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Probing into the Effects of Computerized Dynamic Assessment on Grammar Learning: The Mediating Role of Working Memory

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Abstract

This study investigates the impact of computerized dynamic assessment (C-DA) on grammar learning among Iranian EFL learners, focusing on the moderating role of working memory (WM). A nonrandomized pretest-posttest control group design was employed, with 60 male learners aged 17 to 18 divided into experimental and control groups. The participants were assessed using the Oxford Quick Placement Test (OQPT) to determine language proficiency and a researcher-made test to measure knowledge of past perfect tense. The intervention involved C-DA sessions conducted via the Google Meet platform for the experimental group, while the control group received traditional teacher-fronted lessons. Results from independent-sample t-tests and one-way between-groups ANOVAs revealed a significant improvement in grammar learning among the experimental group compared to the control group. However, no discernable difference was found in the performance of high and low WM learners in response to C-DA. These findings highlight C-DA's potential as a practical instructional approach for grammar learning in EFL contexts. They underscore the need for further research to explore its utility across different learner profiles.

Keywords: computerized dynamic assessment, grammar learning, sociocultural theory, working memory, zone of proximal development

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1. Introduction

Within the realm of second language acquisition (SLA), scholars and educators have noticed a notable surge of interest in applying sociocultural theory principles to teach and evaluate various facets of English language learning among EFL students (Kargar Behbahani & Karimpour, 2024). Dynamic Assessment (DA), rooted in Sociocultural Theory (SCT), offers a framework that merges instruction and evaluation by providing progressive support to learners while documenting and analyzing their guided performance to gauge their evolving abilities (Rassaei, 2023). In a typical DA session, a mediator administers incremental assistance, such as prompts or probing questions, to propel learners beyond their current performance level, recording their responses to mediation, termed learner reciprocity, for further scrutiny. Examining mediated performance and learner reciprocity is integral to DA, as learners' receptiveness to guidance unveils valuable insights into their potential for advancement. (Ableeva, 2018; Levi & Poehner, 2018; Poehner, 2008; Yang & Qian, 2023).

DA is firmly grounded in Vygotsky's SCT, with the zone of proximal development (ZPD) as a cornerstone concept (Vygotsky, 1978). The ZPD represents the space between an individual's independent capabilities and potential with guidance from more proficient peers (Vygotsky, 1978). It signifies the difference between a learner's current skill level and the next achievable level through supportive interventions from educators and peers (Haywood & Lidz, 2007; Zarei & Rahmaty, 2021). Drawing on this principle, various methodologies have emerged in literature, such as DA (Luria, 1961), Group-DA (Azizi & Farid Khafaga, 2023; Malmir & Mazloom, 2021; Poehner, 2009), and peer-DA (Rezai et al., 2022), each emphasizing the collaborative nature of learning within the ZPD framework.

As a cornerstone of DA, mediation involves a diverse selection of support, encompassing standardized cues and interactive mediation (Poehner, 2008). In DA, attempts are made to expand learners' ZPD. Additionally, a striking depiction of learners' advancement and evolving skills is offered through their receptiveness to mediation (For example, Bakhoda & Shabani, 2019; Poehner, 2008). However, it should be noted mediators could only scaffold a limited number of learners due to time limitations. To obviate the problem, researchers have paid attention to technology-enhanced DA and C-DA (Kargar Behbahani & Karimpour, 2024; Rassaei, 2023). C-DA is a variation of DA in which automated mediation and scaffolding are electronically offered to the learners (Sherkuziyeva et al., 2023).

As an individual difference trait, WM is acknowledged as a cognitive mechanism linked to transient storage and handling of the data required for intricate cognitive functions such as comprehending language, acquiring knowledge, and engaging in reasoning (Baddeley, 1992) as it acts as a junction linking perception, memory, and behavioral execution (Baddeley, 2003). Several studies have demonstrated a significant correlation between WM and language abilities, including listening (Daneman & Carpenter, 1980), reading comprehension (Daneman & Merikle, 1996),

writing skills (Abu-Rabia, 2003), and vocabulary acquisition (Kargar Behbahani & Rashidi, 2023; Kargar Behbahani & Razmjoo, 2023). Notwithstanding, several L2 researchers have shown otherwise, claiming that WM's effect on language learning is constrained (See Benati, 2023; Crossley & Kim, 2019; Kormos & Trebits, 2011).

Despite a considerable body of research examining the impact of DA and C-DA on language learning (Birjandi et al., 2013; Estaji & Saeedian, 2020; Kargar Behbahani & Karimpour, 2024, Malmir, 2020 among others), there remains a noticeable gap concerning its specific influence on grammar acquisition among EFL learners. While existing studies have investigated various aspects of language proficiency, including vocabulary acquisition (Van der Veen et al., 2016), reading comprehension (Bakhoda & Shabani, 2019), and writing skills (Rezai et al., 2022), C-DA's effect on the intricate processes involved in grammar learning has received comparatively limited attention (Kargar Behbahani & Karimpour, 2024). This gap is particularly significant given the centrality of grammar proficiency in achieving communicative competence and language fluency. Furthermore, within the context of cognitive mechanisms underlying language acquisition, the role of WM in mediating the relationship between C-DA and grammar learning warrants further exploration. Although WM has been implicated in tasks like listening comprehension and vocabulary acquisition, there is variability in how much WM influences different aspects of language learning (Benati, 2023; Crossley & Kim, 2019; Kormos & Trebits, 2011). Therefore, by investigating the potential impact of C-DA on grammar learning and examining the mediating role of WM, this study aims to address these gaps in the literature and provide insights into the effectiveness of DA approaches in promoting grammatical proficiency among EFL learners. Thus, the study has two main objectives. Firstly, it attempts to scrutinize the effect of C-DA on grammar learning. Secondly, it seeks to moderate the impact of WM on this process.

