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ARTICLE

Exploring the Relationship between Cognitive Resources and L2 Academic Writing Attainment: Insights from Arabic-Speaking L2 Learners

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ABSTRACT

Typical research in the field of English as a Foreign Language has increasingly examined the influence of cognitive factors, particularly working memory capacity (WMC) and phonological short-term memory (PSTM), on second language learning. However, empirical investigations into the effects of WMC and PSTM on second language writing, particularly in real-world contexts involving Arabic-speaking learners, remain underexplored. Hence, the study sample comprised 50 Saudi undergraduate students enrolled in an English language program aimed at developing language and translation skills. WMC and PSTM were assessed using visually presented digit span tasks: a backward-digit span for WMC and a forward-digit span for PSTM. Writing performance was operationalized based on participants' total grades in a writing course. The findings indicated that backward-digit span performance is significantly greater than forward-digit span performance. However, neither WMC nor PSTM significantly predicted academic success in the writing course. By highlighting the complex relationship between cognitive processes and writing outcomes, this study contributes to a broader understanding of English as a Foreign Language writing, particularly its relevance to WMC and PSTM, offering valuable insights for future research. Furthermore, the study addresses methodological limitations, emphasizing the need for future research to consider these shortcomings in order to enhance the robustness of subsequent investigations.

Keywords: Working Memory Capacity (WMC); Phonological Short-Term Memory (PSTM); EFL Writing; Arabic-Speaking Learners of English

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1. Introduction

Writing is a fundamental aspect of language proficiency, especially in second language (L2) learning, where it plays a critical role in academic and professional success. However, L2 writing presents significant cognitive challenges, requiring the coordination of complex processes such as planning, linguistic encoding, and revision. Writers must generate and organize ideas, retrieve appropriate linguistic elements, and construct coherent expressions [1]. Among the cognitive mechanisms that support L2 writing, working memory capacity (WMC) and phonological short-term memory (PSTM) are particularly crucial.

Working memory (WM) is a cognitive system responsible for processing, retaining, and storing information during tasks [2]. Baddeley's model identifies four key components of WM considering PSTM one of these components: (1) the central executive, which manages cognitive processes; (2) the phonological loop, responsible for maintaining auditory information; (3) the visuospatial sketchpad, which stores visual and spatial data; and (4) the episodic buffer, which integrates information across modalities [3, 4]. These components influence key aspects of L2 writing, including grammatical accuracy, lexical sophistication, and fluency [2, 5]. PSTM specializes in temporarily storing and rehearsing verbal information, such as words or phrases [6]. Additionally, PSTM maintains sequences of verbal items—including digits, letters, words, and pseudowords—for brief periods, aiding language learning and processing [7].

Research on the roles of WMC and PSTM in L2 acquisition has produced mixed findings. Some studies highlight strong correlations between cognitive abilities and writing performance [8–10], while others emphasize contextual factors such as task complexity and proficiency levels [11]. Despite increasing research, the role of PSTM in L2 writing remains underexplored, particularly among Arabic-speaking learners of English as a Foreign Language (EFL). Given Arabic's distinct orthographic and phonological features, its impact on WMC and PSTM in writing requires further investigation.

2. Conceptualization of WMC and PSTM

Two major models have shaped research on WM and writing: Hayes's model and Kellogg's model [12, 13]. Hayes's model divides writing into two key dimensions: the task environment (external factors such as audience, social context, and writing medium) and the individual writer (internal factors such as cognitive processes, motivation, and affective states) [12]. A defining feature of this model is its emphasis on WM, which is involved in all non-automated writing activities, including planning, translation, and revision. In contrast, the models developed by Kellogg and Kellogg et al. specifically examine the role of WM in different writing stages [13, 14]. They identify six writing processes—planning, translating, programming, executing, reading, and editing—and assign distinct memory functions to each. While the central executive is involved in nearly all writing processes, visual-spatial short-term memory plays a role in planning, and the phonological loop supports translating and reading. However, this model does not specify the roles of key executive functions such as inhibition, switching, and updating, a limitation acknowledged by Kellogg et al. [14].

