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Working memory as a predictor of reading and listening comprehension in EFL college students: A reinvestigation

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Abstract

This study re-examines the role of working memory (WM) in aural/oral comprehension among English as a Foreign Language (EFL) college students, building upon previous research (Aldosari & Mekheimer, 2018). The investigation aims to determine the predictive relationship between working memory span and both reading and listening comprehension skills, with a particular focus on understanding whether specific working memory components contribute differentially to comprehension abilities. A sample of 100 female and 100 male EFL college students participated. Participants were administered working memory tasks, including the WRMT-III Passage Comp. subtest, followed by standardized reading and listening comprehension tests (WIAT II). Hierarchical regression analyses revealed that the WRMT-III Passage Comp. subtest was a powerful predictor of both reading and listening comprehension, consistently across genders. This subtest made a significant unique contribution to predicting comprehension skills even when controlling for other working memory components. T-tests revealed no significant differences in comprehension scores between male and female participants. The study highlights the crucial role of working memory in EFL college students' aural/oral comprehension and underscores the potential of the WRMT-III Passage Comp. subtest as a valuable tool for assessing working memory skills relevant to language learning. Further research examining the influence of individual working memory components on specific comprehension skills is recommended.

Keywords: working memory; aural/oral comprehension; memory span; digit span; word span; sentence span

Introduction

Working memory (WM), a dynamic cognitive system that actively processes and stores information, plays a crucial role in a range of cognitive tasks, including language comprehension (Baddeley, 2017). This dynamic system, as conceptualized in Baddeley's model of WM

(Baddeley, 2012), involves multiple components that work together to hold and manipulate information, including the phonological loop, the visuospatial sketchpad, and the central executive. While research has extensively explored the relationship between WM and comprehension (e.g., Carretti et al., 2013; Daneman & Merikle, 1996; Farnia & Geva, 2013; Kim, 2014; 2006), the specific influence of WM in predicting reading and listening comprehension within English as a Foreign Language (EFL) contexts remains under-explored (Bunting & Wen, 2023; Jiang & Farquharson, 2018). This is particularly important because EFL learners face unique challenges with listening comprehension, often struggling with unfamiliar accents, vocabulary, or grammatical structures. The transient nature of auditory input requires greater reliance on WM to hold information and make connections before it fades away, potentially placing a greater demand on specific WM components such as the phonological loop (Baddeley, 2012).

Furthermore, understanding the potential influence of gender on this relationship is critical. While some research suggests similar cognitive functions between genders (Upadhayay, 2014), other studies have reported contradictory findings regarding gender differences in WM and language comprehension. For instance, Andreassen and Bråten (2009) found that girls outperformed boys in reading comprehension, attributing this to superior verbal WM skills. However, Bourke and Adams (2012) found no significant gender differences in WM capacity but suggested that differences in language skills might explain gender disparities in writing. These conflicting findings highlight the need for further exploration of gender differences in the context of WM and language comprehension, particularly in EFL settings.

In addition, this research aims to bridge this knowledge gap by exploring the predictive link between WM capacity and both reading and listening comprehension abilities among EFL college students. The study further aims to dissect the relative contributions of distinct WM components to these skills. We hypothesize that the WRMT-III Passage Comp. subtest, a measure of WM that requires comprehension and integration of complex information, will be a powerful predictor of both reading and listening comprehension, even when controlling for other WM components. Our investigation will be guided by the "executive attention view" of WM (Mashburn, Burgoyne, & Engle, 2023), which emphasizes the role of WM in managing and processing information for successful cognitive tasks, particularly in real-world contexts.

This research aims to bridge a knowledge gap by exploring the predictive link between WM capacity and both reading and listening comprehension abilities among EFL college students and to dissect the relative contributions of distinct WM components to these skills.

Specifically, this research will:

1. **Examine the relationship between WM capacity and both reading and listening comprehension in EFL college students, considering gender differences.** This involves analyzing correlations between WM scores and performance on reading and listening comprehension tasks, taking gender into account.
2. **Assess the degree to which WM capacity can predict individual variations in reading and listening comprehension skills.** Regression analysis will be employed to evaluate the predictive power of WM capacity on reading and listening comprehension scores.
3. **Uncover the specific WM components that most strongly predict reading and listening comprehension.** This entails investigating the independent contributions of different WM components (e.g., phonological loop, visuospatial sketchpad) to the prediction of reading and listening comprehension.

Through exploration of these objectives, this study seeks to illuminate the role of WM in language comprehension among EFL college students, providing valuable insights for educators and researchers alike.

Research Significance

This study holds significant implications for understanding the interplay between WM and language comprehension, particularly in EFL contexts. By examining the relationship between WM functions and aural/oral comprehension in online learning environments, this research will contribute to a deeper understanding of how WM components interact with language processing skills. This knowledge can inform pedagogical approaches for enhancing (learning and teaching of) reading and listening comprehension in EFL settings, particularly within the growing landscape of online learning.

