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Cognitive Amplification: Exploring the Impact of Multimodal Input Enhancement on Working Memory and Collocation Acquisition in Iranian EFL Learners across Age Groups

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Abstract

Acknowledging the critical role of working memory in language acquisition, this study examines the effects of multimodal input enhancement on working memory capacity (WMC) and collocation learning in adolescent and adult EFL learners. A cohort of 117 participants was randomly assigned to either experimental groups, receiving enhanced textual and auditory inputs, or control groups, experiencing standard inputs. Assessments included the Preliminary English Test, n-back test, and immediate and delayed collocation posttests. The results indicated that multimodal input significantly improved WMC and the recall and retention of collocations for all learners. Adolescents, in particular, excelled in both immediate and delayed tests and adapted their WMC more effectively in a multimodal context than adults. Additionally, an interaction between age and WMC was noted, affecting collocation recall and retention. These findings affirm the benefits of multimodal materials in enhancing cognitive functions and memory resources, thus improving language learning. The study offers practical insights for educational practices, advocating for the use of varied modalities in teaching materials to cater to different learning styles and cognitive needs. It also highlights the significance of designing age-appropriate materials and managing cognitive load in curriculum development, providing a tailored approach to language education for diverse learner populations.

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Introduction

The interplay between Second Language Acquisition (SLA) and neuroscience has sparked considerable interdisciplinary research, leading to innovative educational strategies. This study investigates the effects of multimodal input enhancement (MMIE) on working memory capacity (WMC) and collocation learning within two distinct age cohorts, aiming to elucidate how MMIE can streamline the language acquisition process.

Working memory (WM) is a critical component in learning, especially in language acquisition, where it influences vocabulary, comprehension, and collocation (Baddeley, 2015, 2017). As a cognitive system, WM retains and manipulates information for various tasks (Baddeley, 2000; Cowan, 2008), but its capacity is limited to approximately 7±2 items for a short time (Baddeley, 2003; Kearns & Lee, 2015), with selective attention being a crucial function.

This research addresses the learners' challenge of assimilating extensive language input into their WM by employing visual and auditory modalities to enhance language form presentation. Achieving proficiency in collocations is essential for second language (L2) learners to advance communicative competence (Lewis, 2000), yet mastering them is challenging. Recognizing the insufficiency of passive language exposure, particularly in L2 contexts, this study implements explicit input enhancement techniques to highlight collocations, thereby making them more salient to learners (Sharwood Smith, 1993).

Additionally, the study investigates age-related variances in MMIE's efficacy, considering that younger learners often display greater cognitive flexibility than older individuals (Singleton & Ryan, 2004; Brickman & Stern, 2009). By examining these subtleties, the research aims to enrich our understanding of SLA, shedding light on the complex interplay between cognitive functions and language learning, and ultimately informing more effective educational practices.

Review of Related Literature

This section provides a review of the relevant literature, encompassing studies on collocation learning, input enhancement, multimodality, working memory, and the influence of age in second language acquisition.

Collocation Learning

Collocations, defined as word pairs that frequently co-occur in a language and convey a specific meaning not deducible from the individual words (Nattinger & DeCarrico, 1992), are essential for second language (L2) learners. They facilitate the production of natural-sounding language and help avoid errors stemming from incorrect word pairings (Lewis, 2000). Achieving collocational competence is thus crucial for L2 learners aiming to attain native-like proficiency (Cao & Badger, 2023).

Ellis (2012) identifies several factors influencing collocation learning: frequency, or the regularity of collocation occurrence in input; salience, or the prominence of a collocation within

input; similarity, or the resemblance of a collocation to the learner's first language (L1); context, or the meaningfulness and relevance of the input for the learner; and feedback, or the information received about the correctness of a collocation use. These elements can significantly affect a learner's attention to, awareness of, and retention of collocations.

Research exploring various instructional techniques for collocation learning has yielded mixed results. Studies have shown that explicit instruction (Skrzypek, 2009), output practice (Laufer & Girsai, 2008), and input enhancement (Momenian et al., 2017) positively impact collocation acquisition. Sun and Park (2023) investigated the efficacy of corpus-based instruction, which employs computer-assisted methods to present authentic language data, finding it beneficial for learners' knowledge, application, and memory of collocations. Conversely, implicit instruction (Boers et al., 2006) and input flooding (Peters et al., 2019) have been reported to have little or negative effects on collocation learning. Additionally, the impact of these instructional methods may vary based on factors such as the type of collocation (adjective-noun vs. verb-noun), the nature of the assessment (recognition vs. production), and the timing of the test (immediate vs. delayed) (Ellis et al., 2008).

Input Enhancement

Input Enhancement (IE) is a pedagogical strategy designed to make certain elements of language input more prominent and noticeable to learners, thereby drawing their attention to specific linguistic forms (Sharwood Smith, 1993). IE can be implemented through various modalities, including textual, visual, and auditory (Kress, 2010). Textual IE involves altering the physical appearance of language forms in written materials, such as through bolding, underlining, or color-coding (Doughty & Williams, 1998). Visual IE adds images or animations to complement the written text, illustrating the meaning or usage of target language forms. Auditory IE modifies the spoken form of language, emphasizing pronunciation or intonation through techniques like stressing, pausing, or repeating (Manley, 2010).

