Verbal Working Memory in Second Language Reading Comprehension: A Correlational Study

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Abstract

This study investigated the correlation and predictive capacity of verbal working memory (VWM) to the reading comprehension of children in their first language (L1) and second language (L2). The term verbal working memory refers to a cognitive system with a limited capacity that can hold and manipulate verbal and auditory information temporarily. A sub-aim was to investigate the contribution of L2 linguistic knowledge in L2 reading comprehension. Sixty-three Grade 3 South African children completed a reading comprehension test and VWM assessment (forward span, backward span, and sentence repetition tasks). L2 participants completed a receptive language assessment to delineate whether their linguistic knowledge (L2 vocabulary and grammar knowledge) would be more predictive of L2 reading comprehension in comparison with VWM. Regression and correlation analyses revealed that VWM is not predictive of L1 or L2 reading comprehension. L2 linguistic knowledge, however, significantly correlates with L2 comprehension and VWM capacity, although it is not a significant predictor of L2 reading comprehension. Our findings suggest that reading in an L2 is a multidimensional skill in which no single isolated variable can account for good versus poor reading comprehension.

Keywords
reading comprehension, working memory, second language, linguistic knowledge

Introduction

Verbal working memory (VWM) is a subset of working memory (WM), a cognitive system responsible for the parallel storage and manipulation of information necessary for a wide range of complex cognitive activities (Baddeley, 2013). VWM has repeatedly been implicated as a key predictor toward reading outcomes in the first language (L1) and second language (L2) (Benales et al., 2015; Gathercole et al., 2006; Nevo & Bretnitz, 2014; Wang & Gathercole, 2013). However, inconsistencies in the literature regarding the role of VWM, especially in L2 reading comprehension, are also becoming more apparent (Van Dyke et al., 2014). There is currently little consensus in research regarding whether VWM as an isolated skill has predictive power in the L2 reading comprehension of young children in particular (Linck et al., 2014). Achieving clarity on this matter can potentially be beneficial to the detection and intervention of L1 and L2 learners with reading comprehension difficulties. For this reason, the present study focused on VWM capacity and its relation to L1 and L2 reading comprehension in young children. The relation of VWM to other mediating influences often mentioned in the literature was also addressed.

WM, as the umbrella structure, comprised three systems respectively (Baddeley & Hitch, 1974). One exists for the temporary storage of verbal-acoustic material (the phonological loop), while a second processes and manipulates visual-spatial material. The third system, the central executive, is the higher order supervisory system that works directly with the phonological loop and visual-spatial sketchpad to provide the cognitive resources of attentional control, response, and behavioral inhibition. The central executive system (when considered in combination with the phonological loop) represents VWM (Benales et al., 2015). VWM, therefore, refers to the simultaneous processing and retention of verbal information due to the heavy involvement of the central executive system (Argyropoulos et al., 2017). In contrast, the term "short term memory" refers to the retention of verbal information and therefore implies the capacity of the phonological loop alone. The present study focused largely on VWM as it has shown to be the WM subcomponent most predictive of reading comprehension across age groups and populations (Oakhill et al., 2011).

The Role of VWM in L1 Reading Comprehension

There are a select few publications which have reported only spurious relationships between VWM and L1 reading outcomes (Cain & Oakhill, 2006; Van Dyke et al., 2014). However, the majority have found that it plays a significant role in the development of various reading skills (Nevo & Bretnitz, 2014; Pham & Hassan, 2014; Sadler, 2011), reading comprehension in particular (Oakhill et al., 2011). This finding is attributable to the concept that reading comprehension in young learners requires words to be actively decoded into their corresponding letter-sound combinations (Preßler et al., 2014). The deconstructed word must be actively maintained by the phonological loop for a period of time significant enough to allow for its meaning to be extracted from semantic long-term memory. In this way, the ability to retain and manipulate phonemes through VWM is a prerequisite for successful decoding and ultimately comprehension (Arrington et al., 2014). Poor VWM capacity may make it difficult to perform phonological processes such as the simultaneous blending and segmentation of text (Pham & Hassan, 2014), disrupting the outcome of reading comprehension. The contradictory phenomenon has also been explored via the verbal efficiency theory (Hamilton, Freed & Long, 2016). Readers with weak decoding skills regardless of VWM capacity frequently allocate more WM resources to aid in basic decoding processes. Resources from the central executive system can therefore not be assigned to execute higher order comprehension processes such as inference generation and semantic association as would typically be the case (Hamilton et al., 2016).

While VWM assists in the basic process of decoding, successful reading is a complex cognitive skill that requires maintenance, storage, retrieval, and manipulation of a constant influx of information (Burton, 2017). Information from the preceding and current text must not only be temporarily held in memory traces but also needs to be integrated into the incoming text for it to be comprehended (Benales et al., 2015). VWM aids this process by recruiting the necessary allied cognitive resources, for example, semantic, orthographic, and phonological resources, to make this integration possible (Jeon & Yamashita, 2014). The efficient integration of the cognitive mechanisms involved in linguistic processing makes inference generation and semantic association during reading possible (Hamilton et al., 2016). Consequently, it is the capacity to generate inferences and semantic associations that is most essential to attaining both local reading comprehension at the sentence level and

global reading comprehension of the structure as a whole (Carlson et al., 2014; Pae & Sevcik, 2011). Thus, the ability to store and process verbal/phonological information through VWM capacity has a considerable role to play in the process of L1 reading comprehension. The role of VWM in L2 reading comprehension is, however, a query that has inflicted much debate.

