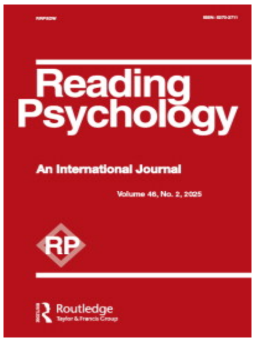

Reading Psychology

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/urpy20

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To cite this article: Jaqueline Harvey (08 Jan 2025): Exploring the Impact of Working Memory Capacity on Academic Reading and Achievement in South African Online Tertiary Students, Reading Psychology, DOI: 10.1080/02702711.2024.2447228

To link to this article: https://doi.org/10.1080/02702711.2024.2447228

Published online: 08 Jan 2025.

READING PSYCHOLOGY
https://doi.org/10.1080/02702711.2024.2447228

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Exploring the Impact of Working Memory Capacity on Academic Reading and Achievement in South African Online Tertiary Students

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ABSTRACT

The relationships between working memory, academic reading proficiency and academic achievement are well-documented globally, but less so in South Africa. This study addresses this gap by exploring these associations among 136 South African undergraduates from an Online Distance e-Learning institution. Participants completed two open-source web-based working memory tasks to evaluate working memory capacity and the online version of the Test of Academic Literacy Levels to examine their academic reading proficiency, while academic achievement was evaluated using their end-of-year grades. Results showed positive correlations between working memory capacity and academic reading proficiency ($\tau = .10$, $p = .050$) and with academic achievement ($\tau = .16$, $p = .003$). Thus, as working memory capacity increases so do academic reading proficiency and academic scores. With varying implications for higher education, this paper discusses pedagogical changes that lecturers can consider so as to take into account the diverse cognitive profiles of their students.

ARTICLE HISTORY
Received 21 May 2024
Accepted 23 December 2024

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Introduction

Mastery of reading for meaning is a cornerstone for academic success, a notion underscored by a wealth of research (Boakye, 2017; Clinton-Lisell et al., 2022; Liu & Read, 2020). It is through reading that students primarily access academic information and, in the sphere of higher education, a lack of proficient reading ability is a significant impediment that contributes to high dropout and low persistence rates (Bharuthram, 2012; Bharuthram & Clarence, 2015; Gorzycki et al., 2016). This challenge is particularly pronounced for students engaged in Open Distance e-Learning (ODeL), where reading is not only a learning tool (Bharuthram, 2012), but a vital conduit for interacting with course materials, peers and instructors (Dabbagh, 2007), as well as for developing the implicit norms and conventions of academic discourse (Center & Niestepski, 2014; Desa et al., 2020; Gorzycki et al., 2016; Howard et al., 2018). Consequently, understanding individual variation in both reading ability and associated cognitive variables is a research area of paramount importance.

Exploring reading ability and associated cognitive factors in South Africa is furthermore important for enhancing student support services. While the country boasts one of "the best tertiary education systems in the developing world" (Mlachila & Moeletsi, 2019, p. 25), entering students show a broad range of reading competencies given their diverse backgrounds in terms of socio-economic status (SES), quality of primary and secondary education attended, home language, amongst other factors (Boakye, 2017; Liu & Read, 2020; Millin, 2015; Sehoole & Adeyemo, 2022). The quantity and expected level of reading can thus be overwhelming (Boakye, 2017; Boakye et al., 2014). To provide effective support, it is noteworthy that reading is a complex cognitive activity that requires effective and efficient use of various cognitive processes. To comprehend effectively, the reader must skillfully juggle maintaining pertinent information while simultaneously assimilating new information from the text (Shin, 2020). This intricate balancing act occurs within working memory (WM), necessitating a judicious allocation of its limited resources.