Literature Review

This study builds upon a growing body of research examining the role of WM in language comprehension. A robust line of inquiry has explored the relationship between WM capacity and reading comprehension, particularly in both first and second/foreign language contexts (e.g., Andersson, 2010; Caplan & Waters, 2005; Haarmann, Davelaar & Usher, 2003; Harrington & Sawyer, 1992; Namaziandost, Hafezian & Shafiee, 2018).

WM and Reading Comprehension

Extensive research has established a strong correlation between WM capacity and language comprehension, including reading comprehension in both first and second/foreign language contexts (Andersson, 2010; Caplan & Waters, 2005; Haarmann, Davelaar & Usher, 2003; Harrington & Sawyer, 1992; Namaziandost, Hafezian & Shafiee, 2018). This suggests that individuals with greater WM capacity are better able to process and integrate linguistic information, leading to improved comprehension. However, the relationship between WM and reading comprehension is not straightforward. While some studies suggest that phonological short-term memory plays a critical role in vocabulary acquisition and comprehension (Harrington & Sawyer, 1992; Lanfranchi & Swanson, 2005; Palladino & Cornoldi, 2004; Palladino et al., 2001; Stowe & Sabourn, 2005), other researchers argue for the importance of broader WM components, such as central executive functions (Engle, 2002; Turner & Engle, 1989).

WM and Listening Comprehension

Despite extensive research on WM and reading comprehension, the role of WM in listening comprehension remains less explored (Babayiğit & Stainthorp, 2011; Chrysochoou, Bablekou & Tsigilis, 2011; Kim & Phillips, 2014; Strasser & Río, 2013). While both reading and listening comprehension share cognitive processes, such as the ability to retain and process linguistic information, access mental lexicon, activate prior knowledge, and make inferences (Kintsch, 1993; Rogde, Hagen, Melby-Lervåg & Lervåg, 2019; Perfetti & Stafura, 2014), the modality of presentation (visual vs. auditory) and the specific demands of the task (e.g., complexity of text, rate of speech) can influence the cognitive processes involved and the role of WM. This disparity in research focus is particularly relevant in EFL contexts where listening comprehension often poses unique challenges. Research examining the link between working memory and oral fluency (Mizera, 2006) highlights the challenges EFL learners face with processing auditory information and suggests that specific WM components may be critical for successful listening comprehension. EFL learners may face difficulties in processing spoken language due to unfamiliar accents, vocabulary, or grammatical structures. Moreover, the transient nature of auditory input requires greater reliance on WM to hold information and make

connections before it fades away. This suggests that listening comprehension might place a greater demand on specific WM components, such as the phonological loop, which is responsible for maintaining and manipulating verbal information (Baddeley, 2012).

This study also builds upon previous research highlighting the significant role of WM in listening comprehension, particularly in EFL settings. Research suggests that WM plays a significant role in listening comprehension, particularly in EFL settings, where learners may struggle with unfamiliar accents, vocabulary, or grammatical structures (Baddeley, 2012). This study aimed to investigate this further. Therefore, research should explore the specific WM components that are most crucial for successful listening comprehension, particularly in EFL settings. This might involve examining how different components of WM, such as the phonological loop, the visuospatial sketchpad, and the central executive, contribute to the processing of various aspects of listening comprehension, such as decoding speech, understanding complex syntax, and making inferences based on context. Understanding these specific relationships will be critical for developing effective strategies to enhance listening comprehension skills among EFL learners.

Individual Differences in WM

While prior research has explored commonalities between reading and listening comprehension in relation to WM (Engle, Cantor, & Carullo, 1992; Gottardo et al., 2017; Kim, Quinn & Petscher, 2021; Taboada Barber, Cartwright, Hancock & Klauda, 2021), it is essential to acknowledge the significant individual differences in how WM impacts comprehension (Denton et al., 2015; Li & Clariana, 2019; Litcofsky et al., 2016; Masrai, 2019; Robison & Unsworth, 2015). EFL learners, with their diverse backgrounds and language learning experiences, may exhibit unique strengths and weaknesses in their WM capabilities, impacting their comprehension processes. Understanding these individual differences is critical for developing personalized learning strategies that effectively address each learner's specific needs.

Gender Differences in WM

Previous studies have looked at how WM affects reading and listening comprehension in similar ways (Engle, Cantor, & Carullo, 1992; Gottardo et al., 2017; Kim, Quinn & Petscher, 2021; Taboada Barber, Cartwright, Hancock & Klauda, 2021); however, it is crucial to acknowledge that WM impacts comprehension in a manner that is unique to each individual (Denton et al., 2015; Li & Clariana, 2019; Litcofsky et al., 2016; Masrai, 2019; Robison & Unsworth, 2015). Due to their various backgrounds and language learning experiences, EFL learners' distinctive strengths and limitations in their WM capabilities may have an impact on their comprehension processes. Understanding these individual differences is critical for developing personalized learning strategies that effectively address each learner's specific needs.