Measuring WMC or PSTM is often complicated by confusion over concepts and methods. Research on WM and L2 writing varies in its approach to measuring WM components. While some studies, such as Michel et al. and Peng et al. [15, 16], combined executive WM, PSTM, and spatial WM into a composite score, most research examines these components separately. Whether WM should be treated as a single latent factor or as a distinct construct influencing L2 writing differently remains an open question, dependent on theoretical and empirical considerations [8].

Current research predominantly relies on operation span tasks (math verification followed by letter recall) to assess verbal WM and digit span tests for PSTM. However, verbal-based assessments are preferable to nonverbal tests due to their stronger predictive power for language learning outcomes [17, 18]. Additionally, incorporating processing components (e.g., reaction time and plausibility judgments) into WM measurements can impact results and should be considered [19].

2.1. The Role of WMC in L2 Writing

The role of WMC in L2 writing is well-documented, with research emphasizing its crucial function in managing the cognitive and linguistic complexities of writing tasks. For instance, Vasylets and Marín demonstrated that WM influences different aspects of writing depending on the writer's proficiency level[10]. Among less proficient writers, WM was associated with higher accuracy, whereas for advanced learners, it played a more significant role in lexical sophistication, reflecting its involvement in higher-order processes such as vocabulary selection and conceptual planning. This shift in WM's focus aligns with the increasing cognitive demands of L2 writing as learners advance in proficiency. Similarly, Mujtaba et al. identified WM as a strong predictor of L2 writing performance[9]. Granena further explores the role of cognitive individual differences in L2 writing, focusing on both the writing process and final product, with a particular emphasis on WM, which is identified as the most extensively studied cognitive factor in L2 writing[20].

However, a comprehensive synthesis by Li presents a more nuanced perspective, suggesting that while WM is largely unrelated to overall writing proficiency, it does significantly predict specific aspects of L2 writing, including complexity, accuracy, and fluency[8]. Supporting this, Manchón et al. found that WM did not exert a significant influence on L2 writing performance[11]. These discrepancies in the literature underscore the need for further empirical investigation into the role of WMC in L2 writing, particularly within EFL contexts.

2.2. The Role of PSTM in L2 Writing

Several studies have examined PSTM's role in L2 acquisition, particularly in vocabulary learning and reading proficiency, but research focusing specifically on its impact on L2 writing remains limited. For example, the relationship between PSTM and WMC and performance in an end-of-year reading, writing, listening, speaking and use of English test were examined by Kormos and Sáfár[21]. Their study indicates that PSTM capacity plays a different role in the case of beginners and pre-intermediate students in intensive language learning. Later, Martin and Ellis explored the impact of PSTM on vocabulary and grammar learning in an artificial foreign language, finding strong correlations between memory capacity and language learning outcomes[22]. Their study also highlighted PSTM's independent effects on vocabulary acquisition, suggesting that learners with higher PSTM capacity may be better equipped to retrieve and utilize lexical items during L2 writing. Additionally, their findings indicate that PSTM and WM contribute to the internalization and application of grammatical structures, which are essential for producing syntactically accurate written compositions.

Similarly, Kaushanskaya and Yoo investigated PSTM and WM performance in bilinguals' native and second languages[23], revealing that PSTM is more language-specific, whereas WM involves domain-general executive processes. This distinction has important implications for L2 writing, as different writing tasks place varying demands on PSTM capacity. For instance, tasks requiring immediate recall of phonological representations, such as dictation or note-taking, may rely more heavily on PSTM. Furthermore, their findings suggest that L2 learners with stronger PSTM in their first language may experience greater difficulty with phonological retention in L2 writing, particularly when dealing with novel or unfamiliar words.