WM is central to a broad range of cognitive activities that require controlled processing (Alptekin & Erçetin, 2010; Li & Brantmeier, 2021) such as emotional regulation, vocabulary learning, reasoning, and problem-solving (Cowan, 2014; Draheim et al., 2022; Teng, 2023). Defined as a *limited capacity* neurocognitive system (Alptekin & Erçetin, 2010; Burin et al., 2018; Li & Brantmeier, 2021) with temporary *simultaneous* storage and processing functions (Burin et al., 2018; de Bruïne et al., 2021), WM is differentiated from other memory systems by the tradeoff for limited mental resources between information storage and information processing. This tradeoff is operationalized as working memory capacity (WMC) with the value indicating the available WM resources for these two functions (Camos, 2017; Gibson et al., 2012; Li & Brantmeier, 2021; Linderholm & van den Broek, 2002). Since the seminal article by Daneman and Carpenter (1980), over 40 years of research have shown that individual differences in WMC influence reading proficiency (Burin et al., 2018; Schurer et al., 2020). Nevertheless, it is worth noting that despite the substantial volume of research on this topic, the interpretive consensus remains elusive (see, for example, Engle, 2018, p. 192), thereby underscoring the persistent need for studies within diverse contexts. Furthermore, studies such as Georgiou et al. (2020) have shown cultural differences in the relationship between working memory and academic reading and achievement. Exploring this relationship in Unisa OdeL first-year tertiary students thus adds evidence from the Global South to the predominantly Global North body of work. In addition, contemporary investigations have elucidated the neural basis of WM (e.g., Christophel et al., 2017; Constantinidis & Klingberg, 2016; Funahashi, 2017), reinforcing the neurobiological validity of WM and supporting continued exploration into this cognitive system.

This paper[1] therefore investigates the following within the novel context of South African ODeL higher education: (1) if WMC is positively correlated to reading proficiency; (2) if WMC is positively correlated with academic achievement; (3) if reading proficiency is positively correlated to academic achievement; and (4) the contribution of WMC and reading proficiency as predictors of academic achievement.

Literature Review

The current study focuses on academic reading which incorporates foundational cognitive skills such as decoding and using information from memory to construct meaning (Gorzycki et al., 2016). Academic reading, however, is also purposeful and critical and requires the reader to analyze, synthesize, and evaluate the information in depth (Bharuthram & Clarence, 2015; Gorzycki et al., 2016). Texts must be read with metacognitive awareness where the reader monitors their own understanding, the text composition, problems, context, genre, as well as the reading strategies which should be used (Gorzycki et al., 2016, 2020). Bearing this in mind, the current study focuses on the common foundational cognitive processes and thus academic reading and reading are used interchangeably. An individual-differences approach has often been adopted to explore the various factors that influence academic reading ability, with WM featuring prominently in these studies as it is regarded as crucial to reading performance.

WM is primarily understood through the lens of Baddeley's multicomponent working memory model (Alshahrani, 2017; Barreyro et al., 2019; Chai et al., 2018; Nouwens et al., 2021). The model proposes a four--module structure comprising the phonological loop, the visuospatial sketchpad, the episodic buffer, and the central executive (Baddeley, 2012). The phonological loop and the visuospatial sketchpad are analogous to short-term memory in that they are domain-specific, storage-based, slave systems (Baddeley, 1992, 2003; Linck et al., 2014; St Clair-Thompson & Holmes, 2008). Phonological and visuospatial information flows from the slave systems through the episodic buffer—which integrates information from various sources into multidimensional episodes—to the central executive (Baddeley, 2017, p. 201). The central executive, the heart of the system, is domain-general and undertakes several functions relating to the processing and manipulation of information (Draheim et al., 2022; Morrison, 2005). The central executive, in essence, conducts executive functions (Miyake et al., 2000; St Clair-Thompson & Gathercole, 2006). This model informs the conceptualization of WM in this study.