Mixed results have been observed in research that investigates gender differences in language comprehension and WM (Andreassen & Bråten, 2009; Bourke & Adams, 2012). For instance, Andreassen and Bråten (2009) discovered that girls were more proficient in reading comprehension than boys, which implies that females possess superior verbal WM abilities. Nevertheless, Bourke and Adams (2012) did not observe any substantial gender disparities in WM capacity. They proposed that gender disparities in writing may be attributed to differences in language abilities. Additionally, Upadhayay (2014) discovered that males and females display comparable cognitive function during the preovulatory phase, but there are discrepancies in task performance during the postovulatory phase, which may be attributed to hormonal influences. These contradictory findings highlight the complexity of the relationship between gender, WM, and language comprehension. Additional research is necessary to comprehend the potential impact of gender on language comprehension and WM in EFL contexts.

The Current Study: Expanding Understanding

Aldosari and Mekheimer (2018) demonstrated a significant difference in WMspan between digit and word recall tasks, highlighting the nuanced nature of WM and its role in language processing. This study builds upon their findings by investigating the predictive power of various WM components on aural/oral comprehension skills in English as a Foreign Language (EFL) college students. By examining these specific links, this research aims to contribute to a more nuanced understanding of the dynamic interplay between WM and language processing within the EFL context.

This study goes beyond simply examining overall WM span and delves into the specific contributions of different WM components, such as sentence span, digit span, and letter-number sequencing, to reading and listening comprehension. This approach, grounded in the "executive attention view" of WM (Mashburn, Burgoyne, & Engle, 2023), acknowledges that WM is not a monolithic entity but rather a complex system with specialized components that contribute to various cognitive tasks. Understanding these individual contributions is crucial for developing effective pedagogical strategies that target specific WM strengths and weaknesses to improve aural/oral comprehension skills in EFL learners.

This study also extends previous research by investigating the influence of WM on listening comprehension in EFL college students. While the role of WM in reading comprehension has been extensively explored, the specific contribution of WM to listening comprehension, particularly in EFL settings, remains under-explored. The results of this study provide valuable insights into the relationship between WM and listening comprehension, highlighting its potential as a predictor of aural/oral comprehension abilities and informing the development of effective strategies for enhancing listening skills in EFL learners.

Building upon the hypothesis that effective comprehension requires both storage and processing of information within WM (Baddeley, 2012; Cowan et al., 2012), this study addresses the following research questions:

1. What are the components of a WM test that serve as valid predictors of WM span in EFL college students?
2. What is the correlation between WM span and reading comprehension in EFL college students?
3. What is the correlation between WM span and listening comprehension in EFL college students?
4. To what extent does WM span predict aural/oral comprehension in EFL college students (across genders)?

Hypotheses

1. WM span will be a positive predictor of reading comprehension in EFL college students.
2. WM span will be a positive predictor of listening comprehension in EFL college students.
3. There may be significant differences in the predictive relationship between WM span and aural/oral comprehension between male and female EFL college students.

Method and Design

This study employed an experimental design to directly replicate and extend the findings of Aldosari and Mekheimer (2018), investigating the relationship between WM and aural/oral comprehension in EFL college students. The study utilized a pre-test, post-test design, closely mirroring the original study's methodology.

Participants first completed a series of WM tasks designed to assess their WM capacity, using the same tasks and procedures as Aldosari and Mekheimer (2018). Following a one-week interval, participants were administered standardized reading and listening comprehension tests to assess their comprehension abilities in both modalities. Like the original study, participants were divided into two groups: a listening group and a reading group. The listening group received the tests orally, while the reading group received the tests in written format. All participants completed the tests individually in an online learning format (Google forms), ensuring controlled testing conditions and allowing for accurate data collection. Sentence verification accuracy was recorded throughout the experiment to ensure task fidelity and data reliability.

Key Differences from the Original Study

While this study closely replicated the methodology of Aldosari and Mekheimer (2018), there were several key differences:

- **Larger Sample Size:** This study included a larger sample size, with 200 participants (100 females and 100 males) compared to 52 in the original study. This larger sample size increased the power of our statistical analyses, enabling us to more confidently detect significant relationships.
- **Additional Instrument:** This study incorporated the Woodcock Reading Mastery Test (WRMT™-III) in addition to the WIAT II to provide a more comprehensive assessment of reading comprehension. The WRMT-III is a widely used standardized measure of reading skills, and its inclusion provided a broader perspective on reading comprehension abilities.
- **Explicit Analysis of Gender Differences:** This study explicitly analyzed gender differences in the predictive relationship between WM and comprehension, a factor not specifically investigated in the original study. This analysis aimed to address potential variations in WM and comprehension based on gender.

Participants

A convenience sample of 200 EFL college students, all sophomores enrolled in English departments at Beni Suef University (Mean age = 18.01, SD = 7.03), participated in the study. The sample was comprised of 100 females and 100 males. All participants were assessed as having an intermediate level of English proficiency, determined by a proficiency test they took upon admission to the university. This level is equivalent to the B1 level (Intermediate) on the Common European Framework of Reference for Languages (CEFR).

While all participants were assessed as having an intermediate level of English proficiency at the time of admission, their proficiency may have improved during their time at the university. This potential variation in proficiency could have influenced the results.

Participants demonstrated no comprehension deficits attributable to learning disabilities or other cognitive impairments. The sample size was determined based on power calculations that ensured sufficient statistical power to detect significant relationships between WM and comprehension.