The theoretical underpinnings of IE are rooted in the Noticing Hypothesis and the Depth of Processing Hypothesis. The Noticing Hypothesis, as proposed by Schmidt (1990), posits that conscious recognition of discrepancies between a learner's current language state (interlanguage) and the target language is crucial for language acquisition. IE aids in this process by enhancing the visibility and memorability of language features. The Depth of Processing Hypothesis, introduced by Craik and Lockhart (1972), suggests that deeper cognitive engagement with a language feature—through processes such as encoding, elaboration, and retrieval—is necessary for its retention in memory. IE supports this deeper processing by rendering language features more meaningful and contextually relevant.

Research examining the effects of IE on second language (L2) acquisition has investigated its impact on grammar (Wong, 2003; Izumi, 2002), vocabulary (Sonbul & Schmitt, 2010; Rassaei, 2015), and collocations (Momenian et al., 2017; Boers et al., 2014). Findings have been mixed, with studies like those by Sonbul and Schmitt (2010) and Momenian et al. (2017) demonstrating positive outcomes, while others, such as Wong (2003) and Boers et al. (2014), have reported negligible or negative effects. Additionally, research by Izumi (2002) and Rassaei (2015) has indicated that the effectiveness of IE may vary based on factors such as the

enhancement type (textual vs. visual vs. auditory), input modality (written vs. spoken), task nature (comprehension vs. production), and learner differences (proficiency level, learning style, attention span). A recent study by Jung and Lee (2023) explored the impact of synchronized textual enhancement with audio input on collocation learning during reading-while-listening activities. Their findings suggest that synchronizing textual and auditory inputs can facilitate collocation acquisition and deepen learner engagement with the enhanced language features, thus affirming the efficacy of multimodal IE.

Multimodality

Multimodal Input Enhancement (MMIE) employs various sensory modalities to underscore linguistic elements in instructional materials, thereby aiding learners' attentional processing and retention of language information (Doughty & Williams, 1998; Kress, 2010). MMIE's efficacy is supported by its ability to engage multiple channels such as textual, visual, and auditory modes, enhancing the salience of language features (Kress, 2010).

MMIE draws upon Working Memory (WM) principles, a cornerstone of cognitive psychology that influences language learning and processing (Baddeley, 2015, 2017). Baddeley (1986) and Mayer (2001) posit that visual and auditory information are processed through separate WM channels, suggesting that multimodal presentation can optimize the brain's capacity to retain information. This is corroborated by the Cognitive Theory of Multimedia Learning (Mayer, 2001) and the Dual Coding Theory (Paivio, 1971), which propose that learners encode information using both verbal codes—language-based symbols like words—and nonverbal codes—sensory-based images like pictures or sounds. Multimedia messages, which integrate both words and pictures, can thus activate dual codes within WM, potentially enhancing comprehension and memory retention.

Research investigating MMIE's impact on second language (L2) acquisition has explored its influence on vocabulary (Akbulut, 2007), grammar (Plass et al., 2003), and collocations (Momenian et al., 2017; Boers et al., 2014). While studies such as Akbulut (2007) and Plass et al. (2003) have reported positive outcomes, others like Boers et al. (2014) have indicated potential drawbacks. Moreover, Mayer and Moreno (2003) and Mayer and Sims (1994) have identified differential effects based on factors like modality type (visual vs. audio vs. textual), input form (written vs. spoken), task nature (comprehension vs. production), and individual learner differences (proficiency level, learning style, cognitive load). Recent research by Mirzaei, Azizi Farsani, and Chang (2023) on L2 formulaic sequences presented through unimodal, bimodal, and multimodal stimuli found that all modalities were effective for learning. Additionally, Momenian et al. (2017) investigated the role of verbal and visuospatial WM in collocation processing, revealing that while verbal WM did not significantly affect collocation processing, visuospatial WM positively influenced learners with higher WM capacities.

Working Memory

Working memory (WM), as defined by Baddeley and Hitch (1974), is a cognitive system that temporarily holds and manipulates a limited amount of information for various cognitive tasks. Working memory capacity (WMC) is the ability to hold and manipulate information in short-

term memory while performing cognitive tasks. WM is integral to various life tasks, including language learning, as it enables learners to process and retain linguistic information (Just & Carpenter, 1992). Daneman and Carpenter's (1980) study affirmed that WMC correlates with language proficiency.

WM comprises multiple components: the visuospatial sketchpad, phonological loop, central executive, and episodic buffer (Baddeley & Hitch, 1974). The visuospatial sketchpad stores spatial and visual information; the phonological loop processes auditory and verbal information; the central executive oversees other components, manages task-switching, and coordinates attention and inhibition processes; and the episodic buffer integrates information from various sources (Baddeley, 2012). WM's capacity is limited both in the amount and duration of information it can hold—typically around 7±2 items (Baddeley, 2003) or four chunks (Cowan, 2001) for up to 30 seconds (Kearns & Lee, 2015). The content of WM includes immediate thoughts, such as directions, phone numbers, or a shopping list (Woolfolk et al., 2003). WM also filters out irrelevant information (Wen et al., 2015). To maintain information in WM beyond its inherent time limit, rehearsal is necessary (Woolfolk et al., 2003).

WM is crucial for acquiring both first (L1) and second languages (L2). However, due to individual differences, the impact of WMC may vary between L1 and L2 (Chincotta & Underwood, 1997). WM is often more critical in L2 learning due to factors like maturational constraints and limited real-life L2 usage opportunities (Miyake & Friedman, 1998).