The Role of VWM in L2 Reading Comprehension

A shift of focus toward L2 reading comprehension is appropriate because L2 language acquisition is characterized by an increased need for effortful language processing as opposed to L1 acquisition (Wen, 2014). Similarly, L2 reading comprehension requires greater explicit cognitive control compared with L1 reading comprehension (Wen, 2014). For this reason, it has been hypothesized that VWM processes will play a more prominent role in L2 reading comprehension due to its increased reliance on cognitive resources (Wen & Skehan, 2011). Likewise, several studies suggest that VWM may be a key contributing factor to the process by which L2 learners become proficient readers, especially in their comprehension skills (Alptekin & Erçetin, 2011; Kormos & Sáfár, 2008; Pae & Sevcik, 2011). One such author concluded that VWM is one of the most important WM components in the learning of any L2 skill (Wen & Skehan, 2011). This opinion was emphasized so greatly that researchers argued that VWM should be treated and investigated separately from the other subsets of WM when it comes to L2 research (Wen, 2012).

Although VWM appears to be crucial to both L1 and L2 reading, certain studies have yielded either inconclusive or contradictory results to the before-mentioned body of literature (Juffs & Harrington, 2011; Sagarra, 2017). For example, Joh and Plakans (2017) and Leeser (2007) found that for L2 learners to efficiently utilize their WM resources, a certain level of prior knowledge in terms of L2 knowledge and knowledge of the topic at hand is required (Joh & Plakans, 2017). In contrast, Alptekin and Erçetin (2011) and Swanson et al. (2011) reported unique contributions of VWM to L2 reading comprehension, regardless of the participants' background knowledge. Similarly, earlier authors have sought to investigate whether L2 linguistic knowledge or proficiency influences L2 reading. As a result, it has been theorized that VWM is associated with L2 reading comprehension more so in low-proficient learners than in highly proficient learners (Hummel, 2009; Leeser, 2007). In highly proficient learners, no or small associations were found, suggesting that L2 proficiency modulates the effect of VWM on L2 reading. In contrast, yet again, Walter (2004) and Gilabert and Muñoz (2010) found no correlation between VWM capacity and levels of L2 proficiency, whereas Fehringer and Fry (2007) found correlations only in proficient L2 learners.

Further inconsistencies can be noted when looking at the various methods that have been used to measure VWM capacity across studies. Because there is no standard method of measuring VWM, the publications in the field have employed a wide range of calculation methods, one being the popular reading span test (RST; Daneman & Carpenter, 1980). In the RST, participants are required to read a sequence of sentences and thereafter repeat the last word of each sentence in order. Regrettably, because the RST in itself requires reading, questions arise as to the accuracy of the correlational results obtained in studies that have used the RST to measure VWM capacity (Oakhill et al., 2011). It has been stated by some researchers that it is unclear whether there are true VWM correlations, or whether VWM correlates with L2 reading comprehension purely because the RST measures reading

comprehension at a basic level (Lépine et al., 2005). Much earlier evidence from Waters and Caplan (1996) also indicated that if various measures of VWM correlate, it is usually reading span tasks that show the strongest correlation. Similarly, Jincho et al. (2008) used the RST and the digit span backward task and found that the RST had little correlation with the digit span reversed task. Therefore, VWM may be only associated with reading comprehension in light of the assessment instrument used. Furthermore, the correlation between VWM and reading comprehension in the L1 and L2 can also be affected by the complexity of specific measurement techniques employed. For example, Sagarra (2017) employed two different versions of the RST, the original one and one with an additional taxing processing component. The results revealed that only the VWM tasks with a higher processing component can predict L2 reading comprehension in beginning readers. The author, therefore, suggested that measurements of VWM only correlate with reading outcomes if they are complex enough to truly tap into the central executive component of WM.

VWM and the Influence of Language and Orthography

Adding to the already extensive range of variables that influence the relationship between VWM and L2 reading comprehension, the language in which WM capacity is measured may also present a potential source of bias. VWM tasks are typically conducted using verbal stimuli (e.g., memorize and repeat digits, sentences, and words or make sentence verification judgments) to measure the capacity of the phonological loop (White, 2018). Therefore, VWM tasks require a basic level of linguistic knowledge (White, 2018) and are inherently affected by language skills (Caffarra, Molinaro, Davidson & Carreiras, 2015). Consequently, in studies that measured L2 VWM capacity, it is difficult to delineate whether there were true WM correlations, or whether the WM capacity of participants varied as a function of language (Alptekin & Erçetin, 2011; Joh & Plakans, 2017). Furthermore, in L2 studies, the orthography of the L1 and L2 in question is potentially another variable that could influence correlational results. According to the cross-linguistic interdependence hypothesis, cross-language links in the acquisition of L2 skills are especially true if the two languages are similar in phonetic and alphabetic structure (Pae & Sevcik, 2011). This statement provides some evidence that VWM may contribute to L2 processes in some languages more than others, especially if the two languages have different orthography systems (McCallum et al., 2006). Upon reflection of the literature reviewed, it is apparent that the relationship between VWM and L2 outcomes is not as clear as previously thought. The contribution of VWM can be affected by an array of mediating variables including L2 proficiency, prior knowledge, the measurement of VWM, and L1 to L2 orthography. As a result, questions related to the relationship between VWM and L2 reading comprehension are still largely unanswered.