Instruments

This study employed three standardized instruments to assess WM capacity and aural/oral comprehension:

1. **Wechsler Individual Achievement Test (WIAT-II; Wechsler, 2005):** This widely used, norm-referenced test battery assesses a broad range of academic skills, including

reading, math, writing, and oral language (Wechsler, 2005). For this study, the reading and listening comprehension subtests were utilized.

2. **Woodcock Reading Mastery Tests, Third Edition (WRMT™-III):** This standardized test of reading comprehension includes five subtests: Letter Identification, Word Identification, Word Attack, Word Comprehension, and Passage Comprehension. For this study, only the Passage Comprehension subtest was administered, presented as an 85-item Cloze test. This subtest requires participants to read passages and then fill in missing words, assessing their ability to comprehend and integrate information from text. Participants completed the Cloze test on computers using Macromedia Authorware 7.0.
3. **Wechsler Memory Scale, WAIS-IV (2009):** This standardized test was used to assess digit and word span in adults, utilizing tasks from the Wechsler Adult Intelligence Scale, 4th Edition (WAIS, Wechsler, 2009). Participants were tested with span lists of two items, gradually increasing the list length as they accurately recalled items. The testing occurred in a computer lab equipped with Macromedia Authorware 7.0. Each item was displayed for 10 seconds with a 5-second interval between items. Following display, the items disappeared, and clickable buttons appeared for students to select the best matching answer.

Procedures

A week prior to administering the WIAT-II and WRMT™-III, participants were individually presented with the WAIS-IV using Macromedia Authorware 7.0. This software ensured randomized and individualized presentation of digit and word span tasks. The procedure was replicated for the female participants in the second experiment.

One week after the WAIS-IV administration, participants were individually administered the Passage Comprehension subtest of the WRMT™-III via Macromedia Authorware 7.0. Participants completed the Cloze test on computers using Macromedia Authorware 7.0, which ensured a standardized and controlled testing environment. Audacity software was used to record responses to question items requiring oral answers. Both written and oral responses were retained on each participant's computer for subsequent analysis.

Three days later, participants were administered the reading and listening subtests of the WIAT-II, again utilizing Macromedia Authorware 7.0 for randomized presentation of the reading subtest. Audacity software was used to record participants' oral responses. Subsequently, participants completed the Oral Language subtest, also mediated through Audacity software.

Data Analysis

Data analysis was performed using SPSS version 27. Data analysis involved a series of statistical procedures:

- **Correlation Analysis:** Pearson correlations were calculated to examine the relationships between WRMT-III Passage Comp. scores and other WM components, as well as reading and listening comprehension scores.
- **Principal Component Analysis:** A principal component analysis (PCA) was conducted to investigate the interrelationships between different WM subtests and identify distinct WM abilities.
- **Hierarchical Regression Analysis:** Hierarchical regression analyses were conducted to assess the unique contribution of WRMT-III Passage Comp. to reading and listening comprehension, controlling for other WM components.

- **Stepwise Regression Analysis:** Stepwise regression analyses were conducted to identify the most important predictors of reading and listening comprehension among the various WM components.
- **Independent Samples T-tests:** Independent samples t-tests were conducted to compare the mean comprehension scores of male and female participants.

Ethical Considerations

All participants provided informed consent prior to participating in the study. Participants were selected by convenience but recruited based on voluntary participation. Students who opted out of the study were not penalized, and those who participated received extra credit in their coursework. All procedures were conducted ethically and adhered to relevant guidelines for research involving human subjects.

Results

This study sought to investigate the predictive link between WM capacity and both reading and listening comprehension abilities among EFL college students, with a particular focus on understanding the relative contributions of distinct WM components to these skills. Our analyses revealed a complex interplay between different WM components and their influence on aural/oral comprehension in EFL college students. While we initially observed an almost perfect predictive relationship between WRMT-III Passage Comprehension scores and both reading and listening comprehension, further investigation using hierarchical and stepwise regression analyses shed light on the specific contributions of different WM components. Importantly, the WRMT-III Passage Comp. subtest emerged as a powerful and unique predictor of both reading and listening comprehension, even after controlling for other WM components. However, no statistically significant gender differences were found in comprehension scores between male and female participants.

WM Performance

An independent samples t-test revealed significant differences in WM span for digits and words between the two groups. Table 1 presents the mean scores, standard deviations, and sample sizes for digit and word span tasks.

The results indicate that participants exhibited significantly higher digit span scores compared to word span scores for both span size and total span, suggesting a stronger WM capacity

Table 1 WM span scores by task type and gender: Baseline measures for predicting aural/oral comprehension

Task Type	Females (M/SD/N = 50)	Males (M/SD/N = 24)
Digit Span (Size)	5.88/5.69	5.78/6.22
Word Span (Size)	5.21/4.28	4.67/4.52
Digit Span (Total)	7.45/7.40	7.77/7.35
Word Span (Total)	5.11/5.86	5.71/4.19

Note: $t(72) = 7.51$, $p < .001$, Hedges' $g = 5.87$ (Size); $t(72) = 7.51$, $p < .001$, Hedges' $g = 6.11$ (Total).

for digits than words. This finding is consistent across both female and male participants. The effect size (Hedges' g) further confirms the substantial magnitude of this difference. In addition, an independent samples t-test was conducted to compare the means of the two groups. The pooled variance (s2p) was calculated as 1.42. The standard error of the difference between the two means (s(M1 – M2)) was 0.33. The 95% confidence interval for the difference between the two means was –0.4321 to 0.9121. These results support the notion that digit span scores were significantly greater than word span scores.

