed in further analyses. However, there are no substantial changes in the psychometric properties of the task if this is not done (Đokić et al., 2018). Given this argument and concerns regarding sample size, this criterion was relaxed to requiring 50% of answers on the processing task to be correct.

Scoring procedures. There are two main scoring procedures: absolute scoring and partial scoring. The partial credit unit scoring method uses all available information, as the partially recalled sets are not discounted. It is therefore a more sensitive scoring method than absolute procedures (Đokić et al., 2018). This is easily seen using the comparison in Figure 12. With regard to psychometric properties, Redick et al. (2012) showed that partial scoring, as opposed to absolute scoring, provided higher test-retest correlations and higher internal consistencies. Đokić et al. (2018) confirmed that partial scoring provides higher internal consistency measures, and their results also indicated slightly higher convergent validity. Given this and the recommendations by, for example, Conway et al. (2005), Đokić et al. (2018), and Redick et al. (2012), the current research project used the partial scoring method.

Figure 12:

Example of difference between partial and absolute scoring procedures



The partial credit system used by Kane et al. (2004) was followed. Within each set of three trials, an item was scored as correct if it was recalled in the correct serial position. A proportion correct score was then calculated within each set, and then the proportion correct score was computed over all sets in the task for the participants' final task score (Kane et al., 2004).

The WMC tasks used in this research project were developed using Tatool (Training and Testing Tool), a Java-based open-source programming framework specifically designed for research utilising cognitive training, experiments, and questionnaires[9]. It furthermore allows for running research projects online via Java Web Start. It has a 'Tatool Online' platform where research projects and participants' data is easily managed with a web-based interface (von Bastian et al., 2013). Although there are other computerised tools available for the assessment of cognitive functions such as WM, they have limitations.

Standardised test kits often have rigid administration procedures that do not lend themselves easily to studies that require modification. There is also a substantial cost to these kits (Stone & Towse, 2015). Computerised WM tasks that are available online tend to rely on expensive software or installations. For example, the Attention and Working Memory Lab (AWM Lab) at the Georgia Institute of Technology has developed free versions of several WM tasks. However, the software used by AWM Lab (E-Prime and Inquisit) is not freely available within South Africa, as it is a licensed and expensive software (Klaus & Schriefers, 2016; Sauter et al., 2020; Stone & Towse, 2015). Another example is the Psychology Experiment Building Language (PEBL), which is an open-source project, but requires installation on the

[9] Tatool is published open source under the GNU Lesser General Public Licence and is available at www.tatool.ch (von Bastian et al., 2013).

participants' device (Stone & Towse, 2015). The platform used in the current study, however, allows for modification and did not require specialised software or any setup or installation.

Tatool Web is open source and allows the researcher to modify the tasks to fit their experimental design, providing flexibility. As Tatool Web tasks are Java-based, they can run on any system where the Java Runtime Environment (JRE) is installed. Running the tasks is therefore simple, as the JRE is often pre-installed on devices. In the rare case that it is not, the JRE is free and easily accessible online (Stone & Towse, 2015). Tasks created with this platform were thus suitable for the experimental design and did not require software or installation. The complex span tasks which were used are now discussed. The Tatool Web settings for the RSPAN are provided in Appendix G as an example, with settings for all tasks available on request.

4.6.3.1. Complex span tasks: Reading span and operation span

During development, the RSPAN and OSPAN used in the current research project were modelled on the automated complex span tasks developed by Redick et al. (2012). These tasks have been made freely available for download from the AWM Lab at the Georgia Institute of Technology webpage (http://englelab.gatech.edu/taskdownloads.html). However, the software used by the AWM Lab (E-Prime and Inquisit) is not freely available (Klaus & Schriefers, 2016; Sauter et al., 2020). The AWM Lab therefore kindly provided use of their stimuli and procedures (C. Mashburn, personal communication, April 4, 2019) and the complex span tasks were developed by the researcher using the Tatool Web platform. However, some modifications were necessary due to the differences between platforms.

Reading span. The RSPAN had 15 trials of 3–7 letters interleaved with sentences (Hicks et al., 2016; Unsworth et al., 2009), with three trials comprising a set. The letters were the storage component, while the sentences were the processing component; for the latter, participants had to judge if the sentence made sense. Previous versions of the RSPAN used words as the storage task, but unrelated letters are used in more recent versions to reduce the influence of language proficiency (Sanchez et al., 2010). The administration of the practice and task trials is now discussed, following which the development of the storage and processing components using Tatool Web is presented.

Administration: Practice. Participants first completed three practice sessions: 1) a simple letter span, 2) the sentence portion of the RSPAN alone, and 3) both the letter recall and sentence portions of the RSPAN together as in an actual trial (Unsworth et al., 2009). The first practice was administered like the digit span above. A series of letters was displayed on the screen (each shown for 1000 ms) and participants were asked to type the series in the same order (Unsworth et al., 2009). Accuracy feedback was provided after each entry. In the second practice, sentences were displayed. For each sentence, the participant had to silently read it and indicate if it made sense or not, using the left and right arrow keys (see Table 6). Accuracy feedback was provided after each sentence. For Unsworth et al. (2009) and other researchers, the second practice served to calculate the time needed by each participant to read the sentence and indicate their response: their mean time to answer +2.5 SD was used to calculate their maximum time allowed on the processing component of the actual task trials (Hicks et al., 2016; Unsworth et al., 2009). The RSPAN in the current research project allowed 9.5 seconds per sentence. This was calculated from the results of the study by Koenig et al. (2015), who conducted an academic literacy intervention with first-year B.Sc. students in the Access Programme of the Qwaqwa Campus of the University of the Free State, Free State province, South Africa. The pre-intervention reading speeds of the control ($N = 60$) and experimental ($N = 60$) groups were 130.7 and 123.6 words per minute, respectively. Using these values, the approximate time needed to read 15 words was calculated (7.1 seconds) and an additional 2.4 seconds was allowed. Participants were instructed to move through the sentences as quickly and accurately as possible. The final practice session presented participants with a series of letters interleaved with sentences as in an actual task. Participants completed three practice trials of a set size of two (Unsworth et al., 2009). Accuracy feedback was provided after each sentence and each letter entry.

Administration: Task. In a trial, participants were presented with a letter, a sentence, a letter, a sentence, and so on. Each letter was displayed for 1000 ms (Unsworth et al., 2009), while the sentences did not have a time limit, as noted above. After this, participants recalled the letters by typing them in the correct order (Hicks et al., 2016; Unsworth et al., 2009). Accuracy feedback was provided after each sentence and each letter entry. Participants completed five blocks of three trials each. The first set size was three and the final set size was seven. Development of the RSPAN using Tatool Web is now discussed.

Storage component. The letter stimuli provided by the AWM Lab (C. Masher, personal communication, April 4, 2019) were used in the current research project. However, their software generates new lists of randomised letters for each trial. In the current research project, the lists for each of the 15 trials were predetermined manually by the researcher in the following manner: 1) all letters were entered into an MS Excel spreadsheet column, 2) the random number function was used to reorder them, and 3) the first letters from each column were then taken for each trial; that is, if it was a three-letter trial then the first three letters were used.

Processing component. The sentence stimuli provided by the AWM Lab (C. Masher, personal communication, April 4, 2019) were used in the current research project and national adaptations were made where relevant (Table 7). All sentences had 10 to 15 words, and half of the sentences made sense. Nonsense sentences were made so by changing a single word (e.g. 'dish' from 'case') (Unsworth et al., 2009). Tatool Web randomly selected which sentences to display in each trial.

Table 6

Examples of stimuli used in the reading span (RSPAN) complex span task

Sentence	Processing task operation answer	Answer by participant
After final exams are over, we'll be able to take a well-deserved rest.	Sensible sentence	Right arrow key indicating TRUE
During the week of final spaghetti, I felt like I was losing my mind.	Nonsense sentence	Left arrow key indicating FALSE

Table 7

List of the original words and national adaptations which were made in the reading span (RSPAN) sentence stimuli

Type of change made	Original word or phrase	South Africa term used
Word with the same or similar meaning but where the replacement is more commonly used in the South African context	mall	shopping centre
	cap	hat
	fall	summer
	plum	apple
	deer; shotgun range	buck; line of fire
	waterbed	bed
	hall (as in a school)	corridor
	sneaker	shoe
	candy bar	chocolate bar
	prom	Matric dance
	college	university
	stereo	radio

Table 7

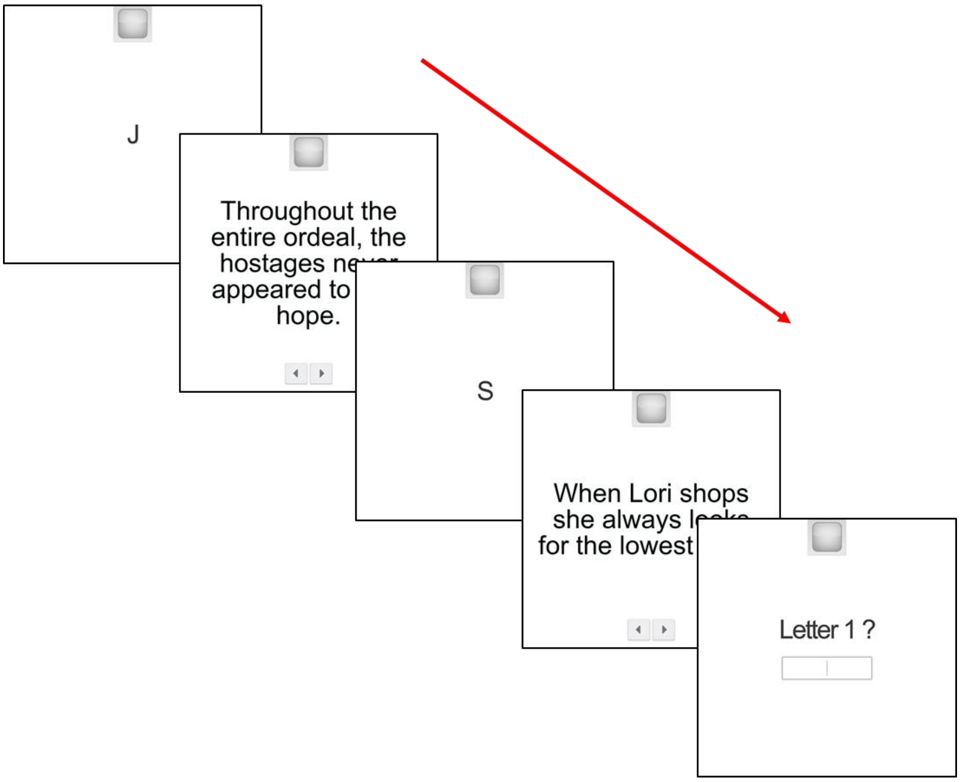
List of the original words and national adaptations which were made in the reading span (RSPAN) sentence stimuli

Type of change made	Original word or phrase	South Africa term used
	football	soccer
	clay	dry
	wrecked	crashed
Name change so as to be contextually representative	Amy	Akhona
	Sue	Unathi
	Jill	Thobeka
	Jim	Mandisi
	Kristen	Ashika
	Sara	Lufuno
	Atlanta	Durban
South African spelling	realizing	realising

An example of an RSPAN trial is provided in Figure 13 below. In the first task, a letter is presented for 1000 ms. This is followed by a sentence, which is judged to be either making sense or nonsense. After the participant has indicated their answer using the keyboard, the next letter is shown and so on. For recall, the correct letters from the current set are typed in the correct order.

Figure 13:

Illustration of the RSPAN task



Operation span. The OSPAN had 15 trials of 3-7 letters interleaved with simple mathematical operations (Hicks et al., 2016), with three trials comprising a set. The letters were the storage component while the operations were the processing component; for the latter, participants had to judge if the answer provided for the final sum was correct. Administration of the practice trials and task was identical to that of the RSPAN, but with mathematical operations (e.g. 3 X 2 + 1 = 7 ?) instead of sentences (Hicks et al., 2016; Unsworth et al., 2009). Development of the OSPAN is now discussed, with examples of the stimuli provided in Table 8 for reference.

Table 8

Examples of stimuli used in the operation span (OSPAN) complex span task

Operation 1	Operation 2	Processing task operation	Processing task operation answer	Answer by participant
(8 / 2)	– 3	(8 / 2) + 9 = 13 ?	13	Right arrow key indicating TRUE
(2 X 2)	+ 5	(2 X 2) – 3 = 7 ?	1	Left arrow key indicating FALSE

Storage component. The letter stimuli provided by the AWM Lab (C. Masher, personal communication, April 4, 2019) were used in the current research project. The same procedure described above for the OSPAN was used to develop the lists of letters in Tatool Web.

Processing component. The software used by Hicks et al. (2016) generated the processing task operations as a combination of two simple mathematical operations: Operation 1 and Operation 2 (see Table 8 for examples). On each trial, the values of Operation 1 and Operation 2 (initial) would be randomly selected from predetermined lists, to provide the combined processing task operation. Algorithms then ensured that the value of Operation 2 provided an answer to the combined operation that was greater than zero: +3 to Operation 2 (initial) value until the final sum was greater than zero. Participants would then be presented with a number and asked to indicate if it was the correct (TRUE) or incorrect (FALSE) answer to the combined operation. Whether the trial was TRUE or FALSE would also be determined randomly. To create a FALSE answer, a random number would be added to the correct answer. If necessary, to ensure that it was greater than zero and not equal to the correct answer, +2 would be added until the criteria were met. This development was done manually for the OSPAN in the current research project.

All Operations (1 and 2) used by Hicks et al. (2016) were entered into an MS Excel spreadsheet and the random number function was used to develop combinations. The researcher then ensured that the answer to each final sum was positive. During the task student participants were asked to indicate if the answer was TRUE or FALSE using their keyboard (see Table 8). The researcher thus also ensured that half of the answers to the final sum were TRUE (24 operations) and half were FALSE. Randomisation was selected in Tatool when the software executed the task, and therefore all participants received randomly selected processing components. Table 9 provides an example from the MS Excel spreadsheet stimuli file for the processing components used by Tatool during task execution.

Table 9

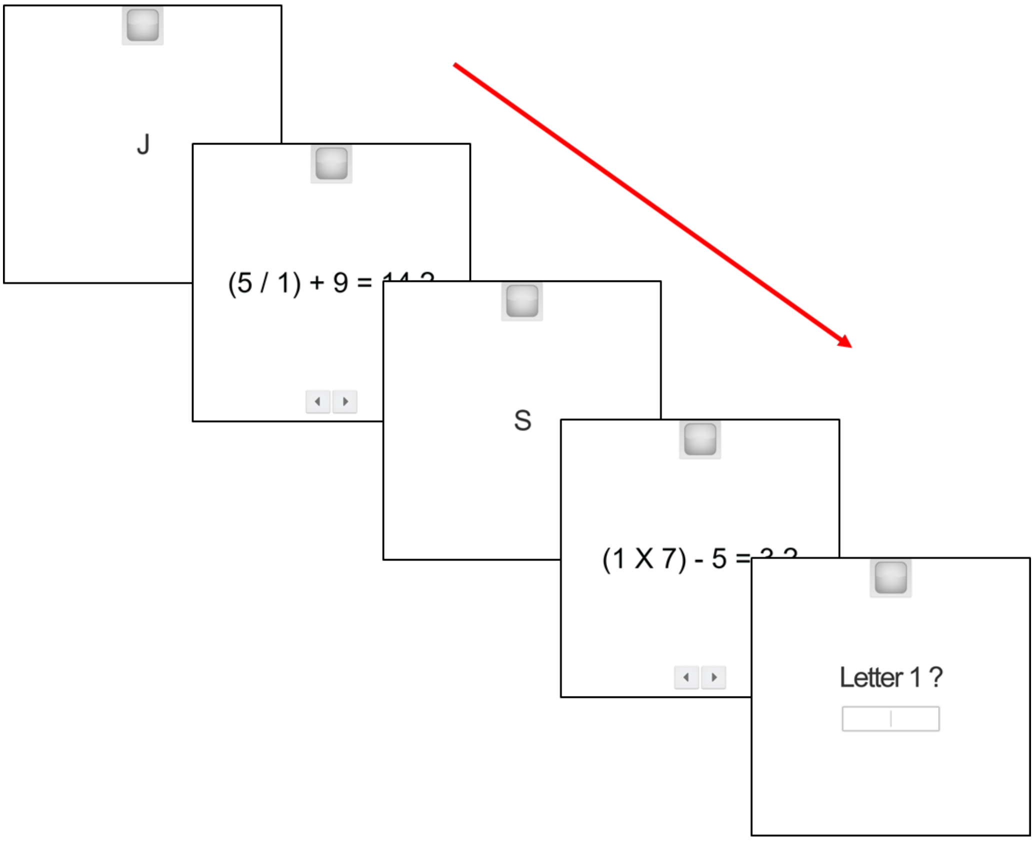
Examples of MS Excel spreadsheet stimuli file used by Tatool Web to run the operation span (OSPAN) complex span task

stimulusValue	stimulusValueType	stimulusValueColor	stimulusType	correctResponse	keyCode	response	keyIndex
(8 / 2) – 3 = 1 ?	text	black	true	true	ArrowRight	true	1
(3 X 2) + 1 = 5 ?	text	black	false	false	ArrowLeft	false	0

An illustration of the OSPAN is provided in Figure 14. In the first task, a letter is presented for 1000 ms. This is followed by a mathematical operation and answer; the latter is judged to be either true or false. After the participant has indicated their answer using the keyboard, the next letter is shown, and so on. For recall, the correct letters from the current set are typed in the correct order.

Figure 14:

Illustration of the OSPAN task



4.6.4. End-of-course grades

End-of-course grades were provided by the university.

4.7. Data management

As students were tracked to obtain their end-of-course grades, the study asked for individually identifiable information such as their student number. In order to protect this information, all data was stored on the researcher's personal computer (password protected) with the folder password protected. In accordance with the Protection of Personal Information Act (POPI) 2013 (Republic of South Africa [RSA], 2013), this data was not placed on portable storage such as flash disks, or on cloud software such as Dropbox. The data sets will be destroyed five years after completion of the study. Only the researcher will have access to this data within that period.

Measures were in place to protect participant data that was collected online. The background survey was hosted on SurveyMonkey, which has several barriers in place to protect participant data. This includes physical security, access control, background screening of personnel, dedicated security personnel, regular vulnerability management and penetration tests, encryption, asset management, incident management, and business continuity management. In terms of compliance, SurveyMonkey has achieved ISO 27001 certification. The latter is a globally recognised, rigorous security standard (Momentive, 2021a, 2021b). The researcher used her own account and did not share the login details. The TALL is administered through the Inter-institutional Centre for Language Development and Assessment (ICELDA). The participants' data was extracted by Mr DJ Cloete in the School of Languages at North-West University, who signed a confidentiality agreement with the researcher. Finally, data collected by Tatool Web was linked to a code assigned to each participant by the researcher. No other personal information, such as name or IP address, was collected by the program, and the researcher linked their anonymous WM task performance to their other data through the codes.

In terms of knowledge production from the research project, students who took part in the intervention and assessments received feedback on their assessment results. The researcher ensured that students were, and are, aware that they may request access to their information at any point. It was also highlighted that the research project plans on disseminating its findings in the form of reports, journal articles, and conference presentations. Both of these points adhere to the POPI Act, as individuals must be able to access their information and know how their information is being used (Republic of South Africa, 2013). With regard to dissemination, no individually identifying information was or will be used, and analyses were performed with aggregated data.

4.8. Data analysis strategies

The Statistical Package for the Social Sciences (SPSS 27.0) was used to analyse the data generated in this study by means of descriptive and inferential measures, where appropriate. Descriptive statistics provide a summary of the data and are used to illustrate large amounts of information in a simple manner (Mishra et al., 2019). Inferential statistics draw conclusions from the sampled data that are used to make predictions about the population from which the sample was selected (Mishra et al., 2019). The data analysis was conducted in a series of steps: 1) descriptive statistics, 2) correlational statistics, and 3) mediation analysis. Although multiple regression analyses were planned, they could not be conducted due to insufficient sample size.

4.8.1. Descriptive statistics

Participants. Descriptive statistics were run on the demographic information provided, to analyse the demographic variables of the sample. The demographic variables included age, gender, L1, registered Unisa college, type of high school, parental education, and parental employment. Parental education was classified as one of the following codes:

0. No formal education
1. Some primary schooling
2. Standard 5 / Grade 7 or equivalent
3. Some secondary schooling
4. Matric / Senior Certificate / Grade 12 or equivalent
5. Undergraduate certificate / diploma
6. Undergraduate degree

7. Postgraduate qualification
8. Don't know
9. Not applicable

An education score (0 through 7, with 0 equal to no formal education and 7 equal to a postgraduate qualification) was thus assigned to each parent, based on the information provided in the survey.

The South African Standard Classification of Occupations (SASCO-2012) was used to categorise parents' occupations as reported by the participants. The nine major groups were used, which is the broadest level of classification. Each group has a one-digit code assigned, with '1' representing the most skilled and '9' the least skilled (see Table 10) (Stats SA, 2012). The coded occupation scores were reverse coded (0 through 9, with 0 equal to unemployed and 9 equal to managers) and assigned to each parent based on the information provided in the survey.

Where the participant response was too vague to code, not applicable, or unknown, a missing variable was assigned. Where their response indicated full-time scholars, homemakers, retirees, or those unable to work due to disability, it was coded separately (as '10') to indicate that they are not economically active, as opposed to employed or unemployed (Stats SA, 2013).

Table 10

SASCO-12 categorisations of parental occupation

<table>
<tr><th>Skill level</th><th colspan="5">Major groups</th></tr>
<tr><td>4</td><td colspan="3">2
Professionals</td><td colspan="2" rowspan="2">1
Managers</td></tr>
<tr><td>3</td><td colspan="3">3
Technicians and associate professionals</td></tr>
<tr><td>2</td><td>4
Clerical support workers</td><td>5
Service and sales workers and armed forces</td><td>6
Skills agricultural, forestry, and fishery workers</td><td>7
Craft and related trades workers</td><td>8
Plant and machine operators, and assemblers</td></tr>
<tr><td>1</td><td colspan="5">9
Elementary occupations</td></tr>
</table>

Note. SASCO-12 indicates the South African Standard Classification of Occupations. Adapted from *South African Standard Classification of Occupations (SASCO) 2012*, by Stats SA, 2012, (http://www.statssa.gov.za/classifications/codelists/SASCO_2012.pdf). Copyright 2012 by Stats SA. Adapted with permission.

A composite score was developed using parental education and occupation. The SES composite score was based on four factors: maternal (or female guardian) and paternal (or male guardian) education and occupation status. The highest education score across both parents as well as the highest occupation score were weighted and averaged, using the formula:

$$(\text{highest education score}*7 + \text{highest occupation score}*9)/2 = \text{SES composite score}$$

Higher values for the SES composite score are a proxy for higher levels of SES in the home. It is noted that using the highest value for parental education and occupation is a limitation of the study, as it may over-estimate the wealth of a given household. However, this process was selected rather than averaging the scores across parents for parental education and occupation. The latter required missing values or values that could not be assigned, such as homemakers or retired parents, to be coded as ‘0’ (indicating unemployment) to ensure consistency when averaging scores. It was considered that this could be misleading. Where the education levels of both parents were unknown (*n* = 3) or neither of their occupations were known (*n* = 6), the SES composite was recorded as missing.

Variables. There were three cluster groups of variables: two independent variables (WMC and English reading) and one dependent variable (academic achievement).

Working memory had continuous scores for WM storage and processing capacity. Descriptive statistics were firstly performed for both the RSPAN and the OSPAN to identify minimum and maximum values, mean, standard deviation (SD), skew, and kurtosis (Hicks et al., 2016). Secondly, the internal consistency reliability of the score was analysed by using Cronbach's alpha as an internal consistency measure (Barreyro et al., 2019). A composite score was then developed using the average of the RSPAN and OSPAN final proportions scores, as done by Ziegler and Smith (2017). The descriptive statistics for this composite WM score were also calculated, as well as the reliability coefficient.

Reading was assessed using the TALL, which rendered continuous scores. Firstly, descriptive statistics were run to identify minimum and maximum values, mean, SD, skew, and kurtosis (Hicks et al., 2016). Secondly, an item analysis was performed in order to indicate the facility values and discrimination indices for each item in the TALL subtests (Le et al., 2011). The former refer to the percentage of correct answers for the entire sample and should show a wide range of values rather than large gaps between scores (Le et al., 2011). An acceptable value for TALL is reportedly between 0.2 and 0.8 (Weideman, 2011). The latter specified the contribution of each subtest item to the test as a whole, as well as the extent to which each subtest item differentiated weaker and stronger participants (Le et al., 2011). The discrimination index (DI) ranges between 0 and 1, with higher numbers indicating greater test reliability (Le et al., 2011). Thirdly, the internal consistency reliability of each score was analysed by using Cronbach's alpha as an internal consistency measure (Barreyro et al., 2019).

End-of-course grades was a continuous variable and descriptive statistics were run to identify minimum and maximum values, mean, SD, skew, and kurtosis (Hicks et al., 2016).

4.8.2. Correlational statistics

Correlational statistics are used to describe and measure the relationship between two or more variables. Importantly, identification of such an association does not mean that one variable *causes* the other, as there may be an unmeasured third variable that is the cause of the correlation (Creswell & Creswell, 2018).

Working memory. A correlation analysis was performed to evaluate the relationship between the RSPAN and the OSPAN scores and if their combination into a composite WMC score could be used in further analysis (Ziegler & Smith, 2017).

Reading. An inter-correlation analysis was performed on the TALL subtests in order to evaluate construct validity (Le et al., 2011).

Correlation analyses were performed to evaluate the relationships between the WMC scores and TALL subtasks (Barreyro et al., 2019; Hicks et al., 2016).

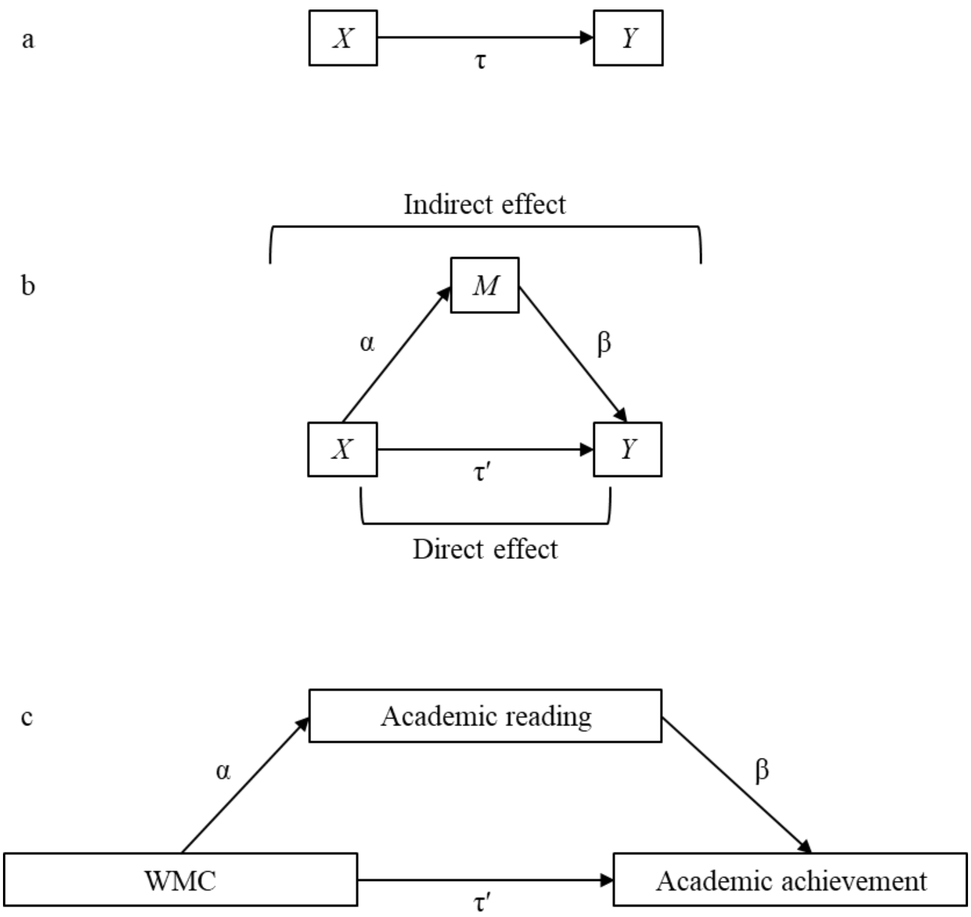
4.8.3. Regression or mediation analysis

A regression analysis will be used to explore the extent to which WMC is associated with academic achievement when other variables, such as gender, students' registered faculty, L1, and SES, are considered. However, if a regression analysis cannot be performed, a mediation analysis will be used.

Mediation is used to explore 'how' a variable influences another variable (Field, 2018). A simple mediation model explores the effect of the predictor variable (*X*) on the outcome variable (*Y*) through the mediating variable (*M*) (Fritz & MacKinnon, 2007; Hayes, 2009; Özdil & Kutlu, 2019). The path diagrams for a simple mediation model are illustrated overleaf, where Figure 15a is the **total effect** of *X* on *Y* (τ) and Figure 15b is the **indirect effect** of *X* on *Y* through *M* (αβ). Figure 15b furthermore shows the **direct effect** of *X* on *Y* while controlling for *M* (τ′) (Fritz & MacKinnon, 2007; Hayes, 2009). A simple mediation model was employed in the current study. Figure 15c indicates the path diagram which examined whether there was an indirect effect of WMC (*X*) on academic achievement (*Y*) through academic reading (*M*). It is proposed that the relationship between WMC and academic achievement partially operates through academic reading.

Figure 15:

Path diagrams for (a) the total effect of X on Y, (b) the indirect effect of X on Y through M, and (c) the indirect effect of WMC on academic achievement through academic reading



Following the recommendation by Field (2018), mediation was tested by computing confidence intervals (CIs) for the indirect effect through bootstrap methods. Bootstrapping is a non-parametric resampling technique which does not require the assumption of normality (Özdil & Kutlu, 2019). Bootstrapping employs multiple resampling processes and calculates the indirect effect for each bootstrap sample. Following thousands of iterations, a representation of the sampling distribution is created, which in turn provides the CIs for the 2.5 and 97.5 percentiles of the indirect effect (Hayes, 2018; Özdil & Kutlu, 2019).

The above method is preferable to Baron and Kenny's regression method as well as the Sobel test, as it does not rely on significance testing (Field, 2018). Rather than focusing on finding significant relationships, estimating the indirect effect and its CI allows for the simple reporting of the degree of mediation (Field, 2018). In addition, bootstrapping has been reported as more appropriate and reliable, with smaller standard errors, for small samples than either the Baron and Kenny method or the Sobel test (Hayes, 2018; Özdil & Kutlu, 2019). A criticism of this method, however, is that the CI endpoints are not fixed, as it is based on random resampling. Two researchers performing the same analysis on the same data will therefore have slightly different results. The simple rebuttal to this concern is to make the variation arbitrarily small, by setting the number of bootstrap samples to a very large number (i.e. at least 5000 bootstrap samples) (Hayes, 2018). This will be done in the current analysis.

The freely available macro for SPSS named PROCESS (v41) was used for conducting the mediation analysis. PROCESS constructs a percentile bootstrap CI to test the indirect effect (Field, 2018; Hayes, 2018).

4.9. Ethical considerations

To gain access to Unisa student data, permission to conduct the research was requested from the Research Ethics Committee of the College of Human Sciences and the Unisa Senate for Higher Research and Innovation Directorate Committee. Ethical clearance certificates are included in Appendix H. Please note that it was the original intention of this study to develop an online intervention, but this was abandoned due to feasibility issues and the title of the project was changed.

With regard to student informed consent, the following information was included so that students could adequately judge whether they would like to participate. Firstly, it was stated that participation was voluntary and that they were able to withdraw from the research project at any point without penalty. The informed consent included the time required in order to take part, as well as the type of content and tasks which participants would be asked to undertake. The potential benefits and risks were discussed. Regarding the former, the informed consent mentioned receiving assessment feedback for personal growth. The informed consent also noted that participants would have access to a website designed by the researcher (https://jaquelineharvey.wixsite.com/harveyproject). This website contained helpful infographics, text, and videos regarding various topics, including the value of peer-to-peer interaction, the brain and learning, study strategies, etc. In terms of risks, the time requirements were restated as well as the possibility of poor test performance. To mitigate these risks, the contact details of the researcher were provided in case participants had follow-up questions. In addition, the contact email address and webpage of the Department of Counselling and Career Development (DCCD) were provided. The DCCD was contacted in advance in case of the need for referrals (see Appendix I). The full participant information sheet is provided in Appendix B. The next section discusses the ethical considerations specifically related to studies which include a cognitive psychology/neuroscience component.

4.9.1. Neuroethics

The increase in research from the neuro- and cognitive sciences, and the corresponding unique ethical issues and challenges, has necessitated the development of neuroethics. The latter includes the ethics of conducting neuroscientific studies, evaluation of the possible ethical, social, and legal impact of the results of those studies, and the promotion of pragmatic, interdisciplinary discovery and application of results (Hardiman et al., 2012). Effective translation of research findings into educational practice, and vice versa, is required to eliminate neuromyths and achieve collaboration between various fields.

In the current research project, care was taken when writing the research outputs to emphasise the limitations of the findings and how or when they are applicable. The research project emphasised the role of WM in learning, but also acknowledged that it is not the ‘silver bullet’ in terms of academic performance. The researcher therefore made it clear to students that while they can use their assessment feedback to gain added insight into their own studying habits, they should not see their scores as determinants of their abilities. Furthermore, the research project content either avoided or clearly explained when common terms were used, such as learning style, so that neuromyths were not perpetuated. The contact details of the researcher were also available so that queries could be made.

4.10. Conclusion

This chapter presented the procedures which were followed in the current research project in order to answer the research questions, and are now briefly summarised. Under the positivist paradigm, a non-experimental ex post facto cross-sectional research design was followed. The target sample was 106 first-year undergraduate students enrolled at Unisa within Pretoria, Gauteng province, South Africa, and a non-probability convenience sampling strategy was followed to solicit their participation. During administration each participant completed an automated demographic questionnaire, the online TALL, and four automated WM tasks. Their end-of-course grades were obtained from their course lecturers. Participants’ data was then analysed using descriptive analysis, correlational analysis, and mediation analysis. The chapter also described the ethical considerations which governed the current research project and its methods.

CHAPTER 5: RESULTS

"To speak a language is to take on a world, a culture" (Fanon, 1967, p. 38).

5.1. Introduction

The preceding chapters provided the background against which the results are presented. An in-depth analysis of the proposed relationships between WMC, academic reading, and academic achievement was provided by the literature review in Chapter 2. In sum, previous research has suggested that WMC can constrain or enable academic reading and academic achievement. Chapter 3 discussed the framework guiding the research and presented WM as a limited capacity neural system within which interactive reading processes take place. The previous chapter presented the non-experimental ex post facto cross-sectional research design which guided the study, as well as the research steps which were followed. In this chapter the results of the study are presented and discussed with reference to the research questions and hypotheses of the study. Both descriptive and inferential data analyses were conducted and are interpreted. Descriptive data analysis focuses on providing a general overview of the sample, including their demographic variables and test scores, and in so doing answers the first research question (§ 1.6). The psychometric properties of the study variables will also be explored. Inferential statistics will then be used to show the statistical relationships between the variables and for hypothesis testing. The latter will be used to provide answers to research questions 2 to 5 (§ 1.6).

5.2. Descriptive statistics

5.2.1. Demographic profile of the sample

Descriptive statistics were first used to explore the profile of the 136 participants with regard to the demographic variables of age, gender, first language (L1), second language (L2), registered Unisa college, type of high school, parental education, and parental employment (Table 11 to Table 16). The average age of the participants was 24.29 years (*SD* = 6.81) and 71% of the participants were female (*n* = 96). The main languages spoken as L1 were English (*n* = 67, 49%), Afrikaans (*n* = 41, 30%), and isiZulu (*n* = 8, 6%), while the most common L2 was English (*n* = 65, 48%). For further analysis, indicated in Table 11, the African languages were grouped into one category termed indigenous South African languages (ISAL)[10] (Boakye, 2012). After having done so, 26 (19%) participants were L1 ISAL while seven participants were L2 ISAL. Most participants who were L1 English (*n* = 67) were either L2 Afrikaans (*n* = 40, 60%) or did not speak a second language (*n* = 20, 30%). There was, however, a small percentage of L1 English participants who spoke an ISAL as a L2 (*n* = 4, 6%) or another language (*n* = 3, 4%). All L1 Afrikaans participants were L2 English. L1 ISAL participants (*n* = 26) were largely L2 English (*n* = 22, 85%), but also indicated L2 ISAL[11] (*n* = 3, 12%), or did not speak a second language (*n* = 1, 4%).