This study holds several potential implications for theoretical understanding and practical SLA application. Firstly, by investigating the specific impact of C-DA on grammar learning among EFL students, this research can contribute to a deeper comprehension of the efficacy of DA approaches in facilitating grammatical proficiency. Understanding how C-DA influences grammar acquisition can inform the development of more targeted and effective instructional strategies tailored to enhance grammatical competence in language learners. Additionally, by exploring WM's mediating role in C-DA and grammar learning, this study can shed light on the cognitive mechanisms underlying language acquisition processes. These insights can potentially advance theoretical frameworks within SLA, particularly regarding the interplay between cognitive factors and instructional interventions in shaping language development. Moreover, the findings may have practical ramifications for language educators and curriculum designers, guiding the selection and implementation of DA tools and techniques to optimize grammar instruction in EFL contexts. Ultimately, this research has the potential to contribute to promoting superior language pedagogy.

2. Literature Review

2.1. Computerized Dynamic Assessment and L2 Learning

As previously mentioned, DA is grounded in the Vygotsky's (1978) SCT principles. According to SCT, mediated minds evolve from social activities that align with the cultural values of a particular community (Ellis, 2015). Vygotsky (1978) contends that learning and development are intricately intertwined with social and cultural contexts. He emphasizes that learning is predominantly a social process rather than an individual one (Mitchell et al., 2019). Fundamentally, Vygotskian SCT is built upon two fundamental tenets: firstly, learning is predominantly a social phenomenon rather than solely cognitive or biological, and secondly, human learning involves mediated processes. It suggests that cultural and social artifacts, activities, and concepts profoundly influence human learning (Lantolf et al., 2021). In essence, social interactions facilitate the transformation of ideas from the social level to the individual level (Lantolf & Thorne, 2006). From this perspective, as Ohta (2001) observes, congruent and contingent mediations assist L2 learners in showcasing abilities they might not exhibit independently. Therefore, such mediations can significantly enhance L2 learners' performance (Birjandi et al., 2013; Lantolf & Poehner, 2014).

In the standard progression of DA, there are three primary stages: testing, teaching, and retesting. In the testing phase, the examiner evaluates the testee's abilities in a task without much assistance. During the teaching phase, the examiner supports the testee in similar tasks. Finally, in the retesting phase, the testee undergoes more independent testing. Mediation's efficacy is gauged by comparing the changes observed between the test and retest stages. DA strategies typically fall into two categories: interventionist and interactionist (Lantolf & Poehner, 2004).

C-DA has emerged as a significant approach in L2 learning. It integrates personalized electronic mediation into student learning, effectively blending instructional and assessment processes (Poehner et al., 2015). This innovative method aligns with the SCT and the learner-centered philosophy of DA, where teachers intervene in students' activities to enhance their learning while diagnosing or evaluating their progress (Van der Veen et al., 2016). In case of incorrect responses, the system triggers an instructional program that revisits the topics using computer technologies. This model aims to assess a wide range of competencies.

In an attempt to uncover the potential of C-DA in enhancing listening skills, Mehri Kamrood et al. (2019) conducted a study involving an interventionist online C-DA aimed at improving English listening skills. They employed a multiple-choice C-DA software based on the framework by Poehner and Lantolf (2013), which provided mediation within learners' ZPD through hints and prompts. The software generated actual, mediated, and learning potential scores. The findings depicted a substantial contrast between learners' initial and mediated scores, indicating the shortcomings of non-DA in measuring learners' responsiveness to support. Additionally, the learning potential score reliably delineated variations among learners of corresponding proficiency levels. Analyzing individual scoring profiles alongside learning potential scores facilitated the

identification of strengths and weaknesses across various language constructs. The study concluded that this approach could aid teachers in developing personalized learning plans and materials for future instruction, emphasizing C-DA's significance in enhancing language skills.

In another study by Yang and Qian (2020), C-DA was applied to teach and evaluate Chinese EFL learners' reading comprehension. In a quasi-experimental setup, control and experimental groups took three tests with different formats featuring multiple-choice questions from TOEFL reading sections. While the experimental group received C-DA instruction, the control group used conventional multiple-choice questions. Moreover, each group underwent separate 4-week enrichment programs, with the experimental group taught using C-DA and the control group using traditional methods. Findings showed that despite similar initial performance, the experimental group showed significantly higher improvement in reading comprehension after four weeks.

Bakhoda and Shabani (2018) investigated L2 learners' abilities in C-DA reading comprehension. Participants selected pre-specified mediations based on their preferences and ZPD to aid understanding of 15 passages. Unlike previous studies, learners actively chose mediations ranging from implicit to explicit. The software presented passages with visual, audio, and textual mediations aligned with learners' preferences. The learning potential score, reflecting mediation effectiveness, showed an improved understanding of the passage's main ideas. Analysis revealed a significant increase in learners' ZPD compared to their abilities, indicating the efficacy of tailored electronic mediations in C-DA reading comprehension, responsive to individual preferences.