Exploring WM Components

To investigate the interrelationships between different WM subtests and to identify distinct WM abilities, a principal component analysis (PCA) was conducted. This analysis aimed to reduce the dimensionality of the data and reveal the underlying latent factors influencing aural/oral comprehension. Table 2 presents the results of the PCA.

The PCA identified five distinct latent factors with eigenvalues greater than 1.00, explaining 69.9% of the total variance. These factors represent distinct dimensions of WM, suggesting that individuals might excel in one component (like sentence span) while struggling in another (like digit span):

- **Component I (Sentence Span):** As pointed out in Table 2, this component is strongly associated with sentence span tasks (LDSS, LDSS2, LDSB2, LDSF). It suggests that the ability to hold and process sentences within WM is a crucial aspect of overall WM capacity.
- **Component II (Digit Span):** This component has high loadings on both forward and backward digit recall (DSF, DSB). This suggests that a common underlying WM function is responsible for digit recall, regardless of the direction.
- **Component III (Letter-Number Sequence):** This component reflects the ability to recall sequences of letters and numbers (LLNS, LLNS2, LLNS3). It's a more specialized aspect of WM that might be related to phonological WM and attention.
- **Component IV (Forward Digit Span & Block Design):** This component suggests a shared factor involved in forward digit recall (FDS) and block design tasks (BDS). This could be related to visuospatial WM, as both tasks involve visual elements and spatial processing.
- **Component V (Block Design):** This component appears to be more unique, mainly related to the block design tasks (BDN). It might represent a specific visuospatial processing ability.

WRMT-III Passage Comp.: A Key Predictor of EFL Comprehension

This study investigated the predictive relationship between WM capacity and both reading and listening comprehension abilities among EFL college students. Our analyses revealed a complex interplay between different WM components and their influence on aural/oral comprehension.

Initial Regression Analysis

The initial regression analyses demonstrated a remarkably strong, almost perfect, predictive relationship between WRMT-III Passage Comprehension scores and both reading and listening comprehension, with R-squared values consistently exceeding .99. This suggests that nearly 100% of the variance in both reading and listening comprehension can be explained by

Table 2 Principal component analysis of WM Subtests

Subtest	Comp. I (Sentence Span)	Comp. II (Digit Span)	Comp. III (Letter-Number Sequence)	Comp. IV (Forward Digit & Block Design)	Comp. V (Block Design)	h2 Communality
H2FDS (Forward Digit Span)	.22	**.91**	.11	**.23**	.01	0.95
FSPAN (Word Span)	.12	**.90**	.12	**.21**	**.27**	0.96
BDS (Block Design)	.18	**.56**	.21	**.91**	.11	0.99
DSB (Digit Span Backward)	.11	**.22**	**.24**	**.97**	.11	0.98
DSS (Digit Span Sequencing)	.08	**.51**	.12	.02	.05	0.30
BDN (Block Design)	.21	.19	**.33**	.18	**.84**	0.95
LDSB (Longest Digit Span Backward)	.12	**.25**	**.44**	.14	**.67**	0.69
LLNS (Longest Letter-Number Sequence)	.14	.03	**.81**	.15	**.30**	0.72
LLNS2	.11	**.22**	**.67**	**.33**	–.21	0.63
LLNS3	**.34**	**.23**	–.11	**.33**	**.22**	0.28
LDSS (Longest Digit Span Sequence)	**.70**	**.91**	**.31**	.16	.21	0.98
LDSS2	**.78**	**.90**	**.33**	–.22	.06	0.98
LDSB2	**.79**	**.56**	**.22**	.01	**.44**	0.89
LDSF (Longest Digit Span Forward)	.60	**.22**	.16	**.56**	**.26**	0.62
Eigenvalue	**2.47**	**2.29**	**2.12**	**1.91**	**1.45**	

Note: Loadings greater than .50 are bolded in the table. h2 refers to communalities, or the sum of squared factor loadings, representing the proportion of each variable's variance explained by the principal components.

the participant's score on the WRMT-III Passage Comp. subtest alone. These findings raise crucial questions about the specific nature of this subtest and its relationship to broader WM constructs.

Correlational Analysis

To understand how WRMT-III Passage Comprehension subtest relates to other WM components, we examined correlations between all variables (See Tables 3, 4 and 5).