In terms of their course selections, the participants constituted a diverse population from various fields of study, including accounting, law, and psychology, etc., in their first year. Most students were registered in the College of Human Sciences (*n* = 39, 30%), followed by the College of Law (*n* = 29, 22%). Five student participants did not indicate their field of study and were coded as missing. Most participants (*n* = 97, 71%) had attended a fee-paying public school[12]. The descriptive analysis indicated that the sample was relatively diverse in terms of

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[10] As noted in § 1.3.2, despite constitutional and policy revisions, there has been a lack of promotion and use of African languages in general, but particularly in the South African education system (Bangeni & Kapp, 2007; Hunter, 2015). The majority of schools continue to use an English medium of instruction (MoI) in all grades or from Grade 4 onwards, indicating that learners who are not L1 English receive their education in a second or third language (Heugh, 2009; Janks, 2014; Thomas & Collier, 2001; Wildsmith-Cromarty & Gordon, 2009). Individuals with an African home language are thus likely to have had similar experiences of receiving education in a language different from their mother tongue and were thus grouped together.

[11] One participant indicated 'Other – SePedi' as an L2 and this was recoded to Sesotho sa Leboa.

[12] One participant indicated 'Other' for school type but indicated the name of a fee-paying public school in the Free State (correlated with EMIS data) and was thus recoded.

Unisa college they were registered in, but lacked diversity in terms of gender, languages spoken, and type of school attended. For example, 85% of Unisa students reported that they were L1 ISAL in 2020 and 81% did so in 2021 (A. Fynn, personal communication, June 27, 2022). With regard to gender, however, the sample was consistent with the demographic profile of the overall Unisa student population: 71% female in 2019, 71% female in 2020, and 70% female in 2021 (A. Fynn, personal communication, June 27, 2022).

Table 11

Participants' profile regarding demographic variables

Demographic variable	Frequency (*N* = 136)	Percent (%)
Gender		
Male	37	27.2
Female	96	70.6
Transgender	1	0.7
Non-binary	2	1.5
I do not wish to say	0	0.0
First language		
English	67	49.3
Afrikaans	41	30.1
ISAL	26	19.1
Other	2	1.5
Second language		
English	65	47.8
Afrikaans	40	29.4
ISAL	7	5.1
I do not speak a second language	21	15.4
Other	3	2.2
College		
College of Accounting Sciences	9	6.9
College of Agricultural and Environmental Sciences	13	9.9
College of Economic and Management Sciences	10	7.6
College of Education	16	12.2
College of Human Sciences	39	29.8
College of Law	29	22.1
College of Science, Engineering and Technology	15	11.5
High school type		
No-fee public school	10	7.4
Fee-paying public school	97	71.3
Independent school	26	19.1
Other	3	2.2

Both parental education and parental occupation were based on reported data from the student participants. Table 12 reports the participants' profile regarding parental education. Overall, approximately three-quarters of both paternal (*n* = 108, 79%) and maternal (*n* = 102, 75%) parents had completed Grade 12 or higher. The most common selection for paternal parent was a Grade 12 or equivalent (*n* = 46, 34%). The second and third most common selections by participants for their paternal guardian was an undergraduate certificate or diploma (*n* = 26, 19%), followed by an undergraduate degree (*n* = 20, 15%). The same pattern was evident for participants' maternal parent. The most common selections were Grade 12 or equivalent (*n* = 47, 35%) and an undergraduate certificate or diploma (*n* = 19, 14%).

Table 12

Participants' profile regarding parental education and occupation

Demographic variable	Frequency (*N* = 136)		Percent (%)	
Parental education	Paternal	Maternal	Paternal	Maternal
No formal education	3	4	2.2	2.9
Some primary schooling	3	1	2.2	0.7
Standard 5 / Grade 7 or equivalent	3	1	2.2	0.7
Some secondary schooling	12	15	8.8	11.0
Matric / Senior certificate / Grade 12 or equivalent	46	47	33.8	34.6
Undergraduate certificate / diploma	26	19	19.1	14.0
Undergraduate degree	20	18	14.7	13.2
Postgraduate qualification	16	18	11.8	13.2
Don't know	7	13	5.1	9.6
Parental occupation	Paternal	Maternal	Paternal	Maternal
Unemployed	5	19	3.7	14.0
Elementary occupations	2	4	1.5	2.9
Plant and machine operators, and assemblers	5	0	3.7	0.0
Craft and related trades workers	18	2	13.2	1.5
Skilled agricultural, forestry, and fishery workers	1	0	0.7	0.0
Service and sales workers and armed forces	11	5	8.1	3.7
Clerical support workers	5	3	3.7	2.2
Technicians and associate professionals	13	22	9.6	16.2
Professionals	34	32	25.0	23.5
Managers	21	19	15.4	14.0
Full-time scholars, homemakers, retirees, or unable to work due to disability	2	18	1.5	13.2
Do not have paternal or maternal parent, don't know, not applicable, or unclear	19	12	14.0	8.8

With regard to occupation, as noted in the previous chapter (§ 4.8.1), SASCO-2012 was used to categorise guardians' occupations, as reported by the participants, into one of nine categories. The nine major groups from the SASCO-2012 classification system were used, where 1 represents the most skilled and 9 the least skilled (Stats SA, 2012). This data was then recoded during data analysis, so that higher numerical values indicated occupations requiring higher skills. Before providing the results, examples are first given of participants' responses and the process of categorisation (Table 13).

Table 13

Examples of parental occupations and coding process

Participant response	SASCO-2012 code and description	Coded	Reverse coded
Domestic worker	9111 – Domestic cleaners and helpers	9	1
Street vendor	9520 – Street vendors	9	1
Bricklaying	7112 – Bricklayers and related workers	7	3
Housekeeping	5152 – Domestic housekeepers	5	5
Bookkeeper	3313 – Accounting associate professionals	3	7
Property valuer	3315 – Valuers and loss assessors	3	7
Doctor	2211 – Generalist medical practitioners	2	8
Mechanical engineer	2144 – Mechanical engineers	2	8

The majority of paternal parents, whose occupations were known, were reported as professionals (n = 34) and managers (n = 21). However, there was a relatively high number of responses coded as missing (n = 19). Categories coded as missing included where the participant indicated that they did not have a paternal parent (n = 8), and where the occupation was unknown by the participant (n = 2), not applicable (n = 3), or unclear (n = 6). For example, responses were coded as unclear when they simply stated "businessman" with no other information. Due to the latter, it is highly recommended that future studies consider providing a list of occupations from which participants can select, as this may assist in clarity when coding. Two respondents indicated that their paternal parent was retired and they were thus coded as not economically active.

Similarly, most maternal parents were reported as professionals (*n* = 32), with the next highest being technicians and associate professionals (*n* = 22). There were, however, also many cases where the responses were unclear (*n* = 9), which were coded as missing. Responses were also coded as missing where the participant did not have a maternal parent (*n* = 1), the occupation was unknown by the participant (*n* = 1), or was not applicable (*n* = 1). There was a high number of responses coded as not economically active, where participants indicated that their maternal parent was a housewife or stay-at-home mother (*n* =14), retired (*n* = 1), or unable to work due to disability (*n* = 3).

Parental education and occupation were used to calculate an SES composite score (§ 4.8.1). Eight participants were excluded from this analysis, as either both parents' education level or both parents' occupation was unknown. One participant was also excluded because both parents were retired. The descriptive statistics of the SES composite score are provided in Table 14, and showed a mean of 48.77 (*SD* = 15.59). Due to the way the SES composite score was calculated, based on reported parental education level and occupation, there were two cases where it was zero. Here the participants indicated that both of their parental figures had no education and were also both unemployed. For ease of reading, skewness, kurtosis, and tests of normality for SES composite score are discussed in the next section, together with the other scale variables.

Table 14

Participants' profile regarding socioeconomic status composite score

	n	Min.	Max.	Mean	SD	Skew	Kurtosis
SES	127	0.00	65.00	48.77	15.59	-1.46	1.31

5.2.2. Psychometric profile of the sample

The analysis results presented in this section aim to answer the **first research question**. This question asked what the profiles of the student participants are on psychometric measures of:

a. English academic reading ability as measured by the TALL; and
b. WM.

Table 16 presents the descriptive data of the participants' age, SES, TALL test score, WMC tests' scores and composite WMC score. Participants' TALL test scores had a mean of 68.2%, with a standard deviation of 19.59. Although slightly higher, this is largely commensurate with what has been achieved in previous studies with South African first-year students (van der Slik & Weideman, 2007). For example, it is roughly similar to that of first-year students from the University of Pretoria tested in 2007 (UP: *M* = 61.11, *SD* = 20.59), Stellenbosch University (SU: *M* = 64.98, *SD* = 20.59), and North-West University (NWU: *M* = 50.44, *SD* = 20.59) (van der Slik & Weideman, 2009). In addition, student participants from UP achieved an average of 55.25% with a standard deviation of 10.54 in the study by Le et al. (2011) (*M* = 55.25, *SD* = 10.54).

The participants performed slightly lower on the RSPAN (*M* = 0.69, *SD* = 0.23) than on the OSPAN (*M* = 0.72, *SD* = 0.20), and had an average composite WMC score of 0.71 (*SD* = 0.19). These results are comparable to those of other WM studies which have used adult samples as well as the same scoring method adopted in this study. For example, see Ziegler and Smith (2017), who indicated means of 0.62 and 0.76 for similar RSPAN and OSPAN tasks, respectively. Another example is that of Kane et al. (2004), where means of 0.67 and 0.65 were attained for these two tasks respectively in a randomised student sample. The average academic achievement of the sample was 75% (*SD* = 11.29), which is considered higher than average.

The overall institution average marks across exam sittings by year is provided in Table 15 (A. Fynn, personal communication, June 27, 2022). This data shows that the average academic achievement of the sample in the current study was approximately 10% higher than the overall Unisa average marks across exam sittings.

Table 15

Overall institution average marks across exam sittings by year

Year	Average marks (%)
2018	65
2019	67
2020	65
2021	64

Regarding skewness and kurtosis[13], both the composite SES variable and academic achievement were skewed and had positive kurtosis. This preliminary analysis did not suggest skewness or kurtosis for the other variables in Table 16 as their values were not greater than +1.0 or less than -1.0 (Osborne, 2010).

Table 16

Descriptive statistics regarding study variables

	n	Min.	Max.	Mean	SD	Skew	Kurtosis
Age	136	18	55	24.29	6.81	-	-
SES	127	0.00	65.00	48.77	15.59	-1.46	1.31
TALL	136	16.00	100.00	68.20	19.57	-0.66	-0.51
RSPAN	136	0.00	1.00	0.69	0.23	-0.87	0.16
OSPAN	136	0.04	1.00	0.72	0.20	-0.86	0.64
WMC	136	0.02	0.99	0.71	0.19	-0.73	-0.06
Achievement	136	13.50	93.30	74.58	11.29	-1.50	6.10

[13] Skewness refers to the shape of the data distribution, that is, its symmetry to the left and right of the centre point, while kurtosis measures the peakedness (Mishra et al., 2019).

Skewness was further evaluated using the Shapiro-Wilk's W test (S-W; parametric) with the significance level set at α = .05. The S-W relies on the correlation between the data and the corresponding normal scores. This normality test has been shown to provide better power than the Kolmogorov-Smirnov test, even after applying the Lilliefors correction to the latter (Ghasemi & Zahediasl, 2012; Mohd Razali & Bee Wah, 2011). The results of the S-W were significant for all variables (Table 17). It is, however, important to also visually examine the data. The central limit theorem notes that when the sample size is sufficient (> 30 or 40) the *sampling distribution* tends to be normal, regardless of the shape of the *sample distribution* (Field, 2018; Ghasemi & Zahediasl, 2012). For null hypothesis significance testing, which will be used in the current study, it is the *sampling distribution* of what is being tested which must be normal, rather than the data distribution (Field, 2018, p. 325). This study has a sample size of 136 participants, which is considered 'big enough' to ensure a normal sampling distribution if variables meet the central limit theorem argument: (a) there was little skew and kurtosis, and (b) graphical representations indicated that outliers were rare (Field, 2018). An additional point by Field (2018) is that as sample sizes become larger, a test of normality is more likely to be significant and should not be a concern. Thus, as tests of normality are considered supplementary to graphical evaluations of normality (Ghasemi & Zahediasl, 2012), the relevant histogram graphs, boxplots, normal quantile-quantile (Q-Q) plots, and detrended normal Q-Q plots were examined.

Table 17

Results of the Shapiro-Wilk test of normality for continuous variables

	Shapiro-Wilk		
	Statistic	df	Sig.
SES	0.80	127	.00
TALL	0.93	127	.00
RSPAN	0.92	127	.00
OSPAN	0.94	127	.00
WMC	0.94	127	.00
Achievement	0.90	127	.00

Figure 16–Figure ***19*** show the histogram, boxplot, normal Q-Q plot, and the detrended normal Q-Q plot for the SES score variable. The histogram was left-skewed, as signalled in the previous analysis by a skew of -1.46 (Table 16). The boxplot shows a longer bottom tail, there are several outliers, and the median is off-centre. The normal Q-Q plot shows that the majority of the observed SES scores are in line with what we would expect to see if the dataset is normally distributed. The detrended normal Q-Q plot shows how strong the existing deviations from normality are: the y-axis of the plot shows that the deviations range from -1.0 to just over 0.4. There is no obvious trend to the deviations. Visual inspection of these four graphs for the SES score suggests non-normality. In addition, skewness was indicated in the previous analysis (Table 16). Data that is not normally distributed is analysed using non-parametric rather than parametric tests (Mishra et al., 2019). The results of both numerical and graphical examination of the variable thus indicate that the appropriate method for inferential statistical analysis using the SES score variable are non-parametric tests.

Figure 16:

Histogram presenting distribution pattern of SES composite scores

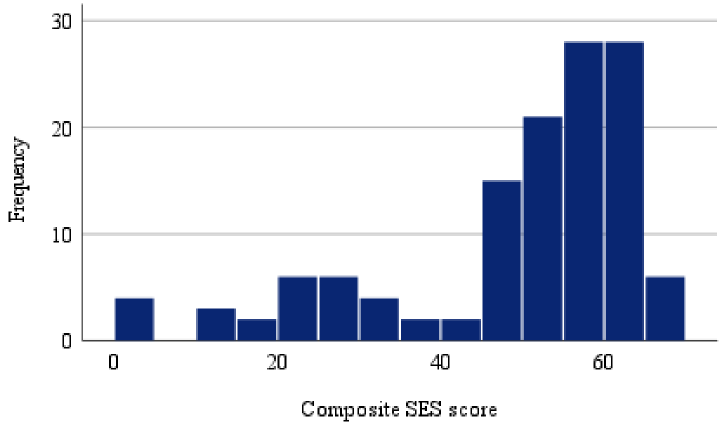


Figure 17:

Normal Q-Q plot for SES composite scores

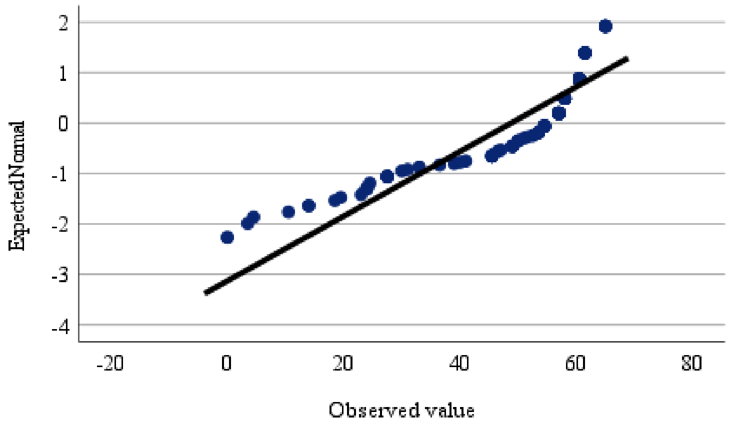


Figure 18:

Boxplot presenting the interquartile range and minimum and maximum values for SES composite scores

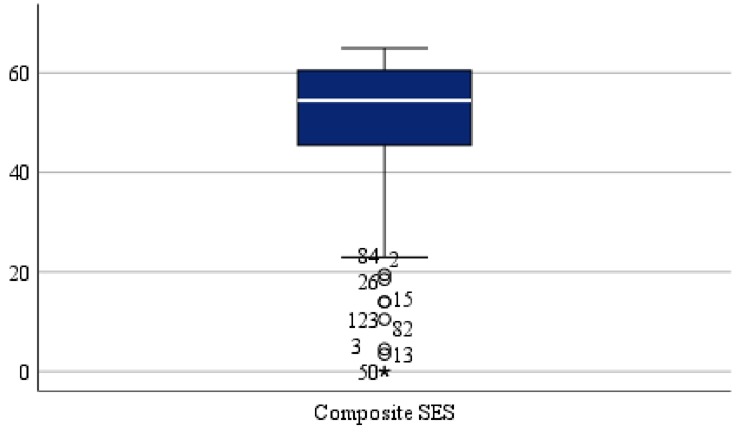


Figure 19:

Detrended Q-Q plot for SES composite scores

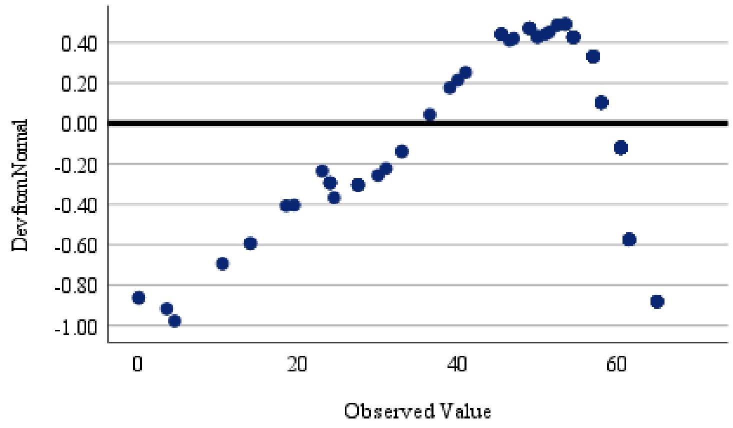


Figure 20–Figure ***23*** show the histogram, boxplot, normal Q-Q plot, and the detrended normal Q-Q plot for the TALL score variable. The histogram had a slightly left-skewed distribution. The boxplot shows a slightly longer bottom tail, but there are no outliers. The median is off-centre. The normal Q-Q plot shows that almost all of the observed TALL score values are the same as what we would expect if this data was normally distributed. The y-axis of the detrended normal Q-Q plot shows that the deviations from normality range from -1.0 to just over 0.25. There is no obvious trend to the deviations. Visual inspection of the four graphs suggests slight non-normality, but skewness and kurtosis were not suggested (Table 16). The results of graphical examination of the TALL score variable suggest that the data could violate the normality assumption of parametric tests, despite skewness and kurtosis not being indicated numerically. Thus, non-parametric tests are considered more appropriate.

Figure 20:

Histogram presenting distribution pattern of TALL scores

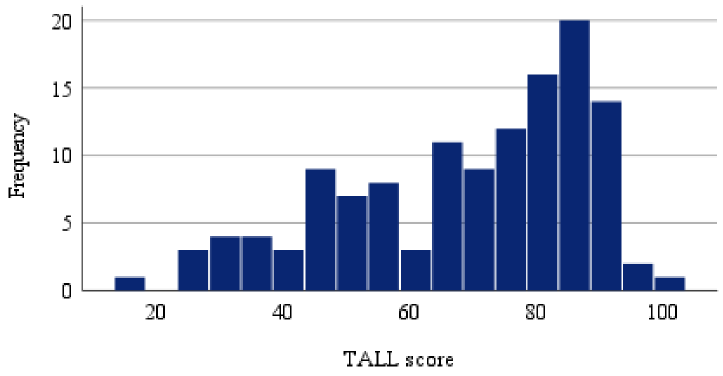


Figure 21:

Normal Q-Q plot for TALL scores

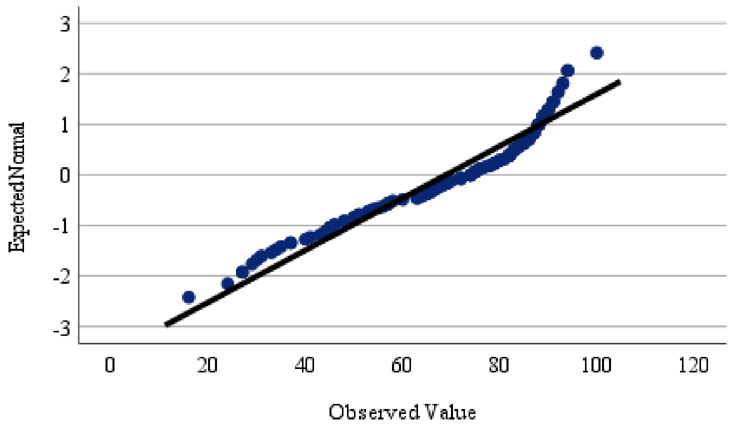


Figure 22:

Boxplot presenting the interquartile range and minimum and maximum values for TALL scores

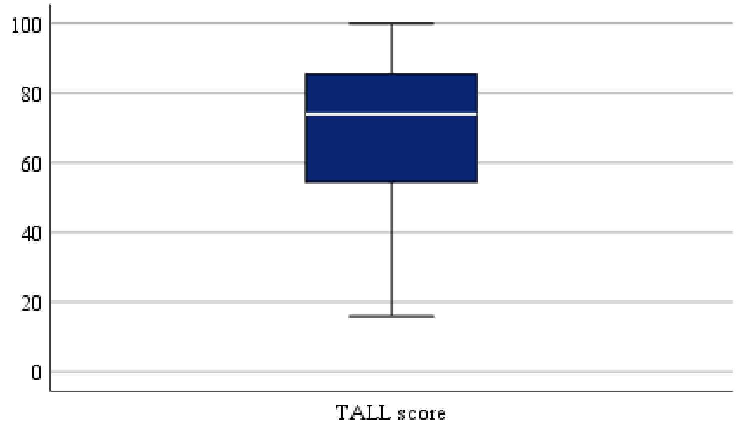
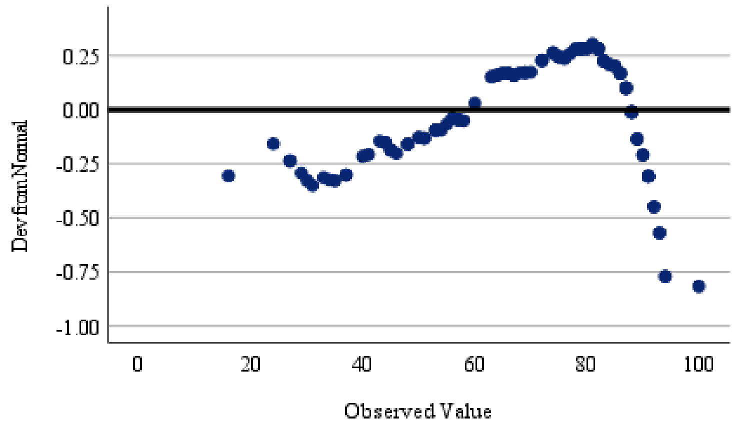


Figure 23:

Detrended Q-Q plot for TALL scores



The RSPAN and OSPAN variables showed graphs that were similar to each other and are thus discussed together (Figure 24–Figure ***31***). The histograms were slightly left-skewed. The boxplots showed slightly longer bottom tails and there were several outliers. The medians were marginally off-centre. The normal Q-Q plots showed that almost all of the observed RSPAN and OSPAN score values are the same as what would be expected if this data was normally distributed. The y-axis of the detrended normal Q-Q plot for RSPAN scores shows that the deviations from normality range from -1.0 to just over 0.25. The range for OSPAN scores was wider and was from just under -1.2 to a little over 0.2. However, there is no obvious trend to the deviations. Visual inspection of the graphs for RSPAN and OSPAN scores suggested slight non-normality. However, the RSPAN and OSPAN did not exhibit values suggesting skewness or kurtosis (Table 16). The results of graphical examination of these two variables suggest that the data could violate the normality assumption of parametric tests, despite skewness and kurtosis not being indicated numerically. Thus, non-parametric tests are considered more appropriate.

Figure 24:

Histogram presenting distribution pattern of RSPAN scores

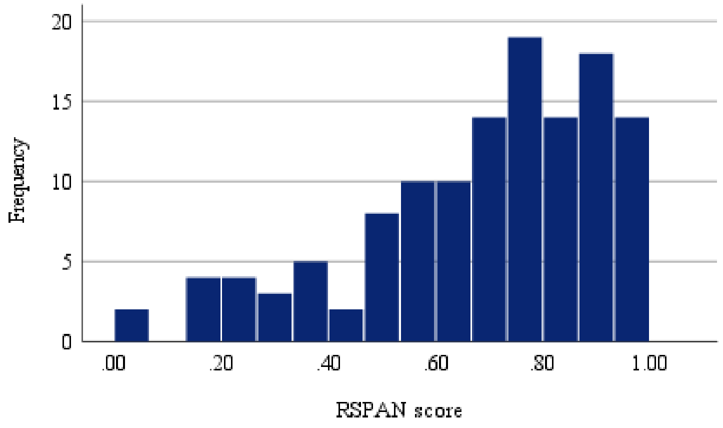


Figure 25:

Normal Q-Q plot for RSPAN scores

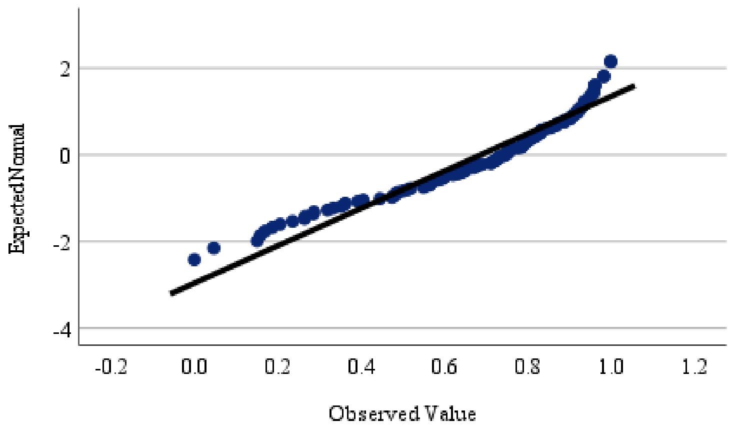


Figure 26:

Boxplot presenting the interquartile range and minimum and maximum values for RSPAN scores

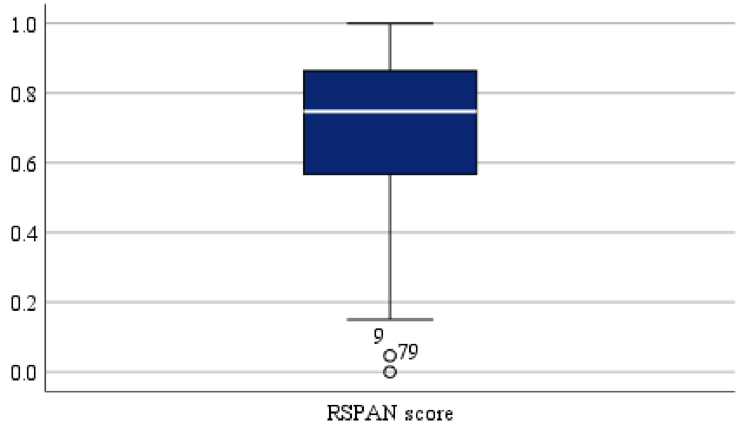


Figure 27:

Detrended Q-Q plot for RSPAN scores

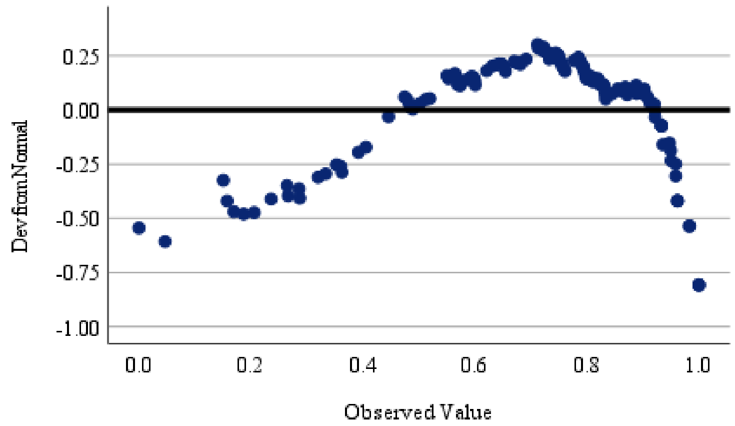


Figure 28:

Histogram presenting distribution pattern of OSPAN scores

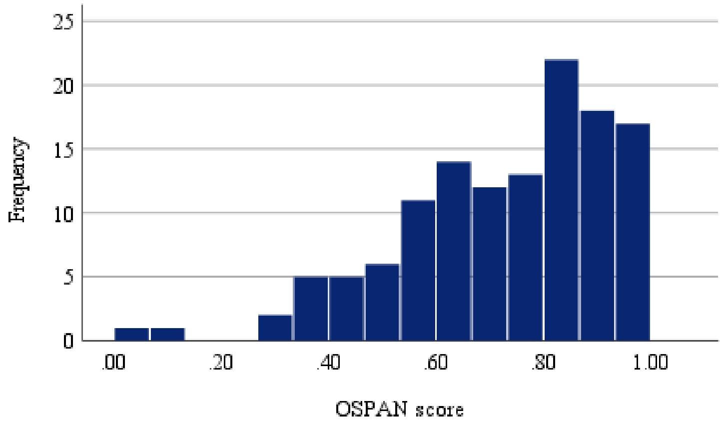


Figure 29:

Normal Q-Q plot for OSPAN scores

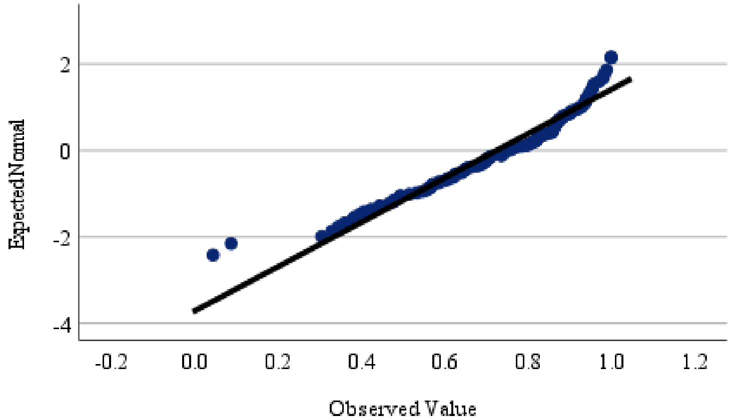


Figure 30:

Boxplot presenting the interquartile range and minimum and maximum values for OSPAN scores

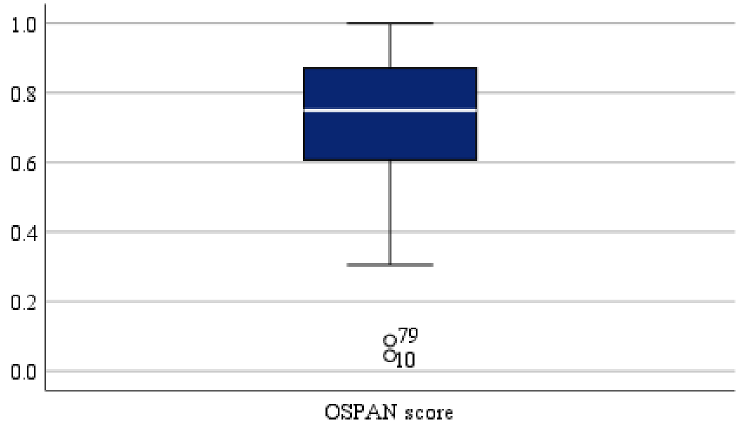


Figure 31:

Detrended Q-Q plot for OSPAN scores

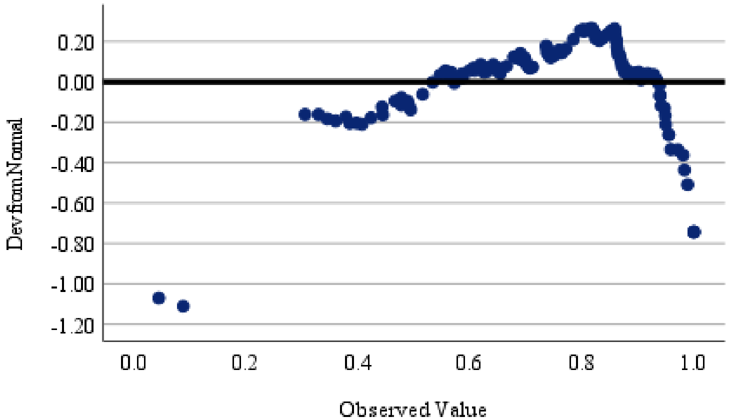


Figure 32–Figure ***35*** provide the graphical evaluations of normality for the WMC scores variable. The histogram was reasonably normally distributed but there was slight left-skew. The boxplot had a slightly longer bottom tail and there was one outlier. The median was off-centre. Appraisal of the normal Q-Q plot showed that the majority of WMC score values are the same as what would be expected if this data was normally distributed. The deviations from normality, shown in the detrended normal Q-Q plot, range from just under -1.0 to a little over 0.2 and do not exhibit an obvious trend. Non-normality is thus suggested from the graphs, but the WMC score did not exhibit values suggesting skewness or kurtosis (Table 16). The results of graphical examination of the WMC score variable suggest that the data could violate the normality assumption of parametric tests, despite skewness and kurtosis not being indicated numerically. Thus, non-parametric tests are considered more appropriate for inferential statistical analysis.