Working Memory Capacity and Academic Reading

WMC is the most widely investigated cognitive factor of reading ability with several studies identifying a significant relationship (Cartwright et al., 2020; Diningrat et al., 2023). A comprehensive overview of the correlational studies can be found in the meta-analysis of Peng et al., 2018 who concluded that the significant relationship between WM and reading was moderate (r = .29, p = .05). A significant, positive relationship has also been concluded in meta-analyses of studies whose samples comprised second language (L2) readers (e.g., Linck et al., 2014; Shin, 2020). Recent studies have confirmed these findings. Burin et al. (2018) showed, within 125 first-year undergraduate students, that WM was the strongest predictor of digital text comprehension. In addition, a higher WMC was associated with increased accuracy in answering comprehension questions (Burin et al., 2018). Moreover, Barreyro et al. (2019) showed that computerized measures of WM were significantly associated with performance on an expository text comprehension test in a sample of 114 college students. Diningrat et al. (2023) furthermore illustrated that first-year students with a high WMC significantly outperformed their low WMC peers in reading comprehension ability, $F(1,108) = 22.221$, p = .000) with a large effect size of h^2 = .17. Available evidence therefore indicates that students with a higher WMC will outperform their peers with a lower WMC, notably in both first language and second language samples as well as using both paper-based and digital testing methods.

This relationship is predicated on the understanding that academic reading proficiency is reliant on sufficient cognitive resources to undertake the reading activity processes.

Fluent academic reading is a cyclical process that depends on the execution and integration of cognitive processes, commonly categorized as lower-level and higher-level (Grabe & Stoller, 2013; Liu & Read, 2020). Lower-level processes translate written symbols into meaningful language units, a task that is largely automated, thus allocating cognitive capacity for more sophisticated mental operations (Kendeou et al., 2014; Verhoeven et al., 2011). Meanwhile, higher-level processes construct a mental schema by integrating units of language with existing knowledge from long-term memory that allows for comprehension (Kendeou et al., 2014; Kopatich et al., 2019; Smith et al., 2021; Verhoeven et al., 2011). Higher-level processes require a larger allocation of cognitive resources (Kendeou et al., 2014; Kopatich et al., 2019). Importantly, all reading cognitive processes take place within WM (Grabe, 2014; Ntim, 2015) with this system acting as a mental workspace wherein each intermediate product is stored and processed until a final mental presentation of the text is developed (Bohn-Gettler & Kendeou, 2014; Kendeou et al., 2014; Ntim, 2015; Prat et al., 2015; Prat & Just, 2011; Shin et al., 2019; Smith et al., 2021). Thus, academic reading proficiency is highly dependent on the ability of WM to adequately process and integrate information into a mental representation (Smith et al., 2021).

Students with high WMC are able to execute lower-level reading tasks such as word recognition efficiently and have additional resources to perform high-level comprehension processes (Diningrat et al., 2023). Individuals low in WMC, on the other hand, have fewer resources to undertake higher-level comprehension processes (Burin et al., 2018; Li & Brantmeier, 2021) as well as integrate information from the text into a working mental model (Schurer et al., 2020). Thus, when cognitive load exceeds available WMC, there is reduced comprehension as a detailed mental representation is not possible (Schurer et al., 2020; Smith et al., 2021). Exploration of individual differences in WM in terms of capacity is thus predictive of performance on academic reading comprehension tasks.

Working Memory and Academic Achievement

With academic achievement long being regarded as the primary indicator of academic success (Amzil, 2022), it is foreseeable that many studies have explored contributing factors. Previous studies have shown WMC to be the best predictor of achievement through its key role in learning