The Present Study

Considering the contradictions regarding research on the topic, the range of mediating variables that influence WM processes, as well as the range of methods used to measure VWM, it is currently difficult to decipher the role of VWM in L2 reading comprehension. Concurring, Linck et al. (2014) advocated in their meta-analyses that further studies are needed to clarify the precise nature of WM's role in L2 development, especially regarding the specific subcomponents of WM that affect L2 processing, learning, and reading skills. Such research is certainly necessary for contexts such as South Africa where a large majority of school-going children are educated in English second language (EL2) classrooms (White,

2018). Such classrooms refer to those whereby the sole medium of instruction is English, albeit that the learners of the classroom do not speak English as the L1 (Sadler, 2011). A better understanding of the cognitive processes involved in reading acquisition can be beneficial to the accurate detection of EL2 students with language delay or impairment, and to future treatment programs in EL2 settings (White, 2018). In response to a recent literature review and in an attempt to fill a necessary research niche, this study aimed to determine the differential correlation between VWM and L2 reading comprehension when compared directly with that of L1 reading comprehension. In addition, the researchers also sought to investigate the differential correlation between L2 linguistic knowledge (operationalized as vocabulary and grammar knowledge), VWM, and L2 reading comprehension. Three research questions were henceforth posed:

Research Question 1: What is the correlation and predictive capacity of VWM (measured by forward span, backward span, and sentence repetition), to L1 reading comprehension?
Research Question 2: What is the correlation and predictive capacity of VWM (measured by forward span, backward span, and sentence repetition), to L2 reading comprehension?
Research Question 3: What is the differential correlation between L2 linguistic knowledge measured by the receptive understanding of vocabulary and grammar, VWM, and L2 reading comprehension?

The identified research questions aimed to address identified gaps in research by replicating methods used from international studies (Pae & Sevcik, 2011) onto a population and context where such research is lacking. The study was also tailored to account for L2 linguistic knowledge as a potential mediating variable. In addition, the present study is the only one to compare the contribution of VWM to L1 reading comprehension, directly with that of L2 reading comprehension.

Method

Design

This study employed a nonexperimental research design of which the primary goal was to determine the relationship among measures of different skills, namely VWM, L2 linguistic knowledge, and L1 and L2 reading comprehension, respectively (Nelson, 2013). We, therefore, employed a correlational study design (Nelson, 2013).

Participants

Sixty-three Grade 3 learners from private schools in South Africa participated voluntarily in this study, without the use of any incentives. Participants were sourced using convenience sampling based on willingness to consent, availability, and suitability according to predetermined inclusion criteria. The inclusion criterion for participant selection is described in Table 1. Grade 3 learners were explicitly chosen because Grade 3 represents a critical year for the development of reading comprehension (Sadler, 2011). It is a year where learners must transition from learning to read, to reading to learn (Geske & Ozola, 2008). At prior grade levels, word recognition becomes automated and learners rely largely on decoding skills moreover than comprehension skills (Sadler, 2011). However, learners advancing through Grade 3 need to simultaneously decode words, interpret their meanings, integrate the meanings of multiple words, maintain and remember what was read, and engage various comprehension strategies (Vukovic & Siegel, 2006). Children at this stage of their

schooling often find it difficult to meet the storage demands of this process while also recognizing the words of the text (Gathercole & Alloway, 2008). The present study therefore explicitly sourced Grade 3 learners to further investigate which variables are associated with better outcomes during their acquisition of reading comprehension skills.

Table 1. Inclusion and Exclusion Criteria for Participant Selection.

Inclusion criteria	Exclusion criteria
No evidence of a history of developmental, neurological, and/or learning difficulty or condition.	Evidence of a history of developmental, neurological, and/or learning difficulty or condition.
Attend schools that follow the CAPS syllabus.	Attend schools that follow a syllabus other than the CAPS syllabus.
Attend schools situated in middle-income areas.	Attend schools that fall in either low-income or upper income areas.
English L1 children who attend school in English as the medium of instruction, OR, Afrikaans L1 children who attend school in Afrikaans as the medium of instruction.	Participants with an L1 other than English or Afrikaans.
	Afrikaans L1 children who have significant exposure to English in their home environment.
	Presence of any other language/s besides English/Afrikaans in the child's home or immediate environment, that is, multilingualism.

Note. CAPS = Curriculum Assessment Policy Statement.

Child assent and parent consent were obtained for all participants before the commencement of the data collection procedures. Ethical clearance was provided for the study before the commencement of data collection by the Research Ethics Committee of the Faculty of Humanities, University of Pretoria (HUM20190401). Participants were between 8 and 9 years old, from middle-upper income areas, and attended schools that follow the syllabus stipulated by the "Curriculum Assessment Policy Statement" (CAPS). CAPS refers to the national curriculum set out by the Department of Basic Education of South Africa. Also, a parent questionnaire was completed for each participant. The questionnaire entailed questions regarding their child's general development and language profile to ascertain that the participants meet the specified inclusion criteria, as described in the table below.