In another study, Zhang and Lu (2019) proposed a new method to assess and improve second language development, merging diagnostic assessment with instructional support. A C-DA listening assessment was conducted in an intermediate Chinese listening and speaking class of nineteen students. Unlike standard tests, this C-DA test not only diagnosed students' current abilities but also identified areas for improvement. It offered graduated mediation for difficult items and tracked mediation levels. Assessment reports included learner profiles detailing independent and mediated language skills. Students were grouped based on test results, receiving tailored support. Analysis revealed that combining diagnostic assessment with instructional mediation led to a practical pedagogical approach for students.

Relatedly, Zangoei et al. (2019) introduced a dissertation integrating assessment and instruction of L2 pragmatics comprehension using an interventionist C-DA. The C-DA test, available online as CDASRI, provided standardized hints ranging from explicit to implicit. Participants included 137 upper-intermediate or advanced high school learners. CDASRI offered three scores for each test-taker: actual, mediated, and learning potential scores based on hint usage. Results showed improved pragmatic comprehension competence. Differences between mediated and actual scores highlighted learners' responsiveness to mediation based on their ZPD levels. This suggests that traditional tests may overlook learners' potential by focusing solely on initial performance.

Moreover, Estaji and Saeedian (2020) explored the feasibility of C-DA. They investigated the effects of mediation provision through computer-only, human-only, and mixed (human and computer) modes on L2 learners' reading comprehension. For this mixed-methods study, twenty students were purposively grouped into three. DIALANG was a placement test complemented by two custom software programs and researcher evaluation. Qualitative analysis of transcripts unveiled dialogic interactions between mediators and learners, while quantitative ANCOVA scrutinized post-test outcomes. The findings showed reduced mediation use and higher non-mediated scores with non-DA. Additionally, there was no statistical difference (p>.05) between the human-only and computer-only groups, suggesting similar influences on reading comprehension. Moreover, the study highlighted the effectiveness of computer-mediated mediation even when a human mediator was present.

2.2. Working Memory and L2 Learning

WM functions as a cognitive system with limited capacity, enabling us to temporarily retain various pieces of information while perceiving, thinking, speaking, and acting (Baddeley, 2003). Pioneering studies by Harrington and Sawyer (1992) and Mackey et al. (2002) have delved into the role of WM in SLA, examining its involvement in text comprehension and L2 interaction, respectively. Baddeley (2017) proposes a multi-componential model of WM, suggesting that it comprises four distinct components: the central executive, the phonological loop, the visual-spatial sketchpad, and the episodic buffer. The central executive serves as a domain-general attention control system without storage capacity. The phonological loop, crucial for passive storage and rehearsal of auditory information, plays a vital role in vocabulary acquisition. Conversely, the visuospatial sketchpad stores and rehearses information in a visual format. Finally, the episodic buffer functions as a temporary storage site for connecting discrete pieces of information, integrating data from various sources and formats, and linking short-term with long-term memory.

Although WM has been found to be crucial to language processing (Baddeley, 2017; Linck et al., 2014), not all studies have supported WM when it comes to acquiring an L2. For example, According to Kormos and Trebits (2011), WM capacity may only influence L2 syntactic production regarding oral production in L2 learners. For Kormos and Trebits (2011), WM's facilitative role in language processing is limited to syntactic production. In addition, even when utilizing numerous WM measures, recent research does not demonstrate a substantial association between WC and L2 listening comprehension (Andringa et al., 2012; Vandergrift & Baker, 2015).

Liping (2023) conducted a meta-analysis of 12 primary experiments examining the influence of WM on language gains following oral corrective feedback. Data from 489 participants were analyzed to determine the average effect sizes of the correlations between WM and language gains. The results revealed a small positive effect size (r =.321), indicating that WM positively contributes to language gains from oral corrective feedback. Furthermore, methodological factors such as the

types of corrective feedback, measures of WM, research settings, and participants' academic status were found to influence the correlation between WM and language gains.

In another study by Teng (2023a), incidental vocabulary learning from various video genres was examined, considering factors such as frequency, vocabulary familiarity, comprehension, and working memory (WM). 210 EFL learners were divided into six groups based on video genres (comedy, education, documentary) and number of viewings (once and twice), with a control group undergoing tests only. Participants completed vocabulary and content comprehension tests before, immediately after, and two weeks later. Results underscored video genres' impact on incidental vocabulary learning, particularly favoring comedy. Repeated viewing significantly affected immediate form recognition, but no other measures were taken. Complex WM influenced delayed meaning recognition and recall, while vocabulary breadth and comprehension played significant roles in incidental vocabulary learning outcomes.

Relatedly, Teng (2023b) investigated how two types of WM affect incidental vocabulary learning across various captioning styles: glossed captions (GCs), full captions, and keyword captions. One hundred twenty-five young learners took part in the study, undergoing pretest, posttest, and delayed vocabulary assessments after watching four videos. They also completed two WM tasks: an operation span test for complex WM and a nonword repetition test for phonological short-term memory. Results showed that GCs were the most effective for incidental vocabulary learning and retention. Moreover, phonological WM had a more significant impact on incidental vocabulary learning and retention than complex WM.

