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THE ROLE OF BILINGUALISM ON THE EXECUTIVE FUNCTIONS IN ALGERIAN CHILDREN

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Abstract: Bilingualism is considered one of the most important factors contributing to learning. To enhance understanding of the interaction between languages and cognition, and due to the lack of sufficient evidence in the Algerian context, our study investigates the potential impact of language learning on cognitive performance in the Algerian educational setting. The study aims to examine the role of bilingualism in performing executive function tasks among Algerian schoolchildren. It compares verbal and visuospatial working memory (WM) and inhibition abilities in 25 bilingual learners, 25 second-language learners, and 25 monolinguals aged 8 to 11 years. Intelligence, language proficiency, and socioeconomic status are controlled by selecting individuals with above-average performance on relevant tasks to match all samples. Digit span (forward and backward), visuospatial, and Stroop tasks are administered to assess participants' performance. The study finds that bilingual children and second-language learners outperform monolinguals in executive function tasks (verbal and visuospatial WM and inhibition). In verbal WM, there is a difference—though not statistically significant—in the forward digit span, while a significant difference in the backward digit span favors bilinguals and second-language learners. In visuospatial WM, bilingual children outperform both second-language learners and monolinguals. Regarding inhibition, the results demonstrate the effect of bilingualism, as bilingual children, followed by second-language learners, outperform monolinguals in the visual selective attention task.

In conclusion, bilingualism and second-language learning appear to be positive factors influencing the cognitive abilities of schoolchildren, with the potential to transfer these benefits to other skills. Therefore, language education should be encouraged in educational practices due to its positive contributions.

Keywords: Bilingualism; executive functions; inhibition; second-language learners; verbal working memory; visuospatial working memory; school children

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1. Introduction

Multilingualism is a common societal phenomenon caused by multiculturalism, affecting all institutions, including schools. Stemming from a single society's diversity, contributing to children's education at the most important stage of development. This effect is related to the interaction of children's cognitive development and cultural formation with learning and acquisition. Bilingualism can appear in childhood school, where the child is exposed to two or more languages in education. Algeria is one of the countries that has linguistic diversity with Arabic and Amazigh as the first language, and French and English as the second language. Due to the need to learn languages for effective communication and knowledge acquisition; children desire to learn new languages due to their developmental nature in acquiring, learning, curiosity, and discovering new things. Children are naturally drawn to learning new languages due to their developmental curiosity, and cognitive capacity to acquire and discover knowledge. Language learning is a self-regulatory process that involves awareness, perception, and interpretation of meaning within social interactions. (Vygotsky, 1978; Tomasello, 2003). They are the first to show interest in learning a new language and quickly develop their ability to perform in these languages. This results from the flexibility and development of the cognitive structure and neural plasticity. Many contributions and evidence have emerged in cognitive neuroscience about the interaction of language with cognition. In addition, to investigate the role of bilingualism on cognition and behavior.

The contributions varied across executive functions such as cognitive flexibility, inhibition, WM, and planning. Most theoretical research agrees on four related but separate components: verbal and visuospatial WM, inhibition, cognitive flexibility, and planning. WM is a limited-capacity processing system that receives stimuli, processes them temporarily, and then stores them in long-term memory. According to Baddeley's (1974) model, WM consists of a central component, inhibitory processing, and two subcomponents: verbal and visuospatial processing (Baddeley & Hitch, 1974). The processing mechanism involves receiving stimuli, relaying them to the central attentional processor for further handling, and directing them to either verbal or visuospatial processing. Additionally, they are stored in long-term memory for retrieval when needed to respond to a situation or stimulus (Cowan et al., 2021; Logie, 2022).