The 63 participants included in this study were divided into two groups, with 32 participants in Group 1 (EL1 Group) and 31 participants in Group 2 (EL2 Group). The EL1 Group had English-speaking children who attended school in English. The participants in the EL1 Group had a maleto-female ratio of 1:1.9. The EL2 Group had Afrikaans speaking children who attended school in Afrikaans as the medium of instruction and were thus proficient in Afrikaans as their L1. The male-to-female ratio for the EL2 Group 2 was 1:1.3.

Procedure

Data collection. A battery of standardized assessments was conducted on an individual basis at the respective schools with each participant by a bilingual English-Afrikaans examiner. The assessment battery included a reading comprehension test via the "Gray Oral Reading Test—Fourth Edition" (GORT-4; Wiederholt & Bryant, 2001), receptive language test via the "Test of Auditory Comprehension of Language—Fourth Edition" (TACL-4; Carrow-Woolfolk & Allen, 2014), and a forward span task, backward digit span task, and sentence repetition task via the "Test of Auditory Processing—Third Edition" (TAPS-3; Martin & Brownell, 2005). This study opted to use span tasks instead of the RST to measure VWM capacity due to the speculation regarding the use of the RST in correlational studies entailing reading comprehension skills. For the EL1 Group, all tests were administered in the L1 (English). For

the EL2 Group, the VWM tasks were also administered in the L1 (Afrikaans), but the reading comprehension test and receptive language test were administered in the L2 (English). For the EL2 Group, the VWM tasks were explicitly conducted in the L1. This was done to ascertain that the results reflect true VWM capacity, uninfluenced by the added processing demands caused by completing the assessment in an L2. The full assessment battery was completed in the same order within 45 min for all participants in the study.

Measures

L2 linguistic knowledge. For the EL2 Group, the participants' level of L2 linguistic knowledge was measured using the English version of the TACL-4 (Carrow-Woolfolk & Allen, 2014). The TACL-4 consists of 142 items that assess the receptive understanding of vocabulary, grammatical morphemes, and elaborated phrases and sentences, respectively. The test consists of three drawings per item accompanied by a verbal phrase. The child is instructed to point to the corresponding picture that best describes the phrase given. The TACL-4 is a highly standardized and widely used measure of receptive language proficiency by speech-language pathologists and related clinicians.

VWM

Forward digit span. The forward digit span subtest of the TAPS-3 (Martin & Brownell, 2005) was used to measure phonological WM as a component of VWM. This subtest requires participants to repeat a series of digits in the exact order of presentation. This subtest is an appropriate measure of the components of the phonological loop, as it taps into both its storage and the rehearsal system, respectively (Jung, 2018). Because the forward digit span does not require participants to actively process or manipulate incoming verbal stimuli, it is a simple measure of VWM as it measures the functions of the phonological loop alone.

Digit span reversed. The backward digit span subtest of the TAPS-3 was used to measure verbal digit WM. This subtest requires participants to recall a series of digits, but in a reversed order of presentation. This task requires an additional processing element as the participant is required to store the information temporarily, while simultaneously manipulating it during the face of interference. Because this test encompasses both the passive and active components of VWM, it is a complex measure of VWM.

Sentence repetition. The sentence repetition subtest of the TAPS-3 was used to measure the participants' verbal sentence short-term memory. The participants were required to repeat verbatim a series of sentences presented by the examiner. The sentence repetition subtest, therefore, measures the participants' ability to recall sentences of increased complexity and length.

For the EL2 Group, an Afrikaans translation of the TAPS-3 was used to measure L1 VWM. The Afrikaans version of the TAPS-3 consists of the same subtests as the English edition with the correct corresponding word and sentence lengths, and semantic complexities for all subtests.

The selected VWM tasks were chosen for the present study because it is known that the most reliable WM predictors of any reading outcome are those that involve the

simultaneous coordination of storage and processing (Dehn, 2011). Therefore, digit spans have been commonly used as reliable measurements of VWM capacity as both storage and processing components of VWM are implicated (Sadler, 2011). The present study also included a third measurement, the sentence repetition task, as a means of increasing the internal consistency of the overall VWM measure.

Reading comprehension. The comprehension subtest of the GORT-4 (Wiederholt & Bryant, 2001) was employed as a measure of reading comprehension for both groups. The test consists of 14 developmentally sequenced reading passages with five comprehension questions that have been normed and standardized. For this test, participants were instructed to independently read a passage, followed by a set of comprehension questions presented in multiple-choice format. In the GORT-4, participants are required to read the passage and corresponding questions with minimal assistance from the examiner. The manual of the GORT-4 states that the examiner may provide help if the reader experiences difficulty; however, each passage has a set limit on the number of words that the examiner may provide for assistance.

Reliability and Validity

Reliability and validity for the study were tested by conducting a pilot study before the commencement of the full study, and by using standardized norm-referenced assessment tools where possible. The pilot study included two participants, one from each group, respectively. The first participant was an English L1 female in Grade 3 who attended an independent English medium school. The second participant was an Afrikaans L1 male who attended an independent dual-medium school in Grade 3. The design of the pilot study was the same as for the main study; however, the materials and data collection procedures were revised and improved. For instance, the development of the parent questionnaire, revision of participant inclusion criteria, and the addition of the TACL-4 as a measure of L2 linguistic knowledge were all factors that were included after the pilot study.