Furthermore, Benati (2023) examined how structured input influences English causative form acquisition in adult L1 Chinese Mandarin learners. Participants, categorized by WM capacity, were divided into high and low WM groups, while a control group received no instruction. Assessments included interpretation and production tasks. Both structured input groups improved significantly from pre- to post-tests, with no difference between high and low WM groups. The effectiveness of structured input persisted over four weeks.

The synthesis of existing literature underscores a significant gap in understanding the specific impact of C-DA on grammar learning within the realm of SLA, particularly among EFL learners. While DA is firmly grounded in SCT, its application in C-DA approaches for enhancing grammar proficiency remains underexplored. Moreover, the role of WM in mediating the relationship between C-DA and grammar learning presents an additional area of ambiguity, as prior research findings regarding the influence of WM on language acquisition processes have been inconsistent. Despite pioneering studies elucidating the cognitive mechanisms underlying language processing, including WM's involvement in text comprehension and L2 interaction, discrepancies persist regarding how much WM contributes to L2 learning outcomes. Therefore, this study seeks to address these gaps in the literature by investigating whether C-DA can impact grammar learning among EFL learners and exploring the potential WM's role, thereby advancing theoretical frameworks within SLA and informing the development of effective pedagogical strategies for

optimizing grammar instruction in EFL contexts. Therefore, the following research questions are addressed:

1. How does computerized dynamic assessment affect EFL learners' grammar learning?
2. What is the influence of working memory on EFL learners' grammar learning in response to computerized dynamic assessment?

3. Method

3.1. Design

We utilized a nonrandomized pretest-posttest control group design to investigate the effects of C-DA on grammar learning. In this design, participants were assigned to either the experimental group (EG), which received the C-DA intervention, or the control group (CG), which followed conventional instruction methods. Pretests were administered to both groups to establish baseline levels of grammar proficiency, followed by implementing the intervention for the EG. Posttests were then administered to assess any changes in grammar proficiency following the intervention, with the CG serving as a comparison to evaluate the effectiveness of the C-DA approach.

3.2. Setting and Participants

This experiment was conducted at a school located in South Iran, involving participants selected from two intact classes. Each class was comprised of 30 male learners, ranging in age from 17 to 18 years old. Random assignment was utilized to divide the participants into an EG and a CG. The OQPT assessment revealed that within the EG, six learners were classified as high-intermediate, while the remaining learners were categorized as lower-intermediate. Similarly, five learners were identified in the CG as high-intermediate, with the remainder classified as lower-intermediate. The participants were selected based on their availability. Furthermore, more proficient learners were selected as mediators responsible for providing scaffolding and mediation to their peers. All participants were native speakers of Persian, with no bilingual background or prior experience of visiting English-speaking countries before the study.

3.3. Instruments

Instruments utilized in the study encompassed a series of assessments to gauge various aspects of learners' language proficiency and cognitive abilities. Initially, the OQPT was administered to ascertain participants' overall language proficiency levels. Following this, Shahnazari's (2013) validated reading-span test was employed to measure learners' WM. This test required participants to memorize the final word in each sentence presented. Analysis of the reading-span test results revealed that 16 learners in the EG and 14 in the CG exhibited high WM capacity, while the remaining participants demonstrated low WM capacity. Subsequently, a

researcher-made test was administered to assess learners' comprehension and the past perfect tense usage, the target form of the study. This test underwent a known-group technique (Ary et al., 2019) for construct validation, wherein it was administered to a panel of language teachers to ensure significant differences in performance compared to the learners in both conditions during the pretest phase. The face and content validity of the test face and content validity were confirmed by two PhD holders in TEFL. The test's reliability was also assessed using the KR-21 formula, yielding a high-reliability coefficient (r=.892). Furthermore, a validated and reliable researcher-made test was administered during the post-test phase with a reliability coefficient of r=.832. Notably, course materials from the Vision 3 coursebook, published by Iran's Ministry of Education, were utilized throughout the study to ensure consistency in instructional content and materials.

3.4. Treatment

The treatment in this study involved the implementation of C-DA for the EG and traditional teacher-fronted lessons for the CG. C-DA sessions were conducted using the Google Meet platform, enabling real-time interaction and collaboration among participants and the instructor. The EG was divided into five smaller groups to facilitate the C-DA sessions, each comprising a mix of high-intermediate and lower-intermediate learners. Within each group, an upper-intermediate learner was designated as the group head, responsible for mediating and supporting their groupmates during the C-DA activities. This peer-mediated approach aimed to foster collaborative learning and scaffold learners' understanding of the target grammar structures.

During a typical C-DA class, learners in the EG convened on the Google Meet platform under the instructor's guidance. The session commenced with a brief review of the previous lesson' s concepts, followed by an interactive presentation of the target grammar structure, in this case, the past perfect tense. Learners then engaged in tasks and activities to elicit their understanding and application of the target structure. For example, the instructor might present a sentence with a missing past perfect verb form and ask learners to complete the sentence correctly. As learners work through the tasks, the designated group head would provide mediation and assistance to their peers, offering explanations, examples, and feedback to support their learning process.

