A Meta-analysis: The Efficacy of Working Memory Span (WMS) on Overall Performance of L2 Learning

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ABSTRACT
In order to investigate the effect of Working Memory (WM) on overall L2 performance and written skills (Reading and Writing) within non-native language learning arenas, a systematic review was conducted on 22 articles extracted from three reputable, local and international scientific databases including Noormags, Science Direct and Sage between 1990 and 2021. The total number of participants in this study included 1466 involving both male and female in all age groups of children and adults. In the selection of articles with 7 different criteria, coding was applied to the extracted studies and a research protocol was precisely presented. After examining the publication bias index and preliminary assumptions, the results showed that WM has been efficient at a significance level of less than 0.05 and with a high impact factor (1.05) with a positive direction in the 95% confidence interval on diverse aspects of second language learning. Secondly, WM has also been significant at a significant level less than 0.05 and with a high impact factor on reading comprehension skills and an impact factor (0.6) with a positive direction in the 95% confidence interval but this effect on L2 writing skills was not significant (p = 0.93). The results were finally analyzed with reference to the limitations of the current systematic meta-analysis.

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1.Introduction

The close interaction between second language learning problems with different individual characteristics of learners (Bengson & Lucke, 2016) on the one hand and psychological theories of language on the other hand has led to the growth of unique research findings in recent years, but diverse results are always accompanied by the selection of diverse research methods. And many differences in the use of factors involved in the process of education and research have confused the researchers in the field of second language education and learning (Jahangiri, Soleimani & Jafari Gohar, 2017). Among the most interesting researches in this field, the relationship between different aspects of working memory and language learning issues, including the mechanism processes and working memory performance in reading and understanding the concepts of difficult texts (Shah Nazari-Darcheh & Adams, 2014; Najari & Mohammadi, 2017) or the related role of listening skills in categorizing and recalling sounds and speech components (Joseph, Iverson, Manohar, Fox, Scott, & Hossein, 2015; Karimi & Naghdivand, 2017; Cohen & Netley, 1984; Wen, Jaffes & Winke, 2020) is significant when recording and maintaining verbal information.

Within human beings' minds, 'working memory' generally refers to a physical space in the brain where information is temporarily stored, and based on the theory of Baddely and Hitch (2000), which is one of the most valid models presented in the field of working memory, it has three basic parts including "the visuospatial sketch pad", "the central executive" and the "phonological loop", which is used to store auditory information. In the modification of the mentioned model in the following years, another section was also added to the model titled "episodic buffer". In the theoretical model presented by Baddeley and colleagues, two vital parts including the executive-central specific for understanding the meaning and the phonological loop are involved in the processing of auditory linguistic information (Baddeley, 2007; Wind Cowell, 2011). In general, working memory in the human brain is responsible for monitoring the performance of a continuous cognitive system, which includes processes related to the mechanism of selective attention on the one hand and suppression of items unrelated to the desired information, and according to the common research available so far, the extent of its involvement in learning depends on the type of activity (new vs. repetitive), whether it is easy or difficult, and the environment in which learning occurs (Baroui Lett & Camus, 2001).

Regarding the mutual influence of working memory span (WMS) on various aspects of second language learning, there were different classes and categories in the research literature (Smith, 2017). Some researches in this field measured learning multiple languages and the positive effect of

such learning on increasing the scope of working memory, learning a second and third language which is thought to help a person increase his/her learning performance by expanding the scope of working memory (Andrew & Karaptsas, 2004). In some other researches, the emphasis was on working memory as a previous variable that affects the learning process of various aspects of language, including verbal production skills (Majaozi & Ahmadian, 2014), or Blasko (1999) who was also among the researchers focusing on the positive role for the amount of working memory magnitude and understanding of metaphorical texts. In the meantime, in some of the Iranian studies, the researchers had considered the expansion or retreat of the working memory space as the result of psychological functions at the same time as the learning situation, including the role of factors such as anxiety (Zoghibi Qanad, Alipour, Shahni Yilaq, Manijeh and Haji Lakhri (1396) or the use of educational tools and equipment (Khazaei, Saeed, Abedi, Zarei and Lotfi (1388). Among other influential factors in this field was the number and order of languages learned (Servis, Simula & Metsanhaimo, 2002; Tali & Stavrakaki, 2020; Karimi & Naghdivand, 2017) or even the type of language practice and the activity that the learner is involved in (Shin, 2020).

2. Review of literature

In the existing literature, the research on the effective relationship between working memory and various aspects of learning in the first language was very extensive, but the research in the second language required more and more detailed review, because in the meantime, some researchers also focused on the total lack of connection between the memory extension as fortified by bilingualism (Namazi &Tordardottir, 2010). In research with a meta-analytical approach by examining 27 articles and considering 88 cases of the effect size index, Grundy and Timmer (2017) represented the scopes of this issue in the second language in such a way that among 2901 people, bilingual people due to the involvement of cognitive flexibility achieved over time, they experience more expansion in their working memory spans than monolinguals, and this issue was much more evident among children than adults. On the other hand, Karbach and Verhaeghen (2014) conducted a meta-analysis on adults (over 60 years old) and concluded that training based on strengthening the efficiency of the executive part of working memory was associated with better performance. Possible reasons for the diversity of the results are the researchers' use of working memory tests (verbal and numerical) (Kamos, 2015). Regarding the relationship between the function of working memory and other parts of the brain in humans, among the research studies conducted until now, it is also important to examine some very subtle points; Because even with the proof of the effect of working memory on language