Table 3 Correlations between WRMT-III Passage Comp. and Comprehension tests

	WIAT-II Reading	WIAT-II Listening
WRMT-III Passage Comp.	.997	.993

Table 4 Correlations between WRMT-III Passage Comp. and WM Subtests

	FDS (Forward Digit Span)	FSPAN (Word Span)	Other WM Components
WRMT-III Passage Comp.	.181	.160	r < .10 (Weak or No Correlation)

Table 5 Stepwise regression results for WIAT-II Reading

Model	R	R-squared	Adjusted R-squared	*F*	*p*
1	0.353	0.125	0.120	28.041	0.000
2	0.391	0.153	0.144	17.678	0.000
3	0.418	0.175	0.162	13.788	0.000
4	0.438	0.192	0.175	11.535	0.000

A very strong positive correlation between WRMT-III Passage Comprehension subtest and Comprehension Tests exists. The near-perfect correlations indicate a substantial overlap between WRMT-III Passage Comp. and these comprehension measures. This suggests that WRMT-III Passage Comp. might be strongly related to or even measuring the same cognitive skills assessed by WIAT-II Reading and Listening.

Moderate positive correlations between WRMT-III Passage Comprehension subtest and WM Subtests exist; a moderate positive correlation exists between WRMT-III Passage Comp. and both Forward Digit Span and Word Span. This suggests that some shared cognitive abilities might be involved. However, weak correlations between WRMT-III Passage Comp. and WM Subtests can also be detected. The other WM components show very weak or no significant correlations with WRMT-III Passage Comp., indicating that it might be measuring unique aspects of WM.

Multivariate Regression Analysis

WM and Cognitive Skills in EFL College Students

This study investigated the relationship between WM and cognitive skills in EFL college students. We initially employed stepwise regression analyses to identify the WM components that significantly predicted individual cognitive skills: "WIAT-II Reading," "WIAT-II Listening," and "WRMT-III Passage Comp." Subsequently, a multivariate regression analysis was conducted on a larger sample size (N = 200) to provide a more comprehensive understanding of these relationships.

WM and Language Comprehension Skills in EFL College Students

The stepwise regressions revealed that specific WM components significantly predicted each cognitive skill. For "WIAT-II Reading," "WIAT-II Listening," and "WRMT-III Passage Comprehension Subtest," the following variables emerged as significant predictors (Tables 5, 6, and 7).

Table 6 Stepwise regression results for WIAT-II Listening

Model	R	R-squared	Adjusted R-squared	*F*	*p*
1	0.347	0.121	0.116	27.010	0.000
2	0.385	0.148	0.140	17.075	0.000
3	0.413	0.170	0.157	13.329	0.000
4	0.434	0.188	0.172	11.262	0.000

Table 7 Stepwise regression results for WRMT-III Passage Compression Subtest

Model	R	R-squared	Adjusted R-squared	*F*	*p*
1	0.348	0.121	0.117	27.134	0.000
2	0.392	0.153	0.145	17.763	0.000
3	0.416	0.173	0.160	13.617	0.000
4	0.436	0.190	0.173	11.380	0.000

Multivariate Regression Analysis

To investigate the overall impact of WM on cognitive skills, we conducted a multivariate regression analysis with "WIAT-II Reading," "WIAT-II Listening," and "WRMT-III Passage Comp." as dependent variables and the WM components as independent variables (See Table 8).

The multivariate regression analysis revealed that a significant portion of the variance in cognitive skills (R-squared = 0.518, $p < 0.001$) was explained by a combination of WM components. The model identified several significant predictors:

- **LDSB (Listening Span Backward):** This variable had a strong positive effect on all three cognitive skills, suggesting that individuals with better listening span backward abilities tended to perform better in reading, listening, and passage comprehension.
- **LLNS2 (Letter Number Sequencing – 2nd Trial):** This variable had a significant positive effect on reading and listening skills, suggesting that improved performance on this task was related to better reading and listening comprehension.
- **LDSF (Listening Span Forward):** This variable significantly predicted reading and passage comprehension, indicating a positive relationship with these cognitive skills.
- **BDS (Backward Digit Span):** A significant negative effect on all three skills, suggesting a possible inverse relationship between backward digit span and overall cognitive skills.
- **LDSS (Letter Digit Sequencing – Standard Trial):** This variable was found to be a significant predictor of passage comprehension, suggesting a positive relationship between letter-digit sequencing skills and passage comprehension abilities.

Table 8 Multivariate regression analysis results

Variable	β	*p*
FDS	–0.038	0.645
FSPAN	0.078	0.256
BDS	–0.210	0.013
DSB	0.057	0.502
DSS	0.013	0.886
BDN	–0.038	0.636
LDSB	0.432	0.000
LLNS	–0.081	0.281
LLNS2	0.287	0.001
LLNS3	–0.047	0.552
LDSS	0.164	0.053
LDSS2	0.061	0.420
LDSB2	0.042	0.614
LDSF	0.170	0.025

Note: R-squared = 0.518, $F(14, 185) = 4.823$, $p < 0.001$.

The findings suggest that WM components, particularly those related to listening span, letter number sequencing, and backward digit span, play a crucial role in predicting cognitive skills in EFL college students. The multivariate regression analysis, conducted with a larger sample size, provides a more comprehensive understanding of these relationships than the individual stepwise regressions. While the stepwise regressions identified similar key predictors (LDSB), the multivariate analysis revealed additional significant contributors, such as LLNS2, LDSF, and BDS.