The instructor would monitor the groups' progress throughout the session, intervening as needed to provide additional guidance or clarification. Learners could also ask questions and seek clarification from the instructor and their peers. After the session, learners would engage in a reflective discussion, sharing insights and identifying areas for further practice and improvement. This collaborative and interactive approach to C-DA aimed to enhance learners' comprehension and mastery of the target grammar structure while promoting peer-mediated learning and collaboration within the EG.

3.5. Data Analysis Procedures

The data analysis procedures involved several statistical tests to measure C-DA's effect on grammar learning and to evaluate the moderating effect of WM on this process. Independent-sample t-tests were conducted to compare the grammar learning outcomes between the EG and the CG at each time interval. These t-tests allowed for the examination of differences in mean scores on grammar assessments between the two groups, providing insights into the effectiveness of C-DA in facilitating grammar learning.

Furthermore, to assess the moderating effect of WM's moderating role on the relationship between C-DA and grammar learning, a one-way between-groups analysis of variance (ANOVA) was conducted at each time interval. This ANOVA allowed for the comparison of mean grammar learning scores across different levels of WM capacity within the EG and CG. By examining the interaction between group membership (EG vs. CG) and WM capacity (high vs. low), this analysis provided insights into whether the effect of C-DA on grammar learning varied depending on participants' WM capacity.

Overall, these statistical analyses enabled the exploration of both C-DA's impact on grammar learning and the potential WM's moderating role in this process, contributing to a comprehensive understanding of the effectiveness of C-DA as an instructional approach in SLA.

3.6. Findings

The Impact of C-DA on Grammar Learning

A t-test was run to measure the impact of C-DA on grammar learning. However, a one-sample Kolmogorov-Smirnov test was carried out before conducting this inferential statistic to ensure the data normality.

Table 1

One-Sample Kolmogorov-Smirnov Test of C-DA Impact on Grammar Learning

		Pretest Scores	Post-test Scores
N		60	60
Normal Parameters	Mean	4.966	8.566
	Std. Deviation	3.857	5.555
Most Extreme Differences	Absolute	.263	.195
	Positive	.263	.195
	Negative	-.138	-.121
Kolmogorov-Smirnov Z		2.039	1.508
Asymp. Sig. (2-tailed)		.218	.221

Table 1 illustrates that data normality was maintained in both time intervals ($p > 0.05$).

Table 2

Group Statistics of C-DA Impact on Grammar Learning on both Pretest and Post-test

	Group	N	Mean	Std. Deviation	Std. Error Mean
Pretest Scores	EG	30	5.233	4.057	.740
	CG	30	4.700	3.696	.674
Post-test Scores	EG	30	13.466	3.266	.596
	CG	30	3.666	1.561	.285

Table 2 illustrates that on the pretest, EG learners (N=30, M=5.233, SD=4.057) performed almost the same as CG participants (N=30, M=4.700, SD=3.696). However, on the post-test, the EG (M=13.466, SD=3.266) outperformed the CG (M=3.666, SD=1.561).

Table 3

Independent Samples Test of C-DA Impact on Grammar Learning on the Pretest

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Pretest Scores	Equal variances assumed	.232	.632	.532	58	.597	.5333	1.002	-1.472	2.539
	Equal variances not assumed			.532	57.505	.597	.5333	1.002	-1.472	2.539

Table 3 demonstrates that on the pretest, there was no significant difference between the two conditions (F=.232, t=.532, df=58, p>0.05).

Table 4.

Independent Samples Test of C-DA Impact on Grammar Learning on the Post-test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Post-test Scores	Equal variances assumed	12.699	.001	14.826	58	.000	9.800	.661	8.476	11.123
	Equal variances not assumed			14.826	41.588	.000	9.800	.661	8.465	11.134

Table 4 reveals a significant impact of C-DA on the post-test (F=12.699, t=14.826, df=58, p=.001) and a considerable effect size equaling .683.

The Moderating Effect of WM on Grammar Learning

An ANOVA was required to measure WM's moderating effect on grammar learning.

Table 5

Descriptive Statistics of WM on the Pretest

WM	Mean	Std. Deviation	N
C-DA High-WM	4.875	4.177	16
C-DA Low-WM	5.642	4.030	14
CG High-WM	4.714	3.891	14
CG Low-WM	4.687	3.646	16
Total	4.966	3.857	60

Table 5 indicates that on the pretest, C-DA high-WM learners (M=4.875, SD=4.177) performed similarly to their low-WM peers (M=5.642, SD=4.030). The table further reveals that CG high-WM participants (M=4.714, SD=3.891) performed similarly to their low-WM counterparts (M =4.687, SD=3.646).

Table 6

Tests of Between-Subjects Effects of WM on the Pretest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	8.674	3	2.891	.186	.905	.010
Intercept	1481.357	1	1481.357	95.433	.000	.630
WM	8.674	3	2.891	.186	.905	.010
Error	869.259	56	15.522			
Total	2358.000	60				
Corrected Total	877.933	59				

Table 6 illustrates no significant effect for WM on the Pretest (df=3, F=.186, p>.05).