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functions, the effect of other mental factors as predictive variables cannot be ignored. Diamond (2006) listed three major cognitive factors in learners' language performance, including inhibition, working memory, and cognitive flexibility, stating that people's cognitive performance changes depending on these three types of stimuli. It seems that the function of working memory should be carefully reviewed in accordance with other cognitive functions. In a research by Letang (2016), the power of mindfulness was considered in this issue. In situations of learning a second or foreign language, which is usually associated with anxiety, this type of mental awareness gives a person more power than the maximum capacity of working memory and is effective in improving performance by creating strategic engagement regulation. Majavezi and Ahmadian (2014) investigated the existence of such a relationship in the first and second language learning skills in self-regulation behavior and indicated the existence of such a positive relationship only in the second (English) but in the first language (Persian), the participants had not used the capacity of their working memory. In this regard, Jaffes and Harrington (2011) believed that there has been an exaggeration regarding the relationship between the components of the second language and the amount of working memory.

In this regard, people somehow pointed to the existence of the type of activity in which the mind is engaged. For example, in practice activities in which the language learner only pays attention to practice and recall (simple exercises) as opposed to difficult exercises in which a person has to perform other processing activities in addition to storing information. In this status quo, the type of performance seems to be different depending on the type of activity. In a systematic review by Link, Stass, Kovis, and Bunting (2014), it was found that, by measuring both types of difficult practice and mental style, working memory is effective in both understanding and producing linguistic data with a high effect size of 0.255.

This matter was proven in the post hoc covariance analysis in this regard in the executive control section (vs. storage mechanism) and verbal scales (vs. non-verbal) of working memory. In another review study on 197 articles, Peng, Barnes, Wong, and Tayo (2018) determined that the effect of working memory is cross-sectional and more evident over multiple periods of time. For example, before a person reaches the 4th grade, all parts of the memory are equally effective in the process of reading in the second language, but after this period, the verbal parts of the working memory become more prominent.

Regarding the development of working memory as an independent variable in research with the approach of focusing on writing skills, in most of the existing researches, positive results were abound. For example, in Alpetkin and Arsentin's (2009) research, in two types of mental processing

including the literal and inferential comprehension, participants with higher working memory levels, since inferential activities such as understanding full texts from the metaphor exert a higher amount of load/pressure on memory, optimal performance is reported in such people. Over time and with increasing exposure to such written-visual activities, it seems that the amount of working memory increases among bilingual people, and this is shown in research in which bilingual people compared with monolingual people are repeatedly compared (Sarani, 2018).

Suzuki (2019) in his research among bilingual people acknowledged that their oral production performance both during and after training, although with the ability to practice metalinguistic rules (Metalinguistic Rule Rehearsal Ability) with the amount of working memory capacity (WMC), its role was limited, and this article, based on the author's explanation, made it clearer that there should be a need to pay attention to the individual differences of disadvantaged students in the morphological learning of the second language. Regarding individual differences in this regard, Mesraei (2020) pointed to the role of oral vocabulary versus written vocabulary and the amount of working memory reading, so that the most important predictors of listening comprehension are oral vocabulary and then the amount of reading but this point was received less effective in the case of written

vocabulary. This issue refers to individual differences on the one hand and working memory on the other. Ambiguities in the field of working memory efficiency in language learning are sometimes related to the division of memory parts into specific and separate work parts (domain-specific) vs. domain-general work. In Baddeley's model (1986), which was the basis for the selection of articles in the present systematic review, it is mainly considered that in the componential model, parts of the phonological loop and central control are related to reading activities such as learning new words and grapheme-phoneme matching (Ellis & Munk, 1994; cited in Peng, Wong, Barnes, & Swanson (2018). Central control sections help with reading comprehension. There were other models in the research literature, including the resource-sharing model (Engle, Cantor and Carrullo, 1992), in which case it is said that the capacity of working memory is very weak and other cognitive parts should be actively involved.

In some researches, the three parts of working memory have been investigated separately. For example, in the research of Kernoldi, Vekina and Tresoldi (1995), referring to the valid model of Baddeley (1986), the researchers acknowledged that among the parts of working memory, the phonological loop plays the most important role in the stages of reading and understanding texts. It has played a role among people who had dyslexia.

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The research related to the extent of working memory without emphasizing its constituent parts in the first language also indicates the existence of a positive relationship between the extent of this type of memory and language learning. In the research by Norambonia, Sayez, Flonets, Ponce and Siles, 2022) among two groups of Spanish-speaking children with the age range of one and two years, it was found that among younger children in terms of punctuation and correct word selection, the amount of working memory span was significant, but such a relationship was evident in older children only in terms of analogical inference. Chu, Mo and Dong* (2021) also mentioned reading anxiety and working memory capacity as two predictive variables in reading and comprehension skills in the second language.