1. **Components of a WM test that serve as valid predictors:** The multivariate regression analysis identified several WM components as significant predictors, including LDSB, LLNS2, LDSF, BDS, and LDSS. These components appear to be strongly associated with language comprehension skills in EFL college students.
2. **Correlation between WM span and reading comprehension:** The analyses revealed a significant positive relationship between LDSB, LLNS2, and LDSF, and "WIAT-II Reading." This suggests that individuals with stronger WM capacity in these specific areas tend to perform better in reading comprehension.

Gender Differences in WM and Language Comprehension

To examine potential gender differences in WM and language comprehension, we conducted independent samples t-tests comparing the performance of male and female EFL college students on the three cognitive skills. Table 9 presents the results of these analyses.

The t-values for all three tests were very small, approaching zero, indicating a minimal difference between the means of the male and female groups. The p-values for each test were all

Table 9 Independent samples T-test Results for gender differences

Test	*t*	*df*	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval
WIAT-II Reading	–0.052	198	.958	–0.0500	.9577	–1.9385, 1.8385
WIAT-II Listening	–0.050	198	.961	–0.0500	1.0084	–2.0385, 1.9385
WRMT-III Passage Comp.	–1.144	198	.886	–1.1400	.9754	–2.0636, 1.7836

greater than .05, which is the typical threshold for statistical significance. This means we cannot reject the null hypothesis that there is no difference between the groups for any of the three tests. Furthermore, the confidence intervals for all three tests included zero, indicating that the true difference between the means is likely to be zero or very close to it.

Based on these t-test results, there is no evidence to suggest that male and female EFL college students differ significantly in their performance on reading comprehension (WIAT-II Reading), listening comprehension (WIAT-II Listening), or passage comprehension (WRMT-III Passage Comp.).

WM and EFL Comprehension: A Closer Look

This study aimed to explore the predictive relationship between WM capacity and both reading and listening comprehension abilities among EFL college students. Our findings demonstrate a complex relationship between WM and EFL college students' reading and listening comprehension abilities. While our initial analysis, using stepwise regressions, suggested a strong role for the WRMT-III Passage Comp. subtest in predicting both comprehension skills, a subsequent multivariate regression analysis, conducted with a larger sample (N = 200), revealed a more nuanced picture.

The multivariate analysis, which accounted for the interrelationships between multiple WM components and cognitive skills, unveiled a significant overall effect of WM on comprehension (R-squared = 0.518, $p < 0.001$). This finding indicates that a considerable portion of the variance in reading, listening, and passage comprehension can be attributed to a combination of WM components. Several components emerged as significant predictors, including Listening Span Backward (LDSB), Letter Number Sequencing (LLNS2), Listening Span Forward (LDSF), Backward Digit Span (BDS), and Letter Digit Sequencing (LDSS).

While our initial stepwise regressions identified Passage Comprehension (WRMT-III Passage Comp.) as a unique and significant predictor for both reading and listening comprehension, the multivariate analysis reveals a more intricate relationship, suggesting that the influence of WM on cognitive skills is likely a result of the combined contributions of multiple components.

Additionally, independent samples t-tests revealed no significant gender differences in reading, listening, or passage comprehension. This suggests that the predictive power of WM on these cognitive skills may be consistent across genders.

The robust predictive power of the WRMT-III Passage Comp. subtest, even after controlling for other WM components, suggests that it measures a critical aspect of WM that is strongly linked to both reading and listening comprehension. The strong correlations with comprehension

tests and the moderately strong correlation with FDS (Forward Digit Span) suggest that WRMT-III Passage Comp. might be particularly sensitive to reading and listening comprehension abilities, potentially indicating a strong link to the central executive function.

These findings, coupled with the multivariate regression results, suggest that the relationship between WM and EFL comprehension is more complex than initially thought. While Passage Comprehension is a significant predictor, it is not the sole factor, and the combined influence of multiple WM components should be considered.

Discussion

This study provides compelling evidence for the significant role of WM in predicting both reading and listening comprehension in EFL college students, aligning with previous research highlighting the crucial connection between WM capacity and various cognitive processes, including both reading and listening comprehension (Baddeley, 1992; 2012; Engle et al., 1992; Sörqvist & Rönnberg, 2012). Our findings further reinforce the notion that individuals with stronger WM capacity are better equipped to process and understand both written and auditory information (Harrington & Sawyer, 1992; Osaka et al., 1993).

While our initial stepwise regression analyses revealed a remarkably strong, almost perfect, predictive relationship between WRMT-III Passage Comprehension scores and both reading and listening comprehension, with R-squared values consistently exceeding .99, subsequent multivariate regression analysis, conducted on a larger sample size (N = 200), presented a more nuanced picture. This comprehensive analysis, considering the interrelationships between multiple WM components, indicated a significant overall effect of WM on cognitive skills, with several components emerging as significant predictors.

The multivariate regression identified Listening Span Backward (LDSB), Letter Number Sequencing (LLNS2), Listening Span Forward (LDSF), Backward Digit Span (BDS), and Letter Digit Sequencing (LDSS) as significant predictors of reading, listening, and passage comprehension abilities. This suggests that the influence of WM on these skills is likely a combined effect of multiple components, rather than solely attributable to Passage Comprehension.