Figure 32:

Histogram presenting distribution pattern of WMC scores

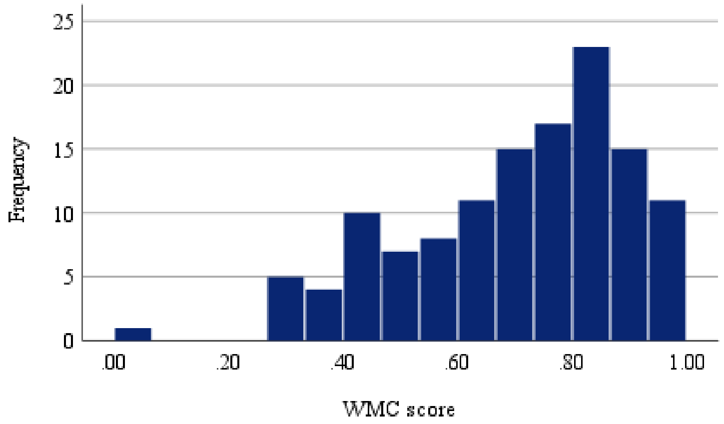


Figure 33:

Normal Q-Q plot for WMC scores

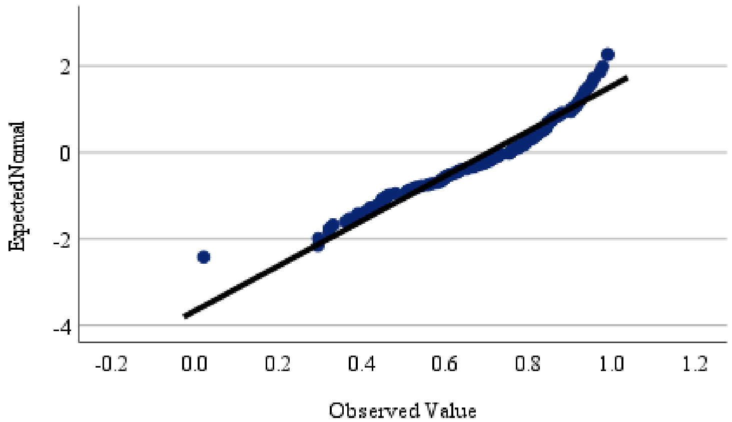


Figure 34:

Boxplot presenting the interquartile range and minimum and maximum values for WMC scores

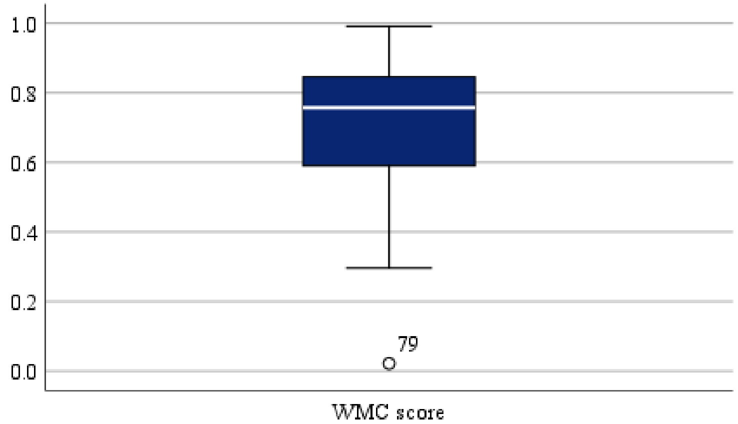
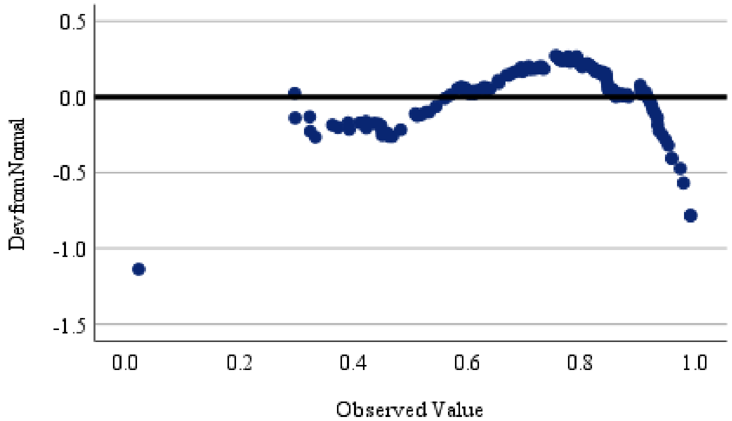


Figure 35:

Detrended Q-Q plot for WMC scores



Figures 36–39 relate to graphical evaluations of normality for the academic achievement variable. The histogram was left-skewed, in accordance with a skew of -1.50, and was leptokurtic (Table 16). The boxplot for academic achievement had a slightly longer bottom tail, exhibited two outliers, but had a central median. The normal Q-Q plot was largely what would be expected were the data normally distributed, while the detrended normal Q-Q plot showed that the deviations from normality range from -3.0 to just over 0.0 without an obvious trend. Visual inspection of the four graphs together with the skewness and kurtosis values suggests non-normality (Table 16). The results of both numerical and graphical examination of the variable thus indicate that the appropriate method for inferential statistical analysis using the academic achievement variable is non-parametric tests.

Figure 36:

Histogram presenting distribution pattern of average achievement

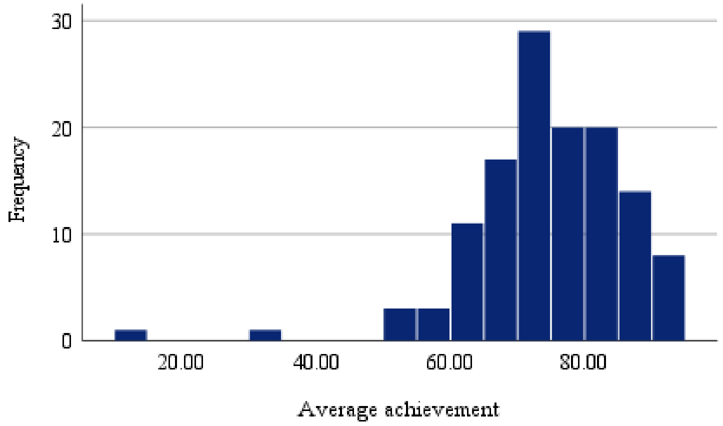


Figure 37:

Normal Q-Q plot for average achievement

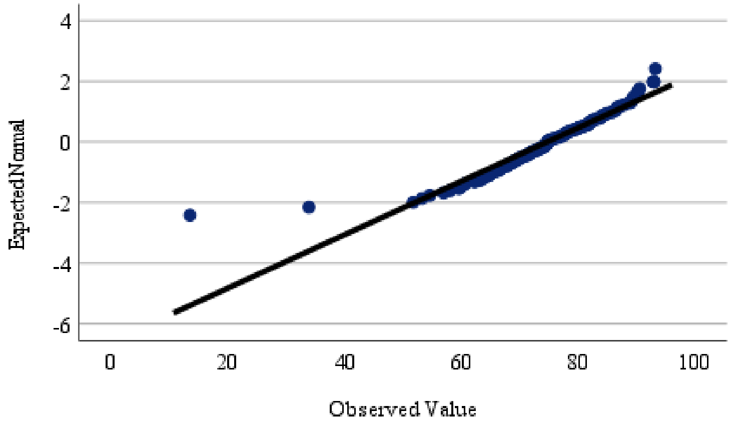


Figure 38:

Boxplot presenting the interquartile range and minimum and maximum values for average achievement

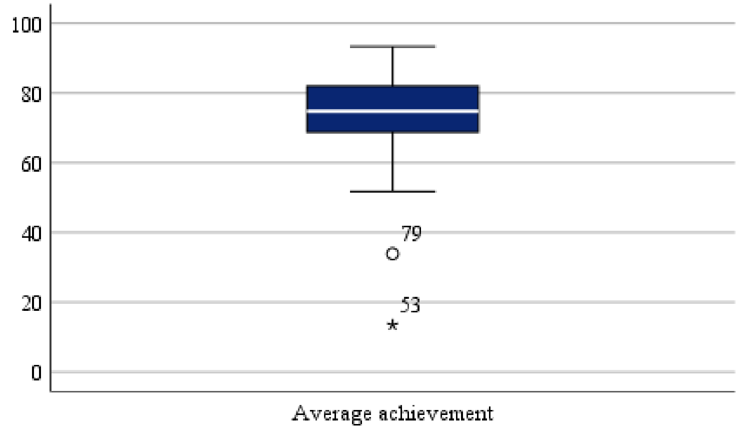
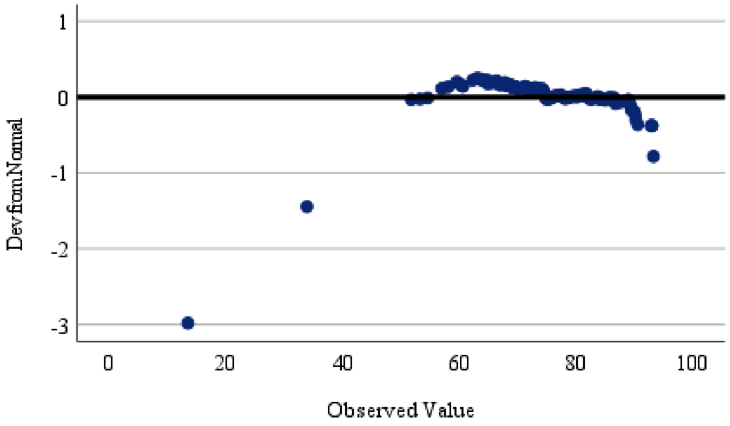


Figure 39:

Detrended Q-Q plot for average achievement



In sum, the composite SES score, TALL score, RSPAN, OSPAN, WMC, and academic achievement variables were considered to be non-normally distributed. In addition to significant results on the S-W test for most of the variables, their graphs suggested non-normality and there were several outliers. As the variables were not normally distributed, non-parametric tests were used in further analyses. The use of non-parametric tests ensured that the correct representative value of the dataset was used for significance level calculations (*p* value), making conclusions meaningful (Mishra et al., 2019).

Finally, Table 18 and Table **19** present the descriptive data of each of the six TALL section scores. The average achievement for the sections ranged between 53% and 82%. The lowest average score was for Section 1, which presented a scrambled paragraph which participants then had to organise into the correct order. This section furthermore had the highest variation, as shown by a standard deviation of 34.06. Section 2 had the highest average score. This section asked participants to interpret graphs and visual information, such as a diagram, to demonstrate their quantitative literacy ability. Skewness was indicated for Sections 2, 4, and 6, while the scores for Sections 1, 2, and 4 showed slight kurtosis during analysis.

Table 18

Average achievement and standard deviation for the TALL test and its sections

Test section	Total test	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
No. of items	64	5	5	24	9	5	16
Average test score (%)	68.20	52.65	81.62	62.13	79.09	74.12	74.13
Standard deviation	19.57	34.06	24.95	22.69	20.15	33.74	27.36

Table 19

Descriptive statistics regarding the TALL test sections

	n	Min.	Max.	Mean	SE	Skew	Kurtosis
Section 1	136	0.00	100.00	52.65	34.06	0.11	-1.11
Section 2	136	0.00	100.00	81.62	24.95	-1.39	1.14
Section 3	136	7.84	100.00	62.13	22.69	-0.49	-0.64
Section 4	136	11.11	100.00	79.09	20.15	-1.19	1.06
Section 5	136	0.00	100.00	74.12	33.74	-0.91	-0.58
Section 6	136	0.00	100.00	74.13	27.36	-1.02	0.02

Skewness was further evaluated using the S-W test with the significance level set at $\alpha = .05$. The results of the S-W test were significant for all variables (Table 20). Further evaluation of the graphical representations (Figure 40–Figure ***63***) indicated that the histogram for Section 1 scores appeared platykurtic (flat), while those for the scores for Sections 2, 4, 5, and 6 had left-skewed distributions. The histogram for Section 3 appeared normally distributed. The boxplots for all sections had off-centre medians with longer bottom tails, although this was less visible for Section 3 scores. Furthermore, Sections 2 and 4 had outliers. Given these results and the small number of items for each of these sections, Sections 1, 2, 4, 5, and 6 are considered non-normally distributed. The third section is normally distributed, as a significant S-W test on its own is insufficient evidence of non-normality. However, non-parametric tests were used in further analyses as the majority of variables were non-normally distributed.

Table 20

Results of the Shapiro-Wilk test of normality for each of the TALL test sections

	Shapiro-Wilk		
	Statistic	df	Sig.
Section 1	0.88	136	.00
Section 2	0.75	136	.00
Section 3	0.96	136	.00
Section 4	0.86	136	.00
Section 5	0.74	136	.00
Section 6	0.85	136	.00

Figure 40:

Histogram presenting distribution pattern of Section 1 scores

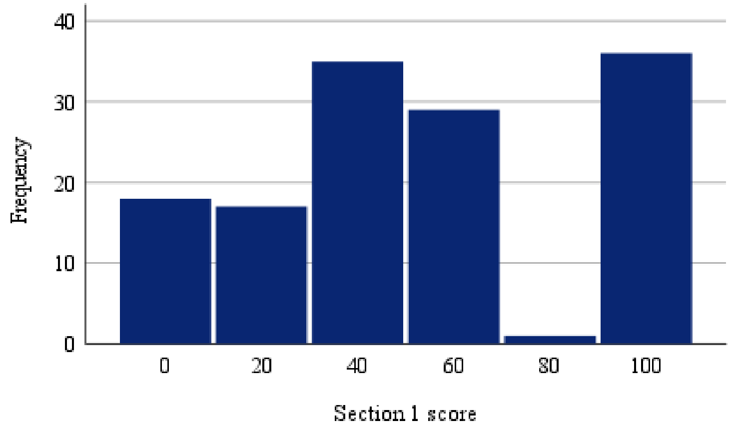


Figure 41:

Normal Q-Q plot for Section 1 scores

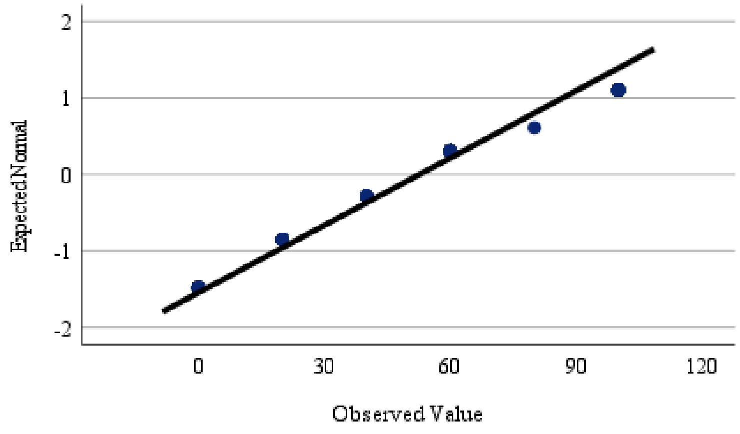


Figure 42:

Boxplot presenting the interquartile range and minimum and maximum values for Section 1 scores

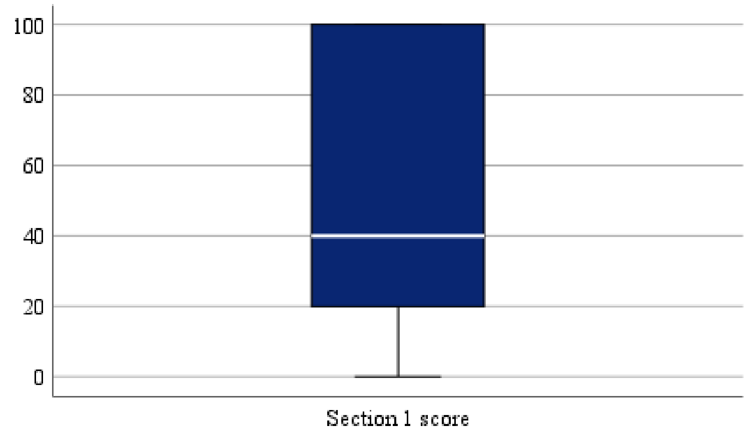


Figure 43:

Detrended Q-Q plot for Section 1 scores

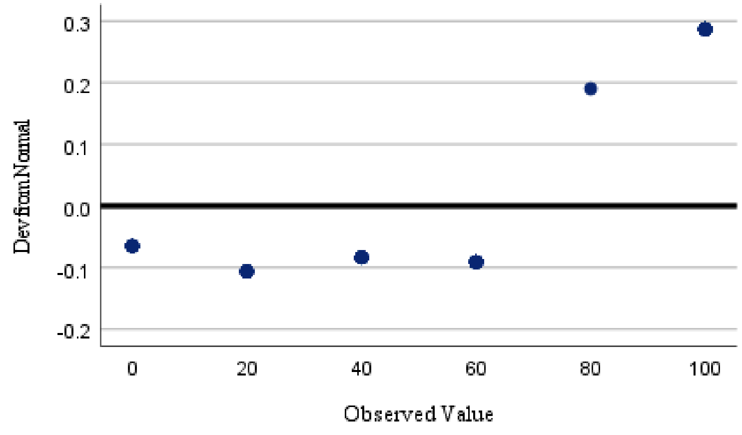


Figure 44:

Histogram presenting distribution pattern of Section 2 scores

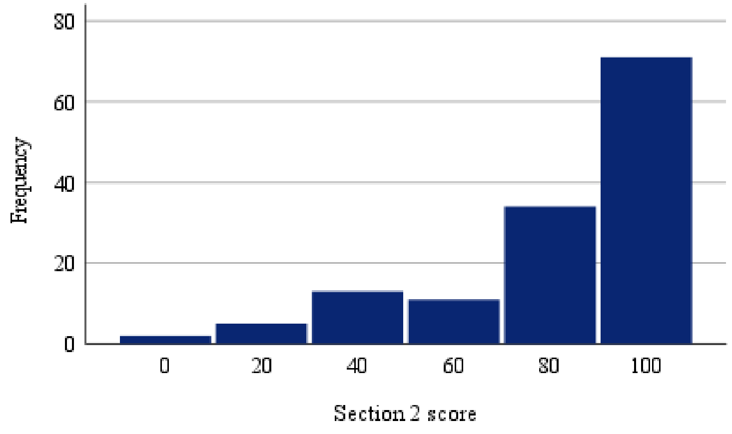


Figure 45:

Normal Q-Q plot for Section 2 scores

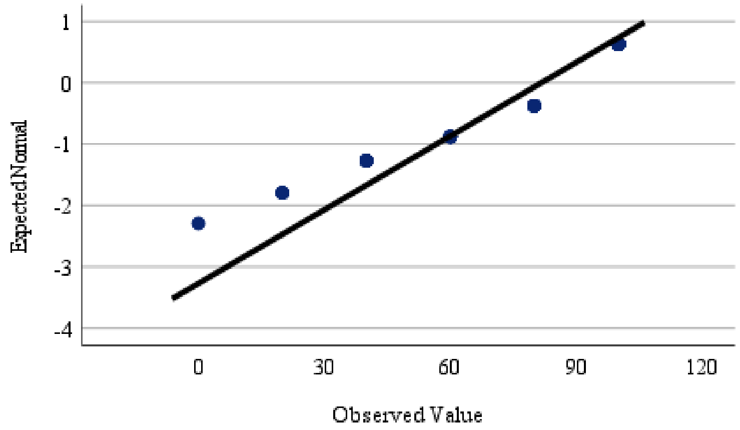


Figure 46:

Boxplot presenting the interquartile range and minimum and maximum values for Section 2 scores

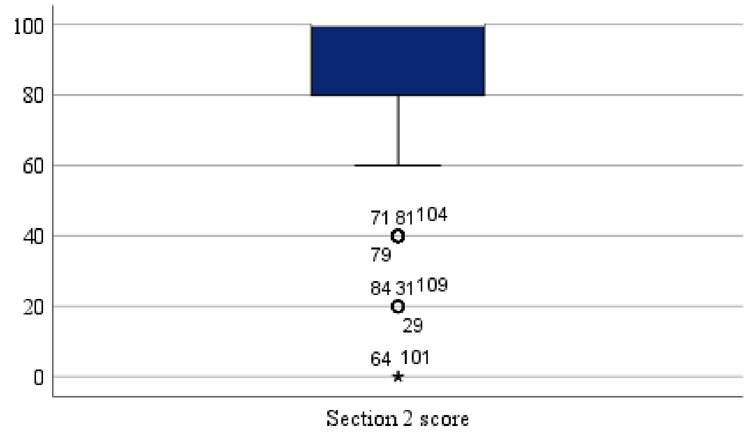


Figure 47:

Detrended Q-Q plot for Section 2 scores

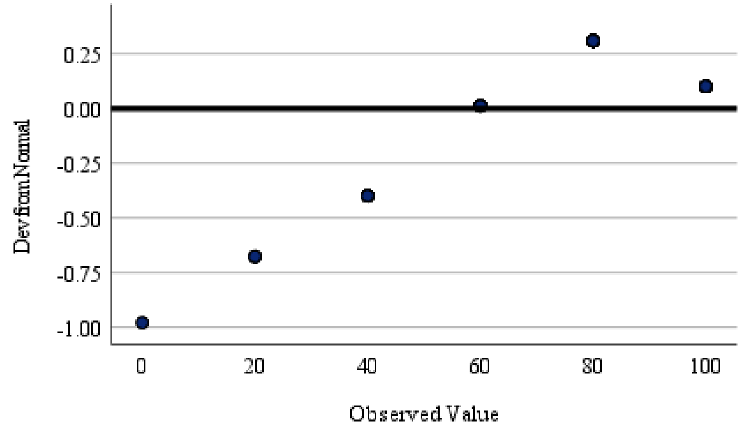


Figure 48:

Histogram presenting distribution pattern of Section 3 scores

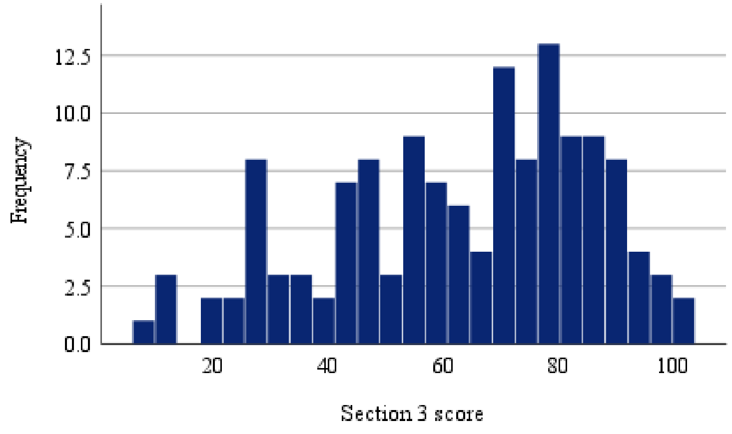


Figure 49:

Normal Q-Q plot for Section 3 scores

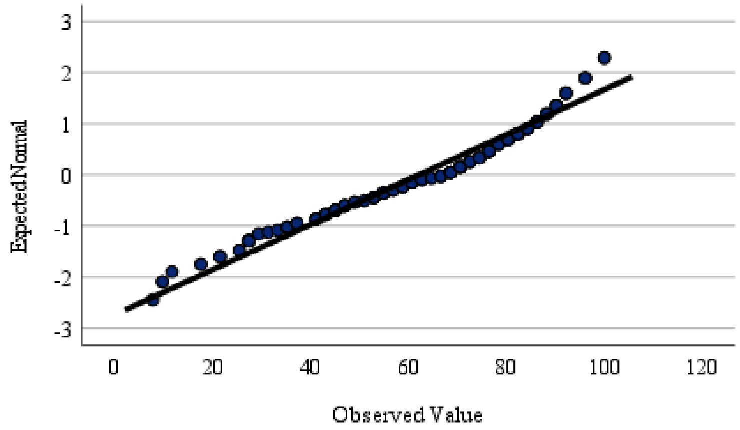


Figure 50:

Boxplot presenting the interquartile range and minimum and maximum values for Section 3 scores

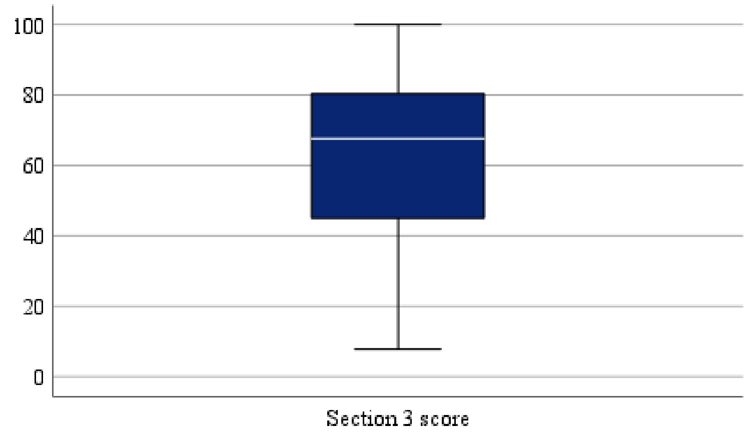


Figure 51:

Detrended Q-Q plot for Section 3 scores

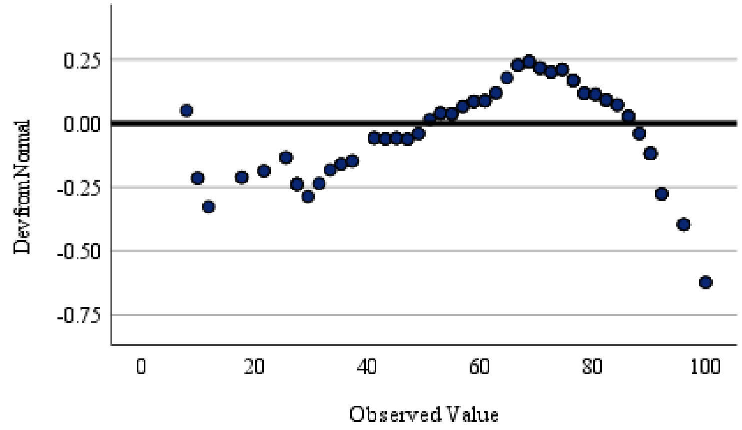


Figure 52:

Histogram presenting distribution pattern of Section 4 scores

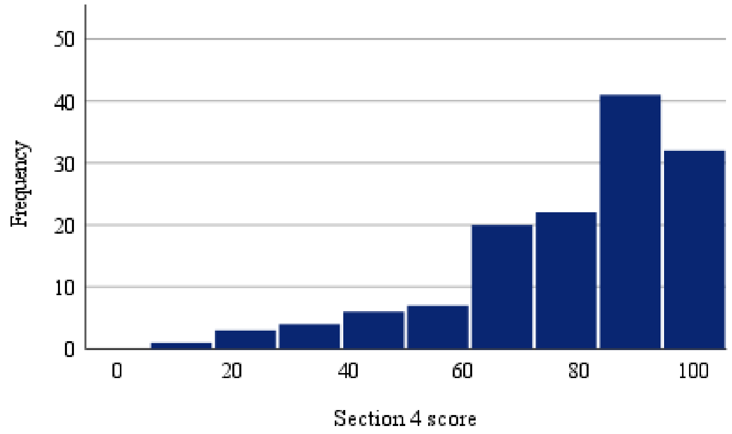


Figure 53:

Normal Q-Q plot for Section 4 scores

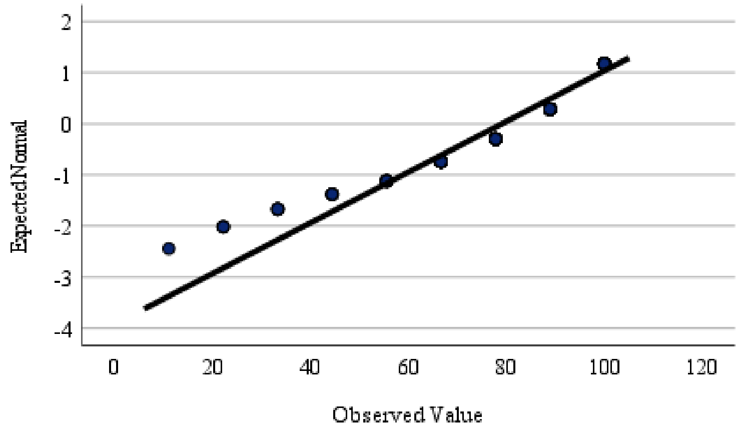


Figure 54:

Boxplot presenting the interquartile range and minimum and maximum values for Section 4 scores

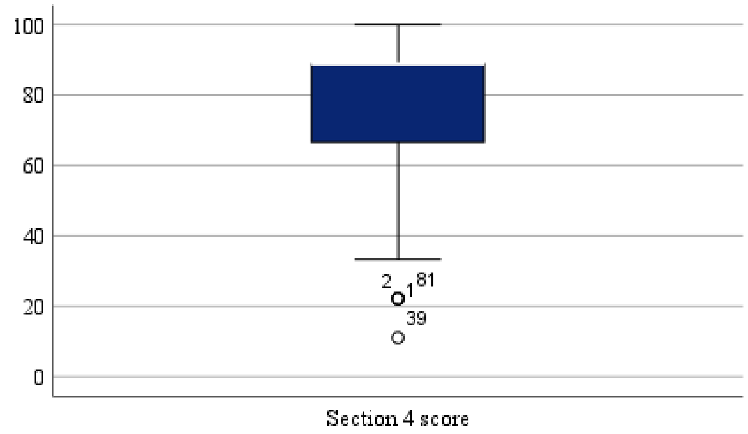


Figure 55:

Detrended Q-Q plot for Section 4 scores

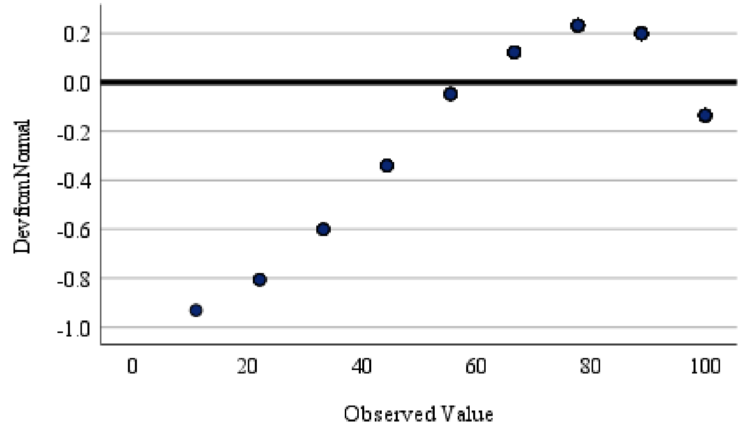


Figure 56:

Histogram presenting distribution pattern of Section 5 scores

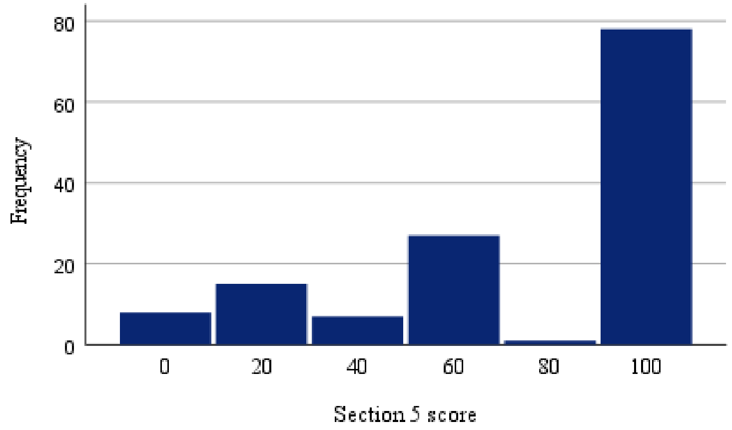


Figure 57:

Normal Q-Q plot for Section 5 scores

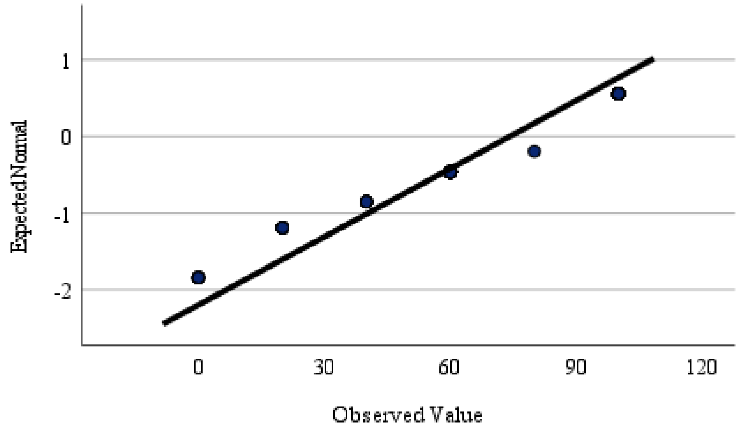


Figure 58:

Boxplot presenting the interquartile range and minimum and maximum values for Section 5 scores

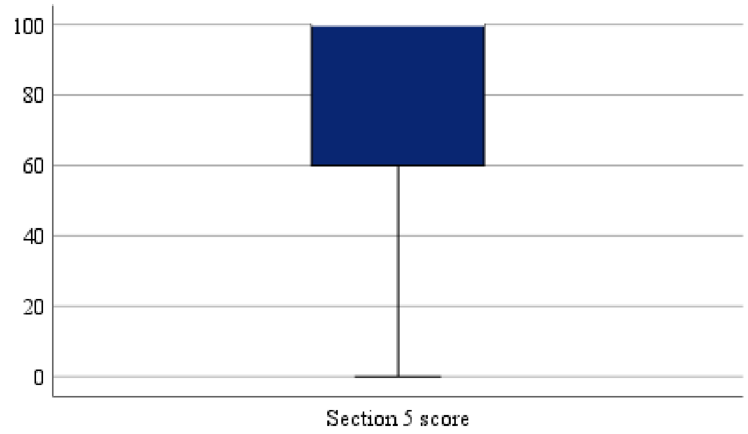


Figure 59:

Detrended Q-Q plot for Section 5 scores

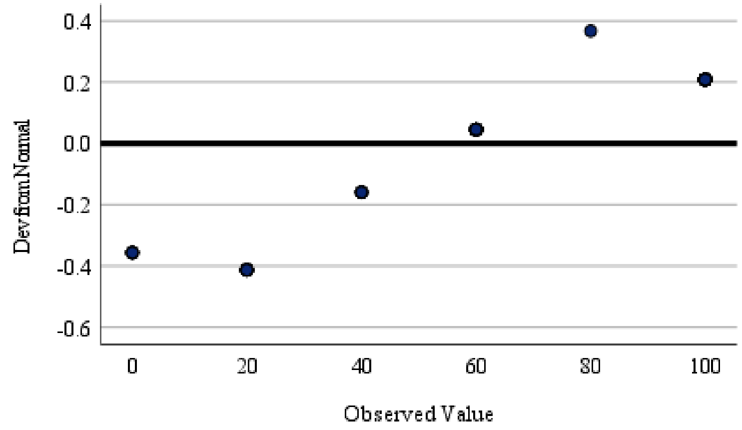


Figure 60:

Histogram presenting distribution pattern of Section 6 scores

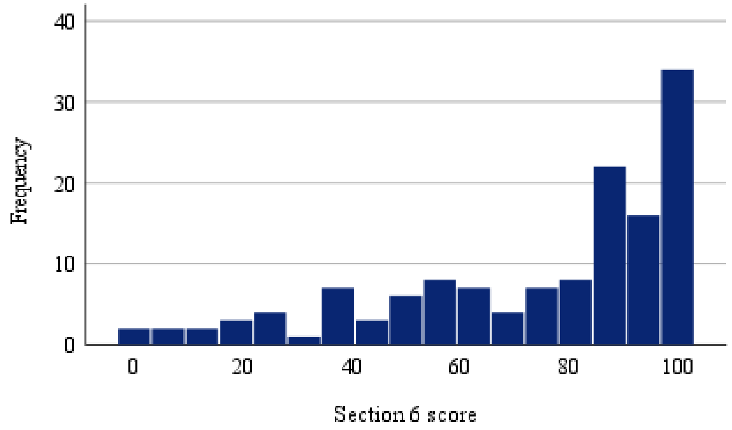


Figure 61:

Normal Q-Q plot for Section 6 scores

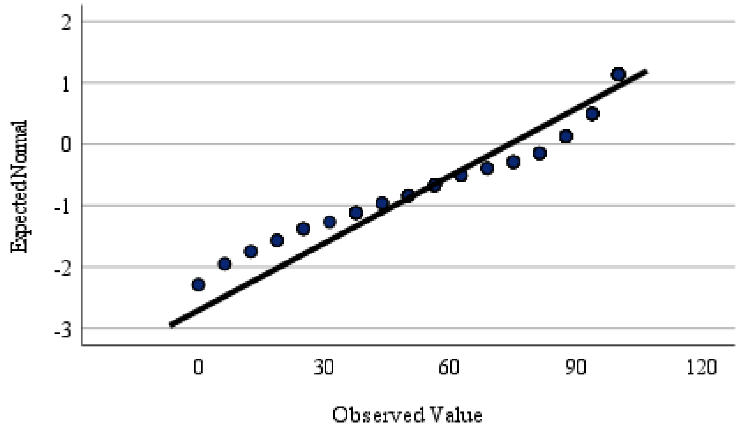


Figure 62:

Boxplot presenting the interquartile range and minimum and maximum values for Section 6 scores

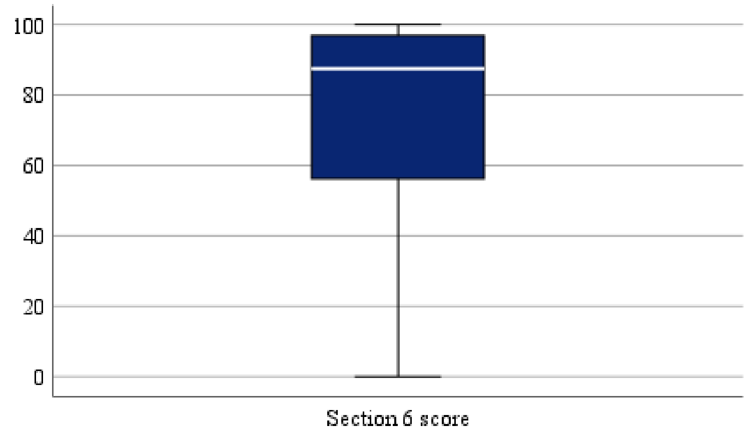
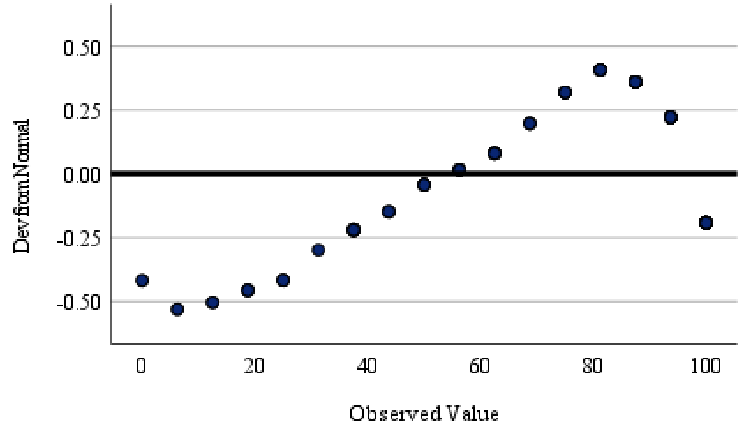


Figure 63:

Detrended Q-Q plot for Section 6 scores



5.2.3. TALL, RSPAN, and OSPAN internal consistency reliability

The internal reliabilities of TALL scores and WMC tests scores were calculated. For these calculations, the total number of participants who completed each test was used. This meant that data from 150, 289, and 367 participants was used for the TALL, the RSPAN, and the OSPAN internal consistency reliability calculations, respectively. These participant numbers can be calculated from the reasons for exclusion in the previous chapter (§ 4.5.3). Internal consistency reliability refers to the internal consistency of the instrument or the degree to which the instrument items behave in the same way (Creswell & Creswell, 2018). Internal consistency reliability is quantified here as the Cronbach's alpha (α) value, which is considered the most conservative reliability test (Creswell & Creswell, 2018; Le et al., 2011). This value ranges between 0 and 1, with optimal values falling between .70 and .90 (Creswell & Creswell, 2018).