(Alloway & Alloway, 2010; Fenesi et al., 2015; Ramos-Galarza et al., 2019). The vast majority of information that needs to be learned and later recalled enters through the WM system and therefore the latter's capacity determines the rate and extent of learning, impacting achievement (Demir & Ercetin, 2020; Fenesi et al., 2015). Studies have found relationships between WM and various academic areas such as L2 learning (Jackson, 2020), written language (Vanderberg & Swanson, 2007), and mathematics (Allen et al., 2019; Berkowitz et al., 2022). Studies exploring overall academic achievement have supported this, such as (Ramos-Galarza et al., 2019). Authors' results using a sample of 175 university students showed a negative correlation between WM challenges and students' average overall grade ($r = -.30$, $p < .001$), and also showed that WM significantly predicted academic performance (Ramos-Galarza et al., 2019). This was also identified by Amzil (2022) who explored the ability of WMC and cognitive regulation to predict the academic achievement of 139 Moroccan undergraduate and graduate students. Focusing on working memory capacity, the results showed a positive significant correlation between this concept (as measured by the digit span) and students' GPA scores. A multiple regression analysis further indicated that both working memory capacity and cognitive regulation significantly predicted students' GPA scores (Amzil, 2022). Scholarship thus indicates that WM difficulties constrain academic achievement and are associated with lower attainment in the education sphere.

Working Memory Measures

Measures of WM can be used within non-Western, low-resource, and developing contexts such as South Africa due to their reduced cultural and socioeconomic bias, when, for example, compared to measures of intelligence or academic ability (Cockcroft et al., 2016; Hicks et al., 2016; Milligan & Cockcroft, 2017). WM is operationalized as WMC, determined by both storage and processing components (Li & Brantmeier, 2021). Experts largely agree that complex span tasks are valid and reliable measures of WMC (Alptekin & Erçetin, 2010; Cartwright et al., 2020). Based on the multicomponent model, complex span tasks are informed by the dual-task paradigm (Alptekin & Erçetin, 2010; Baddeley & Hitch, 1974; Bayliss et al., 2003; Conway et al., 2005; Fenesi et al., 2015) and are designed to measure both storage and processing functions. During complex span tasks, participants are presented with a list of to-be-remembered (TBR) items such as digits, words, or shapes that are interleaved with a processing task. The latter can include reading sentences or solving simple mathematics problems (Li & Brantmeier, 2021). The purpose of including the processing task is to prevent rehearsal of the TBR items and instead require participants to maintain and manage them, engaging the central executive (Draheim et al., 2022). In this way, complex span tasks tax both the storage and processing functions of WM and provide an indication of its capacity.

Use of inappropriate WMC measures may explain discrepant findings where scholars did not identify a significant association between WM and reading. Hummel (2009), for example, did not find a relationship between phonological memory, an aspect of WM as per Baddeley's model described above, and L2 reading comprehension in 77 non-novice English L2 tertiary students. This study utilized a simple span task—the non-word repetition task (Hummel, 2009). Simple span tasks reflect only the storage aspect of WM (Draheim et al., 2022) and thus are considered inadequate measures of WMC (Bailer et al., 2013). Furthermore, these tasks are not considered as reliable and valid predictors of higher-level and real-world cognitive tasks (Engle, 2010). As reading is a complex cognitive skill that requires both storage and processing, it is likely that studies using a complex span task to measure WMC will reveal accurate findings.

Materials and Methods

Participants

One hundred and thirty-six first-year undergraduate South African students (96 females, 37 males; mean age = 24.3 years, $SD = 6.81$) attending the University of South Africa were recruited on a voluntary basis to participate. Of the 11 official South African languages, the main languages spoken as L1 in the sample were English ($n = 67$, 49%), Afrikaans ($n = 41$, 30%), and isiZulu ($n = 8$, 6%) whereas the most common L2 was English ($n = 65$, 48%). In the South African education system, despite constitutional and policy revisions, the majority of schools continue to use an English medium of instruction in all grades or from Grade 4 onwards. Students who enter tertiary education thus have thus received most or all of their schooling in English despite many being non-native speakers (Bangeni & Kapp, 2007; Heugh, 2009; Hunter, 2015; Janks, 2014).