Building on this, Kondo examined the relationship between PSTM capacity and L2 reading proficiency among Japanese EFL learners[24], demonstrating that PSTM significantly contributes to reading proficiency. The finding suggests that PSTM's role in processing phonological information could extend to enhancing writing fluency and accuracy, particularly in tasks that require efficient lexical retrieval and syntactic processing.

Taken together, these studies highlight PSTM's crucial role in L2 language development, yet its specific impact on L2 writing remains underexplored. Research should further investigate how PSTM interacts with different writing processes.

2.3. The Interplay between WMC and PSTM in L2 Writing

The relationship between WMC and PSTM in L2 writing is intricate, as each supports different yet complementary aspects of cognitive and linguistic processes. Their interaction is influenced by various factors, highlighting both distinct and combined contributions to writing performance. Peng et al. examined the impact of three cognitive components: phonological awareness (PA), oral language development (OLD), and WM on English writing performance in Spanish-speaking English Learners (ELs) in Grades 3–5[16]. They found PA in both Spanish and English positively predicted English writing performance, suggesting that strong phonological skills in either language support writing development. They also found WM in both Spanish and English had strong positive effects on English writing, underscoring the importance of memory resources in managing writing tasks. The study highlights that strengthening PA, OLD, and WM—both in the first and second language—can enhance English writing skills in ELs. The study also suggests that educators should integrate cognitive-based strategies into writing instruction to enhance students' linguistic and memory-related skills.

While Peng et al. provide insights into the role of WM in writing, research on PSTM in L2 writing remains scarce, as highlighted by Li [8, 16]. Most studies have focused on verbal WM rather than explicitly examining PSTM's role in writing development. Furthermore, existing research primarily uses regression-based approaches to explore the relationship between WM and overall writing performance, with fewer studies investigating how PSTM influences specific writing subprocesses such as planning, translating, transcribing, and editing.

The discussion above has highlighted several critical research gaps in the study of WMC and PSTM in EFL writing, particularly among Arabic-speaking learners. While some research has explored the roles of WMC and PSTM in L2 acquisition and writing, there has been limited attention to how these cognitive mechanisms function in the EFL writing processes of Arabic speakers.

One significant gap is the absence of empirical studies specifically examining the influence of PSTM on EFL writing performance among Arabic-speaking learners. Given the substantial differences between Arabic and English in terms of orthographic depth, phonological structure, and syntactic patterns, it is crucial to investigate how these linguistic disparities interact with WMC and PSTM during the writing process. Understanding these interactions can provide valuable insights into the cognitive challenges faced by Arabic-speaking EFL learners and inform targeted pedagogical strategies to enhance their writing skills.

To address these research gaps, this study formulates two key research questions:

RQ1: To what extent is the writing attainment of Arabic-speaking learners of EFL influenced by WMC?

RQ2: To what extent is the writing attainment of Arabic-speaking learners of EFL influenced by PSTM?

By examining these questions, this study seeks to contribute a nuanced understanding of the cognitive mechanisms underpinning EFL writing and provide insights tailored to the unique linguistic and cognitive challenges that Arabic-speaking ELs face.

3. Method

3.1. Participants

Data were collected from 50 native Arabic-speaking male participants at a male university in Saudi Arabia. Their ages ranged from 18 to 31 years (M = 21.78). Three participants were excluded from the PSTM data due to outlier scores. All participants were undergraduate students registered in an English language program specifically designed to prepare and qualify professionals in translation. The program includes courses focusing on various English language skills, such as writing, speaking, grammar, and vocabulary, along with intensive courses in translation. All selected participants had completed two writing courses within the program. Participants' grades in the final writing course were used to operationalize academic writing attainment in the current study. The primary textbook for this course is *Longman Academic Writing Series 3: Paragraphs to Essays* [25]. The course focuses on writing well-organized paragraphs covering various topics and contexts. It provides extensive guidance on proofreading and editing to enhance coherence, cohesion, unity, grammar, and overall writing quality.