Studies on WM's impact on L2 have focused on vocabulary (Teng & Zhang, 2023; Shin, 2022), grammar (Pawlak & Biedroń, 2021), collocations (Ellis, 2012; Skrzypek, 2009; Momenian et al., 2017), listening (Satori, 2021), and reading (Joh & Plakans, 2017), with mixed results. Some research has shown a positive relationship between WM and language learning (Teng & Zhang, 2023; Satori, 2021; Joh & Plakans, 2017), while others have found a negative relationship (Shin, 2022; Pawlak & Biedroń, 2021) or no correlation (Ellis, 2012; Skrzypek, 2009; Momenian et al., 2017). Teng (2023) explored vocabulary learning through various genres of captioned videos, highlighting the role of complex WM in vocabulary acquisition. Kargar Behbahani and Razmjoo (2023) examined the interplay between WM and language proficiency, finding that high WMC enhances vocabulary learning. Conversely, Shahnazari (2023) found that WMC significantly relates to L2 reading comprehension development only at the beginner level, not at higher proficiency levels.

Age and SLA

Age is a pivotal factor in language learning, influencing cognitive abilities, motivation, and learning strategies (Singleton & Ryan, 2004). It brings into play a variety of cognitive, psychological, and social factors that affect a learner's acquisition of a second language (L2), including individual capacity, language aptitude, instructional methods, teaching materials, self-consciousness, personality, attitudes, and motivation (Hu, 2016). The relationship between age and L2 learning is complex and debated. Long (2005) posits that older learners may face more difficulties with language syntax, phonology, morphology, and pragmatics, while Ware et al. (2021) argue that second language learning can enhance cognition in older adults.

Herschensohn (2007) observes that older adults might apply their first language (L1) learning strategies to effectively learn grammar, sometimes surpassing younger learners.

Studies focusing on age and collocation learning have yielded mixed results. Some research suggests that older learners may benefit from greater metalinguistic awareness, lexical knowledge, and cognitive strategies (Durrant & Schmitt, 2010; Laufer & Waldman, 2011). On the other hand, other studies highlight potential disadvantages for older learners, such as diminished Working Memory Capacity (WMC), phonological memory, and implicit learning abilities (Ellis et al., 2008).

The interplay between age and input enhancement (IE) is not extensively covered in existing literature. Findings indicate that older learners might gain more from IE due to enhanced attentional control, metacognitive skills, and prior knowledge (Robinson, 1995; Schmidt & Frota, 1986). Conversely, some argue that IE's effectiveness may be compromised in older learners due to reduced WMC, perceptual sharpness, and cognitive flexibility (Craik & Bialystok, 2006; Kroll & De Groot, 2005).

The effects of aging on working memory (WM) are well-established in cognitive aging research (Braver & West, 2008). These studies often debate whether aging impacts the processing or storage aspects of WM more, especially in verbal or spatial tasks. Brickman and Stern (2009) present strong evidence of WM decline with normal aging. Salthouse (1994) discovered that while aging is associated with decreased WM functionality, the primary determinant is processing speed, which influences information encoding. Consequently, this study zeroes in on adolescent and adult learners to investigate these age-related effects further.

Objectives and Research Questions

This study has three primary objectives: to examine the effects of Multimodal Input Enhancement (MMIE) on the recall and retention of collocations, to investigate the influence of WM on these processes, and to explore the mediating role of age. Additionally, it considers the interactive effects of age, MMIE, and WM. The research questions are as follows:

1. What is the impact of MMIE on the WM of adolescent and adult learners?
2. What is the impact of age on the recall and retention of collocations?
2a. What is the impact of age on the recall of collocations?
2b. What is the impact of age on the retention of collocations?
2c. What is the interactive effect of age and WM on the retention and recall of collocations?

Method

Participants

The study involved 117 Persian-speaking adolescent and adult learners of English as a Foreign Language (EFL) from a well-regarded language institute. The adolescent group consisted of 59 individuals aged 13 to 17, classified as middle adolescents (American Academy of Child and Adolescent's Facts for Families, 2008), and the adult group comprised 58 individuals aged 20 to 45, categorized as young and middle-aged adults. Selection began with a Preliminary

English Test (PET) and an n-back test administered to 150 learners. After the PET, 136 participants scoring between 140 and 160 (Level B1) were chosen. From these, individuals scoring 50 to 80 on the n-back test were identified as having lower WM span. Ultimately, 117 participants were selected and randomly assigned to four groups: adolescent control (C1), adolescent experimental (E1), adult control (C2), and adult experimental (E2).

Materials

The primary material was "Collocations Extra: Multi-level Activities for Natural English" by Walter and Woodford (2010), featuring 18 units across various topics and levels. For this study, 14 intermediate-level texts containing 5 to 8 collocations each were selected.

Instruments

Data collection employed four instruments: (1) PET for placement, (2) n-back test for WM assessment, (3) diagnostic achievement test for immediate collocation recall, and (4) delayed posttest for collocation retention.

Instrument 1: PET

The PET, targeting Level B1 of the CEFR, was used to identify low-intermediate learners among 150 participants. It assesses reading, writing, listening, and speaking over 140 minutes, with scores ranging from 120 to 170. The exam's format includes multiple-choice, matching, true/false, gapped sentences, writing tasks, and oral components. While specific reliability metrics were not provided, the PET is recognized for its validity in assessing B1 level proficiency.