Evidence suggests that the effects of bilingualism extend beyond language proficiency and have a positive impact on cognitive functions, particularly executive functions. Bilinguals often outperform their monolingual peers on executive function tasks. The evidence on the impact of bilingualism on executive functions is mixed. However, there is consistent agreement on its positive effect on inhibitory control, with studies showing that bilinguals outperform monolinguals in tasks requiring inhibition and cognitive control. Evidence suggests that bilingualism and ongoing bilingual activity train the skills of control and inhibition in language selection. (Abutalebi & Green, 2007; Kroll, Bobb, and Hoshino, 2014). Bilingualism develops cognitive inhibition, which divides, distributes, and equalizes activation between the two languages. (Bialystok & Craik, 2010; Byers-Heinlein, Burns & Werker, 2010; and Kroll et al., 2012). Learning two languages is a positive factor that contributes to developing brain structure and improving cognitive function. Because of active practice and moving from one language to another. (Bialystok et al., 2004; Costa et al., 2008; Morales, Calvo, and Bialystok, 2013).

This evidence is consistent with the tasks of inhibition, selective attention, and control of visuospatial processing style. Thus, there is an integration of inhibitory and visuospatial tasks. Evidence findings in verbal WM are inconsistent with findings on attentional and visuospatial processes. Some evidence suggests that bilingualism does not affect phonological processing in WM. The performance of bilinguals on verbal WM tasks was equal to or poorer than that of monolinguals. Positive results in which the effect was transferred from attentional and visuospatial control and processing to phonological processing. Some findings of evidence on bilingualism and phonological WM has found a positive role for bilingualism in phonological processing. Bilingual abilities enhanced by the presence of different linguistic representations improve performance on phonological processing and storage tasks. (Mehrani & Zabihi, 2017; Bialystok, 2001; Engle, 2002; Kane, Bleckley & Conway, Engle, 2001), while others (Bonifacci et al., 2011; Engel de Abreau, 2011) found no significant differences in phonological WM capacity between bilinguals and monolinguals. Angel de Abreu (2011) contributed to the assumption regarding the efficiency of WM components and bilingualism. In addition, the experience of language contributes to the training and cognitive control of WM components. Angel de Abreu (2011) found inconsistent results that bilinguals had an advantage in executive control and visual processing abilities, but did not outperform monolinguals in phonological processing compared to monolinguals. On the other hand, there is a less positive result in bilingualism, storage, and phonological processing in WM. Moreover, activating two languages negatively affects the capacity of phonological processing. (Merriënboer & Sweller, 2005; Gollan, Montoya, Cera, & Sandoval, 2008; Bonifacci et al., 2011).

This evidence has provided empirical results for tasks and populations in non-Arab/Algerian settings with different cultural and developmental factors. While the results regarding executive functions are consistent across all evidence, findings related to phonological WM remain unclear. These mixed results suggest that the effect of bilingualism on cognition is neither uniformly positive nor negative. These effects are highly context-dependent and modulated by factors including task complexity, sociolinguistic context, and the nature of the bilingual experience. The variance in the results of phonological WM evidence is considered a research gap that can be investigated in the Algerian context, due to the absence of research investigations and contributions to the effect of bilingualism on executive functions. These mixed results suggest that the impact of bilingualism may vary depending on task demands, language proficiency, or contextual factors. These discrepancies highlight the need for deeper research into how bilingualism relates to executive functions. Specifically, studies must explore how bilingualism interacts with these cognitive processes in multilingual settings. In contexts like Algeria, where linguistic diversity is pronounced, the cognitive demands placed on individuals may differ markedly from those in monolingual environments. Yet, such unique dynamics remain underexplored in existing literature.

The importance and significance of our study appear in the attempt to investigate the interaction between cognition and bilingualism in Algerian schools. Given that, children in Algerian society are exposed to more than one language. In addition, the crucial role of executive functions and bilingualism in learning within Algerian schools is examined. We explore the role of language learning in Algerian children's education and assess its benefits for literacy development and skill acquisition within the school setting.

We investigate how language learning influences Algerian children, focusing on its impact on literacy and skill development in the school setting. Additionally, we attempt to bridge the research gap in the Algerian context regarding the study of bilingualism and executive functions. This involves examining the study variables in a different cultural context compared to the existing literature. Our research also presents a new procedural

perspective on the role of languages in the Algerian environment. Specifically, we explore how these languages influence children's executive function. With the relevance of bilingualism in Algeria as a unique and normative phenomenon given the linguistic and cultural context of Arabic, Amazigh, French, and English. In addition, the potential cognitive and educational effects of these languages in the educational context.