3.2. Data Collection

The data collected for the current study were obtained from three measures: (i) an FDS (a task of PSTM), (ii) an FDS (a task of WMC), and (iii) the final grade a participant received in a writing course.

3.2.1. FDS (PSTM)

The FDS task employed in the current study was adapted from the design developed by Gathercole et al. and implemented using PsychoPy software to precisely control stimulus presentation and data collection procedures [26]. In this task, participants are required to recall sequences of digits immediately after visual presentation. Specifically, each participant views sequences comprising digits ranging from one to nine, presented in a randomized order, and must promptly recall them in the exact sequence presented.

The task begins with the presentation of two lists, each consisting of two digits. If participants correctly recall both lists, the subsequent lists increase incrementally by one digit. If neither of the two lists is correctly recalled, no additional lists are presented, and the task concludes. If participants recall only one list correctly, a third list of the same length is provided as an additional attempt. Should participants fail to recall this third list correctly, the task is terminated. Scoring is determined by identifying the greatest list length at which participants successfully recall at least two lists. The entire task requires approximately five minutes to administer.

3.2.2. BDS (WMC)

The BDS task is similar to the FDS task, as both involve the sequential presentation of digit series. However, in the BDS task, participants are required to recall the presented digits in reverse serial order (e.g., a sequence of 2-3-7 should be recalled as 7-3-2). This reversal engages executive-attentional resources and is presumed to involve not only storage but also cognitive processing—both considered essential components for measuring WMC (see Gathercole et al., 2004, for further details)[27, 28]. Scoring for the BDS task follows the same procedure as the FDS task, where performance is determined by the maximum length at which at least two sequences are correctly recalled. The entire task administration typically requires no more than five minutes.

3.2.3. A Measure of Writing Performance

Participants' writing achievement was operationalized as their total grade in the writing course. This achievement was assessed through various tasks administered during the semester, collectively accounting for 60 points, and a final examination worth 40 points, resulting in a total possible score of 100 points. The university grading system applied to evaluate participants' performance is detailed as follows (**Table 1**):

Table 1. University Grading Scale.

Score Range	Letter Grade	Numerical Code
95 to 100	A+	8
90 to less than 95	A	7
85 to less than 90	B+	6
80 to less than 85	B	5
75 to less than 80	C+	4
70 to less than 75	C	3
65 to less than 70	D+	2
60 to less than 65	D	2
Less than 60	F (Fail)	0

3.3. Results

Table 2 presents descriptive statistics for the Backward-Digit Span (BDS), Forward-Digit Span (FDS), and writing grades of BDS vs. FDS Performance. The mean score for BDS is 4.24, which is lower than the mean score for FDS. The median scores also show that students generally performed better on FDS (5.00) than on BDS (4.00). The standard deviation values indicate that BDS scores (SD = 0.96) exhibit slightly more variability than FDS scores (SD = 0.74). The minimum and maximum scores for both tasks range between 3 and 6, suggesting a relatively narrow distribution of performance. FDS scores are generally higher than BDS scores, reinforcing the idea that recalling digits in reverse order is more cognitively demanding.

Table 2. Descriptive Statistics for BDS, FDS, and Writing Grade.

Variable	N	M	Med	SD	Min	Max
BDS	50	4.24	4.00	0.96	3	6
FDS	47	4.87	5.00	0.74	3	6
Grade by BDS	50	-	4.50	-	1	8
Grade by FDS	47	-	4.00	-		

Note: BDS = backward-digit span (a measure of working memory); FDS = forward-digit span (a measure of phonological short-term memory). Grade by BDS = writing grades of students who completed BDS, Grade by BDS = writing grades of students who completed FDS after excluding three participants. The maximum raw score is 9 for BDS and FDS and 8 for grade.