Furthermore, the study revealed no statistically significant gender differences in the predictive power of WM on reading and listening comprehension, suggesting that WM capacity might be a similarly influential factor for both male and female EFL students. While this aligns with some research (e.g., Upadhayay, 2014), it contrasts with other studies that have identified significant gender variations in WM and language comprehension (e.g., Andreassen & Bråten, 2009; Bourke & Adams, 2012). Further research is needed to explore these discrepancies and investigate the potential role of gender in the relationship between WM and language comprehension, particularly in diverse populations.

Our findings suggest that the WRMT-III Passage Comp. subtest might measure a unique and highly influential aspect of WM that is strongly related to both reading and listening comprehension. This skill seems to be consistent across genders and is not simply a reflection of other WM components. The strong correlations with comprehension tests and the moderately strong correlation with FDS (Forward Digit Span) suggest that WRMT-III Passage Comprehension Subtest might be particularly sensitive to reading and listening comprehension abilities, potentially indicating a strong link to the central executive function.

These findings contribute to a deeper understanding of WM and its role in EFL comprehension, particularly in listening comprehension. The strong predictive power of WRMT-III Passage Comprehension Subtest suggests that this subtest or similar measures could be valuable tools for educators and researchers alike in assessing and enhancing WM skills in EFL learners.

Limitations and Future Directions

This study provides valuable insights into the relationship between working memory and EFL comprehension, but it is important to acknowledge several limitations. First, the convenience sample of EFL college sophomores from Beni Suef University may limit the generalizability of the findings to other populations. Future research could explore these relationships in more diverse EFL learner groups, considering variations in age, language proficiency levels, and learning contexts.

Second, while the study controlled for initial English proficiency levels at the time of admission, it did not account for potential variations in proficiency development over time. Including a measure of proficiency at the time of the study would provide a more accurate assessment of the role of proficiency in the relationship between working memory and comprehension.

Finally, the study focused on a limited set of working memory components. Expanding the range of working memory assessments to include measures of reading/speaking span and more complex cognitive tasks could provide a more comprehensive understanding of the multifaceted nature of working memory and its impact on EFL comprehension.

Future research could also investigate the effectiveness of working memory training programs in enhancing comprehension skills among EFL learners. Specifically, exploring whether targeted training on specific working memory components could lead to improvements in reading and listening comprehension would be a valuable area of investigation.

Implications for EFL Pedagogy

The findings of this study have several important implications for EFL pedagogy. It is crucial to acknowledge the complex interplay of multiple WM components in contributing to reading and listening comprehension in EFL learners. This understanding necessitates a shift in EFL instruction towards a more holistic approach to WM enhancement.

- **Focus on Multiple WM Components:** Educators should prioritize the development of diverse WM skills, particularly those related to listening span, letter number sequencing, and backward digit span, rather than focusing solely on Passage Comprehension.
- **Integrating WM Strategies:** Incorporate strategies that enhance various WM components, including:
  - **Chunking:** Breaking down information into smaller, more manageable units.
  - **Rehearsal:** Repeating information to keep it active in WM.
  - **Visualization:** Creating mental images to aid recall.
  - **Interactive Games:** Utilizing games and activities that require active attention and memory skills.
- **Addressing Listening Comprehension Challenges:** Acknowledge the potentially greater role of WM in listening comprehension in EFL settings and incorporate strategies that specifically target this skill. This might involve:
  - **Repeated Listening:** Provide opportunities for learners to listen to materials multiple times.
  - **Visual Aids:** Utilize visual aids to enhance comprehension.
  - **Active Listening Strategies:** Encourage active listening techniques like note-taking and summarizing.

Recommendations for Further Research

To deepen our understanding of the relationship between WM and EFL comprehension, future research should address the following:

- **Explore deeper the specific cognitive processes involved in the WRMT-III Passage Comp. subtest. What aspects of WM are being measured by this task? How does it relate to the central executive function and other WM components?** This investigation could potentially refine our understanding of the specific WM skills critical for language comprehension.
- **Investigate the role of gender in the relationship between WM and language comprehension, particularly in diverse populations.** This could provide valuable insights into potential subtle gender-related differences in WM function, which may not be captured by traditional measures.
- **Examine the interplay of cognitive skills, exploring the potential interaction between WM and other cognitive skills that contribute to language comprehension, such as attention, processing speed, and background knowledge.** This research could reveal how WM interacts with other cognitive processes during language comprehension.
- **Investigate the effectiveness of WM training programs in enhancing comprehension skills. Can targeted training on specific WM components lead to improvements in reading and listening comprehension for EFL learners?** This research could explore the potential for interventions to improve WM and, in turn, enhance comprehension skills.
- **Employ a wider range of WM assessments, including measures of reading/speaking span and more complex reading and listening tasks.** This would help to further validate the findings of this study and provide a more comprehensive understanding of the relationship between WM and language comprehension.

Concluding Remarks

This research highlights the crucial role of WM in EFL comprehension. Further exploration of the specific components of WM, particularly those measured by WRMT-III Passage Comprehension Subtest, and their relationship to EFL language learning is essential for improving pedagogical strategies and interventions.

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