A Cronbach's alpha of .94 was calculated for the total TALL test, which is an excellent value and similar to what has been achieved in other studies (van Dyk, 2005; Weideman, 2006). This value signifies that the TALL items behave the same. Regarding its different sections, internal consistency reliability for the six sections of the TALL test ranged between .69 and .91 (Table 21), and all but one of the sections had alpha values above the lower bound of optimum values (.70). Section 4 of the TALL had an alpha value of .69, which is not ideal, but this value is still considered acceptable. Overall, the TALL test showed adequate internal consistency reliability.

Table 21

Cronbach's alpha for the TALL test and its sections

Test section	Total test	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
No. of items	64	5	5	24	9	5	16
Cronbach's alpha	.94	.73	.72	.86	.69	.84	.91

To assess the internal consistency of each complex span task, Cronbach's alpha was calculated using performance on all 15 trials (Bailey, 2012). The RSPAN and the OSPAN indicated Cronbach's alpha values of .93 and .86, respectively. Both the RSPAN and the OSPAN showed good internal consistency, indicating that all sets contributed to the individual scores to an equal extent. These values were also similar to those found in the majority of previous studies. For example, Kane et al. (2004) recorded .78 and .80 for the RSPAN and OSPAN, respectively, while Bailey (2012) noted .89 and .93 for the RSPAN and OSPAN, respectively. However, the study by Friedman and Miyake (2005) showed lower alpha values for RSPAN when using three trials per set and proportion scoring: .65 at the first session and .68 at the second session. All tasks used in the current study thus had acceptable internal consistencies.

5.2.4. TALL item analysis

In addition to evaluating its internal consistency reliability, an item analysis was performed on the TALL test scores to investigate: (a) the difficulty of each item, and (b) the ability of each item to distinguish between weaker and stronger participants. Under the classic test theory framework the item difficulty index reflects the proportion of participants who provided the correct answer to an item (Boateng et al., 2018; De Champlain, 2010). The proportion or *P*-value ranges between 0.0 and 1.0, with a lower number indicating more difficult items as fewer participants provided the correct response (Boateng et al., 2018; De Champlain, 2010). An acceptable value falls between 0.2 and 0.9 and is often converted into a percentage (Quaigrain & Arhin, 2017). The *P*-values for this study were calculated using MS Excel. As expected, in the current study the *P*-value showed a broad range of values and is acceptable: 0.27–0.97.

When you multiply the *P*-value by 100 this number is converted to a percentage, which indicates the number of participants who answered the item correctly. Items with a *P*-value between 40% and 60% are considered ideal, as the DI, discussed below, is at its maximum in this range. Thirteen items out of the total 64 were within the ideal range. Values less than 20% (too difficult) or greater than 90% (too simple) require modification (Quaigrain & Arhin, 2017). None of the items were below 20%, as the minimum was 27%, and only four items were above 90%, indicating that they may be too easy and could be revised if necessary. It is noted, however, that the *P*-value is a behavioural measure of the participants' performance rather than an intrinsic property of the item itself (Quaigrain & Arhin, 2017). It is only relative to the performance of the sample that these four items are considered easy. It is possible that this is related to the bias of the sample, who were largely L1 English and high academic achievers. Further exploration in a more diverse sample is recommended.

The ability of the items to discriminate between lower and higher performers was also calculated. For this calculation, it is expected that a higher proportion of the higher-ability participants would correctly answer a particular item (De Champlain, 2010). A common item DI is the point-biserial coefficient which is calculated through correlational analysis between the response on a test item (0 or 1) and a criterion measure, typically the total test score (Boateng et al., 2018; De Champlain, 2010). The point-biserial correlation (ρ_{PBis}) between each item X_j and the total test score Y is as follows:

$$\rho_{\mathrm{PBis}} = \frac{\mu_{+} - \mu_{Y}}{\sigma_{Y}} \sqrt{\frac{p_j}{(1 - p_j)}}$$

In this equation, μ_{+} is the mean test score of the participants who answered the *j*th item correctly, μ_Y is the mean test score for the entire sample with σ_Y as its standard deviation, and

p_j is the item difficulty (Bazaldua et al., 2017). Classification of the discriminating indices was as follows:

a. DI ≥ 0.40: the item is functioning acceptably.

b. 0.30 ≤ DI ≤ 0.39: the item requires little or no revision.

c. 0.20 ≤ DI ≤ 0.29: the item requires revision.

d. DI ≤ 0.19: the item should be removed or completely revised (Quaigrain & Arhin, 2017).

The analysis output indicated a broad range, with correlations ranging between 0.19 and 0.66. There were no items which indicated a negative correlation, which would mean that participants who achieved lower scores were better able to answer the item than participants who achieved higher scores overall. Forty-six of the items were above 0.40 and a further 11 were between 0.30 and 0.39, indicating that these items did not require revision. Six[14] of the remaining items had low point-biserial values (0.20 ≤ DI ≤ 0.29), which indicates that these items were not functioning as intended (De Champlain, 2010; Quaigrain & Arhin, 2017). These items could be flagged for review in future studies. Additionally, one item's low point-biserial value of 0.19 indicated that this item requires removal or revision (De Champlain, 2010; Quaigrain & Arhin, 2017). Before doing so, however, it is important to evaluate the *P*-value of the item. Items which are too difficult or too simple often have low discriminating power, linking to the *P*-value of the item difficulty index described above, but these items are needed so as to be representative of the content being assessed and the objectives of the assessment (Quaigrain & Arhin, 2017). The *P*-value of the item was 61%, which places it just outside of

[14] The TALL is a proprietary test and the licence agreement does not allow for replication of the actual items.

the ideal range. It is thus recommended that this item also be flagged for review in future studies, rather than removed or revised at this stage.

5.3. Inferential statistics

5.3.1. Correlation analyses

This section presents the results of statistical analyses that aimed to answer the **second, third, and fourth research questions**. These questions asked whether the following variables were positively correlated to one another:

a. WMC and academic reading as measured by the TALL,
b. WMC and academic achievement, and
c. Academic reading as measured by the TALL and academic achievement.

As the majority of the variables were not normally distributed, Kendall's tau-b (τ) correlation analyses were performed to answer the second, third, and fourth research questions. Kendall's tau was developed in 1938 and is an extension of the Spearman's rho correlation (Akoglu, 2018; Kendall, 1938). Kendall's tau-b was used rather than Spearman as it is reportedly a more accurate estimate of the correlation within the population, particularly in small samples where many scores have the same rank (Akoglu, 2018; Field, 2018). It is also more resistant to outliers, which were noted in the current dataset (Mellenbergh, 2019). All correlations were one-tailed with significance set at the $\alpha = .05$ level. The strength of the correlation is interpreted as follows: (i) weak: .10 to .39; (ii) moderate: .40 to .69; and (iii) strong: .70 to .99 (Akoglu, 2018).

The RSPAN and OSPAN had a moderate and significant correlation ($\tau = .47$, $p < .001$), as indicated in Table 22, which indicates that they measure the same underlying construct and that the composite WMC score is valid for use in analyses. Regarding the **second research question,** there were significant but weak correlations between scores on the TALL and scores on the OSPAN (τ = .10, *p* = .047) and WMC (τ = .10, *p* = .050). As a high correlation between WMC and performance on another task suggests that WM is "an important target for the task" (R. G. Morrison, 2005, p. 466), these results suggest that WM is required in completing the TALL. Interestingly, there was no significant relationship between scores on the TALL and scores on the RSPAN.

In response to the **third research question**, there were also significant weak correlations between participants' academic achievement and scores on the RSPAN (τ = .16, *p* = .004), the OSPAN (τ = .13, *p* = .011), and WMC (τ = .16, *p* = .003). For the **fourth research question**, a significant, weak correlation was identified between the TALL scores and academic achievement (τ = .36, *p* < .001).

Table 22

Kendall's tau-b correlation matrix between TALL score, RSPAN, OSPAN, WMC, and academic achievement

	1	2	3	4	5
1. TALL	-				
2. RSPAN	.08	-			
3. OSPAN	.10*	.47**	-		
4. WMC	.10*	.76**	.72**	-	
5. Achievement	.36**	.16**	.13*	.16**	-

* Correlations significant at the .05 level (1-tailed).
** Correlations significant at the .01 level (1-tailed).

Kendall's tau-b correlation analyses were used to further explore the data with regard to the sections of the TALL test and thus provide more nuanced answers to the research questions. All correlations were one-tailed, with the significance level set at α = .05, and interpretation of the strength of the correlation was kept as above.

The results of the analysis are presented in Table 23, but it is noted that this table does not include the correlations between WMC test scores, the TALL score, and academic achievement, which have already been provided and discussed. Significant weak to moderate correlations were identified between all section scores of the TALL test, suggesting that they had construct validity. The largest correlation was between Sections 4 and 6 ($\tau = .47$, $p < .001$).

WMC was significantly correlated with all TALL subtest scores except the third and fifth sections. WMC showed the highest significant correlation with Section 2 scores ($\tau = .16$, $p = .007$), followed by Section 1 scores ($\tau = .14$, $p = .013$) of the TALL test, although both are weak correlations. Section 2 of the TALL test asks participants to interpret graphs and visual information, while Section 1 requires participants to organise a scrambled paragraph into the correct order. The lack of association between WMC and Section 3 was a surprising finding, as this section is the reading comprehension portion. Another interesting finding was that the RSPAN was only significantly and weakly correlated with two of the TALL sections, while the OSPAN had four significant weak associations.

Table 23

Kendall's tau-b correlation matrix between TALL section scores and RSPAN, OSPAN, WMC, and academic achievement

	1	2	3	4	5	6
1. Section 1	-					
2. Section 2	.35**	-				
3. Section 3	.25**	.41**	-			
4. Section 4	.32**	.39**	.40**	-		
5. Section 5	.23**	.30**	.36**	.37**	-	
6. Section 6	.21**	.42**	.41**	.47**	.40**	-
7. RSPAN	.10	.12*	.04	.10	.10	.12*
8. OSPAN	.15**	.18**	.05	.13*	.05	.11*
9. WMC	.14*	.16*	.06	.11*	.08	.13*
10. Achievement	.26**	.29**	.31**	.32**	.26**	.32**

* Correlations significant at the .05 level (1-tailed).

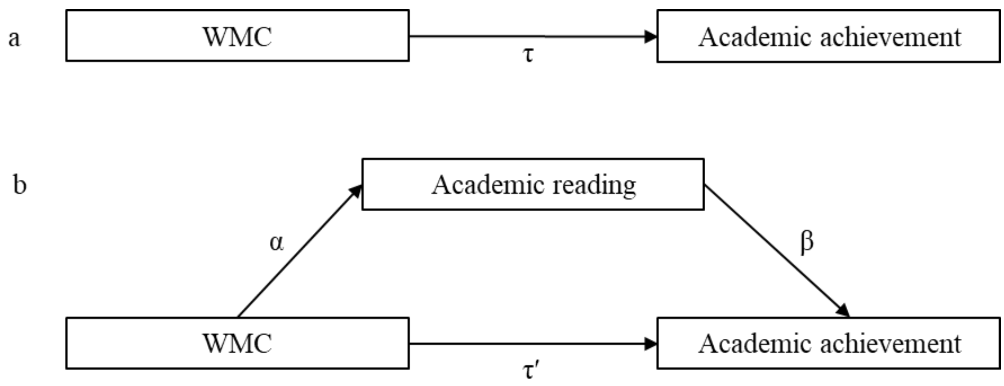
** Correlations significant at the .01 level (1-tailed).

5.3.2. Mediation analysis

This final analysis aimed to provide an answer to the **fifth research question**: What is the contribution of WMC and academic reading to academic achievement? As the majority of variables violated the assumption of normality, a regression analysis could not be performed and instead a mediation analysis was used. A simple mediation analysis was used to investigate the hypothesis that academic reading mediates the effect of WMC on academic achievement. Figure 64 illustrates the pathways which were tested using the PROCESS macro for SPSS (Field, 2018; Hayes, 2018).

Figure 64:

Path diagrams for (a) the total effect of WMC on academic achievement, and (b) the indirect effect of WMC on academic achievement through academic reading.



From the output presented in Table 24 and Figure 65, the first tested pathway was the total effect of WMC on achievement should academic reading not be included in the model (τ). When academic reading is not included in the model, WMC significantly predicts academic achievement: b = 15.55, 95% CI [5.94, 25.17], t = 3.20, p = .0017. The R^2 value indicates that WMC accounts for 7% of the variance in academic achievement, and there is a positive relationship as shown by the positive b value: as WMC increases, so does academic achievement.

When academic reading is included in the model, several important results are indicated. The results show that WMC significantly predicts academic reading: *b* = 19.57, 95% CI [2.60, 36.54], *t* = 2.28, *p* = .0241 (*α*). As WMC increases, academic reading increases. The R^2 value furthermore shows that WMC accounts for 4% of the variance in academic reading. The results of the regression of academic achievement from both WMC and academic reading indicated that 1) academic reading significantly predicts academic achievement: *b* = 0.23, 95% CI [0.14, 0.32], *t* = 5.19, *p* = .0000 (*β*), and 2) WMC significantly predicts academic achievement even with academic reading in the model, *b* = 10.10, 95% CI [2.03, 19.97], *t* = 2.43, *p* = .0166 (*τ′*). The positive *b* for both academic reading and WMC indicates that as these variables increase, so does academic achievement. These relationships are in the predicted direction. The model explains 23% of the variance in academic achievement.

Finally, the indirect effect of WMC on academic achievement via academic reading was explored. Indirect effects were computed for each of the 5 000 bootstrap samples, and the 95% CI was computed by determining the indirect effects at the 2.5th and 97.5th percentiles. As the CIs did not contain zero, it was concluded that there was a significant indirect effect of WMC on academic achievement through academic reading: *b* = 4.55, 95% BCa[15] CI [0.07, 9.94].

[15] BCa refers to ‘bias corrected’, which is automatically included in the PROCESS macro.

Table 24

Results of simple mediation analysis of the relation between WMC and academic achievement

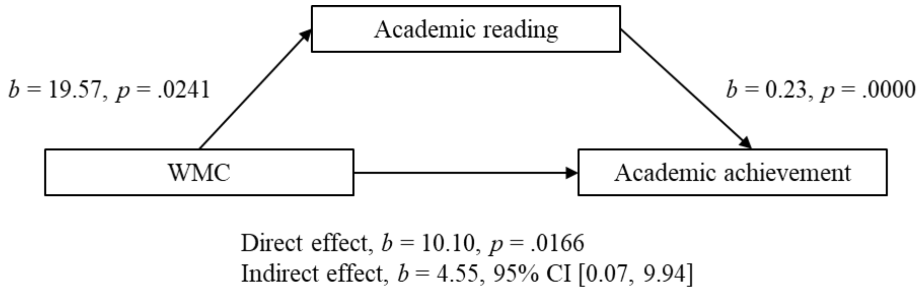
Effect estimate	Tested pathway	Coefficient	SE	Lower	Upper	*t*	*p*	R^2
Total effect τ	WMC →Achievement	15.56	4.86	5.94	25.17	3.20	.0017	0.07
α coefficient	WMC →Reading	19.57	8.58	2.60	36.54	2.28	.0241	0.04
β coefficient	Reading →Achievement │WMC [a]	0.23	0.04	0.14	0.32	5.19	.0000	0.23
Direct effect τ'	WMC →Achievement │Reading [a]	10.10	4.53	2.03	19.97	2.43	.0166	
Indirect effect	WMC →Reading → Achievement	4.55	2.50	0.07	9.94	-	-	-

SE: standard error; WMC: working memory capacity.

[a] The vertical bar indicates that the pathway shown in front of the vertical bar is adjusted for the variable after the vertical bar.

Figure 65:

Results of the mediation analysis



5.4. Conclusion

In this chapter the results of the study were provided and discussed, with reference to the research questions and hypotheses of the study. Descriptive data analyses were used to answer the first research question (§ 1.6) and showed that participants performed similarly to samples from other studies on the TALL and both WM measures. All three of the latter tasks showed adequate reliability indices. Inferential statistics showed the statistical relationships between the variables, answering research questions two to five (§ 1.6). There were significant but weak correlations between scores on the TALL and the OSPAN and WMC. Academic achievement was significantly but weakly related to the RSPAN, OSPAN, WMC, and TALL. The results of the mediation analysis demonstrated that part of the WMC variation in academic achievement can be accounted for by the mediating effect of academic reading. In the next and final chapter, these results are discussed, and conclusions are drawn from the study.

CHAPTER 6: DISCUSSION AND CONCLUSION

"There are few more powerful mirrors of the human brain's astonishing ability to rearrange itself to learn a new intellectual function than the act of reading" (Wolf, 2007, pp. 4–5).

6.1. Introduction

The role of working memory (WM) has been well established in all complex thinking processes and is essential for learning (Just & Carpenter, 1992; McVay & Kane, 2012; Ruiz et al., 2019; Yuan et al., 2006). This limited-capacity neural system has the ability to simultaneously store and process information (Baddeley, 2003; Newman et al., 2013; Peng et al., 2018; Wen, 2021). It is this ability that is the basis for the theoretical relationship between WM and academic reading, the latter also being crucial for learning (Peng et al., 2018). The purpose of the current study, therefore, was to explore the relationships between WM, academic reading, and academic achievement. This final chapter first provides a detailed summary of the purpose and background of the study as well as a broad overview of the method that was followed. The author then discusses and interprets the findings obtained through the descriptive and inferential analyses presented in the previous chapter. The findings are presented in two sections: (i) a discussion in relation to the study's specific research questions and their associated hypotheses, particularly in relation to the literature reviewed in the second and third chapters; and (ii) a brief discussion of the results in an integrated manner. The contributions made by the study are then provided, which precedes the limitations of the study. The chapter concludes with recommendations and suggestions for future research directions, and an overall conclusion of the study.

6.2. Summary of the purpose of the study and method

Poor academic reading ability can be detrimental to academic success in higher education (Bharuthram & Clarence, 2015; Clinton-Lisell et al., 2022; Pretorius, 2000; Roberts & Gous, 2014). This is a concern for tertiary education in South Africa, where students show high variation in their language and reading abilities. This is particularly so for Unisa, which follows an ODeL model of content delivery; as a function of its design, the ODeL model is accompanied by a high academic reading load. As opposed to traditional modes of study where students attend a brick and mortar institution and can also engage with both lecturers and their peers, reading is the primary and often the only way in which ODeL students engage with the content of their courses and the learning process (Bharuthram, 2017; Boakye, 2017; Bohn-Gettler & Kendeou, 2014; Peregoy & Boyle, 2000). It is unsurprising that reading is a factor in student dropout (van Dyk et al., 2013) – which is already substantially higher in ODeL and non-traditional students compared to students attending in-person classes (Gilardi & Guglielmetti, 2011; Khuluvhe et al., 2021; Miller & Lu, 2003; Rovai, 2003; Simpson, 2013). Khuluvhe et al. (2021) show that of the 2017 first-time-entering student cohort, 28% of distance students enrolled in a three-year undergraduate degree had dropped out after the first year compared to 10% of contact students. To develop innovative solutions, research must explore relevant factors and incorporate neural systems, the latter being where cognitive reading processes take place.

The complex activity of reading requires the parallel execution of both lower- and higher-level cognitive processes. During the activity, each intermediate output is briefly stored to update the overall mental representation of the text as it is being read with focused attention (Osaka et al., 2002; Prat et al., 2015). Both the lower- and higher-level cognitive processes take place within WM (Grabe, 2014; Ntim, 2015). In sum, WM stores information from previous reading cycles, connects this information to new reading cycles, and retrieves information from long-term memory (LTM) to link it with the mental representation being built (Barreyro et al., 2012). WM's ability to simultaneously store and process information is what allows the reader to generate intermediate and final outputs (Daneman & Carpenter, 1980; Heriyawati et al., 2018; Just & Carpenter, 1992; Prat et al., 2015; Wen, 2021). Availability of WM resources for storage and processing is termed working memory capacity (WMC) and is limited, with individuals with higher WMC performing better on tasks (Camos, 2017; Demir & Ercetin, 2020; Gibson et al., 2012; Heriyawati et al., 2018; Linderholm & van den Broek, 2002). This is also impacted by the efficiency of reading processes: inefficient, lower-level reading processes require more resources, which limits availability for storage and higher-level processes (Harrington & Sawyer, 1992; Nouwens et al., 2020). WMC can thus enable or constrain academic reading. WMC is furthermore the best predictor of academic success, and plays a crucial role in learning (Alloway & Alloway, 2010; Berkowitz et al., 2022; Fenesi et al., 2015; Ramos-Galarza et al., 2020). The purpose of the current study was to explore the relationships between WM, academic reading, and academic achievement.

To undertake the study, a non-experimental ex post facto cross-sectional research design was followed. The targeted participants were ODeL first-year tertiary students enrolled at Unisa during the 2020 or 2021 academic year and residing in South Africa. All assessments were conducted in English, either on campus or at the student's home. Participants were asked to complete a demographic and background information survey, an academic reading test (Test of Academic Literacy Levels (TALL)), and two WMC tasks. The latter were the reading span (RSPAN) and operation span (OSPAN), which are well-known, complex span tasks that have been used to explore various cognitive measures of interest (Engle, 2010; Hicks et al., 2016; Redick et al., 2012; Redick & Lindsey, 2013; Unsworth et al., 2009). The results of these two tasks were combined to create a composite WMC score. All instruments were self-administered on a computer and the participants indicated their responses using a computer mouse and keyboard. The final end-of-course grades achieved by participants were requested from the university. To answer the five research questions, the generated data from 136 participants was analysed in a series of steps: 1) descriptive statistics, 2) correlational statistics, and 3) mediation analysis. The findings of the study are now briefly discussed in relation to the research questions and the related hypotheses.

6.3. Results in relation to research questions and hypotheses

6.3.1. Research question 1

The first research question asked what the profiles of the student participants were on psychometric measures of:

a. English academic reading ability as measured by the TALL; and
b. WM as measured by the Reading Span (RSPAN) and Operation Span (OSPAN).

The descriptive results revealed that the sample of Unisa ODeL first-year tertiary students achieved a mean of 68% (*SD* = 19.57) on the total TALL test. This is similar to the average score achieved by participants in previous studies (Le et al., 2011; van der Slik & Weideman, 2007, 2009), which suggests that their performance on this test was commensurate with other South African student samples from various higher education institutions across the country. This was somewhat unexpected, as previous studies have reported that Unisa students struggle with regard to academic reading (Bharuthram & Clarence, 2015; Nel & Adam, 2014; Pretorius, 2000; Zulu, 2005). This unanticipated finding may be related to the mode of data collection and the subsequent demographic profile of the sample, which is discussed below.

In response to the Covid-19 pandemic, data collection was conducted solely online, where contact between the researcher and students was primarily through email. There were three ways in which this may have contributed to the bias of the sample, where the majority of participants were L1 English, had parents employed as professionals, attended fee-paying schools, and were high academic achievers (based on their end-of-year examination marks provided by Unisa). Firstly, it is possible that the more English-proficient students were able to engage with the content of the email and its instructions, making them more likely to participate. It is also plausible that second language (L2) English students had less motivation to take part in a study that would assess their English reading ability. Thirdly, as data collection largely took place when campuses were closed, the participants in the study may have been economically advantaged – with their own computer or laptop, as well as a home internet connection – and had more opportunity to develop computer literacy. A more diverse sample of Unisa ODeL tertiary undergraduate students is required to verify the findings of this study, that is, a sample with linguistic and socioeconomic status (SES) diversity.

With regard to the TALL sections, the lowest average score (53%) was for Section 1, which presented a scrambled paragraph that participants had to organise into the correct order. The results of this study suggest that Unisa ODeL undergraduate students may struggle in this area, as the average score was 53%, with a minimum of 0% and a maximum of 100%. Completing this task requires participants to understand how the central idea of the paragraph is being developed through techniques or language (Lukmani, 2012), and thus additional instruction in doing so may be beneficial. Other factors that may be relevant are text cohesion and background knowledge. The former refers to the extent that ideas within a text are connected; texts that have a high degree of cohesion provide the necessary information for the reader to follow the reasoning of the text. Text that has less cohesion requires the reader to make inferences to bridge gaps in connections between ideas, a process that relies on sufficient background knowledge (Schurer et al., 2020). By the nature of the task, Section 1 texts can be considered to have less cohesion, and therefore performance would be influenced by individual differences in background knowledge related to the text and the ability to activate this knowledge (Schurer et al., 2020). This was not assessed in the current study and would be worthwhile including in future studies. Section 2 of the TALL had the highest average score (82%), with scores ranging from 0% to 100%. This section asked participants to interpret graphs and visual information, such as a diagram, to demonstrate their quantitative literacy ability. Further investigation is required to understand why participants scored highly in this area. It is possible that although influenced by English language proficiency, this section is more reliant on mathematical knowledge and skills. An alternative explanation is that, as ODeL students, the participants had greater familiarity with interpreting visual data due to the nature of online communication.

Average scores on the RSPAN (*M* = 0.69, *SD* = 0.23) and OSPAN (*M* = 0.72, *SD* = 0.20) tests of WM as well as the composite WMC score (*M* = 0.71, *SD* = 0.19) were similar to what has been reported in comparable samples using adult participants and an analogous scoring method (Kane et al., 2004; Ziegler & Smith, 2017). This provides additional support to indicate that the developed tasks were functioning well. However, performance on the RSPAN was slightly lower and it is suggested that, as the more language-dependent of the two tests, there was interference due to reading or language ability (Sanchez et al., 2010). It has been previously reported that the OSPAN is the more accurate measure for examining the relationship between WM and L2 processing, as it is less sensitive to reading or language ability (Ruiz et al., 2019; Sanchez et al., 2010; Zhou et al., 2017). The OSPAN has a lower language requirement than the RSPAN, which makes it more likely to reflect L2 participants' actual WMC (Zhou et al., 2017). Language interference may also explain the lack of significant association between the RSPAN and scores on the TALL, related to the second research question. This discussion regarding language interference on the RSPAN is therefore continued in the next section.

6.3.2. Research question 2

The second research question asked if WM, as measured by complex span WMC tasks, was positively and significantly related to academic reading, as measured by the TALL test. The following null and alternative hypotheses were made:

$H_{0.1}$ There is no relationship between WM scores and academic reading.

H_1 WM scores are positively correlated to academic reading.

A Kendall's tau-b correlation analysis with significance level set at α = .05 was used for hypothesis testing. Analyses indicated a significant weak correlation between TALL test scores and the WMC composite score (τ = .10, p = .050). Most of the TALL sections (Sections 1, 2, 4, and 6) were also significantly but weakly related to the final WMC composite score. The findings of the analysis therefore support the alternative hypothesis, and the null hypothesis is rejected. These results concur with those found in a wide range of studies that have showed that aspects of academic reading, such as the ability to understand academic vocabulary, understand relationships between concepts and ideas present within a text, or comprehend an expository text, are cognitive abilities that are supported by the simultaneous storage and processing of information in WM (Bader, 2016; Barreyro et al., 2019; Burin et al., 2018; M. J. Lee, 2014; Peng & Fuchs, 2017). These results are furthermore in line with the theoretical perspective regarding how WM is associated with academic reading. All lower- and higher-level reading processes take place in WM, with the capacity of this system thus acting as an enabler or constrainer of academic reading (Just & Carpenter, 1992). The results of the current study support this theoretical relationship proposed by Just and Carpenter (1992), as readers with higher WMC showed better performance on the TALL test as a measurement of academic reading. However, only one of the complex span tasks was significantly related to TALL test scores.

The positive significant correlation between TALL test scores and the OSPAN, a complex span task, is in accordance with expectations based on Baddeley's multicomponent working memory. Complex span tasks are based on the dual-task paradigm and were designed from the perspective of Baddeley and Hitch's (1974) WM model (Baddeley & Hitch, 1974; Bayliss et al., 2003; Conway et al., 2005; Fenesi et al., 2015). Within this model, complex span tasks require the domain-specific storage systems but primarily assess the domain-general executive-processing central executive (Conway et al., 2005; Sanchez et al., 2010; St Clair-Thompson & Holmes, 2008). As all complex span tasks measure a broad WM construct, this implies that the relationship between the complex span score and a higher-order cognitive task does not require that the processing component of the complex span be similar to the cognitive task (Engle et al., 1991). This was reflected in the findings of the current study where scores on the OSPAN were positively correlated with scores on the TALL test ($\tau = .10$, $p = .047$), despite this task not including a processing task similar to academic reading. Furthermore, the RSPAN and the OSPAN were significantly correlated, which indicates that they do measure the same underlying construct. These results thus support the tenets of the multicomponent WM model and complex span tasks. However, there was no significant relationship between TALL test scores and the RSPAN. The results of the study by Sanchez et al. (2010) provide a possible explanation for this, which follows below.

It was surprising that the current study did not identify a relationship between TALL test scores and scores on the RSPAN, but this may be related to some of the participants being tested in a non-native language. Approximately half of the participants were L1 Afrikaans or Indigenous South African Language (ISAL) and were tested in English. The study by Sanchez et al. (2010) explored the usefulness of both the RSPAN and the OSPAN when administered in English with a non-native-English university student sample, who reported having spoken fluent English for over 10 years. To do so, span scores were regressed against performance on the Raven's Advanced Progressive Matrices, as the latter has a well-established relationship with WMC. For non-native-English speakers, entering OSPAN into the regression model accounted for a significant amount of variance not already accounted for by the RSPAN. For native English speakers, the addition of OSPAN did not account for any further variance. The authors concluded that while the RSPAN and OSPAN were reliable measures for non-native speakers, only the latter was an accurate measure of WMC in this group (Sanchez et al., 2010). In the current study, therefore, the RSPAN – where processing stimuli are sentences rather than mathematical operations – may have been influenced by language-related factors that prevent an accurate measurement of WMC (M. J. Lee, 2014; Sanchez et al., 2010). This may also explain the finding that the OSPAN showed more and larger correlations with the TALL sections in comparison to the RSPAN, which is more task-specific and was thus expected to show larger associations with academic reading measures. It is suggested that future research conduct complex span tasks in the L1 of the participant in order to explore this further. It is important to note that the OSPAN as well as the composite WMC score were still significantly associated with TALL test scores, signifying that these measures were performing both reliably and accurately. This relationship was nevertheless weaker than expected.

There are several possible reasons that the relationship between TALL test scores and WMC identified in the current study ($\tau = .10$, $p = .050$) was weaker than reported in previous investigations. For example, in their meta-analysis, Peng et al. (2018) reported a moderate correlation ($r = .29$, $p = .05$) between WM and L1 reading. A similar correlation was identified in the meta-analysis by Shin (2020) regarding the relationship between WM and L2 reading: $r = .30$, 95% CI [.24, .35]. To explain this difference, it is possible that the TALL did not tax participants' cognitive processes to the extent that their individual WMC was a significant limitation on performance. This can be related to the academic reading proficiency of the participants, the nature of the task, or a combination of both. With regard to participant characteristics, the descriptive results show that the overall TALL score average of the sample was moderate, suggesting reasonable proficiency in English. R. Adams and Shahnazari-Dorcheh (2014) state that as L2 proficiency increases, the relationship between WMC and reading comprehension declines, as low-proficiency L2 readers rely on WM more than high-proficiency L2 readers. A stronger relationship with WMC may thus have been visible with a less linguistically proficient sample. Similarly, regarding assessment of reading, the TALL may not have been sufficiently challenging. In a sample of proficient English L2 learners, Alptekin and Ercetin (2010) illustrated a significant association between WM and inferential comprehension, but not between WM and literal understanding. The former was considered effortful even for proficient readers, thus challenging their WM and demonstrating a relationship (Alptekin & Ercetin, 2010). Language proficiency and the way in which academic reading is conceptualised is thus important in future studies. For example, as suggested by Choi (2013), WMC may play a larger role in comprehending longer rather than shorter passages. Secondly, it is plausible that other notable predictors of academic reading performance carry more weight for South African participants. This includes vocabulary (Choi, 2013) or other executive functions such as planning (Georgiou & Das, 2016) or shifting (Georgiou & Das, 2018). Further investigations need to be conducted.

Correlations between WM scores and the sections of the TALL test were also explored. It has been postulated that WMC exerts a greater effect in times of high demand (Fontanini & Tomitch, 2009) but, based on this, the identified correlations were surprising. Firstly, although Section 3 is the reading comprehension test component of the TALL, there was no correlation with WMC scores or either of the WM measures. This was unexpected as it was assumed that this would be demanding for participants. The same explanations outlined above regarding the weaker than expected relationship between overall TALL test scores and WMC are applicable here. In addition, as described in § 6.3.1 regarding performance on the scrambled paragraph exercise, text cohesion and background knowledge may have played a role. The reading comprehension text of the TALL is likely to be cohesive, and thus to have textual connections making it easier to comprehend (Schurer et al., 2020). Section 3 may therefore not have posed as great a challenge to participants as anticipated, resulting in the lack of a significant relationship with WMC scores. Secondly, WMC showed the highest correlation with Section 2 scores (τ = .16, p = .007). It was also this section where participants scored the highest, suggesting proficiency in the quantitative literacy task type. It is thus unclear why WMC would exert a greater impact in this instance.

Some studies, such as that by Hummel (2009), did not find a significant relationship between WM and reading comprehension. It is argued that these opposing results are due to using a task that measures only the storage ability of WM, rather than a task that measures both storage and processing. Tasks that measure storage only are termed simple span tasks while complex span tasks require both storage and processing to provide a measure of WMC (Bayliss et al., 2003;

Conway et al., 2005; Fenesi et al., 2015). It has been noted that simple span tasks do not significantly correlate with reading comprehension or other higher-order cognitive functions, while medium to large correlations have been identified using complex span tasks (Engle et al., 1991; Kane et al., 2001). This would serve to explain the discrepancy between the results of the current study, which used complex span tasks and did identify a relationship, and the findings of studies which used simple span tasks and did not identify a relationship.