The mean writing grade for students who completed the BDS task is 4.50, while for those who completed the FDS task, the mean grade is 4.00. The range of writing grades extends from 1 to 8 in both groups. This suggests that students with higher WM (as measured by BDS) may have slightly better writing grades, but the overall difference is not large. Writing grades show slight variation between BDS and FDS groups, but there is no strong indication of a direct relationship between memory span and writing performance.

Figure 1 presents a detailed illustration of the mean scores for WMC and PSTM in relation to students' writing grades. The bars indicate that students generally performed better on FDS (PSTM) than on BDS (WMC) across all writing grade levels. This aligns with the descriptive statistics in **Table 1**, where the mean FDS score was higher than the mean BDS score. The bar heights do not show a clear increasing or decreasing pattern as writing grades improve. This suggests that students with higher writing grades do not necessarily have higher WMC or PSTM scores, meaning that memory capacity may not strongly predict writing performance. Although the mean values for each grade are displayed, the absence of a steady upward or downward trend implies that individual differences in memory skills might not directly correlate with writing ability. Other cognitive or external factors could be more influential in determining writing performance.

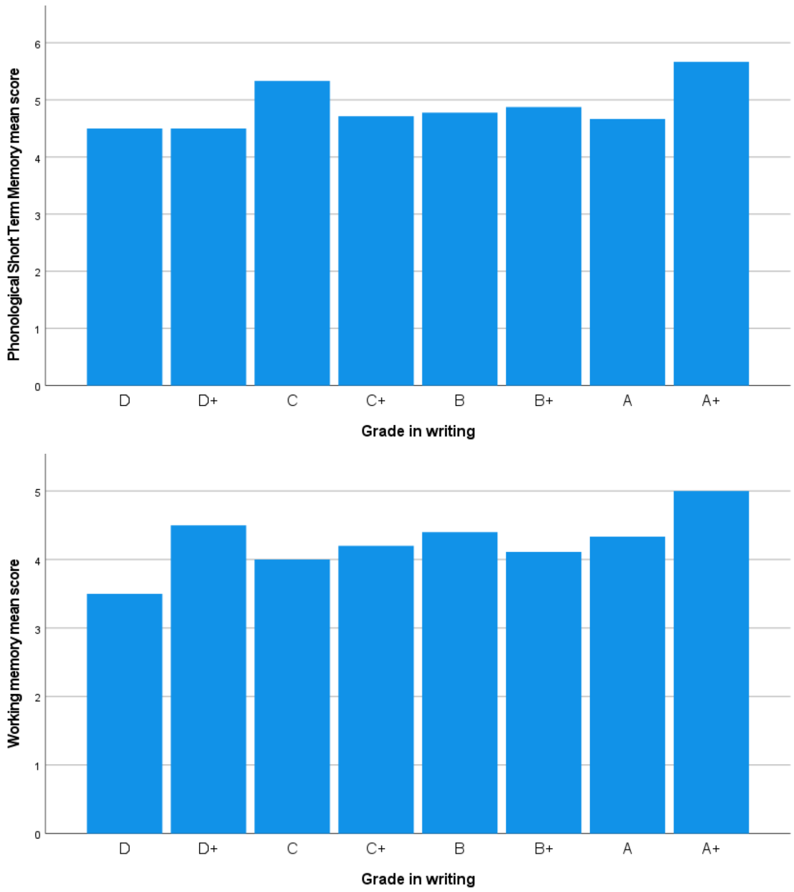

Figure 1. Mean PSTM and WMC scores by students' writing grades.

Preliminary analysis was conducted to examine normality and identify outliers. As indicated previously, the results revealed three outliers in FDS data so they were excluded, while the BDS data did not indicate any outliers. Additionally, the Shapiro-Wilk test indicated that the BDS data and FDS data are not normally distributed, $W = 0.87$, $p = 0.001$; $W = 0.84$, $p = 0.001$, respectively. Consequently, a non-parametric test was used (see **Table 3**).