Instrument 2: N-back Test

The n-back test is a cognitive assessment tool that measures working memory (WM) and working memory capacity (WMC). Participants completed a computerized 2-back task, where they identified if the current stimulus matched one presented two trials earlier. Scores ranged from 118, with those scoring 50 to 80 selected for lower WM span. A post-intervention n-back test assessed the impact of MMIE on WM. The n-back test is known for its validity and reliability in cognitive measurement when administered in a controlled environment.

Instrument 3: Diagnostic Achievement Test

This teacher-made test was developed to assess the immediate recall of new collocations after each session. It was piloted with 30 intermediate learners to ensure reliability, which was reported at 0.81. The test format includes fill-in-the-blank, correction, recognition, and completion items. Its validity was ensured through careful piloting and adaptation to the learning context.

Instrument 4: Delayed Posttest

The delayed posttest is a 40-item multiple-choice test that evaluates collocation retention two weeks post-intervention. This interval was chosen to minimize reliance on short-term memory and to avoid additional learning effects. The test was piloted for reliability, which was also reported at 0.81. It has a 30-minute completion time and is scored out of 20. The delayed

interval and multiple-choice format are intended to provide a valid assessment of long-term retention capabilities.

Procedure

In the first session, participants were informed about the intervention's nature and the overall research objectives. The teacher introduced the concept of collocations, providing a definition and examples on the board. For instance, the teacher clarified that while "quick" and "fast" are synonyms, they are not interchangeable in all contexts—hence, we say "fast train" but "quick shower."

During each session, control groups C1 and C2 were presented with texts containing 5 to 8 non-enhanced collocations displayed on a TV screen. The teacher read the text aloud, then elucidated the meaning of each collocation with examples. To assess collocation recall, a diagnostic achievement test pertaining to that session's collocations was administered at the class's conclusion.

Experimental groups E1 and E2 engaged with the same texts as the control groups, but with both textual and aural enhancements. Researchers had pre-designed multimodal materials to highlight collocations within the text using typographical cues such as bolding, color-coding, varying font sizes, and animations. Concurrently, audio files were prepared where the teacher emphasized collocations by adjusting stress, pace, and inserting pauses, as per Manley (2010)'s recommendations, to enhance salience. These multimodal inputs were then presented together through PowerPoint slides on a TV screen. Similar to the control groups, a diagnostic achievement test was given at each session's end to evaluate collocation recall.

Data Analysis

To assess the impact of textually and auditorily enhanced collocations on working memory capacity (WMC), as well as the retention and recall of these collocations in adolescent and adult populations, a comprehensive data analysis was conducted. This analysis aimed to address the posed research questions utilizing a variety of statistical tests. Specifically, the independent samples t-test, two-way Analysis of Variance (ANOVA), simple effects analysis, repeated measures ANOVA, and two-way Analysis of Covariance (ANCOVA) were employed to determine the effectiveness of the enhancements.

First Null Hypothesis (H01)

Prior to the intervention, a two-way Analysis of Variance (ANOVA) was conducted to confirm the homogeneity of variance among all groups concerning working memory capacity (WMC). The initial research question investigated whether there were significant differences in the posttest scores of working memories (WM) between the control groups and the experimental groups. The null hypothesis stated: H01: MMIE has no effect on WM of adolescent and adult learners.

To evaluate the mean differences in posttest WM scores between the experimental and control groups, a two-way ANOVA was employed. The Levene's test for homogeneity of variances yielded an F-statistic of (F (3, 1113) = 4.16), with a p-value less than .05 ($p < .05$), indicating

heterogeneous variances in posttest WM scores. The results presented in Table 1, (F (1, 113) = 481.59, p >.05, partial η2 = .810) suggest a large effect size and significantly better performance by groups E1 and E2 compared to groups C1 and C2. Consequently, the first null hypothesis was rejected.

Table 1. *Between-Subjects Effects Tests; Posttest of WM by Groups by Age*

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Group	34383.127	1	34383.127	481.596	.000	.810
Age	548.948	1	548.948	7.689	.007	.064
Group * Age	565.671	1	565.671	7.923	.006	.066
Error	8067.532	113	71.394			
Total	952925.000	117				

Second Null Hypothesis (H02)

The second null hypothesis investigated whether there were significant differences in the recall and retention of collocations between adult and adolescent groups, thereby examining the effect of age. Additionally, it considered the potential interactive effect of age and working memory (WM) on these variables. To evaluate these factors, a repeated measures ANOVA and simple effect analysis were conducted. The null hypotheses were articulated as follows:

- H02: Age has no impact on recall and retention of collocations.

This overarching null hypothesis was further broken down into three sub-hypotheses:

- H02a. Age has no impact on recall of collocations.
- H02b. Age has no impact on retention of collocations.
- H02c. There is no interactive effect of age and WM on recall and retention of collocations.

In the repeated measures ANOVA, it is essential that the correlations between the two dependent variables—immediate posttest (recall) and delayed posttest (retention) of collocations—are approximately equal across groups. This requirement is known as the homogeneity of covariance matrices. The results of Box's test were not significant (Box's M = 10.42, p > .001), indicating that the assumption of homogeneity was satisfied. Similarly, Levene's test for homogeneity of variances supported this assumption for both the immediate posttest (F (1, 113) = 1.45, p > .05) and the delayed posttest of collocations (F (1, 113) = 1.07, p > .05).