Instruments

All participants completed two complex span tasks to assess individual WMC: reading span (RSPAN) and operation span (OSPAN). Both tasks have been reported to be moderately reliable (α = .7–.9) and consistently valid predictors of cognitive abilities (Engle, 2010; Hicks et al., 2016; Redick et al., 2012; Redick & Lindsey, 2013; Unsworth et al., 2009). The current tasks were developed using Training and Testing Tool (Tatool), a Java-based open-source programming framework that has been designed for use in cognitive training, experiments, and surveys (von Bastian et al., 2013). Use of the 'Tatool Online' platform allowed the researcher to avoid expensive software and/or installations as well as allow the participants to access the developed tasks easily through their browsers. Previous research has demonstrated that task results are comparable between online and lab-based experiments even if the participants are uncompensated and unsupervised (Huber & Gajos, 2020; Ruiz et al., 2019). In the RSPAN, participants were presented with letters (e.g., J, B, H) as the TBR items while the processing task was judging if the presented sentences made sense or not. Sentences were selected at random (consisting of 10 to 15 words) with half of the sentence stimuli written to make sense. The OSPAN similarly had letters as the storage component but differed in that the processing component asked participants to judge if a mathematical operation was correct or not. The RSPAN reflects a task-specific view of WMC as it varies based on the efficiency of the processes needed to complete the tasks. In contrast, the OSPAN offers a general view of WMC that is independent of the task's nature (Bailer et al., 2013). Language knowledge requirements are furthermore minimized in the OSPAN (Juffs & Harrington, 2011).

Academic reading ability was determined by the Test of Academic Literacy Levels (TALL). The TALL, along with its Afrikaans translation, is the only academic literacy test designed for use in multilingual institutions (Le et al., 2011). Consisting of 64 multiple-choice questions, the TALL has six subtests: Scrambled text; Interpreting graphs and visual information; Understanding texts; Knowledge of academic vocabulary; Text types; and Grammar and text relations. Previous studies have shown that it evinces both good reliability and construct validity (Le et al., 2011; Weideman, 2006, 2009).

Procedures

The study followed a non-experimental ex-post factor cross-sectional research design with all assessments self-administered online in English. Data was collected over the 2020/21 academic years. Students were invited to participate through a solicitation email sent to all first-year undergraduate students that asked them to indicate their interest in participating by completing the informed consent and background questionnaire. Students were excluded at this stage if they had a previous diagnosis of epilepsy, had ever suffered a seizure, or had ever had an adverse reaction to flashing lights to prevent adverse effects of the task stimuli. Thereafter, two tasks to assess WMC were sent to each participant via a personalized email. During online self-administration of both the RSPAN and OSPAN, participants completed three practice conditions: 1) storage task only, 2) processing task only, and 3) interleaved storage and processing task (Redick et al., 2012). Participants thereafter completed the task trials, organized into five blocks of three trials each, starting with a set size of three and ending with a set size of seven. Each letter was shown on screen for 1000 ms (Unsworth et al., 2009) and participants needed to type in the series of letters sequentially in order following the trial. The study utilized the partial scoring method used by Kane et al. (2004) as recommended in other studies (Conway et al., 2005; Đokić et al., 2018; Redick et al., 2012). Within each set of three trials, a TBR item was marked correct if it was recalled in the correct serial position. A proportion correct score was then calculated, first within each set, and secondly over all sets in the task to provide a final score (Kane et al., 2004). The researcher calculated a composite score using the average of the RSPAN and OSPAN final scores, following the approach of Ziegler and Smith (2017). Once the WMC tasks were completed online, participants were sent the link to the comprehension test via email. A request was made to the university for the final end-of-course grades.

Data Analysis

All statistical analyses were carried out using IBM SPSS Statistics 27.0. An alpha value of .05 was adopted for all significance testing. Associations between study variables were examined by correlation coefficients. Mediation was assessed by calculating confidence intervals (CIs) for the indirect effect using bootstrap methods, a non-parametric resampling technique that bypasses the need for normality assumptions (Field, 2018; Özdil & Kutlu, 2019). This method uses thousands of iterations to simulate the sampling distribution, thereby providing CIs at the 2.5 and 97.5 percentiles for the indirect effect (Hayes, 2018; Özdil & Kutlu, 2019; Preacher & Hayes, 2004). As this method provides unfixed CIs, given that they are based on random resampling, the analysis was set to 5000 bootstrap samples to ensure that variation identified in replication studies is arbitrarily small (Hayes, 2018).