6.3.3. Research question 3

The third research question asked if WM, as measured by complex span WMC tasks, was positively and significantly related to academic achievement. The following null and alternative hypotheses were made:

$H_{0.2}$ There is no relationship between WM scores and end-of-course academic performance.

H_2 WM scores are positively correlated to end-of-course academic performance.

A Kendall's tau-b correlation analysis with significance level set at $\alpha = .05$ was used for hypothesis testing. Positive significant weak correlations were identified between academic achievement and scores on the RSPAN ($\tau = .16$, $p = .004$), the OSPAN ($\tau = .13$, $p = .011$), and WMC ($\tau = .16$, $p = .003$). The findings of the analysis therefore support the alternative hypothesis and the null hypothesis is rejected. These results are in line with previous reports that WMC is the best predictor of academic success and plays a significant role in the rate and extent of learning (Alloway & Alloway, 2010; Engle, 2002; Fenesi et al., 2015). Most information to be learned and recalled passes through WM, and thus the rate and extent of learning is heavily influenced by the capacity of this cognitive system (Demir & Ercetin, 2020; Fenesi et al., 2015). The results of the current study suggest that students with low WMC may be constrained in their information processing during learning and assessment (Upahi & Ramnarain, 2020). This in turn leads to academic achievement being less successful when this construct is overloaded (Demir & Ercetin, 2020; Fenesi et al., 2015). Course and content design as well as training can support students. For example, to assist when a great deal of information is provided, students with low WMC can use schema or chunking of information (Upahi & Ramnarain, 2020). Chunking refers to the synthesising of logically or thematically similar individual elements of information into a single chunk (Thalmann et al., 2019; Zhang et al., 2021). This reduces the demands placed on WM and allows capacity for further information (Thalmann et al., 2019). Students can be trained in this strategy, which provides a future avenue for institutional support. Further recommendations are made below.

The relationship between WMC and academic achievement identified in the current study was weak, however – while studies such as that by Ramos-Galarza et al. (2020) identified a moderate significant relationship (r = -.30, $p < .001$). The authors of this study did not use a computerised cognitive test and instead relied on a validated self-report scale regarding the frequency of executive function behaviours. Here, a higher score indicates a WM difficulty (Ramos-Galarza et al., 2020). The difference in measures may have contributed to the dissimilarity in correlation strength. It would be fruitful to explore WM using a self-report scale in a South African student population, as this would provide insight into their behaviours and how they approach their studies, identifying possible means of intervention. The way in which academic performance was calculated also differed, in that the average of the grades that each student obtained in every subject was scored as 0–10 points (Ramos-Galarza et al., 2020). The current study did not perform this second grading, and it is possible that this may have slightly influenced the results.

6.3.4. Research question 4

The fourth research question asked if academic reading as measured by the TALL was positively and significantly related to academic achievement. The following null and alternative hypotheses were made:

$H_{0.3}$ There is no relationship between academic reading and end-of-course academic performance.

H_3 Academic reading is positively correlated to end-of-course academic performance.

A Kendall's tau-b correlation analysis with significance level set at $\alpha = .05$ was used for hypothesis testing. The results showed that there was a positive significant weak correlation between scores on the TALL test and academic achievement ($\tau = .36$, $p < .001$). The findings of the analysis therefore support the alternative hypothesis and the null hypothesis is rejected. This was the largest correlation identified in the current study, which is in line with the vital role that academic reading plays in academic achievement. Academic reading is the foundation of all academic activities and fundamental to academic success (Boakye, 2017; Boakye et al., 2014; Gorzycki et al., 2016). It is particularly important for ODeL education, where academic reading is the primary means of engagement with the course content (Bharuthram, 2012; Desa et al., 2020; Howard et al., 2018; X. Liu & Read, 2020; Roberts & Gous, 2014). As Pretorius (2000) illustrated, students who can read fluently are able to construct meaning from their text and thus derive benefit from their studies. However, students who cannot read fluently are unable to understand their readings, which manifests in poor academic achievement (Pretorius, 2000). The results here also provide further support for studies designing interventions and means of teaching academic reading in undergraduate courses (Bharuthram, 2012; Bharuthram

& Clarence, 2015). It is imperative that this complex cognitive skill is adequately attained by South African students.

6.3.5. Research question 5

The fifth research question regarded the contribution of WMC and academic reading to academic achievement. The following null and alternative hypotheses were made:

$H_{0.4}$ WM and academic reading do not make direct, positive contributions to end-of-course academic performance.

H_4 WM and academic reading make direct, positive contributions to end-of-course academic performance.

$H_{0.5}$ WM does not indirectly influence end-of-course academic performance via academic reading.

H_5 WM indirectly influences end-of-course academic performance via academic reading.

A simple mediation analysis investigated the hypothesis that academic reading mediates the effect of WMC on academic achievement. Results of the analysis indicated that both WMC composite scores and academic reading significantly predict academic achievement. The fourth alternative hypothesis is thus supported and the fourth null hypothesis is rejected. The results also showed that there was a significant indirect effect of WMC on academic achievement through academic reading. The findings of the analysis therefore support the fifth alternative hypothesis and the fifth null hypothesis is rejected. The results thus indicated that WM contributes to academic achievement via academic reading, indicating that both WM and academic reading are important in explaining individual variation in students' academic achievement. With greater WMC, students are better able to comprehend academic text, and subsequently achieve higher marks. This is conceptually similar to the study by Swanson and Fung (2016), where reading mediated the association between WM and word problem solving. However, this study was conducted with Grade 3 learners and included additional tests of WM and mediators. The preliminary results of the current study would therefore be augmented by additional exploration. Furthermore, a substantial proportion of the covariance between WM and academic achievement was not explained by mediating academic reading. This suggests that further variables are important here and need to be explored, which is in line with other studies which have highlighted vocabulary (Choi, 2013) or another executive function such as planning (Georgiou & Das, 2016) or shifting (Georgiou & Das, 2018) as significant.

6.4. Integration of results

Beginning in the 1990s, converging evidence has indicated that individual differences in WMC play a role in academic reading (Barreyro et al., 2019; Heriyawati et al., 2018; Kopatich et al., 2019; M. J. Lee, 2014; Siegel, 1994). It has also been reported that WMC is influential in academic achievement (Alloway & Alloway, 2010; Engle, 2002; Fenesi et al., 2015). The objective of this study was to explore these relationships within an adult South African sample. To do so, a sample of 136 Unisa ODeL first-year tertiary students completed two WMC tasks that were designed using Tatool Web: RSPAN and OSPAN. Their scores on these two tasks were used to create a WMC composite score. They also completed the TALL test to evaluate academic reading and Unisa provided their academic achievement for their first-year examinations. The descriptive results of the study showed that participants achieved comparable RSPAN and OSPAN scores as found in previous studies using similar samples and scoring methods. Their achievement on the TALL was furthermore analogous to other studies conducted in South Africa that have used this measure. However, their academic achievement was slightly higher than the average typically obtained by Unisa ODeL first-year students.

The results of the study showed that the largest significant correlation was between academic reading and academic achievement. This was to be expected, as much research has noted the fundamental role that academic reading plays in education (Unsworth & McMillan, 2013). Although relevant factors such as reading strategies (e.g., Boakye, 2017) as well as individual and textual barriers to reading (e.g., Andrianatos, 2019) have been explored in the scholarship around improving the academic reading of South African students, this study sought to explore an additional factor. The scholarship (e.g., Peng et al., 2018) has indicated a relationship between academic reading and WM, making this a pertinent factor for further analysis. The current study explored this relationship and showed that participants' performance in the TALL test and many of its sections, as a measure of academic reading, was significantly but weakly positively associated with the final WMC composite score. A relationship between WM and the complex cognitive task of academic reading was thus supported. The final WMC composite score was also significantly associated with the end-of-course academic performance, supporting the understanding that WM plays a role in learning. The results of the mediation analysis furthermore demonstrated that part of the WMC variation in academic achievement can be accounted for by the mediating effect of academic reading, even though a substantial proportion of the covariance of participants' WMC and academic achievement remained unexplained. This study has thus motivated for the consideration of WM in discussions around academic reading and academic achievement.

6.5. Contributions of the study

Through describing the relationships between WM, academic reading, and academic achievement this study adds to the corpus of knowledge: to the best of the researcher's knowledge, this is one of few studies which have explored these relationships with South African tertiary students. At present within South Africa a large focus of research has been placed on the study of economic and social factors in explaining poor academic reading and academic achievement. The current study is pioneering in the sense that it also brings attention to the role of students' cognitive architecture. Importantly, it does so within the South African context and thus provides evidence from the Global South to the existing largely Global North body of literature that explores these relationships. It has furthermore done so with both English L1 and L2 students within a diverse, multilingual and unequal context. While the sample was not large enough to allow disaggregated analysis, it has highlighted the value of considering these contextual factors. The insights from this study are thus original and provide meaningful direction for future research. Furthermore, the contributions of this study are important in improving higher education.

The results indicated positive but weak significant associations and support the theory that WMC can enable or constrain academic reading and achievement. These findings can provide pedagogical applications. A higher awareness of individual WM differences can inform curricula as well as educators in their teaching practices. With regard to higher education, although further investigation is warranted, lecturers may find it useful that individual differences in WM are associated with academic reading and academic achievement. For example, this could have a bearing on how they structure their online course content so as to reduce cognitive load (see below in § 6.7.2). An example is the use of linear text rather than hypertext as studies have found it easier for individuals with low WMC to comprehend (DeStefano & LeFevre, 2007; Fontanini & Tomitch, 2009). Also, through acknowledging a relationship between WMC and reading comprehension, educators are able to consciously utilise various techniques to benefit learners with differing cognitive profiles (Neitzel, 2018; Oliveira & Tomitch, 2021). This is particularly important for learners who may have weaker cognitive skills, to mitigate disadvantage (Nyroos et al., 2018). For example, learners with WM challenges are unlikely to process fast-paced instructions quickly enough, leading to loss of information and inability to perform the task (Fewell & Littlefair, 2016). The findings here could also be instrumental in informing successful student interventions through working memory training (§ 6.7.3). Although it is an open question as to whether training that specifically develops WM can directly improve reading ability, understanding the role of WM may assist in identifying students who are less likely to respond to typical reading interventions. This provides an opportunity for specialised intervention plans, such as teaching strategies that reduce cognitive load. Consideration of the role of WM can thus be used to improve higher education in South Africa.

An important contribution of the study is the development of two online WM measures that performed acceptably. Previous investigations have primarily been lab-based, which is a controlled environment where participants are typically tested individually and sequentially. While methodologically rigorous, it is labour-intensive and sample sizes are often small and homogenous (Ruiz et al., 2019). WM tasks that can be completed online are able to offset these limitations, which can have far-reaching effects in South African research. For example, in the current study participants were able to complete the tests at home which resulted in a greater prospect of obtaining a larger sample size. Other advantages to this method of data collection include time and resource efficiency, reduced likelihood of researcher error and researcher effects such as bias, increased sample diversity, improved scalability, and enhanced accessibility (Latkovikj & Popovska, 2019; Leidheiser et al., 2015; Ruiz et al., 2019; Sauter et al., 2020; Unsworth et al., 2005). Due to these advantages, the use of online tests allowed the researcher to navigate the challenges of data collection during a pandemic as well as the low response rate. It is noted that there were challenges to using an online mode, such as reduced experimenter control or a higher possibility of cheating by participants. The current study was therefore able to document these challenges and propose ways in which to overcome them in future studies. This will assist researchers in planning their future studies. These tasks are also open source which has tremendous value for research in South Africa.

It is becoming increasing critical that South African researchers have access to open-source WM tasks. Both within South Africa and internationally, many fields of research have recognised the importance of WM and have devoted substantial resources towards exploring this concept. For example, within South Africa researchers have investigated the ability of WM to predict learner performance on language measures (White, 2021), the extent of WM impairment in school children with and without attention-deficit hyperactivity disorder (Alloway & Cockcroft, 2014; Mphahlele et al., 2022), and the influence of an expressive writing intervention on WMC of middle adolescents and young adults (Swart & Janeke, 2022), amongst others. Given the proliferation of research around WM, it is important that the results are comparable across studies. This can be improved through the use and refinement of the open-access tasks developed in this thesis to limit variability in task aspects such as timing parameters, mode of presentation, and stimuli (Klaus & Schriefers, 2016; Ruiz et al., 2019). Improved comparability would allow for the understanding that participants divided into low- or high-WMC groups in one study would be similarly placed in another study. This would also apply when using the results of WM tasks in statistical analyses, such as factor analysis, regression, and meta-analysis (Klaus & Schriefers, 2016). Using the tasks developed here would prevent researchers from reinventing the wheel, promoting replication of studies as well as proliferation of diverse ‘in-house’ tasks (Ruiz et al., 2019; Stone & Towse, 2015). The open-source WM tasks used in the current study are thus paramount for the furthering of South African research in this area, as they can be easily accessed and do not require any download, set-up, or specialised software. For example, complex span tasks that can be downloaded from the lab website of Draheim et al. (2022) require access to proprietary software (E-Prime) and purchase of an expensive licence. Building on the work of other researchers, both national and international, will ultimately lead towards standardisation and South African norms (developing norms for the South African population is discussed further in § 6.7.1). The WM tasks developed in the course of this study are thus pioneering and can form the basis for comparable, standardised assessment of WM in South Africa.

An additional contribution is the evidence that some complex span tasks may be influenced by home language. Within South Africa and around the world, the proportion of tertiary students who are bi-/multilingual is rapidly rising (Madiba, 2018). It is therefore likely that non-native English speakers will be increasingly represented in studies exploring cognition. As noted by Sanchez et al. (2010), and building on their recommendations, the current study illustrates the need to recognise the linguistic profile of participants, as tasks administered in English may not be valid for those whose first language is not English. The results here indicated that while the OSPAN was an adequate measure, the RSPAN may have been influenced by language proficiency. This is an important acknowledgement for future studies and needs to be considered during their design.

Finally, part of the engagement with participants was through a website specially designed by the researcher (https://jaquelineharvey.wixsite.com/harveyproject). The website allowed students to indicate their interest in participating in the study, but also provided multimedia content around language, learning, and cognition. For example, it included information about how the brain takes in information and how learning occurs, together with suggested study strategies. Informal feedback from participating students indicated that they found the information that was included on the website useful. Expanding on this and exploring how providing this type of information can be used to assist students during their studies could prove to be a key aspect of student support in tertiary institutions. There were several limitations of the study, which are now discussed.

6.6. Limitations

Despite the unique and important contributions of this study, it had several limitations. It is thus noted that generalisations that are made based on the findings of the current study must be done with extreme caution, although every effort was made to ensure that the study was representative of the Unisa ODeL first-year tertiary student population. The reasons for this caution are provided through discussion of the following limitations of the current study and their implications. This includes limitations of the research design, inadequacy of the sample, the challenges of using open-source, web-based measures of WM, and limited insight into other variables.

6.6.1. Limitations of the research design

The research design was non-experimental and used correlational statistics for hypothesis testing. This means that the findings cannot speak to causality as there may be extraneous variables that caused the perceived relationship (Creswell & Creswell, 2018).

6.6.2. Limitations of the sample

Another crucial limitation of this study was the lack of diversity in the sample. The majority of participants were L1 English or Afrikaans speakers. This does not reflect the typical South African or Unisa demographic, where most individuals are L1 ISAL speakers. Furthermore, most of the participants had attended fee-paying public schools or independent schools; only 10 participants attended no-fee public schools. Together with the left-skewed composite SES scores, this indicates that most participants came from economically advantaged backgrounds, which again is not representative of the South African population. In sum, the generalisability of the results of this study are limited. Based on the results of the comparative analysis between the participants who completed the tasks on-campus or at home, it is suggested that the sample would have been more diverse had campuses been open to students.

An additional complication was the small sample size. As has been noted, logistic constraints due to Covid-19 and the availability of time prevented the author from obtaining a larger sample size. In addition, there was a high drop-out rate, which can be considered typical of online testing (Ruiz et al., 2019). Linking to the lack of diversity in the sample, it is possible that the small sample size and mode of participation may have biased the sample towards high-achieving student participants as well as those who spoke English or Afrikaans as a first language. The relationships explored here thus need to be examined with a larger and more representative sample. Nevertheless, publication of the correlation matrix enables other research which combines studies with low power into a single meta-regression study.

6.6.3. Limitations of the method

There were several challenges of using open-source web-based measures of WM in the current study (Table 25). Online testing reduced experimental conditions, which may have introduced confounding variables into the study. For example, the time of day at which the task was completed or technical variability in aspects such as Internet connections may have influenced data collection (Ruiz et al., 2019). This is noted as a limitation, and it is recommended that future studies evaluate the impact of extraneous factors on the task. It would also be worthwhile to explore the ability to limit task access to specific periods of time.

Another aspect was limited participant-researcher interaction, which reduced opportunities for participants to ask questions or clarify any of the task requirements. Any resultant misunderstandings may have impacted participants' scores. To reduce confusion, the task included detailed instructions as well as examples that the participants were required to complete. The examples also had real-time feedback to inform participants if they were correct or if they needed to read through the instructions again. These measures are in line with Sauter et al. (2020), who made a number of recommendations for researchers to ensure that experimental instructions for online tasks are comprehensible without verbal explanation, since online studies tend to have more diverse participants. The lack of interaction with the researcher was further mitigated in the current study by holding an online information session, where the task was demonstrated by the researcher and participants could ask any questions. As this session was poorly attended, however, the demonstration was also recorded, and the link was sent to students who expressed an interest in participating.

Participants' resources are an influential factor when using online measures. South Africa is an unequal society, which has been discussed, and not all students have adequate connectivity or a device – a computer or a laptop – on which to complete the tasks. This introduced bias into the study, where some students were prevented from participating. This would arguably be less of a concern for future studies carried out when not in the midst of a pandemic and when higher education institutions and their computer laboratories are open to students. For example, the current study had entered into an agreement with the institution before the Covid-19 disruption to use their computer laboratories. However, when students do have access to the necessary resources it also cannot be assumed that they have enough experience in using them so as to be equally proficient. That is, some students may be less competent in using technology, which could impact their scores. Future studies can consider streamlining the WM tasks for mobile devices as this is the means through which the majority of individuals access Internet in South Africa.

The most recent General Household Survey reports that South African individuals mainly access the Internet through mobile phones (69%) rather than at home (10%), at work (18%), or at Internet cafes or educational facilities (14%) (Stats SA, 2022). Previous research with Unisa student populations have also noted that individuals access their course information as well as institutional offerings such as counselling services on their mobile phone or tablet (G. van den Berg, 2020; Wells, 2021). Adapting the WM tasks to run on multiple platforms, such as mobile devices or tablets, would thus ensure greater ease of use. Furthermore, Internet access through mobile devices greatly enhances accessibility in rural areas (Stats SA, 2022). This would assist in obtaining a representative sample of participants.

Irregular actions by the participants are challenging to control when using online measurements. Complex span tasks comprise both a storage and processing task and participants must complete both for a valid measurement. It was difficult to ensure that this was the case in an online task. To guard against irregularities, a criterion was applied where 50% of the answers for the processing task must be correct. Although attention to task and data quality between online and lab-based experiments has been noted as comparable (Hauser & Schwarz, 2016; Huber & Gajos, 2020; Ruiz et al., 2019), it is still beneficial to design the online test with participant engagement in mind. As noted above, measures were taken to improve the clarity of the instructions. In addition, participant motivation was also assisted by real-time feedback during the practice trials (Sauter et al., 2020). Lastly, it is a concern that participants may be able to write down the stimuli to be remembered when in an unproctored setting (Hicks et al., 2016). It is possible to prevent this by replacing the to-be-remembered letters from the

RSPAN and OSPAN with memory stimuli that cannot easily be written down, such as pictures (Hicks et al., 2016). Doing so would have improved the validity of the current study. Online testing was, however, necessary due to the disruptions and subsequent restrictions caused by the Covid-19 pandemic.

Test-retest reliability of the WM tasks was not assessed in this study. This is a limitation as there was no signifier that the measurements obtained are both accurate and stable. This should be explored in future studies of measures of WM in South African adult participants, particularly as there are not many studies within this population group. In addition, both the RSPAN and OSPAN tests were administered in English, which was the L2 or L3 for many participants. A lack of language proficiency may have impacted the test scores as well as their internal consistency reliability.

Table 25

Challenges of using open-source web-based measures of WMC

Challenge	Recommendations
Reduced experimental conditions	Evaluate the impact of extraneous factors on the task. Limit task access to certain periods of time.
Limited participant-researcher interaction	Provide detailed instructions as well as examples with real-time feedback. Hold an online information session where the task is demonstrated by the researcher. Provide an accessible recording of the task demonstration.
Limited participant resources	Provide access to required connectivity and technology through the relevant institution. Explore the role of technological proficiency. Develop test versions that run on multiple platforms.
Irregular participant behaviour	Apply a percentage-correct criterion on the processing task. Use memory stimuli that cannot be easily written down, e.g., pictures.

A further limitation related to the method is how information regarding their parent's or guardian's occupation was requested from the participants. An open-ended question was used, and participants were asked to supply a high level of detail, as it was anticipated that this would allow more accurate coding. However, many participants provided ambiguous or unclear answers that could not be coded. In future studies a drop-down list should be provided to participants. The final limitation relates to the measurement of academic achievement. The overall end-of-course examination marks were used to calculate an average for each participant. However, this does not consider the differences across courses, such as the number of modules a given course may have. It would be beneficial in the future to form subgroups of participants by their course registration.

6.6.4. Limited insight into other influencing factors

A wide range of research has explored the relationships between WM, academic reading, and academic achievement. This research has identified many factors which may influence these relationships, but which were not included in the current study to ensure that the participants were not over-burdened. For example, participants were not assessed on their L1 and L2 proficiency (van den Noort et al., 2006), metacognition (Gelderen et al., 2003) or internet skills (Burin et al., 2018).

6.7. Recommendations and future research directions

The findings of this study make a useful contribution to our understanding of the role of WMC in the academic reading and academic achievement of Unisa ODeL first-year tertiary students. However, as noted in the rationale for this study (§ 1.5), the current research project can be seen as the first phase of study into WM and its associations. There are therefore many directions for future research, some of which are summarised here.

6.7.1. Developing a corpus of empirical research

Several directions are first proposed to build on the findings presented here. It is recommended that the results of the current study be verified with a larger and more diverse sample of ODeL first-year students. It would also be worthwhile to compare scores on the WM tasks across laboratory and web-based settings. This would provide added assurance that the mode of assessment does not influence participants' scores. In-depth investigations of the TALL would also be valuable to explore how students experience the various sections of the test. This could include a qualitative component to explore which aspects of the task participants find more challenging or easier.

It is secondly recommended that further research be performed into other factors which may play a role or influence the relationship between WM and academic reading. The possible factors which can be explored are numerous, such as L2 proficiency and knowledge (Demir & Ercetin, 2020; M. J. Lee, 2014), prior knowledge (Burin et al., 2018; Demir & Ercetin, 2020), and general intelligence (Linck et al., 2014). Only the following two examples for future studies are provided here in detail, as they are considered particularly relevant for the South African context. In the current study, only higher-level processes (i.e. inferencing, integrating) and not the lower-level cognitive reading processes (e.g. decoding, word recognition) were measured. It would be worthwhile to explore how WM interacts with both lower- and higher-level processes in a South African ODeL first-year student population, particularly as it is possible that the assumed automisation of lower-level processes has not taken place. This research would also enable exploration of the claim that less efficient lower-level processes are compensated for by high-level processes across both L1 and L2 participants. Another area of future research relates to the WMC resources required for reading in either the L1 or the L2. It has been stated that "the more constraints the reading imposes, the more WMC is required for processing, considering that text processing happens within a limited capacity working memory system" (Fontanini & Tomitch, 2009, p. 2; Linck et al., 2014). As text may pose additional burdens for an L2 reader, more of the available WMC may be required. Additional studies should be conducted with larger samples of L1 and L2 participants to understand differential resource requirements across text type, modality, and reading purpose. These studies could also explore the role of text length and assessment formats (Choi, 2013). Future studies may want to assess WM in the home language of the participant, as it assists in ensuring construct validity, but this may, however, be problematic in the South African population.

South African individuals with an African home language receive the majority of their education in their second or third language, as most schools opt to use English (an additional language for these individuals) as the instructional language from Grade 4 onwards (Heugh, 2009; Janks, 2014; Thomas & Collier, 2001; Wildsmith-Cromarty & Gordon, 2009). Their exposure to and use of academic forms of their L1 may therefore be limited, impacting their performance on tasks even when their home language is used. However, they may also be ill-prepared to read and learn in their L2 by the fourth grade (Pretorius & Currin, 2010), while texts become increasingly complex through this stage and learners fall progressively behind as they move through the educational system (Pretorius, 1995; Pretorius & Currin, 2010). It can therefore also not be assumed that all individuals have the required L2 proficiency to engage with the assessment, even if it uses the language of teaching and learning. Language can therefore be a powerful mediator of test performance (Foxcroft & Aston, 2006) and needs to be taken into account, along with other contextual factors. The scholarship around psychological assessment in South Africa, however, notes that this is not easily accomplished.

Language and culture as well as socioeconomic and educational inequalities have implications for psychological assessment in the multicultural and multilingual society of South Africa (Badat & Sayed, 2014; Janks, 2014; Lucas, 2013; Mlachila & Moeletsi, 2019). South African individuals often exhibit substantially different psychometric test performance on commonly used instruments. The latter are typically developed and normed on Westernised international populations and thus have limited validity for use in the South Africa context (Naidoo et al., 2019; Shuttleworth-Edwards, 2019). Even in studies where participants score comparably to other samples, such as the current study, South Africa has unique contextual factors that require extensive norming. A common and pragmatic solution adopted by South African researchers is to develop local norms for these instruments to facilitate valid assessment (Naidoo et al., 2019; Shuttleworth-Edwards, 2019). An ongoing debate, however, is which methodological approach is more appropriate: population-based norms or within-group demographically stratified norms. The first assumes a relatively homogenous country population and that collected data from a representative sample will be generalisable to the general population (Shuttleworth-Edwards, 2019; Shuttleworth-Edwards et al., 2013). The aim of this approach is to enable location of an individual's ability in comparison to the general population (Shuttleworth-Edwards et al., 2013). Within-group demographically stratified norms instead produce norms specific for subgroups of the general population (Shuttleworth-Edwards, 2019; Shuttleworth-Edwards et al., 2013). These norms are better suited for clinical applications as they consider the unique demographic variables that characterise each individual (Shuttleworth-Edwards et al., 2013). Following this approach assists in preventing negative test bias related to language proficiency, SES, and educational experiences (Shuttleworth-Edwards, 2019). The standardisation approach of the WM tasks must thus be in line with the application of the research.

6.7.2. Course and content design

The current study has provided support that WMC can act as a constrainer on academic reading performance. To take the limit of WMC into account during course and content design, one approach is to decrease the information load of the learning materials provided to students (Demir & Ercetin, 2020; Yuan et al., 2006). This argument is based on cognitive load theory. Cognitive load theory relates the capacity of a given cognitive system to the information-processing demands placed upon its cognitive resources. If cognitive load – referring to the separate elements of information that must be processed together for sense-making – exceeds cognitive capacity, then learning will be negatively impacted (Zhang et al., 2021). It is possible that WMC can be overloaded due to the high processing demands of a cognitive task (Zhang et al., 2021). A possible means of reducing cognitive load is through altering the nature of the textual information provided.

Given the intensive focus on digital reading in ODeL studies, it is unsurprising that many studies have explored the influence of text presentation on cognitive load. This research has shown that certain modes of text presentation may be more demanding and require more memory resources. Fontanini and Tomitch (2009) showed that comprehension of linear text was not related to individual differences in WMC, but comprehension of hypertext showed a positive, medium correlation with WMC scores. It was proposed that linear text, where the linear organisation may aid in understanding, requires fewer resources while the fragmented hypertext is more demanding and requires additional WM resources (Fontanini & Tomitch, 2009). Other researchers have also noted that some formats of online text, such as hypertext (DeStefano & LeFevre, 2007) or a scrolling format (Sanchez & Wiley, 2009), hamper understanding for individuals with low WMC. Further exploration may thus assist in course and learning material design for Unisa students, so as not to overwhelm their available memory resources. An important direction for this research will be to establish the optimum number of concepts to introduce to students as well as the format in which they should be presented.

An additional means through which to reduce the cognitive load caused by the introduction of terminology and concepts during lectures is to provide supplementary resources. Seery and Donnelly (2012) explored the impact of providing online pre-lecture resources to students taking an introductory chemistry module. The resources provided definitions of terminology that would be introduced in the lecture as well as a short quiz to evaluate students' understanding. In the six years before the introduction of the online supplementary resources, students with prior knowledge of chemistry had significantly outperformed students who had no prior knowledge in both the semester test and final examination. Following provision of the resources, the average marks between those with and without prior knowledge were similar with no significant difference in both the semester test and final examination. Interestingly, the online pre-lecture resources also prompted reflection by the lecturer on the high number of terms introduced during the lecture, sparking increased time spent in explaining and relating each term (Seery & Donnelly, 2012). Supplementary resources may thus be an effective means of supporting students with WMC limitations. Another avenue is through working memory training.

6.7.3. Working memory training

The current study has provided supportive evidence for positive associations between WM and both academic reading and academic achievement. It has shown that a higher WMC is correlated with higher academic reading and academic achievement. Over the previous decade a hearty debate has taken place over whether WM training interventions, and in particular those that are adaptive, are able to improve WMC and thus related higher-level cognitive abilities

(Gibson et al., 2012). While it is noted that the effects of WM training can be negligible if training periods are short (such as less than ten minutes) and unsupervised (Klingberg, 2010), it could be beneficial to explore WM training within the South African learner and student populations. As noted by Santacruz and Ortega (2018), two main paradigms have been employed in designing WM training: 1) core training, and 2) strategy training.

Core training of WM refers to participants undertaking repeated, cognitively demanding WM tasks that use various stimuli. The aim of this training is to improve the components of the WM system (A. B. Morrison & Chein, 2011; Santacruz & Ortega, 2018). Various training programmes have been tested, including use of the *n*-back task (Román et al., 2017) and WM training software (Carretti et al., 2013; Chein & Morrison, 2010). For example, research has shown that adaptive WMC training can result in increased performance on non-trained tasks that rely on WM and control of attention, such as reading comprehension (Klingberg, 2010). Interestingly, one study noted structural brain changes for the treatment group, in that there was enhanced connectivity within one specific network that supports the cognitive processes required by the training. These cognitive processes are intelligence, WM and associated processes (interference resolution and inhibition), and task motivation and engagement (Román et al., 2017). The adaptive *n*-back training used within this study was therefore able to effect changes at the structural level. Although promising, further investigation is required.

Strategy training related to WM, in contrast, includes instructing students in how to store and retrieve information more efficiently (A. B. Morrison & Chein, 2011; Santacruz & Ortega, 2018). An example of this type of training is chunking, where logically or thematically similar individual elements of information are synthesised into a single chunk (Thalmann et al., 2019; Zhang et al., 2021). This reduces the cognitive load on WM and allows capacity for further information (Thalmann et al., 2019). Students who are taught to chunk information can realise improved academic achievement. Zhang et al. (2021) showed that ninth-grade students performed better on a geometry assessment when provided with a chunking strategy. The effect of chunking also became greater when the difficulty of the problem increased (Zhang et al., 2021). While these strategies may not aim to increase WMC, they assist students to circumvent their WMC limitations (A. B. Morrison & Chein, 2011). There are thus several avenues through which WM training can be investigated to assist students. Intervention development must, however, consider that students' participation is an additional academic or training workload. Previous studies have noted that some students may experience this as a burden rather than as supportive (Hurst, 2015; Leso, 2018; Makhura et al., 2021). Time spent participating in the programme as well as undertaking exercises or assignments must be reasonable.

6.8. Conclusion

The ability to read and understand what has been read is crucial for academic success, particularly for ODeL students who primarily access their learning experience through reading. It is therefore essential to explore factors that are influential upon the reading process. The current study focused on the role played by WM, a limited-capacity neural system with the ability to both store and process information, which has been associated with academic reading in previous literature. The study explored the relationships between WM, academic reading, and academic achievement of Unisa ODeL first-year tertiary students. Weak positive significant relationships were identified between these variables. The present study can be seen as an initial step in this direction through the exploration of these complex relations. However, the limitations of the study make it difficult to make generalisations based on these findings. Further research is thus required in order to verify these results.

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APPENDIX A: EMAIL INVITATION TO PARTICIPATE IN RESEARCH

Dear Prospective Participant

My name is Jaqueline Harvey and I am doing research towards a PhD in Psychology at the University of South Africa. I am inviting you to participate in a study that aims to find out if there are relationships between working memory capacity, academic reading, and academic achievement.

Working memory is the ability to hold information in your head while you are using it. You are using it right now to read these sentences. There is much research to suggest working memory is crucial for both reading and academic achievement, but not many studies have been done with South African adults. I would therefore like to explore these claims with South African students.

What am I asking from you? I would like you to complete a survey (5 mins), two working memory tests (15 mins), and an academic reading test (64 multiple choice questions). You will need a computer or laptop and an Internet connection as the tests are **online**.

What's in it for you? A personalised feedback sheet for you about your assessment results. This will state what your working memory capacity is compared to the rest of the participants. It will also give you feedback on your academic reading so that you can see your strengths and weaknesses. I have also developed a website for you that provides information on how the brain learns and effective study strategies.

If you want to participate, please complete this survey and I will **email** you: https://www.surveymonkey.com/r/8TVDHDN.

You can withdraw from the study at any point without having to provide a reason.

The full informed consent letter is here for you to read. Please contact me if you have any questions.

Thank you.

Jaqueline Harvey
072 536 4086
53319575@mylife.unisa.ac.za

APPENDIX B: PARTICIPANT INFORMATION SHEET[16]

Research permission reference number: 2017_RPSC_061_AR

04 March 2020

Title: Exploring the relationships between working memory capacity, academic reading, and academic achievement in Online Distance e-Learning first-year students

Dear Prospective Participant

My name is Jaqueline Harvey and I am doing research towards a PhD in Psychology at the University of South Africa. I am inviting you to participate in a study entitled "Exploring the relationships between working memory capacity, academic reading, and academic achievement in Online Distance e-Learning first-year students."

WHAT IS THE PURPOSE OF THE STUDY?

I am conducting this research to find out if there are relationships between working memory capacity, academic reading, and academic achievement.

WHY AM I BEING INVITED TO PARTICIPATE?

I obtained your contact details from your university as you are one of the students enrolled in an online distance e-learning first-year course. I am hoping that at least 118 students will agree to take part.

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[16] Please note that once campuses closed due to Covid-19 pandemic, all references to on-campus testing were removed from the informed consent.

WHAT IS THE NATURE OF MY PARTICIPATION IN THIS STUDY?

If you agree to participate in the research, you will be asked to complete the following: a questionnaire (5 minutes), working memory tests (15 minutes), and an academic reading test (you have 60 minutes). All tests are online, and you can complete them at home.

CAN I WITHDRAW FROM THIS STUDY EVEN AFTER HAVING AGREED TO PARTICIPATE?

Participating in this study is voluntary and you are under no obligation to consent to participate. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. You are free to withdraw at any time and without giving a reason.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

There are several anticipated benefits of taking part in this program for each student:

- Feedback about assessment results which can help you structure your study time
- Access to a website designed by the researcher which provides information regarding the benefits of online discussions, the best study strategies, etc.

ARE THEIR ANY NEGATIVE CONSEQUENCES FOR ME IF I PARTICIPATE IN THE RESEARCH PROJECT?

Participating in the research can be inconvenient as you must undergo testing. I have therefore kept time spent on assessments to as little as possible.

Students are welcome to contact me at any point. I have contacted the university counselling services and can refer you if requested.

WILL THE INFORMATION THAT I CONVEY TO THE RESEARCHER AND MY IDENTITY BE KEPT CONFIDENTIAL?

You have the right to insist that your name will not be recorded anywhere and that no one, apart from the researcher and identified members of the research team, will know about your involvement in this research. Your answers will be given a code number, or a pseudonym, and you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings.

Your answers may be reviewed by people responsible for making sure that research is done properly, including the statistician, questionnaire software developers, or members of the Research Ethics Review Committee. All individuals will be asked to sign a confidentiality agreement before seeing your answers. Otherwise, records that identify you will be available only to people working on the study, unless you give permission for other people to see the records.