Regarding sub-hypotheses $H0_2a$ and $H0_2b$, which required a comparison between adult and adolescent groups on both the immediate and delayed posttests of collocations, the simple-effect analysis presented in Table 2 revealed the following:

Adolescent Group Performance: On the immediate posttest of collocations, the adolescent group (M = 16.97) significantly outperformed the adult group (M = 15.85), with a mean difference of (MD = 1.12, p < .05). This finding led to the rejection of sub-hypothesis $H0_2a$, which posited that age has no impact on the recall of collocations.

Delayed Posttest Results: Similarly, on the delayed posttest of collocations, the adolescent group (M = 6.24) significantly outperformed the adult group (M = 5.32), with a mean difference of (MD = .926, $p < .05$). These results necessitated the rejection of sub-hypothesis $H0_2b$, which stated that age has no impact on the retention of collocations.

Table 2. *Simple Effect Analysis; Comparing Groups on Posttest and Delayed Posttest of English Collocations by Age*

Collocation	(I) Age	(J) Age	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
						Lower Bound	Upper Bound
Posttest	Adolescent	Adult	1.123*	.318	.001	.492	1.754
Delayed	Adolescent	Adult	.926*	.313	.004	.305	1.546

Regarding the third sub-hypothesis ($H0_2c$), the analysis of Between-Subject Effects for the pretest of working memory (WM) across both adolescent and adult groups, as shown in Table 3, revealed no significant interaction between group and age ($F (1, 113) = 1.22$, $p > .05$), with a partial eta squared ($\eta 2 = .011$), indicating a weak effect size in recall and retention of collocations. Therefore, the data did not support the presence of an interaction effect between age and WM on the pretest measures of recall and retention of collocations.

Table 3. *Between-Subjects Effects Tests; Pretest of WM by Groups by Age*

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Group	4.382	1	4.382	.078	.781	.001
Age	28.482	1	28.482	.505	.479	.004
Group * Age	69.009	1	69.009	1.224	.271	.011
Error	6371.203	113	56.382			
Total	569597.000	117				

Table 4 presents the results of the Between-Subject Effects analysis for the posttest of working memory (WM) across both adolescent and adult groups. The findings indicated a significant interaction between group and age ($F (1, 113) = 7.92$, $p < .05$), with a partial eta squared of .066 ($\eta 2 = .066$), denoting a large effect size. These results imply a notable interaction effect between age and WM on the recall and retention of collocations. Consequently, the third sub-hypothesis ($H0_2c$), which posited that there is no interactive effect between age and WM on the recall and retention of collocations, was rejected.

Table 4. *Between-Subjects Effects Tests; Posttest of WM by Groups by Age*

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Group	34383.127	1	34383.127	481.596	.000	.810
Age	548.948	1	548.948	7.689	.007	.064
Group * Age	565.671	1	565.671	7.923	.006	.066
Error	8067.532	113	71.394			
Total	952925.000	117				

Results and Discussion

This study investigated the effects of Multimodal Input Enhancement (MMIE) on Working Memory Capacity (WMC), and the recall and retention of collocations among two age groups. Initially, the research examined the impact of MMIE on WMC by comparing the posttest results of the experimental groups (E1 and E2) with the control groups (C1 and C2). The experimental groups showed significant improvement, indicating that MMIE facilitates the retention of information in WM for both adolescents and adults. This supports Mayer's Cognitive Theory of Multimedia Learning (2001), which suggests that combining words and pictures enhances memory due to the dual-channel capacity of human information processing. Paivio's Dual-Channel Theory (1986) also supports this, emphasizing separate channels for auditory and visual information. The study's approach of presenting 5 to 8 collocations per session with enhanced textual and aural modalities prevented cognitive overload, aligning with Montero Perez's (2020) findings that multimedia input enhances vocabulary learning and retention. Teng and Zhang (2023) similarly acknowledged the benefits of multimodal presentation on L2 vocabulary retention, highlighting the crucial role of WM. In contrast, LaBrozzi and Villegas (2020) did not find a direct link between WMC and vocabulary test scores but recognized the positive effects of image and word enhancement on vocabulary recall, with image enhancement alone aiding retention.

The second aspect of the study focused on the influence of age and the combined effect of age and WM on the recall and retention of collocations. Comparisons of immediate and delayed posttests between the adolescent (C1, E1) and adult groups (C2, E2), along with an analysis of Between-Subject Effects for WM pretests and posttests, revealed that adolescents, especially in the experimental group E1, outperformed adults in both immediate and delayed collocation posttests. These findings highlight the importance of age in collocation recall and retention, with adolescents showing greater proficiency than adults. Additionally, there was a significant interaction between age and WM, suggesting that MMIE has a more substantial positive effect on the WMC of adolescents, as well as their ability to recall and retain collocations. This is consistent with Ur's (1996) view of adolescents' superior language learning abilities but contrasts with Robinson's (2005) claim that adults have greater linguistic and cognitive capacities. The results also agree with Brickman and Stern's (2009) observations on the decline of WM abilities with aging, supporting the general consensus that aging negatively affects WM, leading to a gradual decrease in WMC from adolescence to old age.

Conclusion

This study delved into the nexus of neuroscience and Second Language Acquisition (SLA), evaluating the impact of Multimodal Input Enhancement (MMIE) on Working Memory Capacity (WMC) and collocation learning among EFL learners. Additionally, it explored how age and WMC influence collocation recall and retention. The findings confirmed MMIE's efficacy in strengthening WMC and improving collocation learning, with adolescents demonstrating superior performance in recall and retention compared to adults.