Table 4 presents the Spearman rank-order correlation coefficients (r) between students' writing grades and their scores on BDS and FDS. The correlation coefficient of 0.18 suggests a very weak positive relationship between WMC (as measured by BDS) and writing grades. However, $p = 0.19$, which means this correlation is not statistically significant, indicating that BDS does not strongly predict writing performance. The correlation between PSTM (as measured by FDS) and writing grades is extremely weak ($r = 0.08$) and close to zero. Additionally, $p = 0.59$, which is far above the conventional threshold for statistical significance (typically $p < 0.05$). This confirms that there is no meaningful association between PSTM and writing grades. Neither WM (BDS) nor PSTM (FDS) shows a significant relationship with students' writing grades, as evidenced by **Figure 2**, which reveals no discernible pattern or trend. The results suggest that memory capacity is not a strong predictor of writing performance, implying that other cognitive, linguistic, or educational factors may play a more significant role in writing success.

Table 3. Summary of Shapiro-Wilk Tests for BDS and FDS Scores.

Variable	Shapiro Wilk Test	
	W	P
BDS	0.87	0.001
FDS	0.87	0.001

Table 4. Spearman Rank Order Correlations between measures of memory and participants' grades.

Variable	BDS	FDS
Grade	0.18	0.08

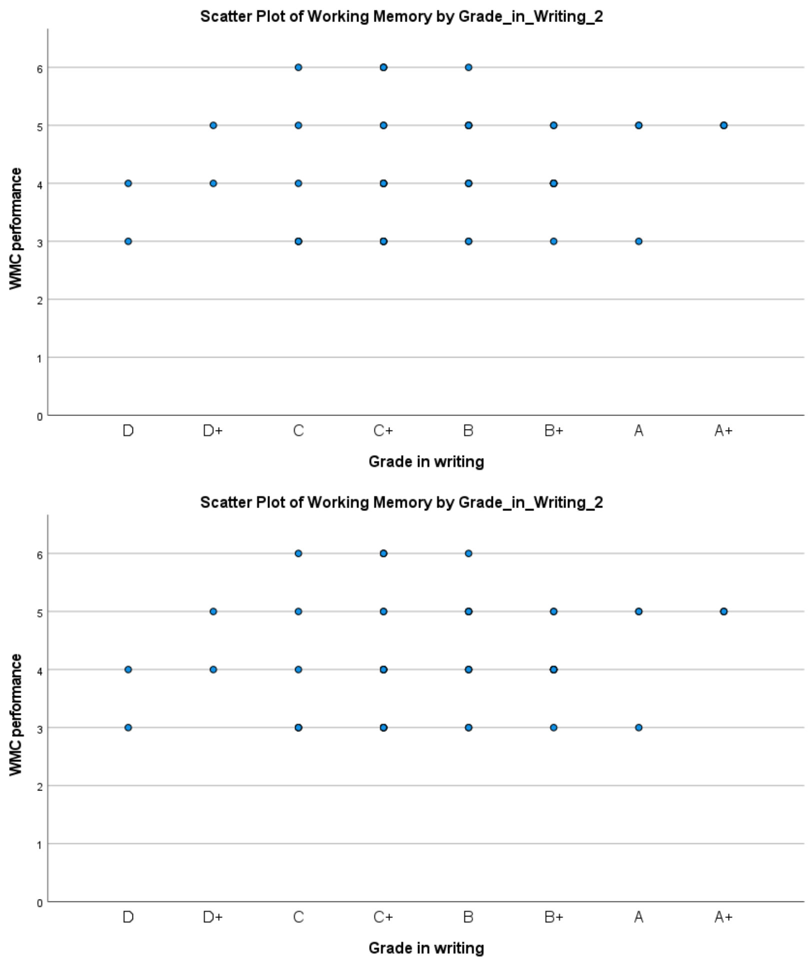

Figure 2. Correlations between WMC and PSTM, and students' grades.

The y-axis represents students' grades in Writing, and the x-axis represents scores on memory tasks.