HOW WILL THE RESEARCHER(S) PROTECT THE SECURITY OF DATA?

All data will be stored on my password protected personal computer for a minimum period of five years for future research or academic purposes. Future use of the stored data will be subject to further Research Ethics Review and approval if applicable. This data will not be placed on portable storage, such as flash discs, or on cloud software, such as Dropbox.

After five years, electronic data will be permanently deleted from the hard drive of the computer through the use of a relevant software program.

WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICIPATING IN THIS STUDY?

There will not be any payment or incentive for taking part in the study.

HAS THE STUDY RECEIVED ETHICS APPROVAL?

This study has received written approval from the Research Ethics Review Committees of the Department of Psychology, the College of Human Sciences, and the Research Permission Sub-Committee (RPSC) of the Senate Research, Innovation, Postgraduate Degrees and Commercialisation Committee (SRIPCC). A copy of the approval letters can be obtained from the researcher if you so wish.

HOW WILL I BE INFORMED OF THE FINDINGS/RESULTS OF THE RESEARCH?

Should you require any further information or want to contact the researcher about any aspect of this study, please contact Jaqueline Harvey on 031 242 5682 or 072 536 4086 or email 53319575@mylife.unisa.ac.za.

You can also contact me if you would like to be informed of the final research findings. The findings are accessible for two years. Please do not use home telephone numbers. Departmental and/or mobile phone numbers are acceptable.

Should you have concerns about the way in which the research has been conducted, you may contact Dr Angelo Fynn on 012 429 8211 or email fynna@unisa.ac.za. Contact the research ethics chairperson of the Department of Psychology Research Ethics Committee, Prof Piet Kruger at krugep@unisa.ac.za if you have any ethical concerns.

Thank you for taking time to read this information sheet and for participating in this study.

Thank you.

Jaqueline Harvey

APPENDIX C: INFORMED CONSENT FORM AND BACKGROUND SURVEY

Research Questionnaire: Student Background Information

This questionnaire includes questions about your age and gender, your language background, as well as your parents' education and occupation. The questionnaire is part of the broader study undertaken by myself, Jaqueline Harvey, to explore the relationships between working memory, academic reading, and academic achievement. At the end of the questionnaire, you will be asked if you would like to complete the working memory and academic reading tests for this study.

The information provided will be used for research purposes and reported anonymously in books, academic journals, at academic conferences, and academic reports.

The necessary ethical considerations have been taken into account in the development of this questionnaire. The ethical clearance reference is: 2017_RPSC_061_AR.

I (please give your full names and surname) ………………………………………
Student number …………………………………………………………………….

hereby give consent to participate in the study and for the researcher, Jaqueline Harvey, to report the data gathered in books, academic journals, at academic conferences, and academic reports.

Signature …………………………………. Date ……………………….

Questions

Please put a cross next to the appropriate option or write down an answer.

1. What is your date of birth? (e.g., 08 January 1988)

---

2. What is your gender?

	Female
	Male
	Transgender
	Non-binary
	Do not wish to say

3. What is your contact number?

---

4. What is your email address?

---

5. What course are you enrolled in?

---

6. What is your first language (home language)?

	Afrikaans
	English
	isiNdebele
	isiXhosa
	isiZulu
	Sesotho
	Sesotho sa Leboa
	Setswana
	siSwati
	Tshivenda
	Xitsonga
	Other:

7. What is your second language (if any)?

	I do not speak a second language
	Afrikaans
	English
	isiNdebele
	isiXhosa
	isiZulu
	Sesotho
	Sesotho sa Leboa
	Setswana
	siSwati
	Tshivenda
	Xitsonga
	Other:

8. Have you ever been diagnosed with epilepsy or had a seizure?

---

9. Do you have any physical conditions that prevent you using a computer, e.g., difficulty using a mouse? If yes, please write it down.

	Yes:
	No

10. Have you ever been diagnosed with a learning disability? If yes, please write down the diagnosis.

	Yes:
	No

11. Have you ever had a traumatic brain injury (had to go to the hospital after hitting your head)?

	Yes
	No

12. What type of high school did you attend?

	No-fee public school
	Fee-paying public school
	Private school

13. When you were in high school, what was the highest level of education **completed** by your mother (or female guardian) and father (or male guardian)?

	(a) Mother / Guardian	(b) Father / Guardian
No formal education		
Some primary schooling		
Standard 5 / Grade 7 or equivalent		
Some secondary schooling		
Matric / Senior Certificate / Grade 12 or equivalent		
Undergraduate certificate / diploma		
Undergraduate degree		
Postgraduate qualification		
Don't know		
Not applicable		

14. When you were in high school, what was your mother's (or female guardian's) **job**?

15. When you were in high school, what was your father's (or male guardian's) **job**?

APPENDIX D: COMPARISON OF THREE WORKING MEMORY MODELS

The multicomponent model has amassed a great deal of supportive research but has also been challenged on several aspects. For example, working memory capacity (WMC) may refer to limited attentional resources or a fixed workspace in which storage and processing demands compete (Chiappe et al., 2002). Therefore, in addition to the multicomponent model of working memory (WM), two other prominent models were considered as guiding frameworks for this thesis: the embedded-processes model and the attention-control model. Both models are attention-based and describe WM as an activated subset of long-term memory (LTM), with attention required for maintaining this information in an active state as well as processing information (Healey & Miyake, 2009). This appendix briefly discusses these two models and illustrates where they differ from the multicomponent model.

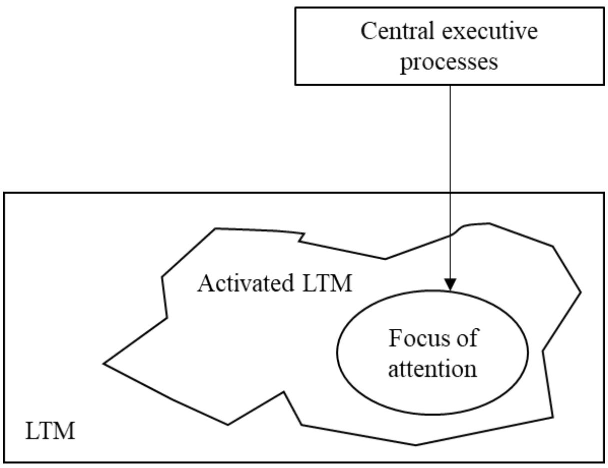
D.1. Cowan's (1988) embedded-processes model

Unlike the modular multicomponent WM model, Cowan (1988, 1999) mostly avoided modules in his theory (Cowan, 2014). The embedded-processes model instead states that different levels of activation divide LTM (Gathercole, 2008). There is thus said to be LTM, a portion of which is in an activated state and, within this portion, a smaller activated subset which is in the *focus of attention* (Figure 66) (Cowan, 2014; Tulsky et al., 2013). The information within the focus of attention receives direct attention from the capacity-limited central executive (Tulsky et al., 2013). This final portion is in conscious awareness, is limited in capacity, and is considered WM (E. J. Adams et al., 2018; Chai et al., 2018; Gathercole, 2008; Gruszka & Orzechowski, 2016). In addition to modularity, another fundamental difference is that the role of attention in the multicomponent model initially received little focus (Baddeley, 2017). In comparison, Cowan's embedded-processes model originated from interest in developmental psychology and attention and activation occurs through attentional processes (Baddeley, 2017; Gruszka & Orzechowski, 2016; Jackson, 2016). The embedded-processes model thus deeply integrates the memory systems with attention (R. G. Morrison, 2005).

To process task-related information, the central executive controls attention to activate the relevant memory traces (Gathercole, 2008; Gruszka & Orzechowski, 2016). This data can be lost in one of two ways. Firstly, attentional focus is capacity-limited to three to five chunks and can thus be displaced by new information. On the other hand, LTM activation is time-limited and is lost through decay if there is no further stimulation (Gathercole, 2008; Gruszka & Orzechowski, 2016; Jackson, 2016). However, it is easier to reactivate information which has been recently activated and this influences processing (Gruszka & Orzechowski, 2016). These mechanisms – attention, memory activation, and LTM – thus comprise a unitary WM system (Jackson, 2016).

Figure 66:

Cowan's embedded-processes model of working memory



Note. Adapted from “Working memory,” by A. D. Baddeley, 2010, *Current Biology*, *20*(4), p. R140. Copyright 2010 by Elsevier. Adapted with permission.

In sum, the embedded-processes and multicomponent models differ regarding modularity, the role of attention, and the way in which WM and LTM interact (Baddeley, 2017; Baddeley et al., 2019). The models also, however, share similarities, with Baddeley (2017, p. 308) stating that "he [Cowan] and I agree that our two models are in fact almost entirely compatible." For example, items with similar features theoretically interfere with one another in both models (E. J. Adams et al., 2018; Cowan, 2014). In the multicomponent model this interference is predicted because items with similar features are held in the same store. In the embedded-processes model, this interference would also take place as items with similar features are concurrently held and are thus dependent on the same neural system (E. J. Adams et al., 2018). The addition of the episodic buffer also assisted in the convergence of these models, as it may be the same as the information located in the focus of attention (Baddeley et al., 2019; Cowan, 2008). Here, the relationship between the central executive and the episodic buffer are viewed as equivalent to the attentional approach of the embedded-processes model (Baddeley, 2010, 2012, 2017; Baddeley et al., 2019). The models are therefore not incompatible so much as different in their emphasis and terminology (Baddeley, 2012).

D.2. Attention-control model of working memory (1999)

Some researchers maintain that WMC is an indication of domain-general executive attention, analogous to the central executive of the multicomponent model (Fenesi et al., 2015). Engle and Kane (2004), for example, proposed the domain-general attention-control model. In this model, WM comprises: 1) activated LTM traces as short-term stores; 2) rehearsal practices to both achieve and maintain activation; and 3) executive attention. From this perspective, it is individual differences in executive attention which account for the relationship between complex span measures and complex cognitive measures such as reading comprehension (Engle & Kane, 2004; Fenesi et al., 2015). It is thus a two-factor model where executive attention firstly maintains goal-relevant information in an active and accessible state. Executive attention then secondly avoids the effects of interference and distraction (Engle & Kane, 2004; Unsworth et al., 2014). WM thus relies on the ability to control executive attention (Cowan, 2008). From this perspective, individuals with high WMC have high executive attention control to maintain information and prevent unnecessary representations from gaining access to WM (Unsworth et al., 2014). The concepts of this perspective are quite similar to those of the multicomponent model: central executive attention processes account for individual differences. However, the attention control model is less modular and ignores storage, equating WM with executive attention processes only (Cowan, 2017; Slattery et al., 2021).

APPENDIX E: HISTORICAL DEVELOPMENT OF THE MULTICOMPONENT WORKING MEMORY MODEL

This appendix provides a brief overview of the historical development of Baddeley's multicomponent working memory (WM) model, the guiding framework for the current study. Organised chronologically, the section begins with the modal model (1968) which formed the foundation of the multicomponent model and culminates with the model as it is today (2000). Over this period, research regarding the development of the complex span tasks provided challenges and different perspectives which prompted revision of the multicomponent model. In this regard, two experiments, the development of the reading and operation spans, are discussed.

E.1. Atkinson and Shiffrin's (1968) memory model

Atkinson and Shiffrin's memory model (1968) comprised sensory stores, a short-term memory (STM) store, and a long-term memory (LTM) store (Atkinson & Shiffrin, 1968; Baddeley et al., 2019; Yuan et al., 2006). Information was first registered in the temporary sensory store which would then pass a limited amount of attended-to information to STM; information not attended to was lost (Baddeley et al., 1988; Yuan et al., 2006). Through storing information for further processing[17], the short-term store controlled the flow of information into and out of LTM (Baddeley, 2010; Yuan et al., 2006). Learning was thus thought to be dependent on this transfer of information from STM to LTM, with time spent in the former impacting the likelihood of long-term learning (Baddeley et al., 1988). The Atkinson and Shiffrin (1968) memory model became considered as a capacity-limited, single (unitary) system for both

[17] Rehearsed information is encoded and saved in LTM for later retrieval whereas unrehearsed information decays after two seconds (Yuan et al., 2006).

storage and processing functions (Was, 2014). Although ground-breaking, it became clear that STM was not enough when two assumptions were disproven.

The first assumption of the above model was that mere maintenance and rehearsal in STM would ensure long-term learning. However, later research indicated that learning depended more on the nature of information processing (Baddeley, 2010). From this perspective, information which has undergone deeper processing is better retrieved, such as when semantic judgements are used (Baddeley, 2010; Craik & Lockhart, 1972; Was, 2014). This is discussed in depth in the levels of processing approach[18] to WM proposed by Craik and Lockhart (1972). Their theory is noted here to emphasise the importance of encoding and retrieval processes in LTM. The second assumption was that inadequate STM, for example, due to injury, would prevent individuals from being able to learn as the information would be lost immediately (Baddeley, 2010). This was contradicted by Shallice and Warrington (1970), who reported that patients with STM deficits were able to learn (as cited in Baddeley, 2010). This would not have been possible in a sequential flow of information. In addition, the patients led cognitively intact lives, which negated the supposition that STM also acted as WM (Baddeley, 2010). The theoretical relationships between WM, STM, and LTM were revised in the multicomponent model.

E.2. Baddeley and Hitch's (1974) tripartite multicomponent theory of working memory

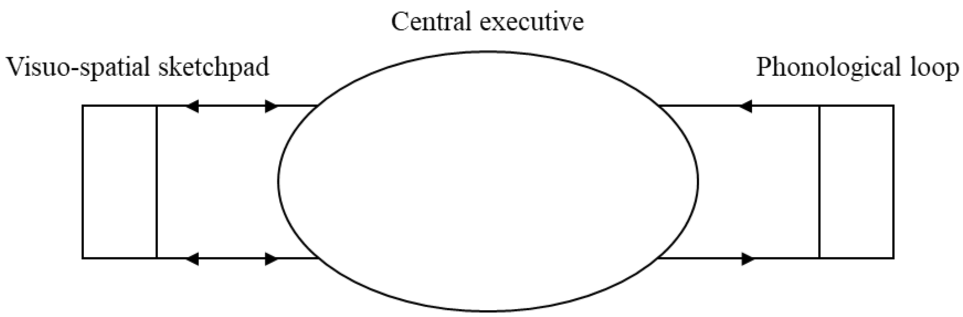
In 1974, the original WM model was proposed by Baddeley and Hitch, and it has since been perceived as the foundation of research in this area (Baddeley, 2017; Baddeley & Hitch, 1974;

[18] The levels of processing approach is not discussed further but was included here to emphasise that it "provides a useful framework in which to develop models of memory and cognition" (Craik, 2002, p. 315).

Christopher & Redick, 2016; Wright & Shisler, 2005). In this conceptualisation, WM was seen as distinct from STM and consisted of three interacting subcomponents (Figure 67) (Baddeley, 2010; Cowan, 2008). This first model included a central executive system and two slave systems: the phonological loop and the visuospatial sketchpad (Baddeley et al., 2019; Cowan, 2008; Wright & Shisler, 2005). In this model the central executive, a limited-capacity attentional system, manages and manipulates the verbal-phonological and visuo-spatial representations held in the slave systems (Baddeley, 2010, 2017; Buchsbaum & D'Esposito, 2008; Christopher & Redick, 2016; Cowan, 2008). The central executive, as the name implies, was thus responsible for many executive functions such as the direction of attentional resources to various cognitive processes needed for higher-level cognition (Wen, 2012). This early conceptualisation of the central executive also included storage capacity which crossed domains of representation. This general memory was removed by 1986 but was later re-added in the form of an episodic buffer (discussed in § 3.4) (Cowan, 2008). Work in language acquisition provided support for the model and its modular construction.

Figure 67:

The first multicomponent model of working memory with three components



Note. From "Modularity, working memory and language acquisition," by A. D. Baddeley, 2017, *Second Language Research*, *33*(3), p. 302. Copyright 2017 by SAGE. Reprinted with permission.

Baddeley et al. (1988) explored language acquisition in a neuropsychological patient who had a deficit specific to the phonological loop. The patient was able to learn to associate pairs of meaningful words in her first language. However, she exhibited a deficit in learning stimuli-nonword pairs (Baddeley et al., 1988). These findings were replicated in a later study which disrupted the phonological loop in otherwise healthy participants (Papagno et al., 1991). The authors thus proposed that this subcomponent was necessary for phonologically based acquisition of language (Baddeley, 2017). Further developmental studies conducted with children showed that the capacity of the phonological loop was correlated with their vocabulary acquisition, and later their reading test scores (Baddeley, 2017; Gathercole & Baddeley, 1993). Together with these and other diverse research, there was support for the multicomponent structure of WM and various roles in reading comprehension. The seminal work by Daneman and Carpenter (1980) supported this model, but also identified a missing element.

Daneman and Carpenter (1980) based their research on two assumptions. The first was that WM has both storage and processing functions; it is the site where operations are performed and then where the products of the executed processes are stored. The second assumption was that WM has limited capacity and therefore can lose information to decay or displacement. Together, this indicated that WM must share limited resources between its two functions. The authors argued that this trade-off between storage and processing would be the foundation of individual differences in reading comprehension. Better readers would have the more efficient processes which would allow more resources to be allocated to storing and maintaining information (Daneman & Carpenter, 1980; Wright & Shisler, 2005). The researchers used this reasoning to develop a measure of WM capacity (WMC) in reading: the reading span.

E.2.1. Daneman and Carpenter's (1980) reading span

Daneman and Carpenter (1980) performed two experiments in order to develop a measure of WMC that would correlate with comprehension measures. In their first experiment, 20 undergraduate first-language English students were given four tests:

1. A reading span test

In this test, participants were asked to read sentences aloud and remember the last word of each sentence. Sentences (60) were grouped into three sets, each containing two, three, four, five, and six sentence levels. The participant was provided with increasingly longer sets until they failed all three sets at a particular level (Bayliss et al., 2003; Conway et al., 2005; Daneman & Carpenter, 1980).

2. Two reading comprehension tests
3. A word span test

Participants were asked to recall sets of individual one-syllable words (81). This was grouped and administered as above (Daneman & Carpenter, 1980).

Participants showed a reading range of 2 to 5 with a mean of 3.15. Results of the experiment indicated that the reading span test correlated with traditional assessments of comprehension, the verbal SAT scores [$r(18) = .59$, $p < .01$)], as well as the two reading comprehension tests [$r(18) = .72$ and .90, $p = .01$]. Readers with smaller spans performed poorly on both tests and were only able to answer approximately half of the questions correctly. The results furthermore indicated that the word span test, which only measured the storage function, was not significantly related to comprehension measures (Daneman & Carpenter, 1980). This set of tests was repeated in the second experiment, but the visual components were replaced with oral components. This was to verify that the same processes in reading occurred in listening and were indicative of WM span. The results corroborated those of the first experiment, with high correlations between WM span and reading comprehension scores (Daneman & Carpenter, 1980). The authors furthermore analysed the errors made on comprehension measures by the participants. It was indicated that errors made by high span readers tended to reflect some understanding of the passage, whereas those made by low span readers related to fundamental misunderstandings of the passage. In addition, high span readers were better able to abstract a theme from the passages (Daneman & Carpenter, 1980). The reading span – a complex span task – was therefore proposed to reflect the limited capacity of WM to perform combined storage and processing functions in a higher-order task (Bayliss et al., 2003; Stone & Towse, 2015; Was, 2014). From these results, the authors proposed that WMC was the source of individual differences in reading.

Returning to the multicomponent model proposed by Baddeley and Hitch (1974), the study by Daneman and Carpenter (1980) also indicated that the limited capacity of the phonological loop was insufficient to account for the storage requirements of the reading span task. Storage in the phonological loop is theorised as 2s, although it can be refreshed by sub-vocal rehearsal. The sentences of the reading span greatly exceed the capacity of the phonological loop. These results posed a problem to the multicomponent model: the model did not adequately account for the maintenance of material in WM nor interaction between the phonological and semantic (within LTM) systems (Baddeley, 2017; Baddeley et al., 2009). The original tripartite multicomponent model therefore required revision. Research by Turner and Engle (1989, as cited in Engle & Kane, 2004) provided additional evidence that the multicomponent model as initially conceptualised was not sufficient in terms of structure.

E.2.2. Turner and Engle's (1980) operation span

Turner and Engle (1989, as cited in Engle & Kane, 2004) argued that if WM comprised multiple subcomponents, then only complex span tasks related to reading skills would indicate the relationship between WM and reading comprehension (Baddeley, 2017; Engle & Kane, 2004) They instead suggested that individuals are good readers because they have an abiding large WMC, regardless of whether the complex span tasks involved reading or performing arithmetic (Engle & Kane, 2004). To test this, Turner and Engle (1989, as cited in Engle & Kane, 2004) adapted the reading span measure used by Daneman and Carpenter (1980). They devised the sentence-word task and the sentence-digit task where participants read and made decisions about sentences and then had to recall words and digits, respectively. Turner and Engle (1989, as cited in Engle & Kane, 2004) also created the operation-word span test and the operation-digit span test. In the first test, participants were presented with an arithmetic operation where they stated if it was correct or not, and then a to-be-remembered word, and so on. The number of words remembered indicated the individual's WM span. In the second test, the to-be-remembered element was a digit rather than a word (Engle & Kane, 2004; Garrison et al., 1997). Results indicated that all four of the complex span tasks were strongly related to reading comprehension (Engle & Kane, 2004; Garrison et al., 1997). They therefore showed that WM predicted individual differences in reading comprehension, irrespective of domain. Turner and Engle (1989, as cited in Engle & Kane, 2004) thus proposed a domain-general cognitive system of WM (Baddeley, 2017; Redick et al., 2012). These results impacted Baddeley and Hitch's (1974) conceptualisation of WM structure. The original multicomponent model (1974), comprising three separate, non-interacting subcomponents, was unable to explain the results of the research regarding complex span tasks. Together with the research by Daneman and Carpenter (1980), this spurred the inclusion of the episodic buffer in the first and only structural revision of the multicomponent model.

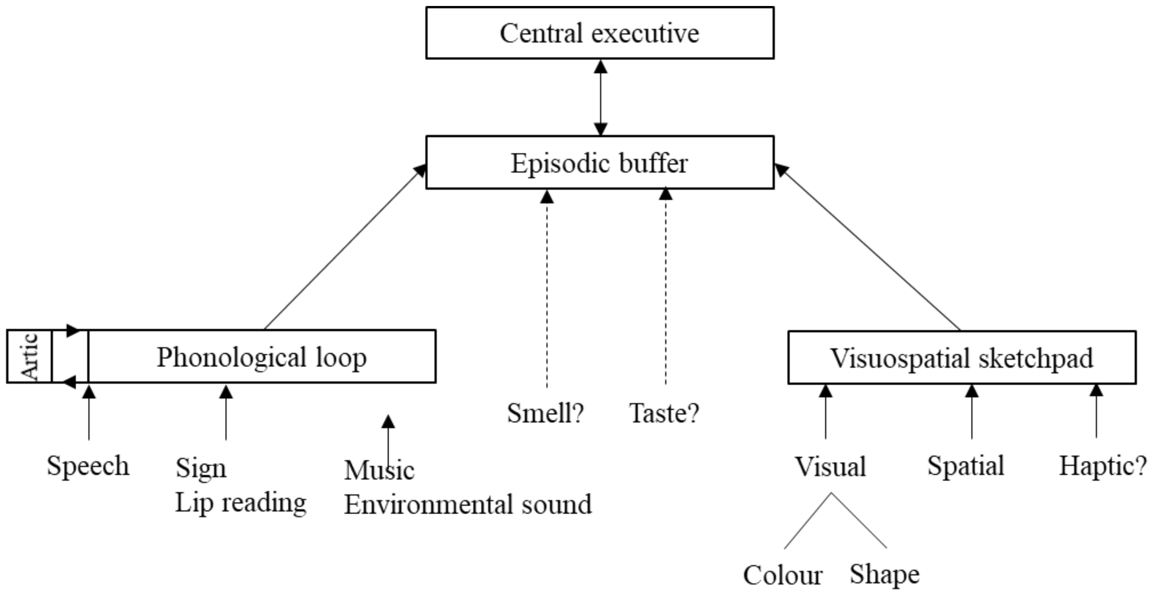
E.3. Baddeley's multicomponent theory of working memory (2000)

The findings from the above two teams of researchers, and other challenges, prompted the first revision of the model in 25 years by adding a fourth component (Baddeley, 2017). The additional component is termed the episodic buffer and is a multidimensional interface which binds information, within or across systems, into episodes (Baddeley, 2012; Baddeley et al., 2019). It is termed episodic because it is capable of maintaining multidimensional 'chunks' and, in so doing, is a buffer allowing the various components of WM to interact as well as allowing interaction between WM and both perception and LTM (Baddeley, 2010, 2012, 2017). This interaction is through participation in a multidimensional code able to integrate information from the senses, from WM, and from LTM (Baddeley, 2010, 2012; Baddeley et al., 2009). The episodic buffer has a limited storage capacity (±4 multidimensional chunks) and is accessible through conscious awareness (Baddeley, 2010, 2012, 2017; Baddeley et al., 2019).

This addition therefore countered the three problems of the original model, i.e. the sentence superiority effect where the number of unrelated words which can be remembered is smaller than the number of words in a sentence which can be remembered, how the visuo-spatial and verbal-acoustic systems interacted (i.e. cross-domain associations), and how the cognitive system as a whole interacted with LTM (Baddeley, 2012, 2017; Cowan, 2008). The current multicomponent model therefore proposes a structure of four key subcomponents or modules: the central executive, the visuospatial sketchpad, the phonological loop, and the episodic buffer (Baddeley, 2012; Barreyro et al., 2019; Jackson, 2016). This model has been elaborated so as to provide more detail and refinement, but essentially retains this structure (Figure 68) (Baddeley, 2017). As noted, this model is the dominant perspective of the structure of WM and this construct is therefore generally viewed as the combination of multiple components which work together (Alshahrani, 2018; Barreyro et al., 2019; Cowan, 2008). Regarding its neural basis, although the functions of WM require integration of the brain as a whole, Chai et al. (2018) depicted each component as associated to specific brain regions. Tasks requiring the central executive, measured in the current study, have been typically associated with activation of the prefrontal cortex (Chai et al., 2018; Morais et al., 2018).

Figure 68:

The current elaboration of the multicomponent model



Note. From "Modularity, working memory and language acquisition," by A. D. Baddeley, 2017, *Second Language Research*, *33*(3), p. 307. Copyright 2017 by SAGE. Reprinted with permission.

APPENDIX F: RESEARCHER'S CRITICAL REFLECTION

Reflexivity during the research process has long been considered important, albeit usually in relation to qualitative research (Ryan & Golden, 2006; Walker et al., 2013). Being reflexive requires honesty and openness from the researcher regarding how, where, and by whom data was collected. This positions the researcher as a participant in the research process and can provide crucial insight into the complex dynamics between researchers and participants. This is particularly imperative as researchers must overcome any boundaries in communication between themselves and their participants. This is true for both qualitative and quantitative research (Ryan & Golden, 2006). The purpose of this reflection is to examine the PhD journey in terms of the initial planning stages, the challenges of data collection, balancing studies and work throughout, and the final writing of the current study. A reflective narrative framework is adopted.

F.1. Planning

While my submitted proposal seemed well thought out at the time, it now serves as an exemplar of overambition. Extensive reading had provided me with an engaging topic, but the depth and breadth of the available scholarship had caused me to envisage an elephant that I had no hopes of eating. I thus note my naïveté in initially proposing an eight-week working memory (WM) training intervention, doubly so when it is remembered that I had not established prior relationships with students, lecturers, or computer laboratory staff. Unfortunately, this seems to be common failing for PhD students. My supervisor was, however, able to guide me onto a more attainable path that was still able to provide original, novel research. This is just one reason that the PhD supervisory relationship is a cornerstone of the PhD journey:

> The importance of the PhD supervisory relationship cannot be overstated—at a minimum, it is a one-on-one relationship of close collaboration that lasts several years and establishes the student's career prospects but may be as critical as setting the foundation for the student's future career as an independent researcher. (Madan, 2021, p. 5229)

In these beginning stages of my study, my supervisor had a hands-on approach to my supervision. There were many back-and-forth discussions regarding the content of the study as well as technical aspects, such as how to navigate the ethical clearance application. As the study progressed and I became increasingly self-directed, these discussions became more focused and, in my own evaluation, less instructional. Alongside this development, however, the stress also intensified, and my supervisor provided increasing encouragement and support. Overall, in agreement with the above quotation, this PhD supervisory relationship was fundamental to the study as well as to my personal growth as an independent researcher.

F.2. Challenges of data collection

Throughout the data collection period, various challenges necessitated adaptions, negotiations, and growth as a researcher. The initial set-up of the first data collection on the Unisa Sunnyside campus in Gauteng was difficult. Strike action by Unisa staff as well as student protests in late January 2020 and early February 2020 were frustrating, as they delayed the start date of data collection, creating uncertainty around timelines. Not only could I not enter the campus, but the registration deadline for first-year students was postponed multiple times; the initial invitation email could not be sent out until the majority of students had registered or we risked lower participation rates. Also related to the set-up of the study, it was challenging to contact Unisa staff to organise access to the computer laboratories, as they did not respond timeously to emails. This again speaks to the need to have established relationships as it greatly assists with implementation. The challenges of initiating fieldwork made me feel unprepared, inefficient, and anxious as I was not able to move forward. There were questions about whether the study was achievable – unfortunately not for the last time.

Once the first data collection on campus had begun, it was taxing to provide appealing information about the study to staff as well as to students. I had to balance being a courteous guest at the campus and develop relationships, while also being persistent in undertaking data collection in a timely and effective manner. Furthermore, my natural engagement style is quiet and reserved, which made the high-energy interactions quite draining. I often returned home exhausted. The experience prompted me to consider my development as a researcher and to realise that fieldwork, with all its challenges, is a vital skill that may be harder for me to foster. When planning future studies, I will need to take into account my limits and allow for ‘down time’ between engagements.

After students had volunteered to participate and been informed of the date that they should arrive at the computer laboratory, another setback arrived at the end of February 2020 in the form of a burst major water pipeline. This caused the campus to be closed and I had to reschedule the assigned sessions. When sessions could again be held on campus, further rescheduling was necessary as loadshedding meant that the campus was without power for periods of time on certain days. These changes were detrimental to the newly formed researcher-participant relationships, likely leading to attrition. Finally, the start of the Covid-19 pandemic terminated on-campus data collection as higher education institutions in South Africa, and indeed worldwide, close their physical spaces. This meant that data collection needed to be conducted entirely online.

Online data collection had its own set of challenges. I was no longer able to engage with the students in-person, which created a physical barrier between participants and myself. It was also difficult to ensure that participants fully understood the instructions before completing the tasks, although all queries were attended to promptly. I attempted to mitigate this by hosting an online information session, but it was very poorly attended and thus ineffective. If future studies are conducted online, other strategies need to be developed such as working with lecturers and tutors to include information about the study. An additional difficulty was keeping professional boundaries while also being responsive and friendly towards students. For example, several communications began with concerns regarding the study, before the student would turn to asking personal or inappropriate questions, such as a request for money. I attempted to answer with innocuous information before explaining the ethical constraints and ending the conversation kindly. The negotiation of these researcher-participant boundaries was complex. Many students also approached me for assistance navigating Unisa processes, which made me aware that they perceived me in a similar way to a staff member, rather than as a student. In this I did try to direct them to someone who could assist, as your first year of higher education is challenging enough even without an ongoing pandemic.

My PhD data collection was certainly a testament to the adage that there are always elements outside of your control. When planning my study, however, I am probably not alone in failing to include a contingency plan should a global pandemic ensue. Nevertheless, the knowledge and skills which were acquired during this period will be an asset in my career and projects going forward. This includes critical thinking, a tolerance for frustration, and improved problem-solving ability. For example, being frustrated allows for questioning and going through the process of determining what went wrong in your research process and how to avoid making the same error in the future. Focusing on my opportunities for growth, obtaining the required sample size was the largest milestone.

Beyond the challenges and setbacks, there was an ever-present awareness that I needed to obtain above a certain number of participants to complete my data analysis, causing me a great deal of anxiety. This came to a critical point after the second online data collection, when a decision needed to me made: would I continue with the study as planned or submit a new proposal and start again? Part of the need to make this choice was that I was employed as a PhD intern with the Human Sciences Research Council; my contract stipulated that I would complete my doctorate within the three-year period. This decision was a radical moment in my development. It required that I more objectively view the feasibility of the study, as well as my ability to complete it or another study within the given timeframe, and decide which of my two options was more likely to succeed. I also needed to take ownership of my study—my supervisor could offer a soundboard but could not make this decision for me. To fully understand the pathways available to me, I explored other options, spoke to other experienced researchers, and wrote a short proposal for a secondary data analysis dissertation. Deciding to continue with my original project was an acknowledgment of the value and contribution of my efforts thus far, as well as a rejection of imposter syndrome. It would not have been possible, however, had my supervisors at the Human Sciences Research Council not motivated for an extension of my contract. This speaks to the high quality of my work and the need to balance studies and workload effectively.

F.3. Balancing act

Working at the Human Sciences Research Council at the same time as completing my doctorate was stressful but rewarding. It did require strong time management and the ability to prioritise.

It was easy to 'forget' about the doctorate while making progress on work-related tasks, as productivity in one area made it easy to overlook stagnation in others. This was detrimental to the doctorate, as it is a type of procrastination that was easier to justify. I therefore had to ensure that I was completing tasks in both areas, rather than neglecting one or the other. Keeping track of how many hours I spent on my PhD and work in a spreadsheet was helpful. The other change I made was to stop delaying working on my PhD to a future, perfect day when I had completed all other tasks and had a chunk of time to devote to my doctorate. Not only was this another favourite procrastination technique, but when the day came, it was almost always impossible to complete the lengthy list of tasks I had deferred. I had to learn to work on a task whenever there was time available.

My work and collaborations at the Human Sciences Research Council enabled me to work on several projects and to co-author publications. This gave me a sense of legitimacy and the ability to think of myself as a researcher. The delays in completing my doctorate, however, still made me feel like I was failing in my attempts to advance. I felt stuck and this feeling contributed to my resolve to complete this chapter of my academic studies. Completing the doctorate feels like the final hurdle in entering my chosen field, as I will then have the requisite qualification to participate in that space, such as applying for grants and running future projects. It was an interesting position to be in, where I could see the progress in aspects of my career but also know that I was somewhat stagnant until I had completed my doctorate.

My colleagues provided one of my main sources of support. They were understanding, reassuring, and provided a sounding board when I needed to brainstorm or quickly run an idea by someone else. Their guidance helped shaped the researcher I am becoming. It also provided a space where others had insight into my experience and could understand, better than friends and family, the challenges and why it was ‘taking so long’. This sense of community was particularly important as I was completing my doctorate at an online institution. A Unisa PhD programme does not have taught classes, and there is limited contact with other postgraduate students. This can become isolating, and it was thus crucial to create a sense of community.