Having sought the two keywords "language skills" and "working memory" among 26,991 extracted articles in the Science Direct database, in just three years (2021-2023), the types of cognitive and verbal skills of the research participants were examined in the first language, but this issue needs more examination in the second language. Therefore, in the current research, the researcher tried to clarify the ambiguous aspects of this issue by conducting a research with a systematic meta-analytical approach in a second and/or foreign language (here, English) having the following two questions in mind:

1. Overall, among the experimental research conducted in the last three decades, have the results indicated the existence of a meaningful relationship between the extent of working memory and various aspects of second language learning or not?

2. If there is a significant coefficient, in which second language learning skills as output variables, expansion/recession of working memory span this has been significant?

3. Method

In the current research, the goal of the researcher was to investigate the functioning of learners' working memory in the overall performance of learning and accepting second language data. In this research, the meaning of second language is the non-native language of learners, both second and foreign languages. By referring to the effect coefficients calculated by the data mining software of Systematic Review Analysis (Comprehensive Meta-Analysis (CMA), version 3.3 (2014), the researcher tried to determine the interactive effect of the level of working memory recall of learners on the performance of writing skills, including reading and writing in their non-native language.

Selection of the Articles

Researches were selected from both types of correlation and differential designs and within a time interval of 31 years from 1990 to 2021. At first, using reliable local (Noormags) and foreign databases (Science Direct & Sage) and a total of 71 articles in the target area of this research and citing

keywords including *working memory*, *working memory Span* (WMS), *Memory Span*, *Working memory*, *Language skills*, *Language learning* and search was finally done in both English and Farsi languages. All articles obtained in each database based on the filtering of the main keyword - working memory - and the aspects of second and foreign language learning, respectively, including Noormags and in the fields of Literature and Languages (1922), Magiran initially without subject filter (61488) and then the text review and finding related sources, Science Direct in the field of Arts and Humanities (629), and in the field of Arts and Humanities and Social Sciences in the Sage database (44632) and by referring to an overview of the extracted abstracts and the titles according to the inclusion and exclusion criteria, articles were classified and finally 71 articles were entered in the first stage. During the review of the articles, the emphasis was on the selection of articles published in journals, so conference articles, theses, book reviews, and editor's short articles were excluded, and only one article printed from the conference booklet was selected.

The criteria for entering the articles into the analysis stage included 1) checking the extent of working memory and in different types of working memory according to Baddeley and Hitch model including visual and auditory working memory, as well as different parts of working memory, including the executive control, the phonological loop,

and visual-spatial sketch board in general performance of foreign or second language learning (English, French, Spanish...) with or without emphasis on one of the four skills of reading and understanding the concepts of listening, writing, reading and speaking, 2) the use of quantitative experimental designs by researchers, including Correlation, regression analysis and examination of the means, including t-test, ANOVA, MANOA, ANCOVA and MANCOA, 3) the use of valid questionnaires in the field of measuring the extent of working memory within learners, including Weksler's questionnaire (1998), etc. 4) allocation of the working memory span variable (effectiveness) as an independent variable, 5) Four language skills including reading, listening, speaking and writing in the second language as a dependent variable, 6) related skills were studied only in language learning areas- the second and foreign languages- so the analysis was not done in the studies that emphasized the first language. 7) the selection of the learners could have been done randomly or purposefully and convenient sampling. Regarding the third criterion - the selection of a valid questionnaire - according to the emphasis of the latest sources, the emphasis of the current systematic review that was conducted on the components of second language learning, this was based on the selection of researches in the method section that relied on information processing indicators including the Weksler

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questionnaire and others, which, in addition to creating uniqueness in the results, it is one of the questionnaires in this field that has many references in the field of second and foreign language.

Codifying the Articles

In order to analyze the inclusion and exclusion criteria of the articles, an expert in the field of psychology and an expert in applied linguistics were also consulted and their opinions were sought and some criteria were removed. In cases where the researchers considered different criteria in addition to the criteria in this research, only parts of the data that were completely consistent with the protocol were determined in the present research. For example, in some researches, in addition to language skills, the effect of working memory on other language variables, including determining language learning strategies, time to start learning a second language, effective bilingualism, accuracy and fluency in the second language, vocabulary acquisition, etc., were examined, which those parts were not included in the final analysis. In some cases, by referring to the reference section of those articles, other similar researches were examined and if the conditions of the seven criteria were met in the current research, a random selection was made in related articles and 5 articles were added to the analysis list in this way. If an article did not meet only one of the seven criteria of the current research, it was excluded from the selection. Table 1 shows the names of articles, authors, type of article, year of publication, indexing database and type of research design used.

Table 1

Describing the Extracted Articles

No.	Database/ Publication Year	Research design	Article Type	Author(s)	Article name
1	Local 2017	Correlational	Journal of Modern Research in English Language Studies	Nabi Karim, M & Naghdi Vand, R	Literal and Inferential Listening Comprehension: The Role of L1 vs. L2 Auditory Working Memory Capacity
	Local 2014	Correlational	Applied Research on	Shahnazari-Dorcheh, M. & Adams, R.	The relationship between