4. Discussion

This study aimed to investigate the influence of WMC and PSTM on EFL writing performance among Arabic-speaking learners. Contrary to expectations, the findings revealed that neither WMC nor PSTM showed a significant correlation with writing grades. Consequently, determining whether these cognitive factors serve as reliable predictors of writing performance was not feasible within the scope of this study.

4.1. Relationship between WMC and Writing Attainment

The lack of a significant correlation between WMC, as measured by the BDS, and writing grades is unexpected according to some prior research. Studies by Mujtaba et al. and Vasylets & Marín indicate that WMC contributes to grammatical accuracy, lexical sophistication, and coherence in L2 writing, particularly among advanced learners [9, 10]. Additionally, Hayes theorizes that WMC plays a crucial role in higher-order writing processes [12]. However, these findings align with the results of Li [2], who found that WM is largely unrelated to overall writing proficiency. Similarly, Manchón et al. reported that WM did not significantly impact L2 writing performance [11]. Their study, which examined the effects of WM, L2 proficiency, and task complexity on writing outcomes, found that L2 proficiency, rather than WM, was the strongest predictor of writing quality across different task complexities.

One possible explanation for this discrepancy is the proficiency level of the participants. Manchón et al. highlighted that while WM was not a significant factor, L2 proficiency played a decisive role in writing performance [11]. This suggests that at certain levels of proficiency, WMC may not be a limiting factor for writing success, as other linguistic and cognitive resources may compensate for potential WM constraints.

Another possible explanation for the lack of a significant correlation between WMC and writing grades relates to how WMC is measured. The BDS task primarily assesses numerical WM and attentional control, but it does not account for other components of WM that may be more directly involved in writing, such as verbal and visuospatial WM [2–4, 13]. Verbal WM plays a crucial role in sentence construction, lexical selection, and syntactic processing, all of which are fundamental to writing fluency and coherence. Meanwhile, visuospatial WM supports the planning and organization of the text, helping writers structure their ideas and maintain coherence throughout a composition [2, 29]. Since the BDS task does not specifically target these aspects of WM, it may not fully capture the cognitive resources that contribute to L2 writing performance. As a result, its predictive power for writing grades may be limited.

4.2. Relationship between PSTM and EFL Writing

Regarding PSTM, measured by the FDS, there was also no significant correlation with writing grades. This finding contrasts with research by Peng et al. [16], which emphasizes PSTM's role in positively predicting English writing performance for novice L2 writers. Furthermore, the results of Martin and Ellis, highlighted PSTM's independent effects on vocabulary acquisition and concluded that PSTM contributes to the internalization and application of grammatical structures, which are essential for producing syntactically accurate written compositions [22]. It also deviates from the results by White which showed that PSTM correlates with language performance and showed PSTM is implicated in the acquisition of syntax, semantics and pragmatics at different points throughout the year [30].

The proficiency level of participants likely influenced these results. Kormos and Sáfár pointed out that PSTM's impact diminishes as learners develop more advanced and automated linguistic systems [21]. Since participants in this study had completed two academic L2 writing courses, they were likely beyond the initial stages where basic vocabulary and grammar acquisition dominated their writing processes. As a result, their more advanced linguistic abilities may have shifted the cognitive load from PSTM to WMC, which supports higher-order processes such as text planning and coherence.

Another consideration is the language-specific nature of PSTM [23]. Arabic-speaking learners of English face unique phonological challenges due to the differences between Arabic and English sound systems and orthographic depth. The FDS task, which involves recalling numerical sequences, may not adequately capture the demands of English writing. Tasks such as nonword repetition or English sentence recall could provide a more accurate measure of PSTM's role in supporting L2 writing.