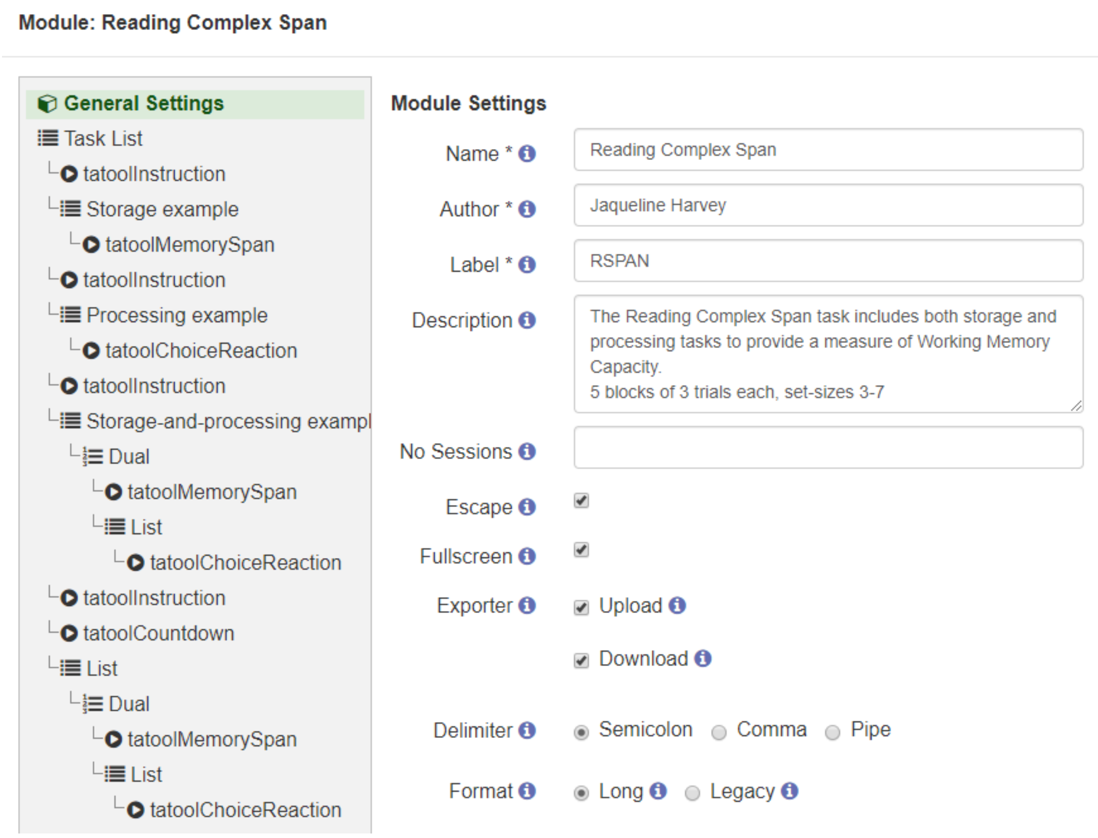
F.4. The art of writing

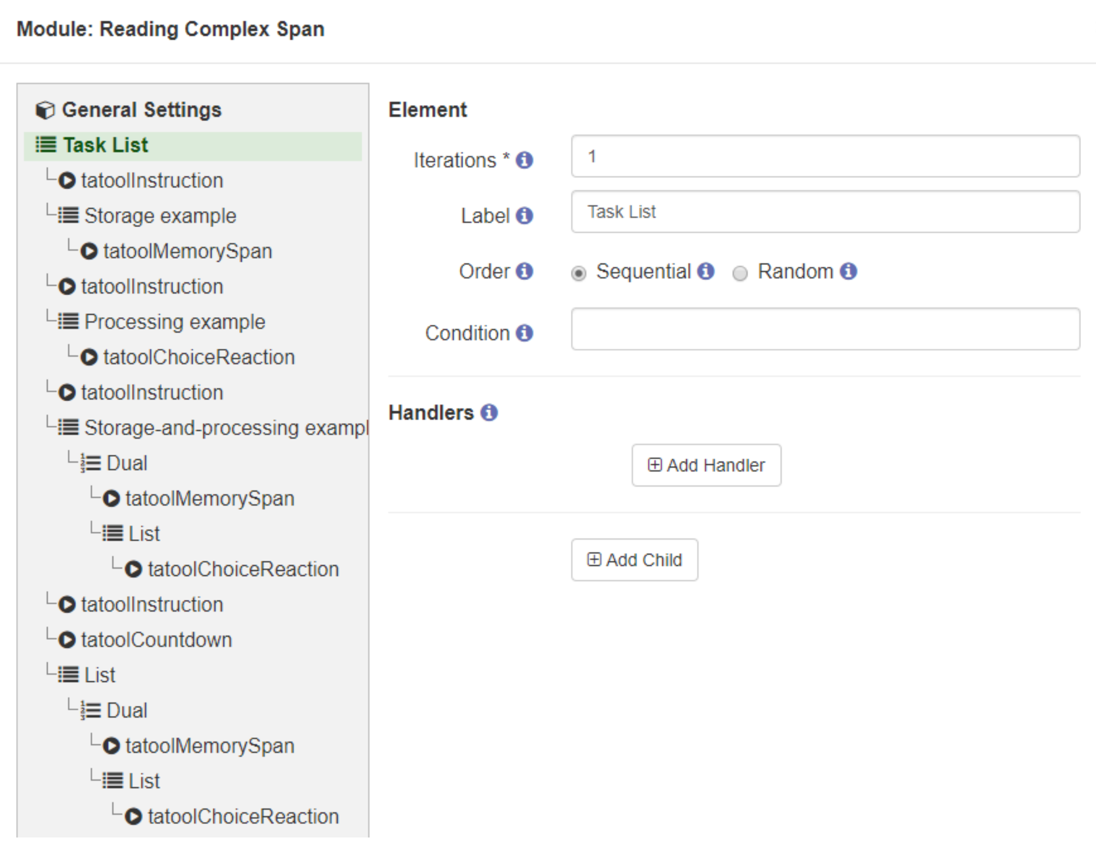
Writing a thesis is difficult for many reasons. For me, it was challenging to form my own academic voice. The general point I wanted to make was often clear to me, but it was demanding to express it clearly and succinctly in my own words to an audience; my rephrasing and integration of multiple authors’ work often seemed clumsy in comparison to their wording. Imposter syndrome was also a hindrance, as it made me question myself when I questioned other authors’ work or attempted to express my own stance. My academic voice was thus cloaked in the first drafts of my thesis. As one colleague pointed out to me after reviewing my work, I tended to begin paragraphs or arguments with the work of well-established researchers. Re-reading and editing made me more aware of when this was appropriate and when it needed to be reworked to show my voice. This process also made me think more deeply about my arguments and to consider if there was a logical flow throughout the thesis. Ultimately, I was able to move from writing from a place of fear and anxiety—if it was clear I had read extensively and was justified in my conclusions, if my understandings were correct, if my arguments were logical, etc.—to a position of confidence. This placed me in a better position, where I could speak to the work of previous researchers, thus providing sufficient evidence for my claims but adding my constructions, interpretations, and position.

F.4. Closing remarks

The PhD journey was both intellectually and emotionally challenging and certainly cannot be taken lightly. It is full of oxymorons: rewarding but humbling, confidence-building but disheartening, exhausting but thrilling. There is not, however, any replacement for the training, growth, and development that will take place over the course of completing your PhD thesis. I feel even more certain that this career path is mine to walk and that I am equipped to do so. I am a researcher.

APPENDIX G: TATOOL WEB TEST INSTRUMENT SETTINGS FOR RSPAN

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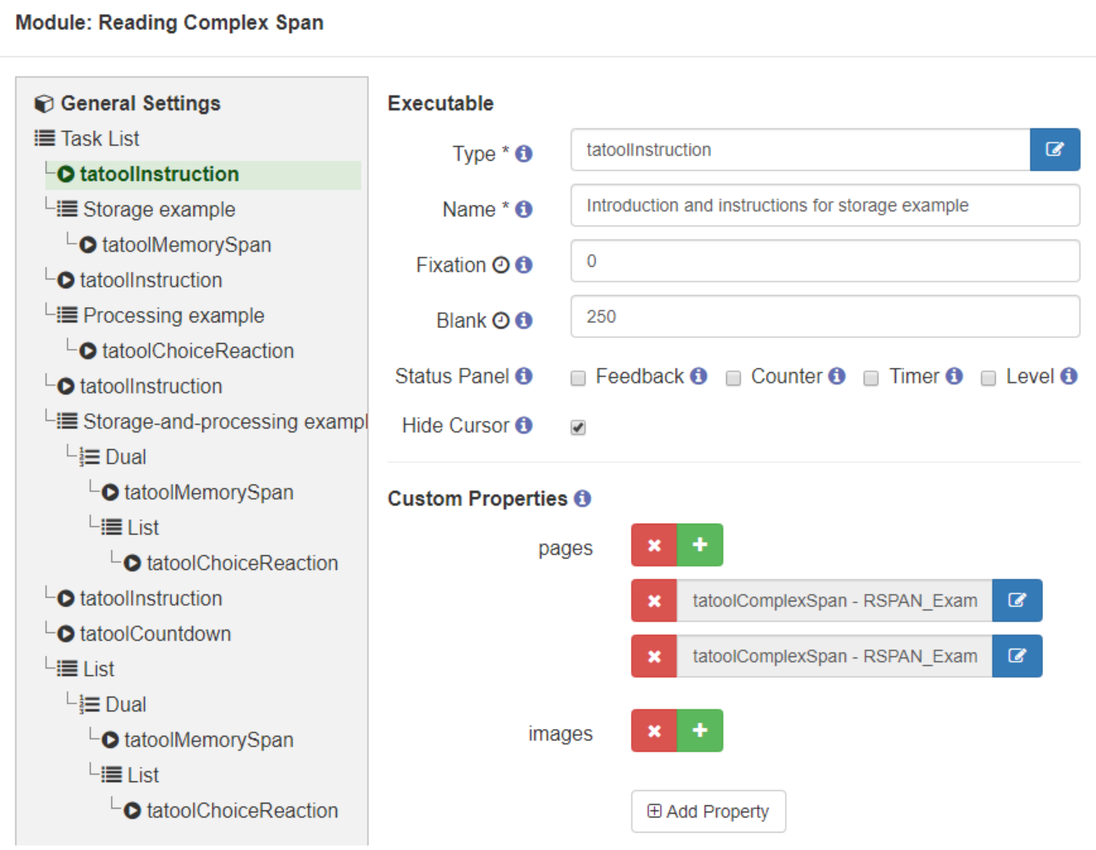
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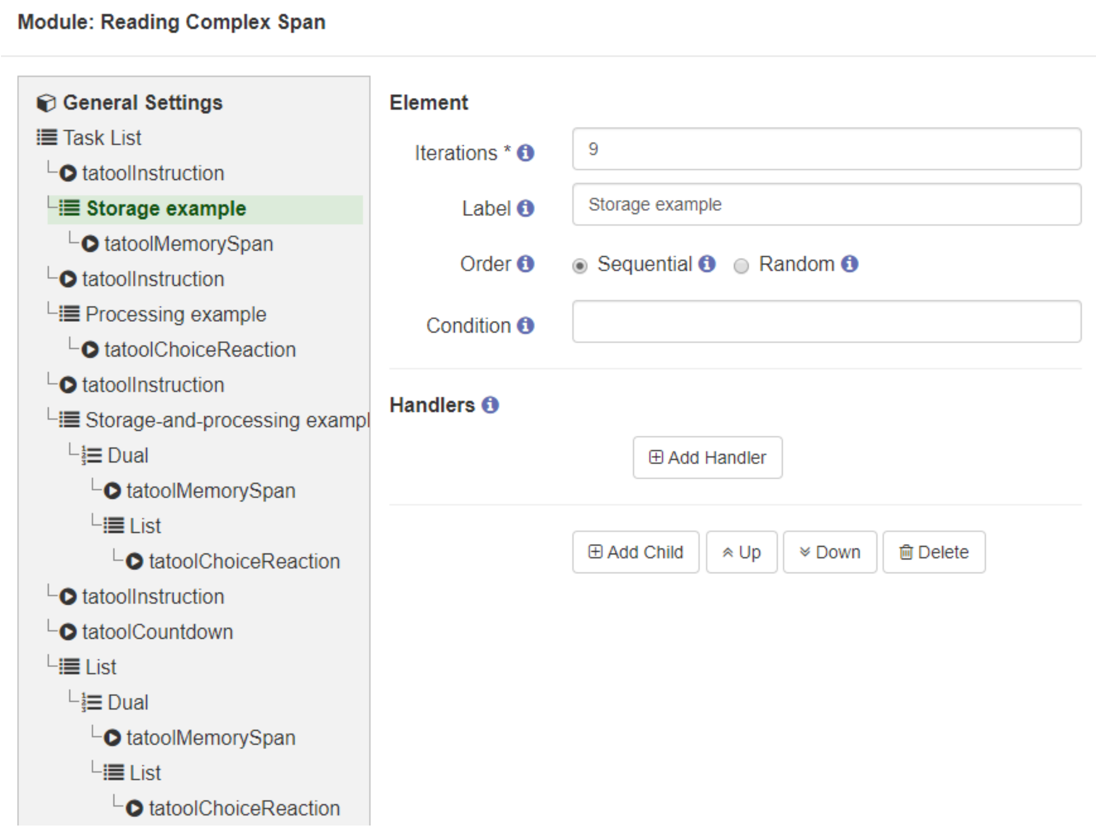
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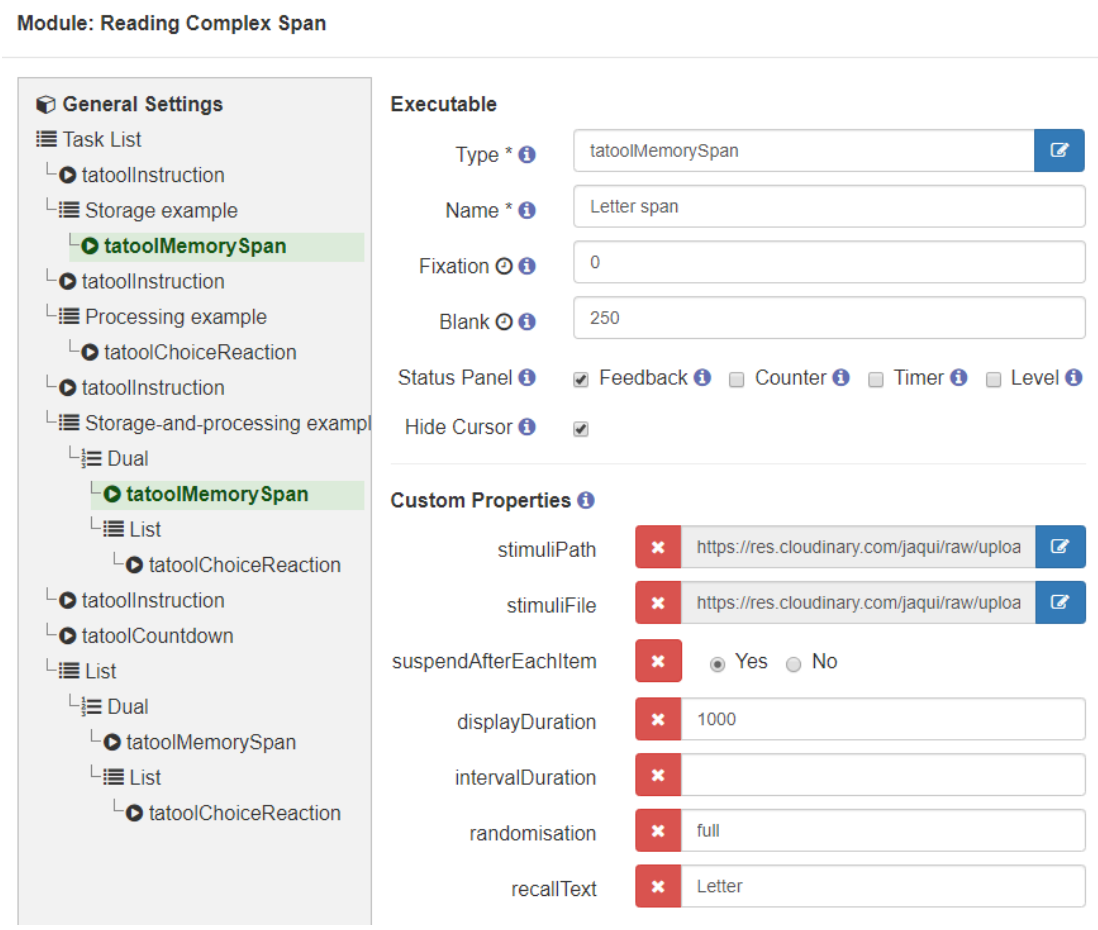
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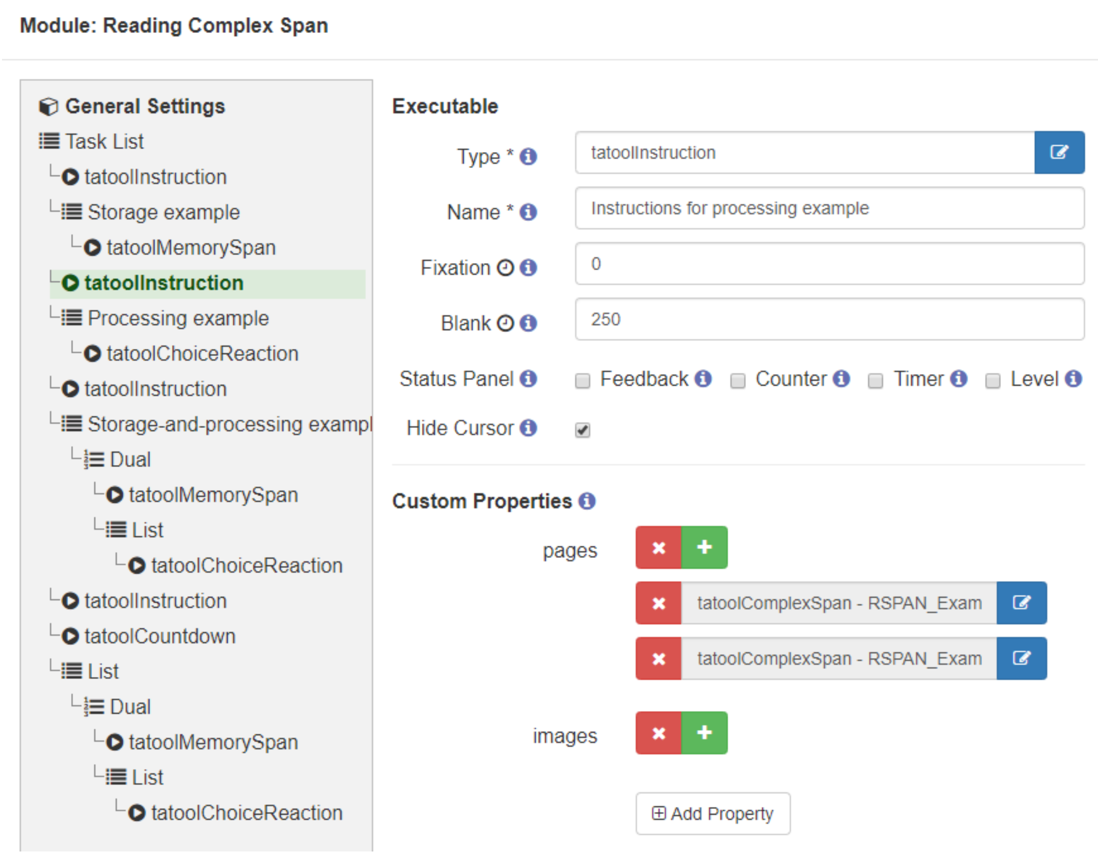
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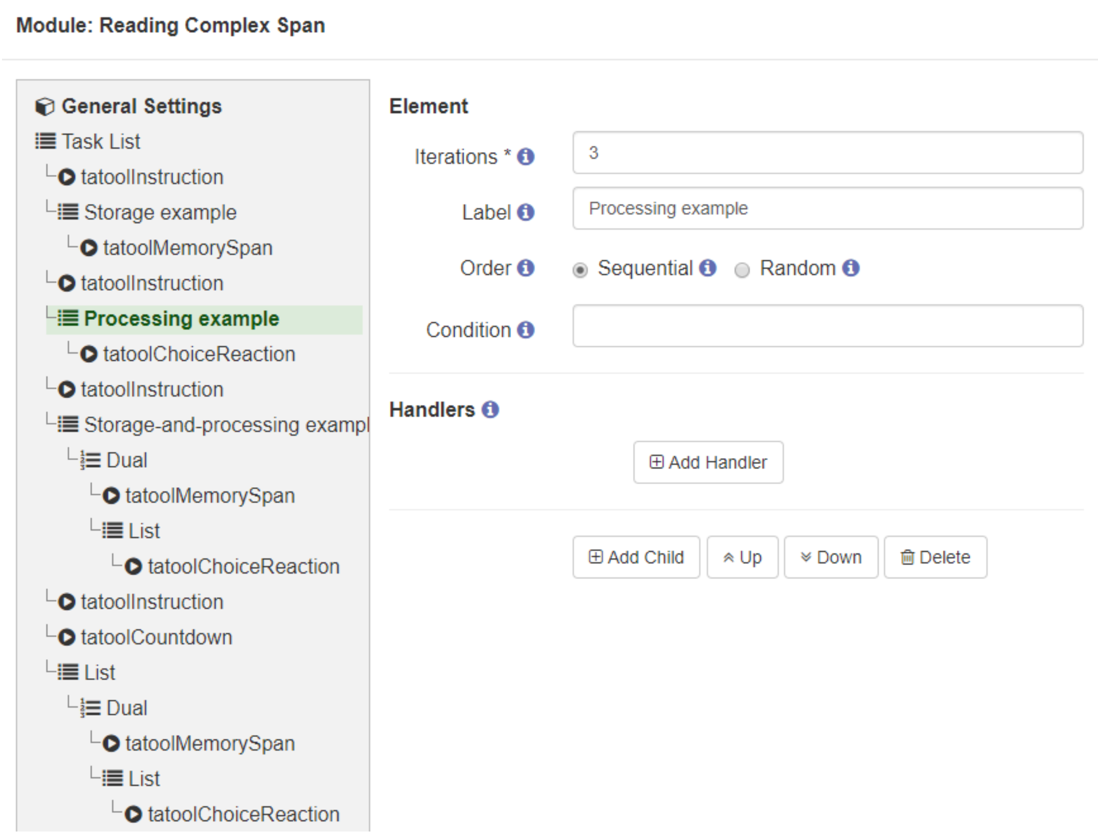

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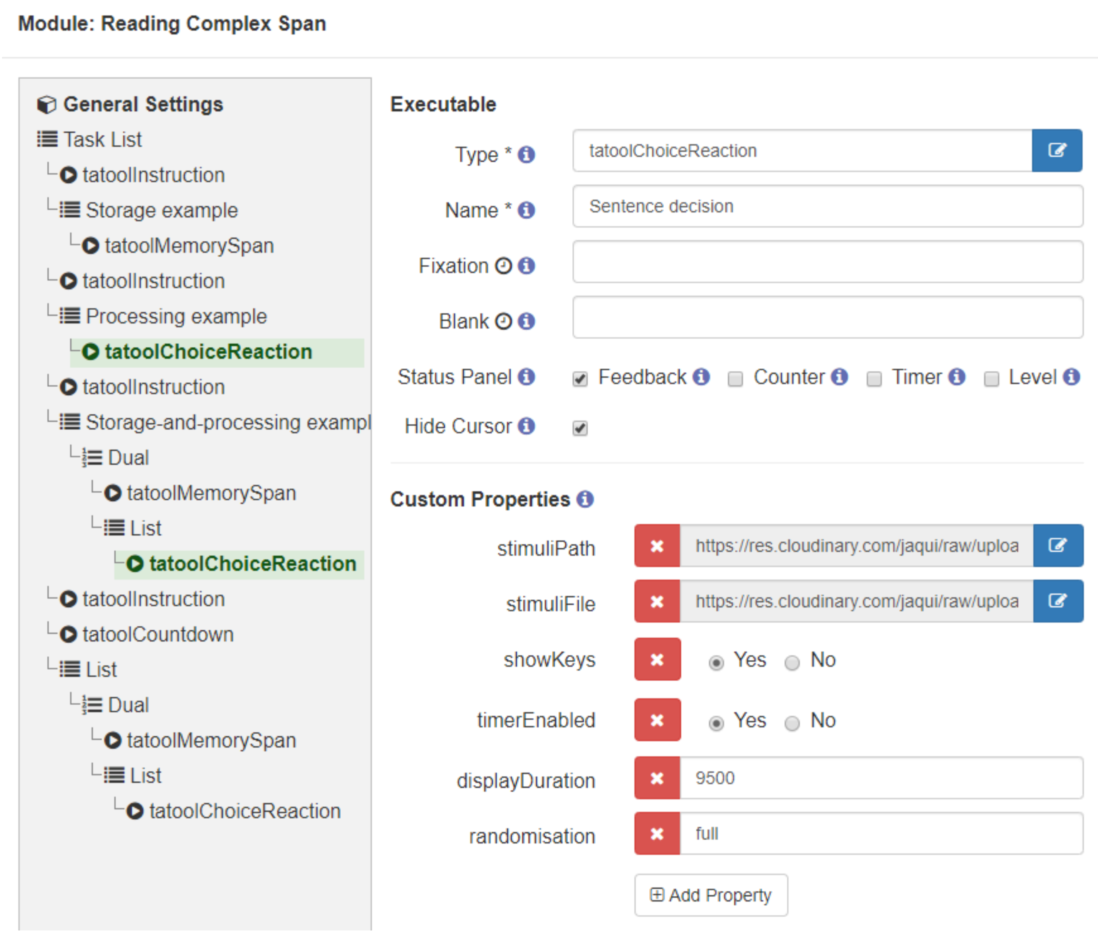