			English language		working memory and L2 reading comprehensio n

2	Local 2017	Differential	Applied Research on English language	Ekaningrum, V., Cahyono, B., Irawati, E.	The Effect of Preview, Question, Read, and Summarize (PQRS) Strategy on Indonesian EFL Students' Writing Ability across Working Memory Capacity Levels
3	Sage, 2019	Correlational	Journal of Learning Disabilities	Toffalini, E., Marsura, M., Garcia, R. B., & Cornoldi, C.	A Cross-Modal Working Memory Binding Span Deficit in Reading Disability
5	Sage, 2021	Correlational	International Journal of Bilingualism	White, M. J.	Phonological working memory and non-verbal complex working memory as predictors

					of future English outcomes in young ELLs
6	Sage, 1990	Correlational	Journal of Learning Disabilities	Lee Swanson, H., Cochran, K. F., & Ewers, C. A.	Can Learning Disabilities Be Determined From Working Memory Performance?
7	SD, 2015	Correlational	Brain & Language	Lum, J. A., Ullman, M. T., & Conti-Ramsden, G.	Verbal declarative memory impairments in specific language impairment are related to working memory deficits
8	SD, 2014	Correlational	Learning and Individual Differences	Vulchanova, M., Foyn, C. H., Nilsen, R. A., & Sigmundsson, H.	Links between phonological memory, first language competence and second 9language competence in 10-year-old children
9	SD, 2013	Correlational	The 9th International Conference on Cognitive Science	Abd Ghani, K., & Gathercole, S. E.	Working memory and study skills: a comparison between dyslexic and

					non-dyslexic adult learners
10	SD, 2016	Correlational	Journal of Applied Research in Memory and Cognition	Macnamara, B. N., & Conway, A. R.	Working Memory Capacity as a Predictor of Simultaneous Language Interpreting Performance
11	SD, 2015	Correlational	Journal of Experimental Child Psychology	Archibald, L. M., Levee, T., & Olino, T.	Attention allocation: Relationships to general working memory or specific language processing
12	SD, 2019	Correlational	Journal of Second Language Writing	Michel, M., Kormos, J., Brunfaut, T., & Ratajczak, M.	The role of working memory in young second language learners' written performances
13	SD, 2019	Correlational	Journal of Second Language Writing	Li, S., & Roshan, S.	The associations between working memory and the effects of four different types of written

					corrective feedback
14	SD, 2021	Correlational	Journal of Second Language Writing	Vasylets, O., & Marín, J.	The effects of working memory and L2 proficiency on L2 writing (1)
15	SD, 2021	Correlational	*	Vasylets, O., & Marín, J.	The effects of working memory and L2 proficiency on L2 writing (2)
16	SD, 2011	Correlational	Learning and Individual Differences	De Abreu, P. M. J. E., Gathercole, S. E., & Martin, R.	Disentangling the relationship between working memory and language: The roles of short-term storage and cognitive control
17	SD, 2021	Correlational	Learning and Individual Differences	Chow, B. W. Y., Mo, J., & Dong, Y.	Roles of reading anxiety and working memory in reading comprehension in English as a second language

18	SD, 2015	Correlational	System	Kadir Kozan a, *, Gülcan Erçetin a, Jennifer C. Richardson	Input modality and working memory: Effects on second language text comprehensio n in a multimedia learning environment
19	SD, 2017	Correlational	System	Medina, A., Callender, A. A., Brantmeier, C., & Schultz, L.	Inserted adjuncts, working memory capacity, and L2 reading
20	SD, 2017		مجله System	Jeongsoon Joh a, Lia Plakans	Working memory in L2 reading comprehensio n: The influence of prior knowledge
21	SD, 2018	Correlational	System	Cho, M.	Task complexity, modality, and working memory in L2 task performance
22	SD, 2021	Mean differences	System	Petrone, C., D'Alessandro, D., & Falk, S.	Working memory differences in prosodic imitation

In cases where the researchers had used different designs including mean difference and correlation, if they matched the criteria in this research, both designs were included in the analysis as study 1 and 2, but in cases where different aspects were focused, the estimation of working memory including the relationship of pseudo words with the same terms(s) or pseudo words separately had a similar result (row 13 above), or different activities were considered by the researcher (row 12 above), only the first row of the aforementioned research was included in the data analysis, and in cases where it was different, it was included in the analysis as the name of author but specified as 1 and 2. It should also be noted that in some articles, there were two types of tests including immediate and delayed, which in these cases, data were included in the analysis models to eliminate the possible effect of recalling the test result with a delay (rows 10 and 13). In the evaluation of different aspects of writing skills, some authors, for example (row 14), had examined the role of working memory in separate sections including syntactic and lexical complexity, which in case of having a different result in terms of significance level,

in the form of study 1 and 2 were separately entered into the analysis.

Analysis of the Articles

Using the random and fixed model in CMA software, the criterion for determining the efficiency of the effective memory capacity in this research was the significant impact coefficient according to the software calculation. An output variable including language skills was also included in the analysis equations. Publication bias was also examined by software-generated funnel plots and regression models. Data heterogeneity was also controlled by Cronbach Q test (Hedges & Olkin, 1985).

Descriptive Statistics of the Articles

The total number of 22 articles out of 71 related articles as obtained from reliable databases were finally included in the present review analysis. Among the articles, 20 used correlation designs and only two had used mean comparison designs. The total number of participants included 1466 men and women and in different age ranges from children to adults (Mean age range: 31 years).

Publication Bias

In order to reduce the publication bias in the extracted articles, the dispersion index was calculated using the funnel diagram drawn by the software.