The study underscored the vital role of memory resources and cognitive functions in language acquisition and multimedia input processing. It emphasized the importance of WM in language learning and the need to consider the material load and presentation modality. The

findings confirmed that materials enhanced through various modalities could expand learners' WM capacity and aid their learning process. This multimodal approach captures learners' attention and activates different input channels, allowing for more effective and prolonged retention of information. However, managing the load and modality of input to avoid cognitive overload is essential. The study carefully calibrated the input and presentation modes for collocations to prevent overwhelming the learners' WM.

On a broader scale, understanding the mind and memory's capabilities can inform educators in devising strategic educational plans. The insights from this research have significant pedagogical implications for teacher training, educators, material developers, course designers, and curriculum specialists. It offers practical guidelines on utilizing materials from different modalities to enhance teaching methods. By integrating visual, auditory, textual, kinesthetic, and animated materials, educators can diversify their teaching methods and accommodate various learning styles, enriching the educational experience. Additionally, this research can inspire the creation of effective language learning resources with enhanced audio input, especially beneficial in contexts like Iran, where English is a foreign language, and L2 usage opportunities are scarce. It also addresses challenges related to underdeveloped cognitive structures or verbal skills, contributing to a comprehensive language learning environment.

Nevertheless, this study is not without limitations. The participants, selected from an English institute in Guilan through non-probability purposive sampling and random assignment, could be complemented by including English university students in future research. The study did not account for gender effects, although it included both male and female Iranian EFL learners. Further studies are needed to explore MMIE's effects and its interaction with WM in other L2 acquisition areas, such as grammar, reading, and speaking. Future research could also investigate MMIE's impact on students' learning styles and strategies. Additionally, while this study focused on the recall and retention of collocations, future investigations could examine both oral and written production of collocations. The n-back test was the sole instrument for assessing WM; other tests like the complex-span task, RAVL test, updating tasks, and reading span tasks could be utilized for data collection in subsequent studies.

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References

Akbulut, Y. (2007). Effects of multimedia annotations on incidental vocabulary learning and reading comprehension of advanced learners of English as a foreign language. *Instructional Science,* 35(6), 499-517. https://doi.org/10.1007/s11251-007-9016-7

Baddeley A. (2000). The episodic buffer: A new component of working memory? *Trends Cognitive Sciences,* 4(11), 417-423. https://doi.org/10.1016/S1364-6613(00)01538-2

Baddeley, A. D. (1986). *Working memory*. Oxford University Press.

Baddeley, A. D. (2003). Working memory and language: An overview. *Journal of Communication Disorders,* 36(3), 189-208. https://doi.org/10.1016/s0021-9924(03)00019-4

Baddeley, A. D. (2012). Working memory: Theories, models, and controversies. *Annual Review of Psychology*, 63(1), 1-29. https://doi.org/10.1146/annurev-psych-120710-100422

Baddeley, A. D. (2015). Working memory in second language learning. In Z. Wen, M. Mota and A. McNeill (Eds), *Working memory in second language acquisition and processing* (pp. 17-28). Multilingual Matters.

Baddeley, A. D. (2017). Modularity, working memory and language acquisition. *Second Language Research,* 33(3), 299-311. https://doi.org/10.1177/0267658317709852

Baddeley, A., & Hitch, G. J. (1974). Working memory. In G. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (pp. 47-90). Academic Press.

Boers, F., Demecheleer, M., Coxhead, A., & Webb, S. (2014). Gauging the effects of exercises on verb-noun collocations. *Language Teaching Research,* 18(1), 54-74. https://doi.org/10.1177/1362168813505389

Boers, F., Eyckmans, J., Kappel, J., Stengers, H., & Demecheleer, M. (2006). Formulaic sequences and perceived oral proficiency: Putting a lexical approach to the test. *Language Teaching Research,* 10(3), 245-261. https://doi.org/10. 245-261.

Braver, T. S., & West, R. (2008). Working memory, executive control, and aging. In F. I. M. Craik and T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 311-372). Psychology Press.

Brickman, A. M., & Stern, Y. (2009). Aging and memory in humans. In P. R. Hof & C. V. Mobbs (Eds.), *Handbook of the neuroscience of aging* (pp. 243-248). Elsevier Academic Press.

Cao, D. & Badger, R. (2023). Cross-linguistic influence on the use of L2 collocations: The case of Vietnamese learners. *Applied Linguistics Review*, 14(3), 421-446. https://doi.org/10.1515/applirev-2020-0035

Chincotta, D., & Underwood, G. (1997). Digit span and articulatory suppression: A cross-linguistic comparison. European *Journal of Cognitive Psychology*, 9(1), 89-96. https://doi.org/10.1080/713752545

Cowan N. (2008). What are the differences between long-term, short-term, and working memory? *Progress in Brain Research.* 169, 323-338. https://doi.org/10.1016/s0079-6123(07)00020-9

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences,* 24(1), 87-114. https://doi.org/10.1017/S0140525X01003922

Craik, F. I. M., & Bialystok, E. (2006). Cognition through the lifespan: Mechanisms of change. *Trends in Cognitive Sciences,* 10(3), 131-138. https://doi.org/10.1016/j.tics.2006.01.007

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of Processing: A Framework for Memory Research. *Journal of Verbal Learning and Verbal Behavior,* 11(6), 671-684. https://doi.org/10.1016/S0022-5371(72)80001-X

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning & Verbal Behavior,* 19(4), 450-466. https://doi.org/10.1016/S0022-5371(80)90312-6

Doughty, C., & Williams, J. (1998). *Focus on form in second language acquisition classroom*. Cambridge University Press.