This study aimed to investigate the role of bilingualism and learning L2 on the performance of executive function tasks. Our study contributes to the role of language learning on cognition, and the interaction between them in the potential effect of language exposure on cognition in phonological, visuospatial, and attentional processing. The inconsistency in some findings and the study variables in different cultural settings and contexts leads us to question whether learning a second language and bilingualism may affect executive functions in schoolchildren.

Research question:

1. Are there statistically significant differences between monolinguals, bilinguals, and second language learners in performance on the verbal WM task?
2. Are there statistically significant differences between monolinguals, bilinguals, and second language learners in performance on the visuospatial WM task?
3. Are there statistically significant differences between monolinguals, bilinguals, and second language learners in performance on the inhibition task?

Given the lack of evidence in the Algerian context, to avoid bias or presumption, and the need for an objective basis to test the alternative hypothesis related to the effect of bilingualism on executive functions in the context of the literature, we hypothesized the null hypothesis.

Research hypotheses:

There are no statistically significant differences between monolinguals, bilinguals, and second language learners in performance on the verbal WM task.

There are no statistically significant differences between monolinguals, bilinguals, and second language learners in performance on the visuospatial WM task.

There are no statistically significant differences between monolinguals, bilinguals, and second language learners in performance on the inhibition task.

2. Methodology

A quantitative research design was used to address the impact of bilingualism on executive functions and to investigate the study questions related to the differences between monolinguals, bilinguals, and second language learners in executive functions tasks. Data were collected through structured interviews and participant observations to ensure a comprehensive understanding of participants' performance on study tasks using a descriptive and causal-comparative approach between groups. Participant data were analyzed with SPSS using analysis of variance and descriptive statistics to investigate the study hypotheses.

2.1. Participants

Seventy-five children were enrolled from six Algerian primary schools, aged between 8 and 11 years, and from various cultural backgrounds. Participants were divided into 25 monolingual Arabic speakers, 25 bilingual Tamazight Arabic speakers, and 25 bilingual Arabic French speakers. Parental consent was obtained by interviewing them, a language proficiency questionnaire was administered for parents to assess children's language use, and

information was taken about the children, their linguistic situation, and their socioeconomic status and cultural level. Participants were selected based on the criteria: absence of a history of developmental, neurological, or psychological disorders and family problems, excluding cases of low IQ, and learning difficulties.

2.2. Research Instruments

2.2.1. Language proficiency questionnaire

In the questionnaire, parents indicated the child's linguistic background (children's languages according to acquisition and dominance), the age at which language was acquired, the percentage of language proficiency, and what languages the child interacts with parents, siblings, friends, and teachers). The age at which their child starts speaking languages (Arabic, Berber, and French). In addition, there was a section related to information about the cultural level and the socio-economic status of the child's environment and parents, and related to factors of educational and professional level, income, characteristics of the geographical area, and access to resources that affect the quality of life.

2.2.2. Non-verbal intelligence task

Raven's Color Matrices (Raven, 1938) were used, which is a non-verbal test based on a set of shapes and matrices, divided into three parts A, B, A, B.

2.2.3. Verbal WM task

It is a subtest of the WISC 3 battery (Wechsler, 1999); children are given numbers and repeat them sequentially and inversely.

2.2.4. Visualspatial WM

It is a subtest of the WISC-III battery (Wechsler, 1999). It consists of two tasks: digit span forward (DSF) and digit span backward (DSB). Children are visually given lines and asked to redraw or complete the lines as they saw them.

2.2.5. Inhibition

It is a sub-test of the NEPSY 2 battery (Korkman, Kirk, and Kemp, 2007); children select faces similar to the target face from a set of different faces representing false stimuli.