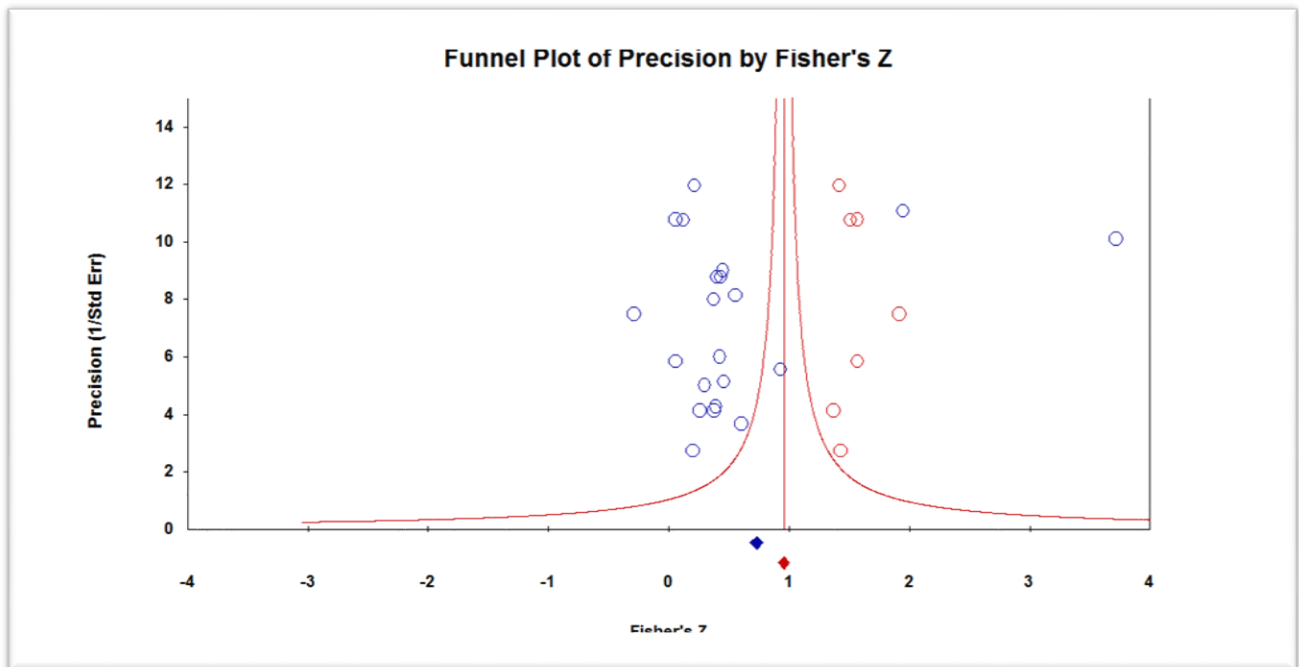Figure 1 below shows the relevant funnel diagram:

Figure 1 Funnel diagram for article publication bias

In the present research, Dual and Tweedy statistical index were used to calculate the publication bias. Table 2 below shows the results of this survey.

Table 2

The results of Dual and Tweedy methods

Q value	Random Effects	Excluded Studies	
1353.230	9.519		right side) Observed Values (
1597./799	0.673	7	(right side) Justified Values
1353.230	0.519	0	(left side) Observed Values
1353.230	0.519	0	(left side) Justified Values

According to table 2, the influence coefficient with 95% confidence for the combined studies on the left side was equal to 0.519 (0.109-0.777) unchanged, but on the right side, the average calculated value of the coefficient (0.673) was slightly different from each other based on the random model

of the data. (0.420-0.829); But according to the funnel diagram, since the impact factor of the reviewed and non-reviewed studies were almost equal, it could be concluded that the existence of the error of diffusion distortion was either non-existent or very low. Also, the results of the statistics (fail-safe N) calculated

by the software were also cited to ensure and check the datasets more closely (Table 3).

Table 3

Classic fail-safe N Results

21.67123	Standard scores in observed studies
0.000	Significance level in the observed studies
0.05	Alpha
1.95996	Standard scores for alpha
21	The number of observed studies
2547	number of missing studies

According to table 3 above, in order to change the effect coefficients obtained in this research, 2547 other studies should have been included in the analysis to change the calculated overall coefficient. However, according to the table, it could be concluded that due to the high number of calculated articles (2547), the existence of publication bias error in this review was almost ruled out, so to report the results, the overall impact coefficient was analyzed in the rest of the results.

4. Results

At first, the first output of the software was extracted regarding the overall effect coefficient in two fixed and random models (Table 4).