The individual assessment tools are widely used in clinical and academic practice as they each have a high degree of validity and reliability according to their respective manuals. The Afrikaans version of the TAPS-3 is also considered to be a valid and reliable measure of Afrikaans WM as it was translated in precise accordance with the stimulus length and semantic complexities of the English version.

Data Analysis

We conducted hypothesis testing on raw scores of sample means assuming equal population variance. Hence, the raw scores from each subtest in the assessment battery were used for statistical analyses. Overall scores for VWM capacity were used for analyses by using the sum of raw scores from the forward digit span, digit span reversed, and sentence repetition task.

Two primary types of statistical analyses were performed, namely, correlation analysis and regression analysis. The Pearson correlation test was used to measure the strength of the linear relationship between VWM and reading comprehension in the L1 and L2. The alpha value for individual correlations in the Pearson correlation test was set to .05 (Asuero et al., 2006). All the assumptions for the Pearson correlation test were met. The correlation

coefficients were analyzed according to a scale whereby >.7 indicates a strong positive correlation; .7 to .5 indicates a moderate to strong positive correlation; .3 to .5 indicates a moderate positive correlation; and <.3 indicates a weak positive correlation.

Regression analysis through "Analysis of the Variance"(ANOVA) was used to examine the variance of correlations between VWM, L2 reading comprehension, and L2 linguistic knowledge. Furthermore, regression analysis was also done to determine the predictive strength of the variables in question.

Results

The first objective of this research was to determine the correlation and predictive capacity between VWM and L1 reading comprehension. An examination of the overall scores obtained by the participants demonstrated that there was little within-group variation of scores in the EL1 Group. Thus, most participants scored in the average to above-average range on L1 reading comprehension and L1 VWM. The results from the Pearson correlation test indicated that the correlation between L1 VWM and L1 reading comprehension is weak and insignificant, $r(30) = .21$, $p = .25$. Additional results from the ANOVA also suggest that the correlation between VWM and L1 reading comprehension is not statistically significant and lacks strong correlation, $F(2, 30) = 1.42$, $p = .24$. Overall, these results indicated that there was a large amount of unexplained variance in the data and that VWM is not predictive of L1 reading comprehension, $R^2 = .05$.

The second objective of this research was to determine the correlation and predictive capacity between L1 VWM and L2 reading comprehension. A look at the general trend of the data in a histogram revealed that the VWM scores for the participants in the EL2 Group are greater than their L2 reading comprehension scores. In addition, their L2 reading comprehension scores cover a large range of values. Therefore, there is a lot of variance in the sample of the EL2 Group with some participants scoring in the average to the below-average range, whereas others score in the average to the above-average range for L2 reading comprehension. Overall, most of the participants had low-mid L2 proficiency levels according to the TACL-4, with average to above-average VWM capacity according to the TAPS-3. The Pearson correlation test indicated that there is no linear relationship between the two variables and that the correlation is not statistically significant, $r(29) = .02$, $p = .92$. The ANOVA analysis further revealed that there is a large amount of unexplained variance in the correlation between VWM and L2 reading comprehension and VWM does not predict L2 reading comprehension, $F(2, 29) = .01$, $p = .93$, $R^2 = \sim.00$.

The correlations that have been displayed thus far assist in determining the differential role of VWM in L1 versus L2 reading comprehension. Although a significant correlation was absent in both cases, it can be seen that VWM correlates better with L1 reading comprehension ($p = .25$) when compared with L2 reading comprehension ($p = .92$). Therefore, the computation for VWM and L1 reading comprehension is nearly half of that of L2 reading comprehension. Furthermore, results from regression analysis revealed that VWM is predictive of neither L1 nor L2 reading comprehension.

The third research objective was to determine the differential correlation between L2 linguistic knowledge (represented by the TACL-4 scores), VWM, and L2 reading

comprehension. When reviewing the TACL-4 scores of the participants in the EL2 Group, the majority of the participants displayed average to below-average L2 linguistic knowledge. These results suggested that the participants in the EL2 Group are not fully proficient in English as their L2. Thus, the majority of the participants had average to above-average VWM scores, and average to below-average L2 reading comprehension and L2 linguistic knowledge scores.

When looking at the correlational data in Figure 1 below, a weak positive correlation between VWM, L2 linguistic knowledge, and the L2 reading comprehension scores can be seen. The strongest correlation, however, was between L2 linguistic knowledge and L2 reading comprehension, yielding a moderate positive correlation, $r(29) = .42$, $p = .02$. The correlation between L2 linguistic knowledge and L2 reading comprehension is therefore statistically significant ($p < .05$). The ANOVA results also indicated that a statistically significant prediction exists, $R^2 = .15$, $p = .02$. However, it should also be noted that there was a large amount of unexplained variance in the correlation between the scores of the two tests ($0 << r^2 \leq .3$). Furthermore, there was also a weak positive correlation between VWM and L2 linguistic knowledge, although statistically insignificant, $r(29) = .16$, $p = .38$. Figure 1 depicts the individual correlations between VWM, L2 reading comprehension, and L2 linguistic knowledge.