Results

A complete list of descriptive statistics for the study variables can be found in Table 1. As the assumption of normality was not met for most of the study variables and the study had a small sample, Kendall's tau-b (τ) one-tail correlation analyses were used to explore associations (Akoglu, 2018; Field, 2018). Correlation strength was interpreted as follows: (1) weak: .10 to .39; (2) moderate: .40 to .69; and (3) strong: .70 to .99 (Akoglu, 2018).

The first research question asked if WMC was positively correlated to academic reading proficiency. As shown in Table 2, there were significant but weak correlations between academic reading proficiency and the OSPAN (τ = .10, p = .047) and WMC composite (τ = .10, p = .050). Surprisingly, there was no significant association between the RSPAN and academic reading proficiency. Regarding the second research question, there were significant yet weak correlations between participants' academic achievement and their scores on the RSPAN (τ = .16, p = .004), the OSPAN (τ = .13, p = .011), and WMC composite (τ = .16, p = .003). In answer to the third research question, asking whether academic reading ability is related to academic achievement, analysis showed a significant but weak correlation between academic reading proficiency and academic achievement (τ = .36, p < .001).

A simple mediation analysis answered the fourth research question, given that the assumption of normality was not met so a regression could not be performed. This analysis examined the roles of WMC and academic reading proficiency as predictors of academic achievement. It was hypothesized that academic reading proficiency mediates the impact of WMC on academic achievement. Figure 1 shows the pathways tested using the PROCESS macro for SPSS (Field, 2018; Hayes, 2018) while Table 3 indicates the coefficients and associated *p*value. When academic reading was excluded from the model, WMC significantly predicted academic achievement (b = 15.55, 95% CI [5.94, 25.17],

Table 1. Summary of study variables.

Variable	Mean	SD	Range
WMC composite	0.71	0.19	0.02–0.99
RSPAN	0.69	0.23	0.00–1.00
OSPAN	0.72	0.20	0.04–1.00
Reading comprehension	68.20	19.57	16.00–100.00
Achievement	74.58	11.29	13.50–93.30

Note: SD: standard deviation.

Table 2. Results of the correlation analyses.

Variable	1	2	3	4	5
1. WMC composite	–				
2. RSPAN	.76**	–			
3. OSPAN	.72**	.47**	–		
4. Reading comprehension	.10*	.08	.10*	–	
5. Achievement	.16**	.16**	.13*	.36**	–

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

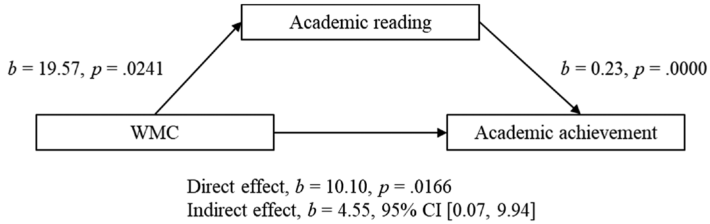

Figure 1. Results of the mediation analysis.

Table 3. Results of simple mediation analysis of the relation between WMC and academic achievement.

Effect estimate	Coefficient (SE)	Lower	Upper	*t*	*p*	R^2
WMC → Achievement	15.56 (4.86)	5.94	25.17	3.20	.0017	0.07
WMC → Reading	19.57 (8.58)	2.60	36.54	2.28	.0241	0.04
Reading → Achievement | WMC [a]	0.23 (0.04)	0.14	0.32	5.19	.0000	0.23
WMC → Achievement | Reading [a]	10.10 (4.53)	2.03	19.97	2.43	.0166	–
WMC → Reading → Achievement	4.55 (2.50)	0.07	9.94	–	–	–

Note: 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.