Table 4

Overview of Data and Impact Factors per Article and Overall

Standard error	Variance	Upper limit	Hedges's g	Lower limit	Model	Study name	Z-Value	p-Value	Hedges's g and 95% CI	Weight (Fixed) Relative weight	Weight (Random) Relative weight
0.17	0.03	0.76	0.43	0.09		Caterina202	2.51	0.01		14.65	5.56
0.18	0.03	0.48	0.12	-0.24		Pascale201	0.65	0.52		12.43	5.53
0.19	0.03	0.60	0.24	-0.13		Jarrad2015	1.28	0.20		12.29	5.53
0.24	0.06	1.39	0.92	0.44		Mila2014	3.78	0.00		7.22	5.41
0.24	0.06	1.29	0.81	0.34		Nabi	3.33	0.00		7.13	5.41
0.25	0.06	1.38	0.89	0.41		Jeongsoon2	3.60	0.00		6.94	5.40
0.26	0.07	1.27	0.75	0.23		Enrico2018	2.84	0.00		6.10	5.36
0.27	0.08	-0.04	-0.58	-1.11		Olega 2	-2.10	0.04		5.63	5.33
0.28	0.08	1.71	1.16	0.60		Kartini	4.11	0.00		5.35	5.31
0.34	0.11	0.78	0.12	-0.54		Lisa2015	0.35	0.73		3.76	5.15
0.36	0.13	1.55	0.86	0.16		Minyoung	2.40	0.02		3.35	5.09
0.40	0.16	1.38	0.59	-0.20		Vindy	1.46	0.15		2.61	4.94
0.42	0.18	1.75	0.93	0.10		Almitra2017	2.21	0.03		2.41	4.89
0.48	0.23	1.71	0.77	-0.17		Kadir2015	1.60	0.11		1.85	4.68
0.48	0.23	1.45	0.51	-0.44		Rebeca201	1.05	0.29		1.84	4.67
0.50	0.25	1.72	0.74	-0.24		Shaofeng	1.48	0.14		1.71	4.61
0.51	0.26	3.09	2.09	1.08		Brooke2016	4.06	0.00		1.61	4.56
0.61	0.37	2.41	1.21	0.01		Michelle202	1.98	0.05		1.13	4.20
0.64	0.41	8.04	6.79	5.54		Lee	10.62	0.00		1.04	4.10
0.68	0.46	1.71	0.37	-0.96		Marije2019	0.55	0.58		0.92	3.95
4.06	16.47	48.89	40.94	32.98		Bonnie	10.09	0.00		0.03	0.34
0.07	0.00	0.73	0.61	0.48	Fixed		9.31	0.00			
0.24	0.06	1.53	1.05	0.57	Random		4.32	0.00			

To investigate the first question of the current research, whether the results indicated the existence of a significant relationship between the extent of working memory and various aspects of second language learning at the world level, datasets in table 5 were used.

Table 5

Effect Coefficients in two Random and Fixed Models

	Effect coefficients model in 95% confidence interval							
P-value	**Z-value**	upper bound	lower bound	variance	standard error	impact factor	Number of articles	
0.00	9.31	0.73	0.48	0.00	0.07	0.61	21	Fixed
0.00	4.32	1.53	0.57	0.06	0.24	1.05	21	Rndom

Based on table 5, it could be concluded that working memory was significant at 0.05 and with a high influence coefficient (1.05) with a positive direction in the confidence interval, so it could be concluded that this variable had an effect on learning aspects of learning a second language. The basis of the Cohen's effect coefficient (0.1 weak, 0.3 medium and 0.5 high) was very effective.

As to the second question of the current research, the researcher investigated an output variable using the analysis of subgroup studies in the software. The purpose of this question was to investigate the relationship between the positive effects of working memory on the four skills of

second language learning. To investigate this question, after entering the intermediate variable as an outcome and retrieving the output tables, the tables were extracted. Table 6 shows the effect coefficients model regarding the effect of working memory on four different skills and Table 7 shows the effect coefficients on four skills of second language learning if there was a significant effect coefficient, as intermediate variables, along with the extent/regression of working memory skills. In case the researchers were interested in the field of second language teaching and learning, the results were re-examined.

Table 6

Effect Coefficients in Two Random and Fixed Models Based on the Output of Four Skills