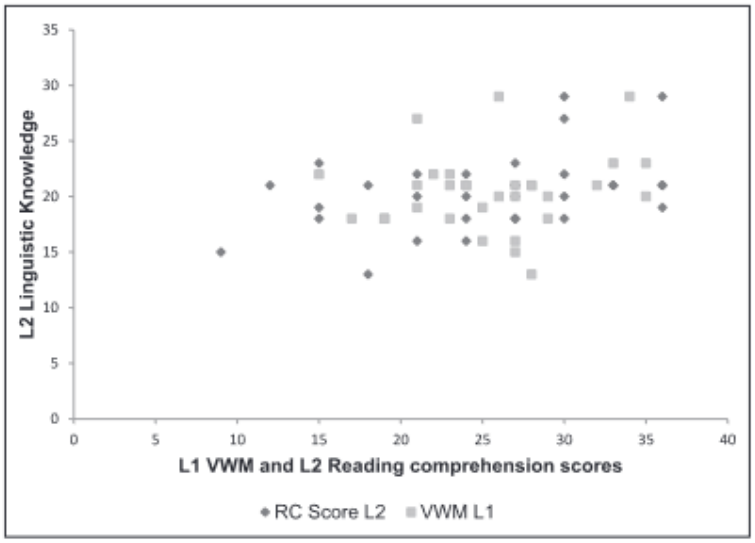

Figure 1. The correlation between L2 reading comprehension, L2 linguistic knowledge, and VWM in the EL2 Group. *Note.* VWM = verbal working memory; EL2 = English second language.

Discussion

In this study, we sought to investigate whether VWM plays an equivalent role in the reading comprehension of an L2 versus an L1 in young children in Grade 3. Many studies have investigated WM—including its verbal component and its role in the development of reading skills (Joh & Plakans, 2017; Leeser, 2007; Oakhill et al., 2011; Pham & Hassan, 2014; Wen, 2014). As yet, a consensus has not been reached as to whether VWM contributes directly toward the reading comprehension of children. This statement is especially true for the L2. This study aimed to seek clarity on the matter by correlating VWM with L1 and L2

reading, and by correlating L2 linguistic knowledge with VWM and L2 reading comprehension.

The first objective of this study aimed to determine the correlation and predictive capacity between VWM and L1 reading comprehension. Statistical analyses revealed a weak and insignificant correlation between the two variables, and that VWM is not a strong predictor of L1 reading comprehension in Grade 3 learners. This finding aligns with one earlier study by Cain and Oakhill (2006). The authors conducted investigations using participants similar in age as the present study to determine the profile of weaknesses in children who perform well in text comprehension versus those who perform poorly. It was found that poor vocabulary and poor general cognitive ability (measured by the participants' SAT scores) lead to poor comprehension, not VWM capacity. The authors concluded that a single underlying cause of poor comprehension is unlikely. Our results are in line with this hypothesis from Cain and Oakhill (2006) because VWM as an isolated variable did not contribute toward L1 reading comprehension in the sample of this study.

On the contrary, however, the finding that VWM is not predictive of L1 reading comprehension is still largely inconsistent with many previous studies that have investigated VWM and reading comprehension in children (Nevo & Bretnitz, 2014; Pham & Hassan, 2014; Sadler, 2011). Nonetheless, it should be noted that the other studies in the field have used participants of varying ages, and have used various methods in which to measure VWM capacity. To the best of our knowledge, there are no other studies that have investigated VWM and L1 reading comprehension, while employing only Grade 3 participants in the sample and using the same VWM measurements. Our findings, although contradictory to the general trend in the field, involve a novel population and a deliberate variation in the typical method used to measure VWM capacity. As a result, we can concede that VWM contributes to reading comprehension differently for different ages and populations, or because VWM capacity is highly sensitive to the methods used to measure it. We further hypothesize that VWM interacts reciprocally with other important developmental areas such as vocabulary and general cognitive development and that VWM alone cannot predict a complex skill such as reading comprehension (Cain & Oakhill, 2006). Although these theories were not tested explicitly in this study, we do concur with previous studies that the relationship between VWM and L2 reading comprehension is indeed a complex one, which operates differently in different populations and across measurement procedures.

The second objective of this study was to determine the correlation and predictive capacity between VWM and L2 reading comprehension. No significant correlation or predictive capacity was found. These results can be compared to some extent with those of Joh and Plakans (2017), and Pae and Sevcik (2011). In the present study, the participants had no previous exposure or background knowledge of the topic of the text that they were confronted with. Our results thus align with those of Leeser (2007) and Joh and Plakans (2017) who concluded that readers generally need a certain level of background knowledge and cultural familiarity with the text for them to efficiently use their VWM capacity during reading comprehension. Therefore, we speculate that the lack of correlation found in this study could be due to the lack of content familiarity experienced by the participants in the sample. This speculation is based on previous studies that have reported that VWM is only predictive of L2 reading comprehension when such background knowledge is firmly in place.