$t = 3.20$, $p = .0017$) and accounted for 7% of the variance. When academic reading was included in the model, the following key findings were noted:

1. WMC significantly predicts academic reading in that as WMC increases so does academic reading ($b = 19.57$, 95% CI [2.60, 36.54], $t = 2.28$, $p = .0241$), explaining 4% of the variance in academic reading proficiency.
2. The regression of academic achievement from both WMC and academic reading showed that, firstly, academic reading significantly predicted academic achievement ($b = 0.23$, 95% CI [0.14, 0.32], $t = 5.19$, $p = .0000$). Secondly, WMC remained a significant predictor of academic achievement even when including academic reading proficiency in the model ($b = 10.10$, 95% CI [2.03, 19.97], $t = 2.43$, $p = .0166$). As the academic reading and WMC variables increase, so does academic achievement. The model explained 23% of the variance in academic achievement.
3. To explore the indirect effect of WMC on academic achievement via academic reading, indirect effects were calculated for each of the 5 000 bootstrap samples, and the 95% CI was determined by computing the indirect effects at the 2.5th and 97.5th percentiles. Since the CIs did not include 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].

Discussion

The current study examines the associations between WMC, academic reading proficiency, and academic achievement in a sample of undergraduate ODeL students. Notably, the strongest significant correlation emerged between academic reading proficiency and academic achievement. This observation supports previous research that highlighted the fundamental importance of academic reading in education (Unsworth & McMillan, 2013). Particularly in ODeL settings, academic reading serves as the primary means of interaction with course materials and the significance of attaining this skill cannot be overstated (Bharuthram, 2012; Desa et al., 2020; Howard et al., 2018; Liu & Read, 2020). Consequently, it is essential to investigate factors that can be enhanced through targeted intervention to improve academic reading proficiency. Further insights from the current study suggest that focusing on WMC may offer a promising avenue for such improvements.

The analysis identified significant, albeit modest, correlations between WMC and both academic reading proficiency and academic achievement. Mediation analysis further confirmed that both WMC and academic reading proficiency are significant predictors of academic achievement, underscoring their interdependent roles. Moreover, the mediation analysis indicated that academic reading proficiency partly explains the influence of WMC on academic achievement, although a considerable portion of the covariance of participants' WMC and academic achievement is still left unaccounted for and requires investigation. These results agree with previous scholarship that has illustrated how the dual functions of WM—storage and processing—support cognitive aspects of reading such as understanding vocabulary, conceptual relationships, or expository texts (Bader, 2016; Barreyro et al., 2019; Burin et al., 2018; Lee, 2014; Peng & Fuchs, 2017). These findings furthermore support the theoretical view that, as both lower- and higher-level cognitive processes of reading take place in WM, the limited WMC can either enable or constrain reading proficiency (Burin et al., 2018; Just & Carpenter, 1992). However, the association between the OSPAN, and WMC, and academic reading proficiency was weaker than anticipated which is possibly due to the diverse language profile of the sample.

Approximately half the participants in the current sample were tested in their native language which may have influenced the extent to which the TALL taxed cognitive processes, potentially reducing the impact of WMC on performance. Language may have also played a role in that, of the two WMC tasks, only the OSPAN was significantly related to academic reading proficiency. As complex span tasks follow the dual-task paradigm and are aligned with Baddeley's multicomponent working memory model, it is expected that they show an association with higher order cognitive tasks requiring both storage and processing such as reading (Baddeley & Hitch, 1974; Conway et al., 2005; Fenesi et al., 2015; Sanchez et al., 2010). Thus, the positive significant correlation between the OSPAN and academic reading proficiency aligns with expectations for complex span tasks. However, the RSPAN did not show a significant association, and it is suggested that the language-based nature of its processing tasks interfered with the accurate measurement of WMC for non-native language speakers (Lee, 2014; Sanchez et al., 2010). Further studies in multilingual contexts should be cognizant of this finding within their design.