Model	Standard error	Variance	Upper limit	Std diff in means	Lower limit	Group by Outcome	Study name	Z-Value	p-Value	Std Residual		Outcome
	0.50	0.25	1.51	0.53	-0.46	1 reading	Rebeca201	1.05	0.29	-0.60		1 reading
	0.27	0.07	1.28	0.76	0.24	1 reading	Enrico2018	2.84	0.00	-0.44		1 reading
	0.29	0.08	1.73	1.17	0.61	1 reading	Kartini	4.11	0.00	-0.09		1 reading
	0.19	0.03	0.48	0.12	-0.24	1 reading	Pascale201	0.65	0.52	-0.99		1 reading
	4.09	16.71	49.25	41.24	33.23	1 reading	Bonnie	10.09	0.00	9.41		1 reading
	0.51	0.26	1.80	0.81	-0.18	1 reading	Kadir2015	1.60	0.11	-0.37		1 reading
	0.43	0.19	1.80	0.95	0.11	1 reading	Almitra2017	2.21	0.03	-0.26		1 reading
	0.25	0.06	1.39	0.90	0.41	1 reading	Jeongsoon2	3.60	0.00	-0.32		1 reading
Random	0.49	0.24	2.24	1.28	0.32	1 reading		2.61	0.01			
	0.25	0.06	1.30	0.82	0.34	2 listening	Nabi	3.33	0.00			2 listening
Random	0.25	0.06	1.30	0.82	0.34	2 listening		3.33	0.00			
	0.42	0.17	1.43	0.61	-0.21	3 writing	Vindy	1.46	0.15	0.60		3 writing
	0.74	0.55	1.87	0.41	-1.05	3 writing	Marije2019	0.55	0.58	0.21		3 writing
	0.52	0.27	1.79	0.77	-0.25	3 writing	Shaofeng	1.48	0.14	0.77		3 writing
	0.28	0.08	-0.04	-0.58	-1.13	3 writing	Olega 2	-2.10	0.04	-1.43		3 writing
Random	0.39	0.16	0.99	0.22	-0.55	3 writing		0.56	0.57			
	0.17	0.03	0.77	0.43	0.09	4 speaking	Caterina202	2.51	0.01			4 speaking
Random	0.17	0.03	0.77	0.43	0.09	4 speaking		2.51	0.01			
	0.65	0.42	2.55	1.28	0.01	5	Michelle202	1.98	0.05	-0.27		5
	0.65	0.42	8.14	6.87	5.60	5	Lee	10.62	0.00	3.60		5
	0.19	0.04	0.61	0.24	-0.13	5	Jarrad2015	1.28	0.20	-1.10		5
	0.24	0.06	1.41	0.93	0.45	5	Mila2014	3.78	0.00	-0.57		5
	0.53	0.28	3.17	2.14	1.11	5	Brooke2016	4.06	0.00	0.33		5
	0.34	0.12	0.79	0.12	-0.55	5	Lisa2015	0.35	0.73	-1.17		5
	0.36	0.13	1.59	0.87	0.16	5	Minyoung	2.40	0.02	-0.60		5
Random	0.56	0.31	2.77	1.68	0.58	5		3.01	0.00			
Random	0.12	0.02	0.87	0.63	0.38	Overall		5.03	0.00			

Table 7

Effect Coefficients on the Output of Four Skills in the Fixed Model

Effect coefficients model in 95% confidence interval								
P-value	Z-value	Upper limit	Lower limit	Variance	Standard error	Impact factor	Number of articles	Related Skill
0.00	6.06	0.87	0.45	0.01	0.11	0.66	8	Reading
0.93	-0.09	0.38	-0.42	0.04	0.20	-0.02	4	Writing
0.00	3033	1.30	0.34	0.06	0.25	0.82	1	Listening
0.01	2.51	0.77	0.04	0.03	0.17	0.43	1	Speaking
0.00	6.85	1.06	0.59	0.01	0.12	0.82	7	Other language scales
0.00	9.29	0.74	0.48	0.00	0.07	0.61	21	Total

results indicated a significant effect of this variable on the specified learning aspects of a second language (here English). In the second step, by examining a dependent variable here as the output variable, the analysis of the results showed that among the two skills examined in the current research, the role of working memory on the general performance of learners in second language writing was not significant.

In studies with a systematic review approach, it is possible to test the accuracy and validity of previous results to some unknown points in psychological issues and language education (here English) through access to more generalizable results. In a recent study with this approach by Meunier, Boyche, Armendon, Boudin and Ballochi (2022) and on 117 similar studies, it was found that bilingualism is related to the characteristics of working memory in the second language (English), but the existence of such a relationship was less in the first language.

Based on the review research on the role of working memory on aspects of learning a second language, the consensus of various language researchers is that working memory is not a single structure and does not directly fit into the definition of memory, and its role depends on the age of the learners and the type of tests determined as well (Jaffes & Harrington, 2011). Some researchers such as Ingle (2007) consider working memory not a part of the memory system, but an important

Since the number of articles obtained in listening and speaking skills was less than expected, besides 7 articles that had not determined the type of specific skills and only measured various aspects of language scales including semantics, pragmatics, syntax, vocabulary, etc. due to not being fully compliant with the criteria in the second question, they were excluded from the data analysis in this part of the research and only the data of each has been reported. As a result, the analysis of writing skills including reading (comprehension) and writing (production) in a second language, based on Table 7, it could be concluded that working memory at a significance level of less than 0.05 and with a high influence coefficient on reading skills and understanding concepts (0.6) with a positive direction in the 99% confidence interval had a significant effect, but this effect was not significant in writing skills ($0.93 < 0.05$). Therefore, it could be concluded that this variable was not effective on learning aspects of writing in the second language.

5. Discussion and Conclusion

In the current research, the researcher aimed at studying a cognitive variable - working memory span- on some aspects of learning a second language including written skills, through conducting a systematic review based on the articles published in both local and international scientific-research databases and considering 7 specific criteria during the last three decades. The overall

role by using a systematic review with a quantitative comparison of research impact coefficients as well as data analysis in subgroup articles on a second language (here writing skills include reading and writing).

In this review, the effect of working memory recall with reading skills and comprehension skills in the second language was evaluated positively. There are countless researches about such a relationship in the first language, but in the second language, fewer researchers have paid special attention to this aspect. In Sawyer's research (2001; cited in Adams and Shah Nazari Dorcheh, 2014), this issue was analyzed by examining verbal, numerical, and reading skills in the second language among Japanese learners, and the results showed a positive relationship between the variables, which is in line with the present review. Regarding writing skills in the second language, one of the reasons for the inefficiency of higher working memory performance with aspects of writing in the second language can typically be multiple activities to strengthen writing in the second language. For example, in Li and Roshan's (2019) research, which was among the analytical articles in this review, the results showed that short-term memory performance as a predictor variable had a positive role in the use of direct corrective feedback, but the phonological loop and using direct feedbacks have been negatively correlated. In other words, the role of memory as a function of the type of feedback and different parts of working memory could have worked

part of cognition, which has the task of regulating linguistic and non-linguistic information. In some systematic review studies, regarding the issue of bilingualism in terms of the relationship between the extent of working memory as an independent variable and various aspects of learning a second language, the direction of the relationship is reversed and this time assuming the existence of bilingualism in favor of working memory span. Memory was found to be effective in combination with the age factor (Baialistak, Craig & Luke, 2012). This means that with increasing age, the amount of working memory decreases, and for this reason, studies that included different age ranges were used in the present review.