Table 7

Descriptive Statistics of WM on the Post-test

WM	Mean	Std. Deviation	N
C-DA High-WM	13.812	2.786	16
C-DA Low-WM	13.071	3.812	14
CG High-WM	3.285	1.540	14
CG Low-WM	4.000	1.549	16
Total	8.566	5.555	60

Table 7 reveals that C-DA high-WM learners (M=13.812, SD =2.786) performed similarly to C-DA low-WM participants (M=13.071, SD=3.812). Similarly, CG high-WM learners (M= 3.285, SD=1.540) performed the same as low-WM learners in the same condition (M=4.000, SD =1.549).

Table 8

Tests of Between-Subjects Effects of WM on the Post-test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1448.510	3	482.837	72.642	.000	.796
Intercept	4358.907	1	4358.907	655.786	.000	.921
WM	1448.510	3	482.837	72.642	.000	.796
Error	372.223	56	6.647			
Total	6224.000	60				
Corrected Total	1820.733	59				

Table 8 discloses a significant effect of WM on the posttest (df=3, F=72.642, p = .001) with a gigantic effect size equaling .796.

Table 9.

Pairwise Comparisons of WM on the Post-test

(I) WM	(J) WM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
	C-DA Low-WM	.741	.944	1.000	-1.840	3.322
C-DA High-WM	CG High-WM	10.527	.944	.000	7.946	13.107
	CG Low-WM	9.812	.912	.000	7.319	12.306
	C-DA High-WM	-.741	.944	1.000	-3.322	1.840
C-DA Low-WM	CG High-WM	9.786	.974	.000	7.120	12.451
	CG Low-WM	9.071	.944	.000	6.491	11.652
	C-DA High-WM	-10.527	.944	.000	-13.107	-7.946
CG High-WM	C-DA Low-WM	-9.786	.974	.000	-12.451	-7.120
	CG Low-WM	-.714	.944	1.000	-3.295	1.866
	C-DA High-WM	-9.812	.912	.000	-12.306	-7.319
CG Low-WM	C-DA Low-WM	-9.071	.944	.000	-11.652	-6.491
	CG High-WM	.714	.944	1.000	-1.866	3.295

Table 9 shows no difference between C-DA high-WM learners and their low-WM classmates (Mean Difference=.741, p>0.05). However, the table illustrates that C-DA high-WM learners outperformed CG high-WM learners (Mean Difference=10.527, p=.001) and CG low-WM participants (Mean Difference=9.812, p =.001). Similarly, the table indicates that C-DA high-WM participants outstripped CG high-WM learners (Mean Difference=9.786, p=.001) and CG low-WM learners (Mean Difference=9.071, p=.001).

4. Discussion

We probed the potential of C-DA on grammar learning and the moderating effect of WM on this process. The findings corroborate prior studies indicating the positive impact of C-DA on grammar learning among EFL learners. The significant improvement in post-test scores for the EG compared to the CG underscores the efficacy of C-DA in facilitating language learning. These results align with previous studies (e.g., Mehri Kamrood et al., 2019; Yang & Qian, 2020) delineating C-DA's effectiveness in enhancing various language skills.

Furthermore, examining WM's impact on grammar learning outcomes provides intriguing insights. Contrary to expectations, no difference was found between high and low-WM learners in the C-DA condition. While both high-WM and low-WM learners benefited from C-DA, the magnitude of improvement did not significantly differ between the two groups. This unexpected finding challenges conventional notions about WM's role in language learning and suggests that other factors may contribute to the effectiveness of C-DA.

The integration of peer mediation within the C-DA framework also warrants attention. This study capitalized on sociocultural learning principles by dividing the EG into smaller groups and assigning upper-intermediate learners as group heads responsible for providing mediation (Vygotsky, 1978). EG's superiority over the CG highlights the importance of collaborative learning environments in promoting language development (Lantolf & Thorne, 2006; Zangoei et al., 2019).

This study's novelty lies in exploring the moderating effect of WM concerning learners' response to C-DA, an area hitherto unexplored in existing literature. While a plethora of experiments have studied the effectiveness of C-DA in language learning and its impact on various language skills, none has delved into how individual differences in WM may moderate the efficacy of C-DA interventions.

The results of this study advance the field of language education by providing empirical evidence of the efficacy of C-DA in enhancing grammar learning among Iranian EFL learners. By demonstrating significant improvements in post-test scores for the EG compared to the CG, the study underscores the effectiveness of C-DA as an instructional approach. Moreover, examining WM's influence on grammar learning outcomes offers valuable insights into the complex interplay between cognitive factors and language learning processes. Contrary to expectations, the study found no discernable difference in the magnitude of improvement between high and low-WM learners in the C-DA condition, challenging conventional notions about WM's role in language learning. These findings underscore the mechanisms underlying language acquisition and highlight the need to consider factors beyond WM, such as social interaction and mediated learning, in instructional frameworks like DA. Overall, the study advances the field by providing empirical support for the effectiveness of C-DA and shedding light on its interaction with individual differences in WM, paving the way for more personalized and effective language teaching practices.

The outcomes align closely with the theoretical framework of DA rooted in SCT. Vygotsky emphasizes the importance of social interactions and mediated processes in learning, suggesting that learning occurs through collaboration and guidance within a cultural context (Vygotsky, 1978). In this study, C-DA effectively integrates personalized electronic mediation into language learning, reflecting the principles of DA and SCT. The results demonstrate the significant impact of C-DA on grammar learning, indicating that personalized electronic mediation enhances language skills by providing tailored support and feedback to learners. This finding supports that congruent and contingent mediations, as emphasized in Vygotskian theory, can significantly improve L2 learners' performance.