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Name *
Sentence decision
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Blank
Status Panel
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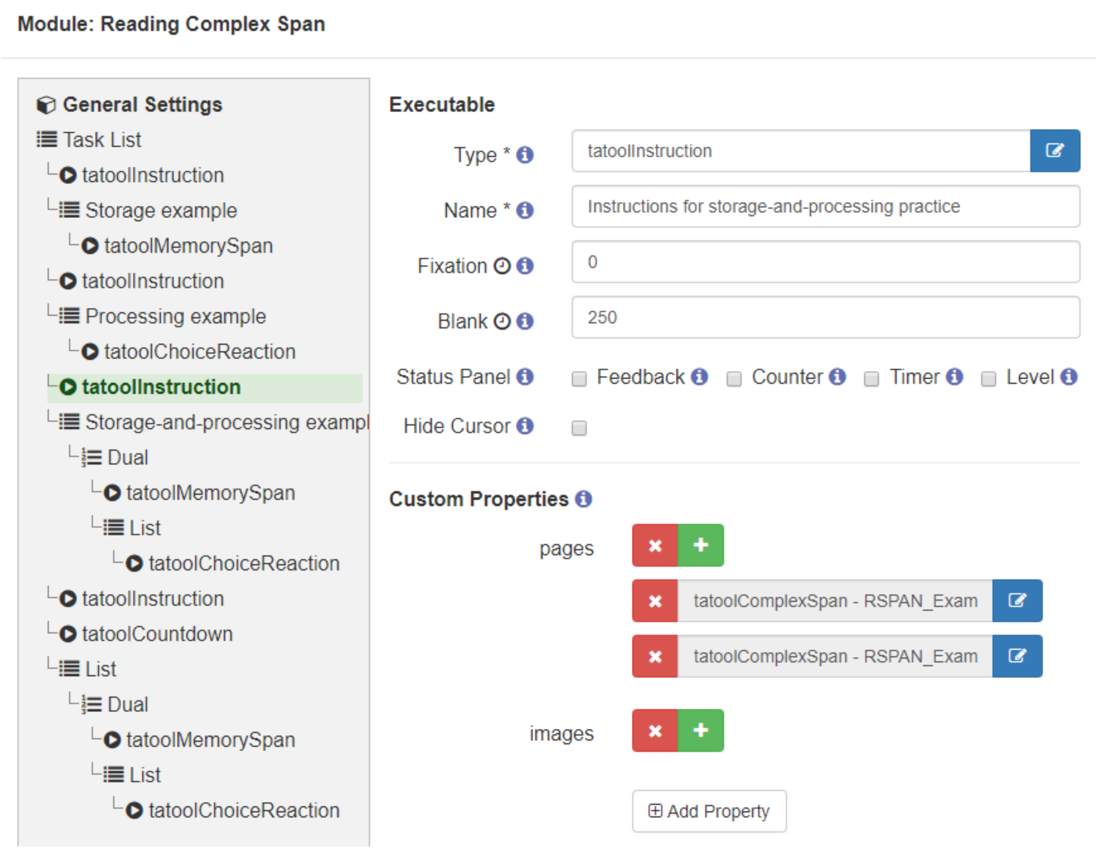
Hide Cursor
Custom Properties
stimuliPath
https://res.cloudinary.com/jaqui/raw/uploa
stimuliFile
https://res.cloudinary.com/jaqui/raw/uploa
showKeys
Yes
No
timerEnabled
Yes
No
displayDuration
9500
randomisation
full
Add Property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Name *
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Hide Cursor
Custom Properties
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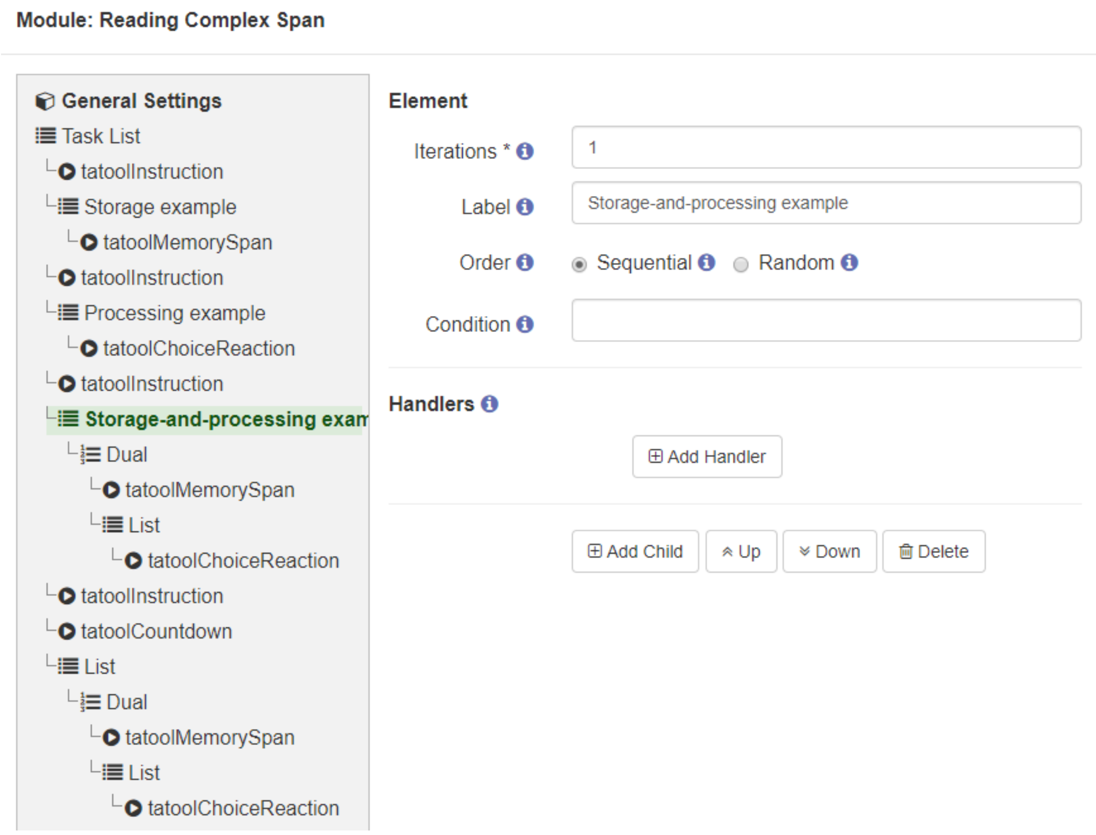
images
Add Property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Iterations *
1
Label
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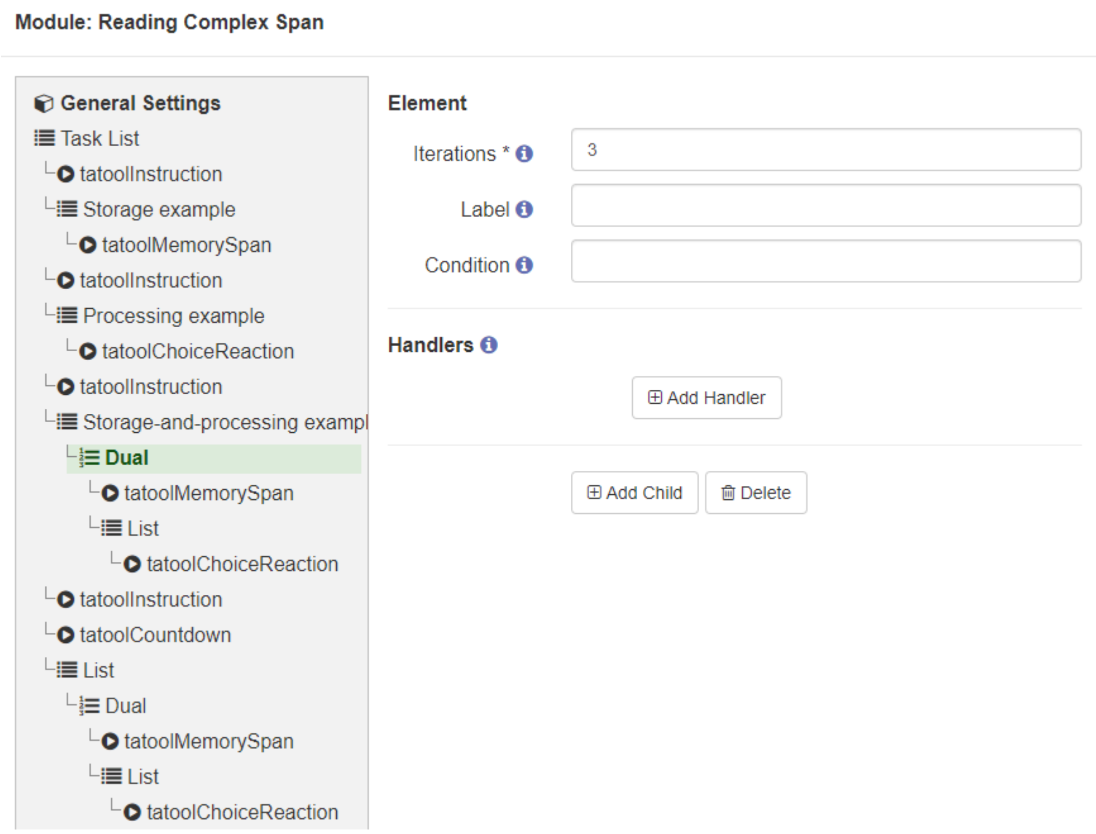
Condition
Handlers
Add Handler
Add Child
Up
Down
Delete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tatoolChoiceReaction
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List
Dual
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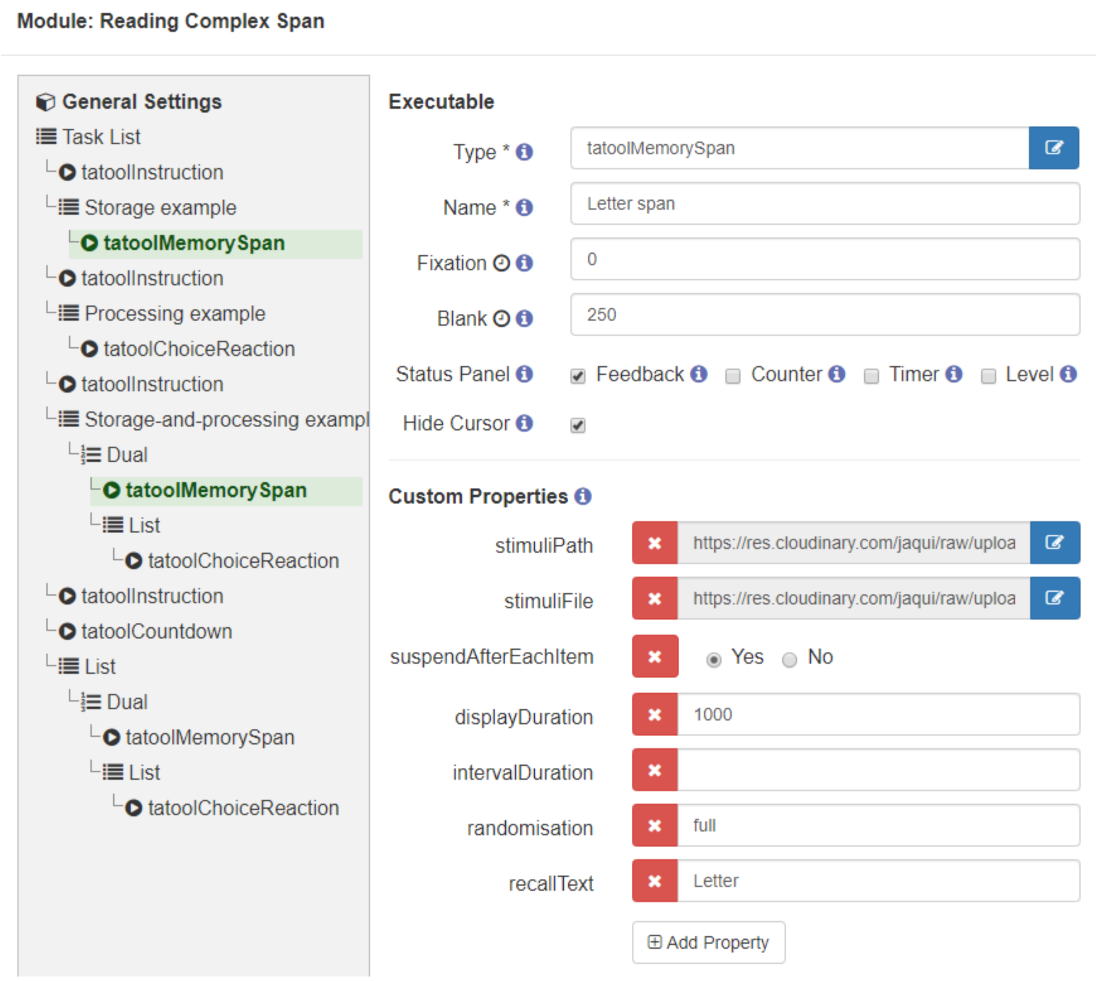
tatoolChoiceReaction
Element
Iterations *
3
Label
Condition
Handlers
Add Handler
Add Child
Delete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tatoolChoiceReaction
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tatoolCountdown
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Dual
tatoolMemorySpan
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tatoolChoiceReaction
Executable
Type *
tatoolMemorySpan
Name *
Letter span
Fixation
0
Blank
250
Status Panel
Feedback
Counter
Timer
Level
Hide Cursor
Custom Properties
stimuliPath
https://res.cloudinary.com/jaqui/raw/uploa
stimuliFile
https://res.cloudinary.com/jaqui/raw/uploa
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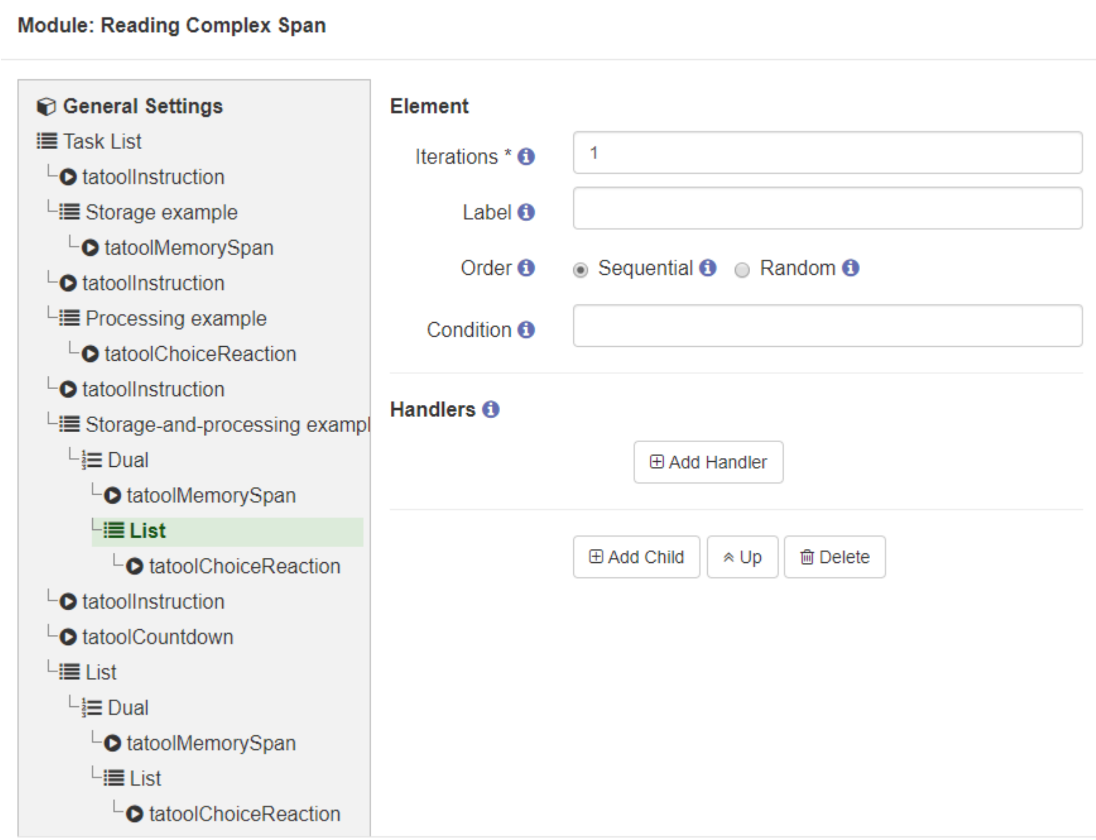
Yes
No
displayDuration
1000
intervalDuration
randomisation
full
recallText
Letter
Add Property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Dual
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Element
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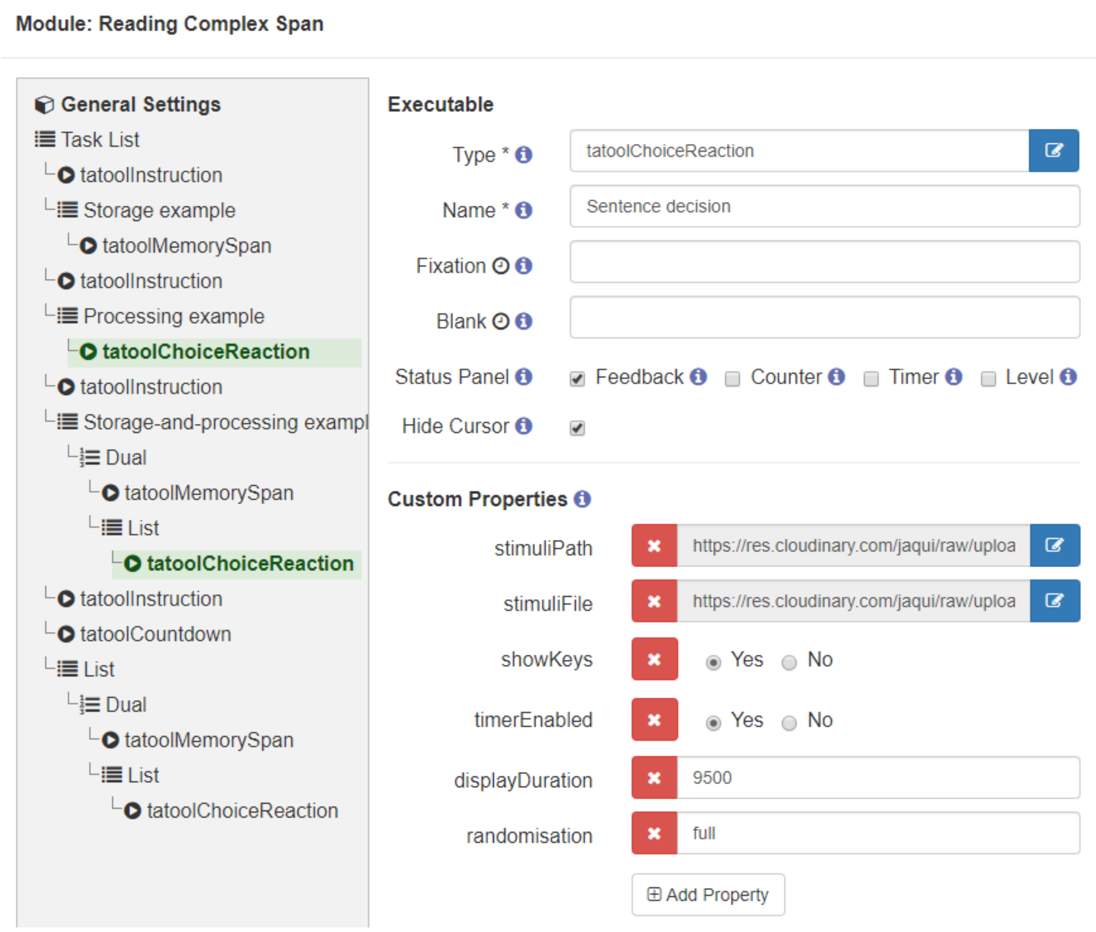
Label
Order
Sequential
Random
Condition
Handlers
Add Handler
Add Child
Up
Delete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Name *
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Timer
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Hide Cursor
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https://res.cloudinary.com/jaqui/raw/uploa
stimuliFile
https://res.cloudinary.com/jaqui/raw/uploa
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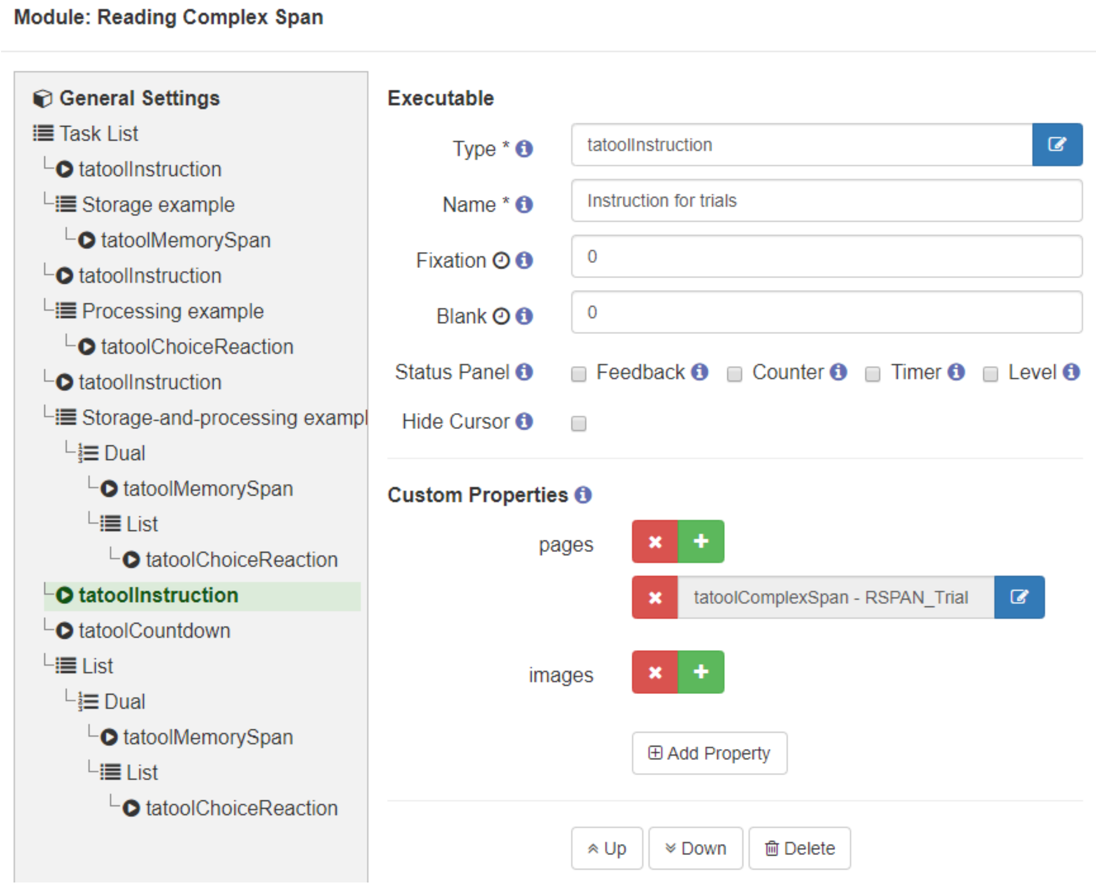
timerEnabled
Yes
No
displayDuration
9500
randomisation
full
Add Property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Executable
Type *
tatoolInstruction
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Instruction for trials
Fixation
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Status Panel
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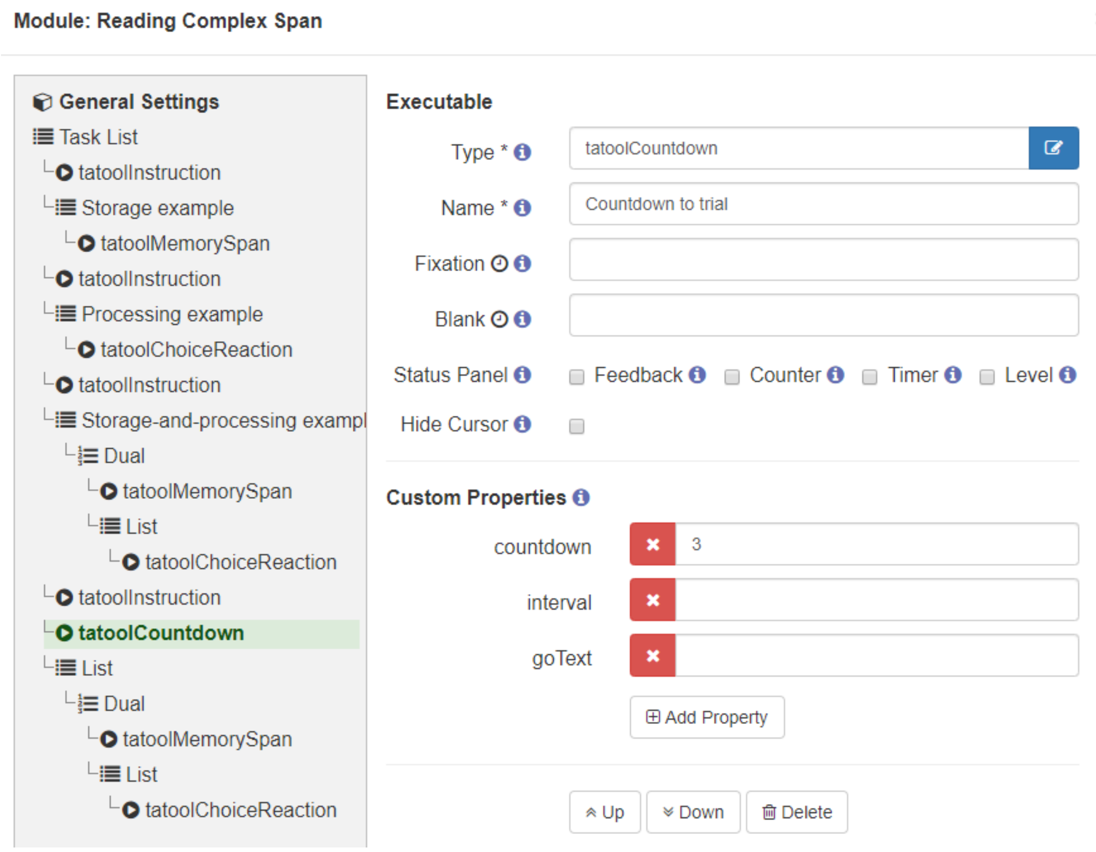
images
Add Property
Up
Down
Delete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Fixation
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countdown
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Add Property
Up
Down
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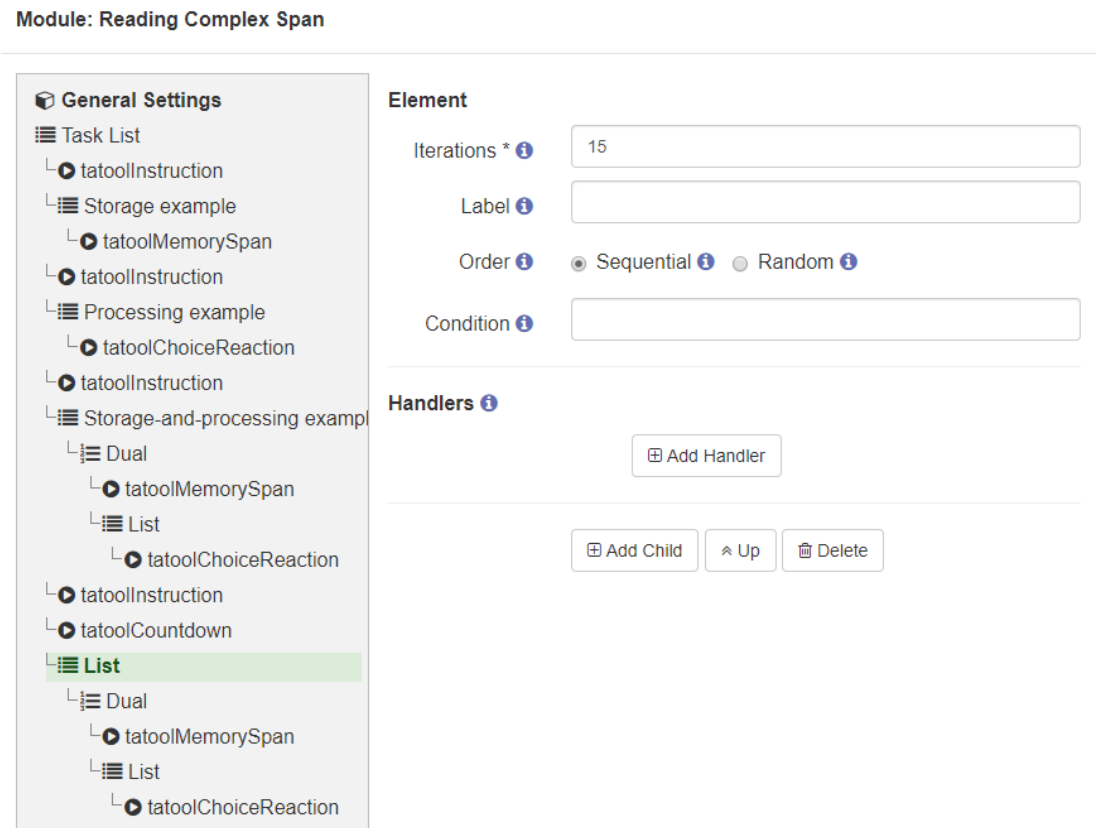
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tatoolCountdown
List
Dual
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Element
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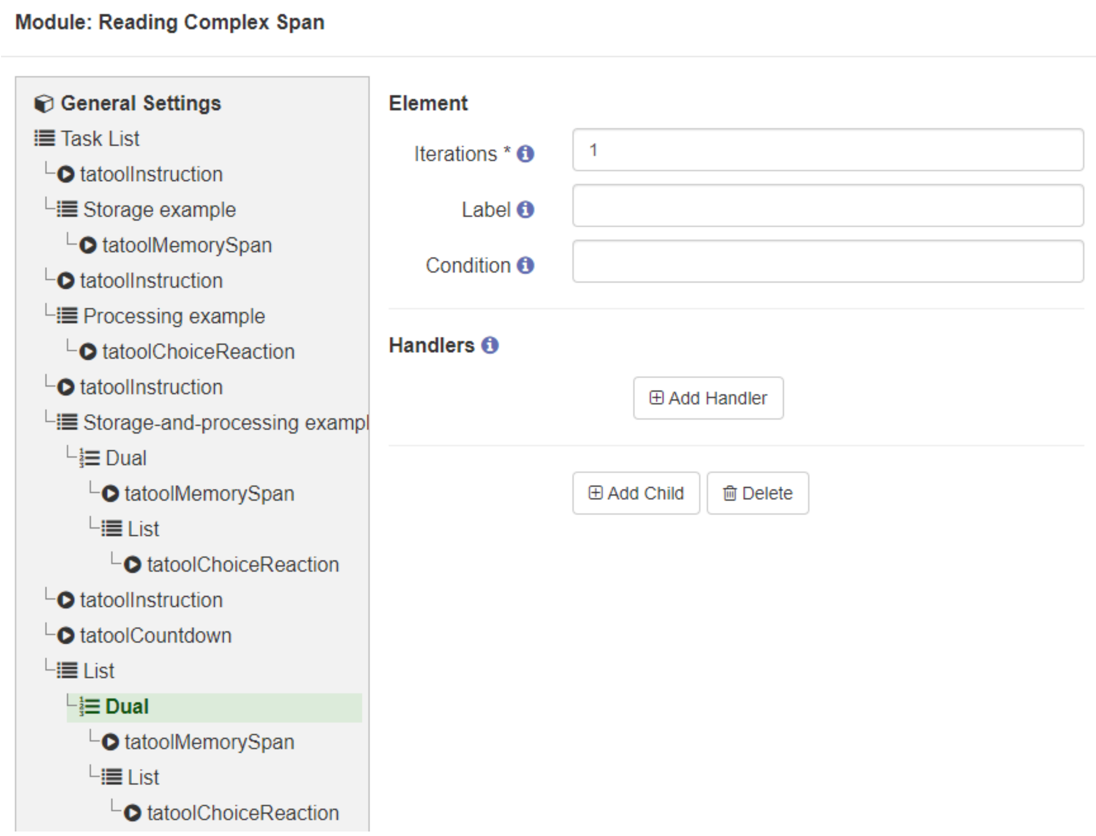
Label
Order
Sequential
Random
Condition
Handlers
Add Handler
Add Child
Up
Delete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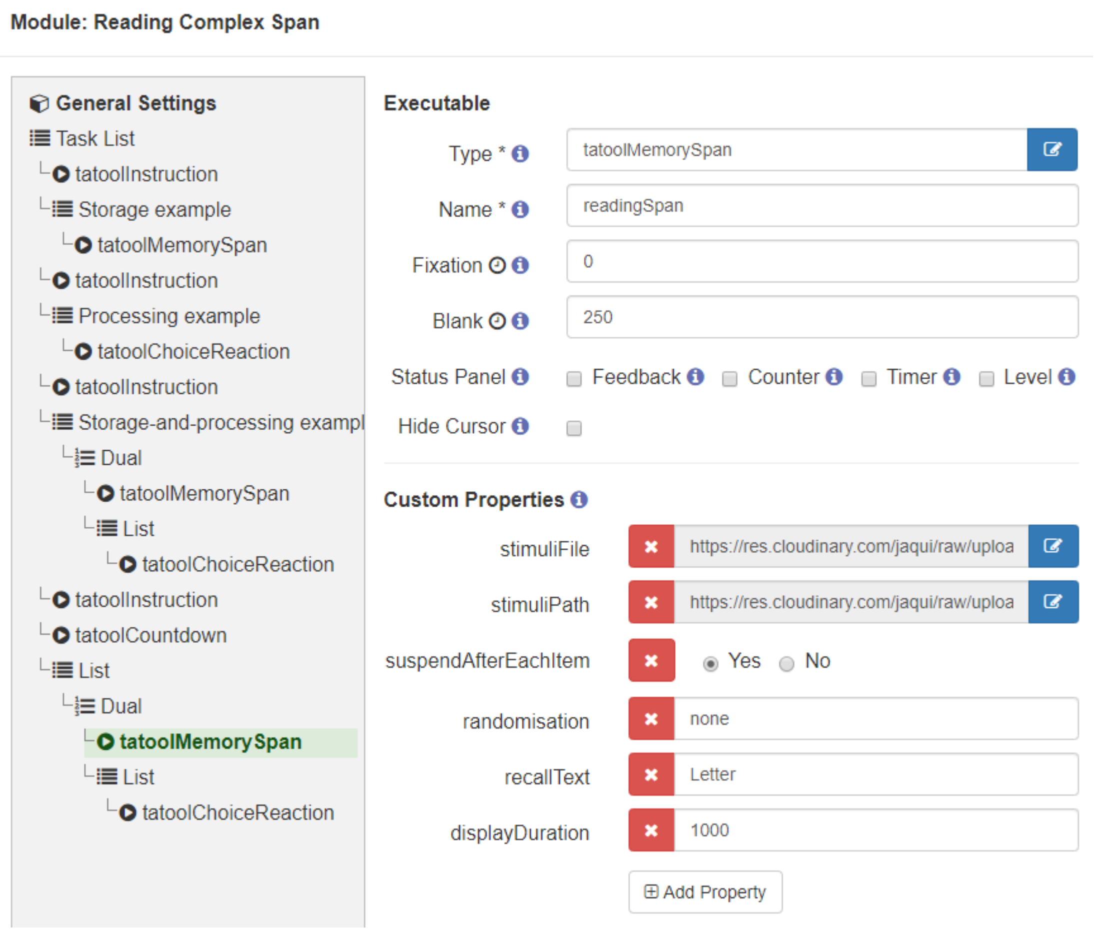
Label
Condition
Handlers
Add Handler
Add Child
Delete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tatoolMemorySpan
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tatoolMemorySpan
Name *
readingSpan
Fixation
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Blank
250
Status Panel
Feedback
Counter
Timer
Level
Hide Cursor
Custom Properties
stimuliFile
https://res.cloudinary.com/jaqui/raw/uploa
stimuliPath
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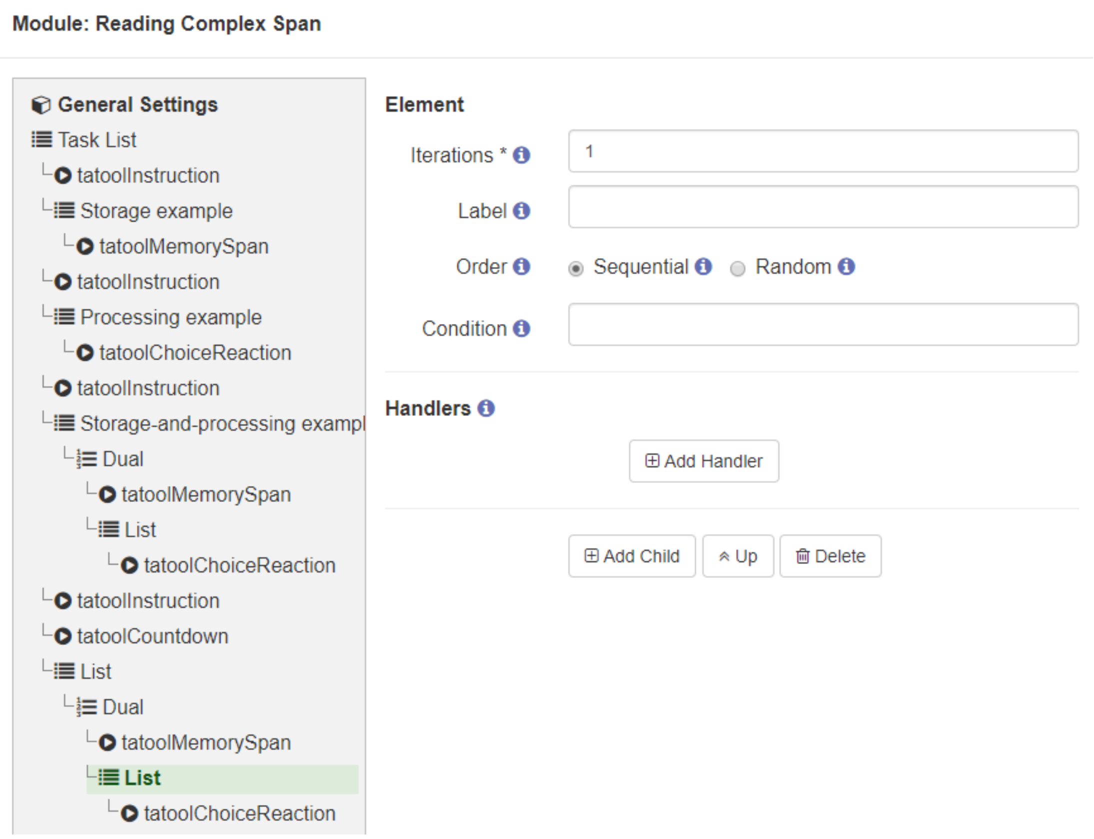
suspendAfterEachItem
Yes
No
randomisation
none
recallText
Letter
displayDuration
1000
Add Property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List
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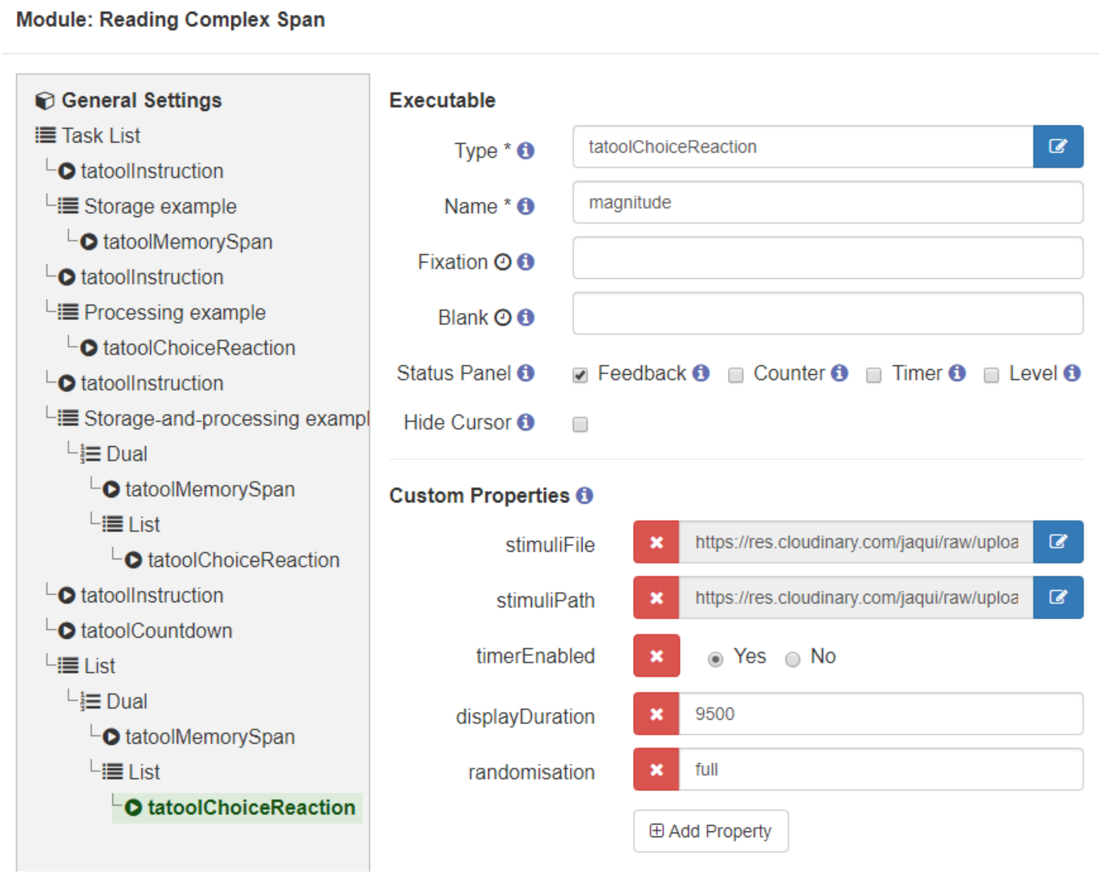
Element
Iterations *
1
Label
Order
Sequential
Random
Condition
Handlers
Add Handler
Add Child
Up
Delete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Type *
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Feedback
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Timer
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Hide Cursor
Custom Properties
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https://res.cloudinary.com/jaqui/raw/uploa
stimuliPath
https://res.cloudinary.com/jaqui/raw/uploa
timerEnabled
Yes
No
displayDuration
9500
randomisation
full
Add Property

APPENDIX H: ETHICAL CLEARANCE CERTIFICATES

UNISA university of south africa

RESEARCH PERMISSION SUB-COMMITTEE (RPSC) OF THE SENATE RESEARCH, INNOVATION, POSTGRADUATE DEGREES AND COMMERCIALISATION COMMITTEE (SRIPCC)

7 June 2017 (Date of issue)

23 October 2019 (Date of amendment)

2 December 2019 (Date of second amendment)

Ref #: 2017_RPSC_061_AR
Ms. Jacqueline Harvey
Student #: 53319575
Staff #: N/A

Decision: Research Permission Approval from 23 October 2019 until 30 June 2023.

Principal Investigator:

Ms. Jacqueline Harvey
Department of Psychology
School of Social Sciences
College of Human Sciences
Unisa
jharvey@hsrc.ac.za; 031 242 5682/ 072 536 4086

Supervisor: Dr. Angelo Fynn;
fynna@unisa.ac.za; 012 429 8211/ 082 904 6175

A study title: Developing an online intervention to assist Online Distance e-Learning first-year University of South Africa students.

Your application regarding permission to extend the study permission period and effect some amendments to the study procedures, in respect of the above study involving Unisa students has been received and was considered by the Research Permission Subcommittee (RPSC) of the UNISA Senate, Research, Innovation, Postgraduate Degrees and Commercialisation Committee (SRIPCC) on 14 October 2019.

It is my pleasure to inform you that permission has been granted for the study. You may:

1. Gain access to the MyLife email addresses of the students registered for the following signature modules: SUS1501, AFL1501, BPT1501, EUP1501, GGH3708 & SJD1501

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

UNISA university of south africa

COLLEGE OF HUMAN SCIENCES RESEARCH ETHICS REVIEW COMMITTEE

30 July 2019

NHREC Registration # :
Rec-240816-052
CREC Reference # : 2019-CHS -53319575

Dear J.C Harvey

Decision:
Ethics Approval from 30 July 2019 to 30 June 2023

Researcher(s): J.C Harvey

Supervisor(s): Dr. A.W.R Fynn

Tel: **012 429 8211**

Email: **fynna@unisa.ac.za**

Developing an Online Intervention to assists Online Distance e-learning First Year University of South Africa Students.

Qualification Applied: Masters in Psychology Research Consultation

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Thank you for the application for research ethics clearance by the Unisa Department of Psychology College of Human Science Ethics Committee. Ethics approval is granted for three years.

The ***Medium risk application*** was ***reviewed*** College of Human Sciences Research Ethics Committee. on the **(19 July 2019)** in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the Department of Psychology Ethics Review Committee.

www.unisa.ac.za

Ref. No: PERC-17026

UNISA university of south africa
Department of Psychology

Ethical Clearance for M/D students: Research on human participants

The Ethics Committee of the Department of Psychology at Unisa has evaluated this research proposal for a Higher Degree in Psychology in light of appropriate ethical requirements, with special reference to the requirements of the Code of Conduct for Psychologists of the HPCSA and the Unisa Policy on Research Ethics.

Student Name: Jaqueline Harvey **Student no.:** 53319575

Supervisor: Dr. Angelo Fynn **Affiliation:** Department of Psychology, Unisa

Title of project:

Developing an online intervention to assist Online Distance e-Learning first-year University of South Africa students.

The proposal was evaluated for adherence to appropriate ethical standards as required by the Psychology Department of Unisa. The application was approved by the departmental Ethics Committee on the understanding that –

- All ethical requirements regarding informed consent, the right to withdraw from the study, the protection of participants' privacy and the confidentiality of the information will be met to the satisfaction of the supervisors;
- Clearance is to be obtained from the university from which the participants are to be drawn, and all conditions and procedures regarding access to staff/students for research purposes that may be required by the institution will met.

Signed:

Prof P Kruger
[For the Ethics Committee]
[Department of Psychology, Unisa]

Date: 18 September 2017

APPENDIX I: DEPARTMENT OF COUNSELLING AND CAREER DEVELOPMENT REFERRAL LETTER

UNISA university of south africa

02 October 2017

RE: REFERRAL AGREEMENT FOR UNISA STUDENTS DURING RESEARCH PROJECT

To whom it may concern,

This serves to certify that as the Directorate for Counselling and Career Development (DCCD) at the University of South Africa (Unisa), we will support the students / participants referred by Ms Jaqueline Harvey during her research project.

Ms Jaqueline Harvey is a PhD candidate in the Department of Psychology with the student number 53319575 (jaquelineharvey@gmail.com; 031 242 5682). Her research project is under the supervision of Dr Angelo Fynn (fynna@unisa.ac.za; 012 429 8211).

Her research project entitled "Developing an online intervention to assist Online Distance eLearning first-year University of South Africa students" aims to support literacy skills development. The eight-week intervention includes self-reflection exercises, working memory training sessions, and support of online student interaction for participating students enrolled in a Unisa signature course. This project has received ethical clearance from the Ethics Committee of the Department of Psychology (Ref. No: PERC-17026).

This letter means that Ms Harvey is able to refer students who request counselling to the DCCD during the course of her research project. This information will also be clearly stated in the informed consent form.

Kind regards

Dr Matome J Mashiapata
Director: Counselling and Career Development (DCCD)
Eskia Mphahele Building A-160
Sunnyside, Pretoria
Email: mashimj@unisa.ac.za ; 012 4415364

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