In this regard, some researchers such as Ingo (2014, cited in Rahmati Pasand, Afraz and Razmjo, 1401) believe that based on Overload hypothesis, working memory has a limited capacity and its amount is saturated during the writing process in a person and therefore, it should be with strategies such as creating free space in working memory, and turning ideas into text. In their review of the articles published from 1995 to 2010, Jaffes and colleagues confirmed the fact that in processing sentences, the higher the amount of working memory, the better their performance is due to the ability to activate mind control indicators through attention. Regardless of the reason for this association, this result is similar to the general results of the present review, but the innovation of the present analytic review was to examine this

there is an increasing trend, then it can be expected that the amount of memory expansion has been influenced by skill learning, rather than claiming that the individual's reliance on memory is reduced. In Manochehri, Soleimani and Jafari Gohar's research (2016), the role of working memory in learning simple and complex language structures was noted only in explicit learning environments, and the researchers stated that working memory does not play a role in learning in implicit learning environments, but its effect in explicit learning environments is obvious. In their research, this problem highlighted the role of working memory as a biological factor in foreign language learning compared to the first language; Thus, in learning a skill in a foreign language, unlike when learners implicitly strengthen their skill range in their first language, the role of working memory is revealed because learners should play the roles of self-control by maintaining the role of their working memory when using the language.

In the present meta-analytic review, the role of working memory was positively evaluated among both groups of participants with normal and poor reading ability in second language learning writing skills (Swanson, Cochrane, & Evers*, 2021). As a result, it can be generally claimed that strengthening the domain of this type of memory can improve learning. Another important point is the parallel role of working

differently, in which case other hidden components should be found in the meantime with more detailed analyses and on other learners with different characteristics. To clarify the issue of the relationship between writing skills, the type of desired activity and the type of performance of the memory parts were also measured separately. In this research, since the overall performance of memory was considered, it is still not possible to imagine the non-significant result of the role of memory on writing skills.

In the research by Michael, Krems, Branfat and Ratajczak (2019), the researchers stated that the effect of working memory in writing among children is positive and significant, which can be a guide to determine the role of age as a predictor variable in regression equations in future review research. In another research, regarding the relationship between language skills and working memory, it was found that in the second language, since the learners do not have a complete mastery of the language, they must put more pressure on the working memory, and as the skill increases, the person's reliance on memory decreases (Sarvis, Simola, Mitshaihemno & Mawari , 2002). This point is important from the point of view that it makes the role of working memory more prominent in the initial stages of learning a second language and that over time with the increase in a person's ability to use a language, the amount of memory of a person should be measured regularly and if

age of the people is 31 years. Considering the uneven distribution of age in various researches, it is very difficult to control the issue of age along with other criteria, and on the other hand, in learning second language skills, this variable can be considered in future researches.

Future Studies

In the current research, seven different criteria were highlighted for the inclusion of articles, and in some cases, the inclusion of other variables such as age and gender due to the uneven distribution in various researches was thought to have had a great impact on the number of articles obtained in this area. In order to clarify the issue and gain other hidden truths from this point of view, especially in oral skills, it is suggested that researchers consider this point in the future. In the researches extracted in the present corpus, the results of the researches that were analyzed in the oral aspects of the language with the approach of memory problems were not reported, and the results in some cases indicated that the relationship between the two variables of working memory and the oral aspects of the language was weak (Petron, Alessandro & Falk*, 2021). Of course, this issue can be considered as a predictive variable in learning language skills along with mental functions regarding the categories of the first language, which should be considered by future researchers in prospective review researches.

memory recall in the initial stages of learning a second language, which occurs at a younger age, the load on the mind decreases, and the older a person is, the more necessary interventions are to improve memory performance (White*, 2021).

Limitations in this Meta analysis

In the current research, although the research participants were from people with different age groups and abilities, among learners with specific language disabilities, there is still a concern as to whether learning efficiency can be helped by strengthening working memory in them or not. It is expected that researchers in the future will address the other unclear aspects that have been mentioned in view of the limitations mentioned in the current research. Among other things that should not be overlooked is the type of tests used to measure working memory capacity. Working memory span tests usually measure the amount of stored information with an emphasis on reading the maximum number of words or sentences recalled by the subject, which is different from the way of measuring the duration of recall used as to the more modern tests. Regarding the measurement of this type of memory, the researchers could influence the accuracy of the results since they had used different types of valid tests. Therefore, it is recommended that researchers use other methods in this regard at the same time as performing language activities, such as eye tracking, event-based abilities, and magnetic-functional imaging. In the present analytical review, the average

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