In addition to a lack of background knowledge, the correlational data can also be interpreted in light of the particular L1 and L2 languages of the participants. For example, Pae and Sevcik (2011) showed that the patterns of correlation between VWM and L2 reading comprehension were different in two different groups of bilingual child participants. For English-Korean bilinguals, a moderate positive correlation was indicated, but for Korean-English bilinguals, the pattern of correlation diminished into a weak positive correlation. It was theorized by Pae and Sevcik that the orthography and structure of the two languages under investigation largely affected the patterns of correlation that were found. The Korean language has a transparent orthography where the phoneme-grapheme correspondence is shallow and regular. The orthography of the English language is complex and has a much broader phonological repertoire. Therefore, it was far more difficult for the Korean-English bilinguals to perform reading comprehension tasks in English. Due to the increased difficulty of reading in English as an L2, it is likely that additional factors beyond VWM are required to enable these readers to comprehend text efficiently. Such factors include variables such as background knowledge or linguistic knowledge in English. The findings from the present study align with those of Pae and Sevcik (2011) because English has a deep opaque orthography and Afrikaans has a shallow transparent orthography (De Sousa et al., 2011) similar to the two groups used in their study. Therefore, the participants in the present study were also required to read in an L2 with a much more complicated orthography than their L1. The resultant weak positive correlation that was indicated for VWM and L2 reading comprehension, therefore, supports the theory that VWM may influence the acquisition of L2 language and reading abilities of some languages more than others, depending on the similarities in the phonological structure of the languages in question.

Although our results do align with a few previous studies, there are also numerous publications which, in contrast to the findings of the present study, have indeed found a correlation between VWM and L2 reading comprehension (Alptekin & Erçetin, 2011; Jeon & Yamashita, 2014; Kormos & Sáfár, 2008; Sagarra, 2017). One proposed explanation for the contrastive results is the use of the RST in several of these publications as the primary measurement of VWM capacity (Alptekin & Erçetin, 2011; Jeon & Yamashita, 2014; Sagarra, 2017). As previously mentioned, the RST in itself requires participants to perform reading comprehension at a basic level. Furthermore, it is also possible that the forward digit span, digit span reversed, and sentence repetition tasks are not complex enough to produce the correlations that have been found in some previous studies. As suggested by Sagarra (2017), only VWM tests with an additional taxing processing component can predict L2 reading development in beginning readers. It can therefore be hypothesized that in the present study, the lack of correlation is attributable to the fact that digit span methods of measuring VWM are not complex enough to truly tap into the functions of the central executive system. Finally, it is also important to note that the literature in the field has been diverse, comprising samples with varying ages and language proficiency, as well as different research designs and methods used to measure VWM capacity. This study is currently the only one to work with children between 8 and 9 years old, who are also not proficient in the L2 of testing. The literature in the field has entailed primarily adolescents (Kormos & Sáfár, 2008) or adults in the sample (Alptekin & Erçetin, 2011; Sagarra, 2017) with either low or highly proficient participants. The population of the present study is therefore a novel one, which was reflected in the unforeseen results that were found.

The third objective of this research investigation was to determine the differential correlation between L2 linguistic knowledge (operationalized as vocabulary and grammar knowledge), VWM, and L2 reading comprehension. We found that L2 linguistic knowledge correlates in the moderate positive range with both variables, but the correlation was most significant with L2 reading comprehension. This can be attributed to the fact that VWM is predominantly a cognitive skill, whereas both L2 reading comprehension and L2 linguistic knowledge are skills rooted in the linguistic domain. The link between early language development and later reading ability has also long been documented in research. Concomitantly, it was also found that while the two variables correlate well, L2 linguistic knowledge is not necessarily a strong predictor of L2 reading comprehension. We speculate that this finding is related to the multidimensional nature of reading comprehension, whereby one variable alone cannot successfully and consistently predict reading comprehension. The correlational results that were found are consistent with several studies, including Jeon and Yamashita (2014), Joh and Plakans (2017), and Walter (2004). In particular, Jeon and Yamashita (2014) investigated 10 key variables that have been found to correlate with L2 reading in children aged 12 years and older. Their results indicated that of all the variables under consideration, L2 grammar and vocabulary knowledge accounted for most of the variance in L2 reading comprehension and correlated most significantly (r = .85 and r = .79, respectively). In contrast, the contribution of VWM to L2 reading comprehension was nearly half (r = .42), which is extremely consistent with the results of the present study. In addition, Walter (2004) confirmed that a delicate interrelationship among WM, L2 proficiency, and L2 reading comprehension exists.

The results from the two before-mentioned studies along with those of the present study suggest that L2 reading is largely influenced by language ability; however, there is no single determining factor. Furthermore, the correlation between VWM and L2 reading comprehension is also mediated by language ability. In the present study, VWM did not correlate or predict L2 reading comprehension in a sample of children with low to intermediate proficiency in the L2. This is consistent with publications such as Fehringer and Fry (2007) and Hummel (2009) who found VWM correlations only in intermediate to highly proficient L2 participants. Therefore, we support the conclusion proposed by Joh and Plakans (2017) that VWM is associated with better L2 reading only among participants with higher target language knowledge, and not for those who lack such knowledge. For these lower proficiency learners, their L2 reading comprehension is primarily determined by L2 linguistic knowledge. For example, in the present study, the participants had average to above-average VWM capacity and average to below-average L2 linguistic knowledge. Because they lacked the relevant knowledge of the target language during reading, they were unable to use their existing VWM to aid in L2 reading processes. Therefore, VWM resources were not allocated to aid in the initial decoding of text, leading to a failure of reading comprehension (Joh & Plakans, 2017).