4.3. Interplay between WMC and PSTM

Although WMC and PSTM were examined separately in this study, it underscores their complementary roles in L2 writing. In complex writing tasks that require both linguistic precision and organizational planning, the combined contributions of WMC to PSTM may become more evident. Li highlights that WM plays a predictive role in specific aspects of L2 composition, such as complexity, accuracy, and fluency [2]. Additionally, the influence of WM varies depending on factors such as genre, proficiency level, target linguistic structures, instructional approach, and task demands. However, the summative assessment of writing used in this study may have obscured the nuanced interplay between these cognitive systems, particularly during specific writing sub-tasks such as lexical retrieval and coherence maintenance.

4.4. Limitations and Future Directions

Several limitations of this study should be noted. First, the study relied on a single measure for each memory construct (BDS for WMC and FDS for PSTM). While these tasks are well-established, they may not capture the full complexity of memory processes relevant to L2 writing. Incorporating additional measures, such as sentence span or complex span tasks, could provide a more comprehensive assessment of these cognitive constructs and consequently could reveal different results.

Second, the operationalization of writing attainment as a final grade in a writing course may not adequately capture the nuanced dimensions of writing. Grades typically reflect a blend of linguistic accuracy, organizational skills, and compliance with assessment criteria, but they often fail to isolate the specific cognitive contributions of WMC and PSTM. Future research could employ more precise measures, such as linguistic complexity, accuracy, and fluency, to better capture these relationships.

Third, the study focused exclusively on male Arabic-speaking learners in a specific educational context. While this provides valuable insights, the findings may not generalize to other populations or gender groups. Expanding the sample to include diverse linguistic and cultural backgrounds would enhance the generalizability of future studies.

4.5. Implications for Teaching and Learning

Despite the lack of significant correlations, the findings offer valuable implications for L2 writing instruction. First, educators should recognize that cognitive resources such as WMC and PSTM interact with task complexity and proficiency. Designing writing tasks that gradually increase in complexity can help learners develop the cognitive flexibility needed for advanced writing. Second, targeted interventions to enhance WMC and PSTM, such as memory training or strategic scaffolding, may benefit learners struggling with cognitive or linguistic challenges.

5. Conclusions

This study examined the relationship between WMC, PSTM, and English writing performance among Arabic-speaking EFL learners. Results of correlation analysis revealed weak, non-significant relationships between writing grades and both BDS and FDS, indicating that neither WMC nor PSTM strongly predicts writing performance.

Contrary to some previous research, WMC, as measured by BDS, did not significantly influence writing grades. Possible explanations include participants' proficiency levels and the nature of the BDS task, which assesses numerical memory rather than verbal or visuospatial components critical for writing. Similarly, PSTM, measured by FDS, did not correlate with writing grades, possibly due to participants' advanced linguistic skills reducing reliance on PSTM. Arabic-English phonological differences may also have influenced results.

Although the present study yielded valuable findings, several limitations warrant consideration. First, the sample was limited to male Arabic-speaking learners from a single university. Future research should endeavor to include female learners and participants from more diverse linguistic and educational backgrounds to enhance generalizability. Second, writing ability was assessed solely based on final course grades. Future investigations would benefit from employing more nuanced measures of linguistic performance, including linguistic complexity, fluency, and syntactic accuracy, to better understand the cognitive mechanisms underpinning L2 writing proficiency. Finally, relying exclusively on single-task memory assessments for evaluating WMC and PSTM, differentiated only by digit recall order, may be insufficient. Therefore, incorporating alternative memory tasks, such as sentence span or complex span tasks for measuring WMC, is recommended for future research.

Author Contributions

Conceptualization, S.A., M.A.; methodology, S.A.; software, S.A.; validation, S.A., M.A.; formal analysis, S.A.; investigation, S.A.; data curation, S.A.; writing—original draft preparation, M.A., S.A.; writing—review and editing, M.A., S.A.; project administration, S.A., M.A. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The study was conducted in accordance with the Declaration of a Saudi University, and approved by the Ethics Committee.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data set of this study is available upon request to the corresponding author on salsulmi@ksu.edu.sa.

Conflicts of Interest

The authors declare no conflict of interest.

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