Furthermore, the study addresses WM's role in language learning, a cognitive factor often considered crucial in SLA. While previous research has suggested a significant association between WM and language processing, the findings of this study challenge this notion. Contrary to expectations, no significant difference existed between high and low-WM learners in the C-DA condition. This unexpected result underscores the complexity of language learning processes and highlights the need to reconsider the exclusive focus on WM in SLA research. It suggests that factors

beyond WM, such as social interaction and mediated learning, may significantly shape language learning outcomes within a dynamic assessment framework. In this way, our results resonate well with the studies that had failed to detect an impact of WM on language learning (Andringa et al., 2012; Benati, 2023; Crossley & Kim, 2019; Kormos & Trebits, 2011; Vandergrift & Baker, 2015).

Mehri Kamrood et al. (2019) explored enhancing listening skills among Iranian EFL learners using an interventionist online C-DA approach. Similar to your study, they emphasized the effectiveness of C-DA in improving language skills. However, their study specifically targeted English listening skills, whereas ours concentrated on grammar learning. Additionally, Mehri Kamrood et al. highlighted the discrepancy between learners' actual and mediated scores, which was not a focus of our study.

Yang and Qian (2020) investigated the use of C-DA for teaching and assessing reading comprehension among Chinese EFL learners. Like our study, they found advantages in using C-DA over conventional methods for enhancing language learning outcomes. However, while our study focused on grammar learning, theirs centered on reading comprehension improvement among Chinese EFL learners.

Bakhoda and Shabani (2018) aimed to examine the effectiveness of C-DA in addressing individual learning preferences and enhancing reading comprehension among Iranian EFL learners. Similar to our study, they emphasized the efficacy of C-DA in comprehension improvement. However, while their study focused on reading comprehension, ours concentrated on grammar learning.

Zhang and Lu (2019) introduced a framework that merged diagnostic assessment with instructional mediation to develop personalized pedagogical approaches for Chinese listening and speaking skills. Similar to our study, they emphasized the importance of personalized approaches in language learning. However, while their study focused on Chinese listening and speaking skills, ours focused on grammar learning among Iranian EFL learners.

Zangoei et al. (2019) investigated the integration of assessment and instruction of L2 pragmatics comprehension using interventionist C-DA. Similar to our study, they highlighted the importance of considering learners' potentialities overlooked by traditional tests. However, their focus was on pragmatic comprehension, while ours was on grammar learning.

Estaji and Saeedian (2020) explored the feasibility of C-DA in enhancing reading comprehension among L2 learners. Like our study, they demonstrated the effectiveness of computer-mediated mediation in language skills improvement. However, while their study focused on reading comprehension, ours focused on grammar learning.

4.1. Implications of the Study

The study has ramifications for everybody involved in language learning. For language teachers, our study offers valuable insights into the effectiveness of C-DA for learners with varying

levels of WM. Contrary to previous assumptions, our findings reveal that C-DA affects both high and low-WM learners similarly. This suggests teachers do not need to tailor their instructional strategies based on learners' WM capacities when implementing C-DA interventions. Instead, teachers can focus on integrating DA techniques into their teaching practices to provide personalized feedback and support to all learners, regardless of their cognitive profiles. By leveraging the adaptability and flexibility of C-DA, teachers can create more inclusive and engaging learning environments that promote language development for all students. Practically speaking, language teaching can benefit significantly from the study findings by incorporating DA techniques into instructional practices. Specifically, language teachers can integrate C-DA methods to provide personalized feedback and support tailored to individual learners' needs and abilities. By implementing peer-mediated approaches within C-DA sessions, teachers can foster collaborative learning environments where learners support and scaffold each other's understanding of language concepts, promoting language development and social interaction. Additionally, leveraging the adaptability and flexibility of C-DA allows teachers to create more inclusive and engaging learning environments. They can adjust instructional strategies based on learners' responses and progress, ensuring all students receive appropriate support to optimize their language learning outcomes.

Relatedly, by incorporating DA principles into language instruction, learners can benefit from personalized support and feedback tailored to their cognitive profiles. This approach allows learners to engage with learning materials at their own pace and in a manner that best suits their learning styles and abilities. Additionally, DA's collaborative and interactive nature fosters peer-mediated learning environments, enabling learners to benefit from shared knowledge and support from their peers. Furthermore, by embracing DA techniques, language learners can better understand language structures and concepts, enhancing language proficiency and communicative competence. The study suggests that integrating DA into language learning practices can empower learners to take ownership of their learning journey and achieve tremendous success in language acquisition.

For materials developers, our study highlights the critical role of integrating DA principles into designing language learning materials and resources. By incorporating features that adapt to learners' cognitive profiles, such as offering graduated prompts and personalized feedback, materials developers can significantly enhance the effectiveness and engagement of learning materials. This approach ensures learners receive support tailored to their cognitive abilities, optimizing their learning experiences and outcomes. Moreover, our findings underscore the importance of collaboration between materials developers, educators, and researchers to integrate evidence-based DA techniques into existing language learning materials. This collaborative effort fosters a more learner-centered and adaptive approach to language education, allowing for the creation of instructional materials that are responsive to the diverse needs and learning styles of language learners. By embracing DA principles in material development, developers can create

more effective, inclusive, and engaging learning resources that facilitate meaningful language acquisition and proficiency development.