Durrant, P., & Schmitt, N. (2010). Adult learners' retention of collocations from exposure. *Second Language Research,* 26(2), 163-188. https://doi.org/10.1177/0267658309349431

Ellis, R. (2012). *Language teaching research and language pedagogy*. Malden, MA: John Wiley and Sons.

Ellis, R., Sheen, Y. H., Murakami, M., & Takashima, H. (2008). The effects of focused and unfocused written corrective feedback in an English as a foreign language context. *System,* 36(3), 353-371. https://doi.org/10.1016/j.system.2008.02.001

Herschensohn, J. (2007). *Language development and age*. Cambridge University Press.

Hu, R. (2016). The Age Factor in Second Language Learning. *Theory and Practice in Language Studies,* 6(11), 2164-2168. http://dx.doi.org/10.17507/tpls.0611.13

Izumi, S. (2002). Output, input enhancement, and the noticing hypothesis: An experimental study on ESL relativization. *Studies in Second Language Acquisition,* 24(4), 541-577. https://doi.org/10.1017/S0272263102004023

Joh, J., & Plakans, L. (2017). Working memory in L2 reading comprehension: The influence of prior knowledge. *System,* 70(1), 107-120. https://doi.org/10.1016/j.system.2017.07.007

Jung, J., & Lee, M. (2023). Incidental collocational learning from reading-while-listening and the impact of synchronized textual enhancement. *International Review of Applied Linguistics in Language Teaching*. https://doi.org/10.1515/iral-2023-0029

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review,* 99(1), 122-149. https://doi.org/10.1037/0033-295X.99.1.122

Kargar Behbahani, H., & Razmjoo, S. A. (2023). The contribution of working memory and language proficiency to lexical gain: Insights from the involvement load hypothesis. *Teaching English as a Second Language Quarterly,* 42(3), 117-146. https://doi.org/10.22099/tesl.2023.48255.3220

Kearns, T. & Lee, D. (2015). *General psychology: An introduction*. University System of Georgia.

Kress, G. (2010). *Multimodality: A social semiotic approach to contemporary communication*. Routledge.

Kroll, J. F., & de Groot, A. M. B. (Eds.). (2005). *Handbook of bilingualism: Psycholinguistic approaches.* Oxford University Press.

LaBrozzi, R. M., & Villegas, A. (2020). The effects of dynamic visual enhancement and working memory on the recall of Spanish vocabulary. *Hispania*, 103(2), 245-258. https://doi.org/10.1353/hpn.2020.0035

Laufer, B., & Girsai, N. (2008). Form-focused instruction in second language vocabulary learning: A case for contrastive analysis and translation. *Applied Linguistics*, 29(4), 694-716. https://doi.org/10.1093/applin/amn018

Laufer, B., & Waldman, T. (2011). Verb-Noun collocations in second language writing: A corpus analysis of learners' English. *Language Learning*, 61(2), 647-672. https://doi.org/10.1111/j.1467-9922.2010.00621.x

Lewis, L. K. (2000). Communicating change: Four cases of quality programs. *International Journal of Business Communication*, 37(2), 128-155. https://doi.org/10.1177/002194360003700201

Long, M. (2005). Methodological issues in learner needs analysis. In M. H. Long (Ed.), *Second Language Needs Analysis* (pp. 19-76). Cambridge University Press.

Manley, M. S. (2010). Enhanced input in LCTL pedagogy. *NCOLCTL, 9*.

Mayer, R. (2001). *Multimedia learning*. Cambridge University Press.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, 38(1), 43-52. https://doi.org/10.1207/S15326985EP38016

Mayer, R. E., & Sims, V. K. (1994). For whom is a picture worth a thousand words? Extensions of a dual-coding theory of multimedia learning. *Journal of Educational Psychology*, 86(3), 389-401. https://doi.org/10.1037/0022-0663.86.3.389

Mirzaei, A., Azizi Farsani, M., & Chang, H. (2023). Statistical learning of L2 lexical bundles through unimodal, bimodal, and multimodal stimuli. *Language Teaching Research*. https://doi.org/10.1177/13621688231193079

Miyake, A., & Friedman, N. P. (1998). Individual differences in second language proficiency: Working memory as language aptitude. In A. F. Healy, & L. E. Bourne (Eds.), *Foreign Language Learning: Psycholinguistic Studies on Training and Retention* (pp. 339-364). Mahwah, NJ: Lawrence Erlbaum Associates.

Momenian, M., Mohammad Amini, J., & Ghafar Samar, R. (2017). The effect of verbal and visuospatial working memory spans on collocation processing in learners of English. *Journal of English Language Teaching and Learning University of Tabriz*, 9(20), 157-186.

Montero Perez, M. (2020). Incidental vocabulary learning through viewing video: The role of vocabulary knowledge and working memory. *Studies in Second Language Acquisition*, 42(4), 749-773. https://doi.org/10.1017/S0272263119000706

Nattinger, J. R., & Decarrico, J. S. (1992). *Lexical phrases and language teaching*. Oxford University Press.