The current study furthermore found a significant correlation between WMC and academic achievement, corroborating earlier findings that posit WMC as a strong predictor of academic success (Alloway & Alloway, 2010; Engle, 2002; Fenesi et al., 2015). Students who have low WMC may experience cognitive overload more readily and be constrained in their information processing (Demir & Ercetin, 2020; Fenesi et al., 2015; Upahi & Ramnarain, 2020). The current results therefore underscore the critical role of exploring pedagogical strategies or adjustments that take into account WMC and mitigate challenges faced by students with diverse cognitive profiles.

Implications

The study provided empirical evidence that WMC can facilitate or limit academic reading proficiency and academic achievement which can inform higher education pedagogy. Higher awareness of the role of WMC differences can apprise both curricula structure as well as teaching methods. Firstly, lecturers may organize their online course content to minimize information and cognitive load such as using linear text rather than hypertext as the former has been found easier for individuals with low WMC to comprehend (Demir & Ercetin, 2020; DeStefano & LeFevre, 2007; Fontanini & Tomitch, 2009; Yuan et al., 2006). Another example is to provide definitions of terminology and concepts in the form of supplementary material prior to the lecture (Seery & Donnelly, 2012). Consciously using teaching techniques, such as providing slow-paced instructions, that benefit all students regardless of cognitive resources could also mitigate disadvantage and support learning (Fewell & Littlefair, 2018; Neitzel, 2018; Nyroos et al., 2018; Oliveira & Tomitch, 2021). Guidance on strategies to assist with processing a great deal of information, such as the use of schema or chunking of information, can also be helpful as these techniques reduce the demands placed on WM and frees mental resources (Thalmann et al., 2019; Upahi & Ramnarain, 2020; Zhang et al., 2021). The efficacy and benefit of incorporating such strategies should be investigated.

Limitations of the Study

The study highlights the importance of students' cognitive architecture as it relates to their academic reading proficiency and academic achievement, a relatively unexplored area within South African education studies. Nevertheless, some limitations of the present study are worth mentioning. Given the small sample, the results are not intended to be generalized to the overall student population. Rather, they are to be used as initial findings that demonstrate the importance of the research question and suggest further investigation with a larger and more diverse sample. Nevertheless, publication of the correlation matrix allows for possible inclusion in a meta-regression study. However, as the study is correlational any effects do not imply causation. The study also did not provide insight into other factors that influence the relationships under study such as vocabulary knowledge or other executive functions (Choi, 2013; Georgiou & Das, 2016, 2018). Future studies should include broader samples as well as measures of other relevant study variables. Finally, the study made use of online instruments that participants completed at home and the lack of experimental settings may have introduced confounding variables.

Conclusion

The capacity to effectively read and comprehend text is paramount for academic achievement, remarkable for ODeL students who largely engage with their coursework and lecturers through written materials. Given substantial evidence that WM—a limited-capacity system known for its dual functions of storage and processing information as well as its role in higher-order cognitive abilities—plays in reading, this study explored its relationships with academic reading proficiency and academic achievement of ODeL undergraduate students at Unisa. While only modest associations were observed among these variables, the findings provide valuable initial insights into the complex dynamics of WM in educational settings. Despite the study's limitations which caution against generalizations, these results highlight the necessity for further research to confirm these patterns and refine intervention strategies. Considering WMC variation could represent a significant lever for improving educational outcomes, suggesting a crucial area for lecturers to target to support students.

Note

1. This paper is based on a PhD thesis completed by the author at the University of South Africa.

Acknowledgements

This paper was based on a PhD thesis completed by the author at the University of South Africa, under the supervision of Dr Angelo Fynn. The author expresses their gratitude for their guidance and support.

Ethical approval

This study was granted ethical approval by both the Research Ethics Committee of the College of Human Sciences and the University of South Africa Senate for Higher Education and Innovation Directorate Committee.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was funded by the University of South Africa through a postgraduate bursary as it was completed as a PhD thesis.

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Data availability statement

The data that support the findings of this study are available from the corresponding author, JH, upon reasonable request.

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