For syllabus designers, our study underscores the importance of integrating C-DA techniques into language learning curricula. Our findings reveal that C-DA interventions can effectively support both high- and low-WM learners in their language acquisition journey. This suggests that syllabus designers should consider incorporating C-DA activities and tasks that cater to diverse learner needs and cognitive profiles. By including C-DA components in language curricula, designers can promote a more personalized and adaptive approach to learning, enabling students to receive targeted feedback and support tailored to their abilities. Moreover, integrating C-DA into syllabi can enhance the diagnostic capabilities of language assessment, allowing instructors to identify learners' strengths and weaknesses more accurately and provide timely interventions to address areas of difficulty. Including C-DA in language learning and syllabi can lead to more effective and learner-centered teaching practices. Practically, in curriculum development, integrating DA principles into language learning materials and resources is crucial. Curriculum developers can design materials adapting to learners' cognitive profiles, providing graduated prompts and personalized feedback. Considering learners' diverse needs and cognitive profiles is essential when developing language curricula. By including C-DA activities and tasks that cater to different learner abilities, curricula become more personalized and adaptive, ultimately enhancing learning experiences and outcomes.

For policymakers, our study underscores the importance of supporting research and initiatives that promote the integration of DA techniques into language education policies and practices. Policymakers can foster innovation and improvement in language teaching and learning by investing in professional development programs and resources that equip educators with the knowledge and skills to implement DA approaches. Additionally, our findings highlight the potential of C-DA to address equity issues in language education by providing personalized support to learners with diverse cognitive profiles. Therefore, policymakers play a crucial role in advocating for policies that prioritize the integration of DA principles into language education frameworks, ultimately promoting more inclusive and effective language learning environments. Policymakers play a significant role in fostering dynamic assessment approaches in language education. They can support professional development programs and resources to equip educators with the knowledge and skills to implement DA techniques effectively. This includes providing training on C-DA strategies and integrating them into language education practices. Additionally, policymakers can advocate for policies that prioritize the integration of DA principles into language education frameworks. Policymakers can promote more inclusive and effective language learning environments by ensuring that learners with diverse cognitive profiles receive personalized support and interventions.

5. Conclusion

In conclusion, this study investigated C-DA's influence on grammar learning among Iranian EFL learners and examined the moderating WM's effect on this process. The findings demonstrated that C-DA significantly enhanced grammar learning outcomes compared to traditional teacher-fronted instruction. Importantly, our study revealed that C-DA was equally effective for both high and low-WM learners, highlighting its potential to accommodate diverse cognitive profiles. This study contributes to the existing literature by providing empirical evidence of the efficacy of C-DA in language learning contexts and by shedding light on its interaction with individual differences in WM. Overall, this experiment underscored the importance of incorporating innovative assessment approaches like C-DA into language education practices to promote more personalized and compelling learning experiences for students.

The key takeaways of this study highlight C-DA's efficacy in enhancing grammar learning outcomes among EFL learners, irrespective of their WM capacity. The findings underscore the importance of incorporating DA principles into language teaching practices to provide personalized support and feedback to learners. Additionally, the study emphasizes the role of peer-mediated learning environments in promoting collaborative learning and scaffolding learners' understanding of language structures. Furthermore, the study contributes to the existing literature by exploring WM's impact on C-DA and grammar learning, challenging conventional notions about the exclusive WM's role in language acquisition processes. These key findings offer insights for language educators, curriculum developers, policymakers, and learners, informing the development of practical language learning approaches.

Certain limitations bound this study. Firstly, due to the study's limited sample size, caution is advised when extending the findings to broader populations. Future studies could benefit from larger and more diverse participant groups to ensure broader applicability. Additionally, the study focused exclusively on male learners from a specific geographical region, which may restrict the representativeness of the results. Including participants from different demographic backgrounds and geographic locations could provide a broader perspective of C-DA's impact on grammar learning.

Furthermore, this study only examined the short-term effects of C-DA on grammar learning outcomes. Longitudinal studies are needed to assess these effects' sustainability over time and explore potential differences in learning trajectories. Additionally, while this study investigated the WM's moderating effect on C-DA and grammar learning, other individual differences such as motivation, language aptitude, and cognitive styles could also influence learning outcomes. Future research could explore the interplay between C-DA and various learner characteristics to develop more tailored and effective instructional strategies.

Another limitation is the reliance on a reading-span test written in Persian. Using more objective measures of WM, such as cognitive tasks or neuroimaging techniques, could provide more

reliable data on the role of WM in the learning process. Additionally, this study focused specifically on grammar learning, and future research could investigate C-DA's efficacy in other language skills, such as vocabulary acquisition, speaking, and writing.

Overall, although this study provides insights into the potential of C-DA to enhance grammar learning outcomes, further research is needed to address the abovementioned limitations and fully elucidate the mechanisms underlying its effectiveness. By addressing these gaps, future studies can contribute to developing more evidence-based and personalized approaches to language teaching and learning.

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