Paivio, A. (1971). *Imagery and verbal processes*. Holt, Rinehart, and Winston.

Paivio, A. (1986). *Mental representations: A dual-coding approach*. Oxford University Press.

Pawlak, M., & Biedroń, A. (2021). Working memory as a factor mediating explicit and implicit knowledge of English grammar. *Annual Review of Applied Linguistics,* 41, 118-125. https://doi.org/10.1017/S0267190521000052

Peters, E., Noreillie, A. S., Kris, H., Bulté, B., & Desmet, P. (2019). The impact of Instruction and out-of-school exposure to foreign language input on learners' vocabulary knowledge in two languages. *Language Learning,* 69(3), 1-36. https://doi.org/10.1111/lang.12351

Plass, J. L., Chun, D. M., Mayer, R. E., & Leutner, D. (2003). Cognitive load in reading a foreign language text with multimedia aids and the influence of verbal and spatial abilities. *Computers in Human Behavior*, 19(2), 221-243. https://doi.org/10.1016/S0747-5632(02)00015-8

Rassaei, E. (2015). Effects of Textual Enhancement and Input Enrichment on L2 Development. *TESOL Journal*, 6(2), 281-301. https://doi.org/10.1002/tesj.149

Robinson, P. (1995). Attention, memory, and the "noticing" hypothesis. *Language Learning,* 45(2), 283-331. https://doi.org/10.1111/j.1467-1770.1995.tb00441.x

Robinson, P. (2005). Cognitive complexity and task sequencing: Studies in a componential framework for second language task design. *International Review of Applied Linguistics in Language Teaching,* 43(1), 1-32. https://doi.org/10.1515/iral.2005.43.1.1.

Salthouse, T. A. (1994). The aging of working memory. *Neuropsychology*, 8(4), 535-543. https://doi.org/10.1037/0894-4105.8.4.535

Satori, M. (2021). Effects of working memory on L2 linguistic knowledge and L2 listening comprehension. *Applied Psycholinguistics,* 42(5), 1313-1340. https://doi.org/10.1017/S0142716421000345

Schmidt, R. (1990). The role of consciousness in second language learning. *Applied Linguistics,* 11(2), 129-158. https://doi.org/10.1093/applin/11.2.129

Schmidt, R., & Frota, S. (1986). Developing basic conversational ability in a second language: A case study of an adult learner. In R. Day (Ed.), *Talking to learn: Conversation in second language acquisition* (pp. 237-369). Rowley, MA: Newbury House.

Shahnazari, M. (2023). The role of WM in second language reading comprehension: Does L2 proficiency level matter? *Learning and Motivation,* 82(2), 101875. https://doi.org/10.1016/j.lmot.2023.101875.

Sharwood Smith, M. (1993). Input enhancement in instructed SLA: Theoretical bases. *Studies in Second Language Acquisition*, 15(2), 165-179. https://doi.org/10.1017/S0272263100011943

Shin, J. (2022). Korean EFL children's working memory, vocabulary and reading comprehension: A path analysis approach. *Journal of Applied Linguistics and Language Research,* 9(3), 1-11.

Singleton, D., & Ryan, L. (2004). *Language acquisition: The age factor* (2nd ed.). Clevedon.

Skrzypek, A. (2009). Phonological short-term memory and L2 collocational development in adult learners. *Eurosla Yearbook,* 9(1), 160-184. https://doi.org/10.1075/eurosla.9.09skr

Sonbul, S., & Schmitt, N. (2010). Direct teaching of vocabulary after reading: Is it worth the effort? *ELT Journal,* 64(3), 253-260. https://doi.org/10.1093/elt/ccp059

Sun, W., & Park, E. (2023). EFL learners' collocation acquisition and learning in corpus-based instruction: A systematic review. *Sustainability*, 15(17), 13242. https://doi.org/10.3390/su151713242

Teng, M. F. (2023). Incidental vocabulary learning from captioned video genres: vocabulary knowledge, comprehension, repetition, and working memory. *Computer Assisted Language Learning*, 1-40. https://doi.org/10.1080/09588221.2023.2275158

Teng, M. F., & Zhang, D. (2023). The associations between working memory and the effects of multimedia input on L2 vocabulary learning. *International Review of Applied Linguistics in Language Teaching* 61(3), 1021-1049. https://doi.org/10.1515/iral-2021-0130

Ur, P. (1996) *A course in language teaching: Practice and theory*. Cambridge University Press.

Walter, E., & Woodford, K. (2010). *Collocations extra: Multi-level activities for natural English*. Cambridge University Press.

Ware, C., Dautricourt, S., Gonneaud, J., Chételat, G. (2021). Does second language learning promote neuroplasticity in aging? A systematic review of cognitive and neuroimaging studies. *Front Aging Neuroscience*, 13, 706672. https://doi.org/ 10.3389/fnagi.2021.706672.

Wen, Z., Mota, M. B., & McNeill, A. (2015). *Working memory in second language acquisition and processing*. Multilingual Matters.

Wong, W. (2003). Textual enhancement and simplified input: Effects on L2 comprehension and acquisition of non- meaningful grammatical form. *Applied Language Learning*, 13(2), 17-45.

Woolfolk, A. E., Winne, P. H., & Perry, N. E. (2003). *Educational psychology* (2nd ed.). Pearson Education.