These findings also shed light on the age-old question posed by Alderson and Urquhart (1984) regarding whether reading in an L2 poses a language problem or a reading problem. It appears as though L2 reading comprehension is primarily a language problem, but that is facilitated by cognitive processes when these language abilities are firmly in place. For instance, although L2 linguistic knowledge was the strongest correlate of L2 reading comprehension in this study, it was not a strong individual predictor. Therefore, L2 linguistic

knowledge is not sufficient enough to predict poor versus good reading comprehension as an isolated variable. A more reasonable conclusion is that L2 linguistic knowledge has additive effects with other variables such as VWM to result in good comprehension. There is therefore at all times reciprocity among subsystems of spoken and written comprehension. In other words, skills from several cognitive and linguistic components must converge in real time for successful reading comprehension to occur. The question is therefore not whether L2 reading is a language or reading/cognitive problem. The question concerns which individual skills across both cognitive and linguistic systems are insufficient in an individual with reading comprehension difficulties. We, therefore, concur with a component skills approach to reading, which views reading as composed of multiple processes (including processes such as decoding, vocabulary knowledge, syntactic processing, and WM; Jeon & Yamashita, 2014).

Furthermore, it should also be noted that L2 linguistic knowledge and VWM has a reciprocal causative relationship with reading comprehension. That is, although individuals with efficient cognitive skills initially become good readers precisely because of their cognitive advantage, it is through reading that they acquire knowledge that facilitates further reading success. The knowledge that they naturally acquire through reading is knowledge about the vocabulary and grammar of the language. Conversely, poor readers who often experience reading difficulties will grow to avoid reading and, as a result, will miss the opportunity to gain such linguistic knowledge. We, therefore, concur with the consensus in research that L2 reading comprehension is primarily a linguistic process, but that is largely dependent on and can be mediated through additional cognitive and linguistic factors (Jeon & Yamashita, 2014; Joh & Plakans, 2017; Linck et al., 2014).

Limitations

The findings from this study should be interpreted in light of a few limitations. The first limitation is that we used an overall VWM score, which comprised both simple and complex measures of VWM. Although statistical analyses showed no significant difference between each subtest of the TAPS-3, there is evidence that complex VWM is more predictive of reading outcomes than simple measures (Jung, 2018). Therefore, the results may have presented differently had the assessment battery included primarily complex measures of VWM. Second, it would have been beneficial to include a sample of participants with a wider age range. Because we only included children between 8 and 9 years of age who attend the same schools, the results cannot necessarily be generalized to a larger population. The third limitation is that the research protocol did not explicitly control for language proficiency in the EL2 Group. Although the study did control for the amount of exposure the participants had to English, a predetermined criterion for L2 language proficiency was not incorporated.

However, this study still provided valuable information regarding VWM and L2 reading comprehension, as it provided the opportunity to test findings from previous similar research onto a population and context where this research is lacking. Future studies should follow a similar pursuit, however, while broadening the scope of the research project in two ways. The first is to include all the possible factors that might influence the correlation between VWM and L2 reading comprehension, not limited to L2 linguistic knowledge.

Second, future studies should ideally include a larger age group, for example, children between 8 and 13 years, and a wider range of assessment tools for measuring VWM capacity.

Conclusion and Implications

A series of regression analyses and correlation analyses revealed that VWM, measured by digit forward span, digit backward span, and sentence repetition, is predictive of neither L1 nor L2 reading comprehension in Grade 3 children in South Africa. Furthermore, for Afrikaans-English bilingual children, their L2 linguistic knowledge plays a large role in their L2 reading comprehension, although it is not a significant individual predictor.

These results suggest that the relationship between VWM and L2 reading comprehension is multidimensional, where poor VWM capacity could be related to poor comprehension for one learner, but not necessarily for another similar learner. We speculate that the complexity of this relationship is because the mechanism by which VWM interacts with L2 reading outcomes can be affected by several variables. These variables include factors such as background knowledge/topic familiarity, the orthography or phonetic structure of the two languages under investigation, the particular measurement of VWM capacity and complexity thereof, and the language proficiency of the L2 learners in the sample. Although it was beyond the scope of this research project to investigate VWM's interaction with each possible mediating variable, there is certainly no single underlying cause of poor comprehension.

The implications of our findings for practitioners in the field serve as a reminder that the assessment and treatment of learners with reading comprehension difficulties should include a wide range of possible deficit areas. In other words, practitioners should be ever conscious of the reciprocity that exists between different subskills of verbal and written comprehension. Intervention objectives should not target memory-related skills in the absence of related linguistic skills that work in conjunction with VWM to enhance reading comprehension. Finally, although it is often difficult to conduct comprehensive language and literacy assessments in EL2 contexts, practitioners should refrain from relying on VWM capacity as a powerful predictor of L2 outcomes.

In conclusion, the findings from the present study added novel views on the mechanism by which VWM intervenes in the process of L2 reading. The present study is, to the best of our knowledge, the only one to make direct comparisons between VWM's contribution to L1 versus L2 reading. The study also involved a novel population, with characteristics that differ from previous studies concerning the age and the language profile of the participants. The only other publications with samples and assessment measures similar to the present study are those of Pae and Sevcik (2011) and Sadler (2011). However, the results of the present study still differ from these prior mentioned publications, despite similarities in the sample. Therefore, new research questions should be formed regarding whether and how WM's role may change across different populations and under different conditions. We recommend further research involving L2 learners from a variety of backgrounds to improve the understanding of interwoven relationships among the variables that ultimately result in reading comprehension.

Declaration of Conflicting Interests
The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding
The author(s) received no financial support for the research, authorship, and/or publication of this article.

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