The study tasks have strong psychometric properties, are valid and reliable, and have been repeatedly administered in the Algerian environment.

2.3. Research Procedures

The research process began with visits to primary schools and contact with the children's parents. After obtaining consent, we distributed a language proficiency questionnaire to the parents to assess the children's language background. According to this, we selected the children who would participate in the study tasks. The tasks were administered to each child individually and were designed to assess different cognitive skills. verbal WM task, then visuospatial WM task, and finally inhibition task were administered . The tasks were conducted in controlled conditions within the school, ensuring minimal distraction. To facilitate the process, the teacher and speech and language therapist assisted each child. The teacher ensured the child's comfort and understanding of the instructions, while the speech and language therapist provided support during the more complex tasks and guided the child through the exercises as needed. The session was structured to allow sufficient time for each task, with breaks to maintain focus and engagement. The session was conducted in the morning and the tasks were administered with each child. Each task took less than 10 minutes.

In the methodology, we controlled for intelligence, language experience, and socioeconomic status to ensure that these variables did not confound the results and to isolate the effects of the study tasks and ensure that any observed differences could be attributed to the tasks themselves and not to external factors such as intelligence, language experience, or socioeconomic status. Only children within the above-average IQ range of 80 on the Raven's Matrices were included in the analysis to reduce the influence of cognitive disparities. Children's exposure to and use of language at home and socioeconomic status were assessed. To ensure that children with significantly different language backgrounds and socioeconomic status were not included, children from similar backgrounds were grouped together for the analysis, reducing the potential influence of correlated factors on the results.

It is worth noting the importance of the division between bilinguals (Arabic-Amazigh and Arabic-French) and second language learners from a theoretical point of view in several aspects. The theoretical significance of the distinction between bilinguals (Arabic-Amazigh and Arabic-French) and second language learners lies in several linguistic and cognitive aspects. Bilinguals (Arabic-Amazigh or Arabic-French) often develop in a bilingual environment, where the individual is exposed to both languages from childhood. This is called simultaneous or early bilingualism. Second language learners, on the other hand, acquire the other language at a later age (usually after childhood), which falls under second language acquisition. This difference affects the individual's linguistic cognitive structure.

3. Results

To validate the hypotheses, we conducted a statistical analysis SPSS 23 using one-way ANOVA, where the results of the hypotheses are as follows:

3.1. Verbal WM

As Table 1 shows, there are statistically significant differences in the DSF between monolinguals, bilinguals, and L2 learners; the calculated value of p = 3.84, which is statistically significant at the significance level of 0.026.

Table 1

Descriptive statistics on verbal WM DSF task

Source of variance	Sum of squares	Df	Mean squares	P value	Sig level
between groups	36.82	2	18.41	3.84	0.026
within groups	344.96	72	4.79		
Total	381.78	74			

WM= working memory, DSF= digit span forward

For the binary comparison between the means and to ensure that the differences favored any group, the post-test Tukey method was used, and the results were as follows:

Table 2

Shows the results of the two-way comparisons between groups' means using the Tukey post-test

The group	Groups	Difference in means	Statistical sig
Monolingual	L2 Learners Bilingual	-0.160 -1.560 *	no sig 0.03
L2 Learners	Monolingual Bilingual	0.160 -1.400	no sig no sig
Bilingual	Monolingual L2 Learners	1.560 * 1.400	0.03 no sig

** Significance at level less than 0.05*

Using the post-test Tukey, it was shown that the differences in the means were statistically significant at the significance level of 0.03 only between monolinguals and bilinguals, in favor of bilinguals who have the highest mean of 11.04, as shown in the following table:

Table 3

Shows the differences in the means in the DSF

Groups	Sample	MS	SD
monolingual	25	9.48	2.36
L2 Learners	25	9.64	2.36
Bilingual	25	11.04	1.79

DSF= digit span forward, SD= standard deviation, MS= mean

It can be said that there are statistically significant differences in the DSF between monolinguals, bilinguals, and L2 learners, in favor of bilinguals.

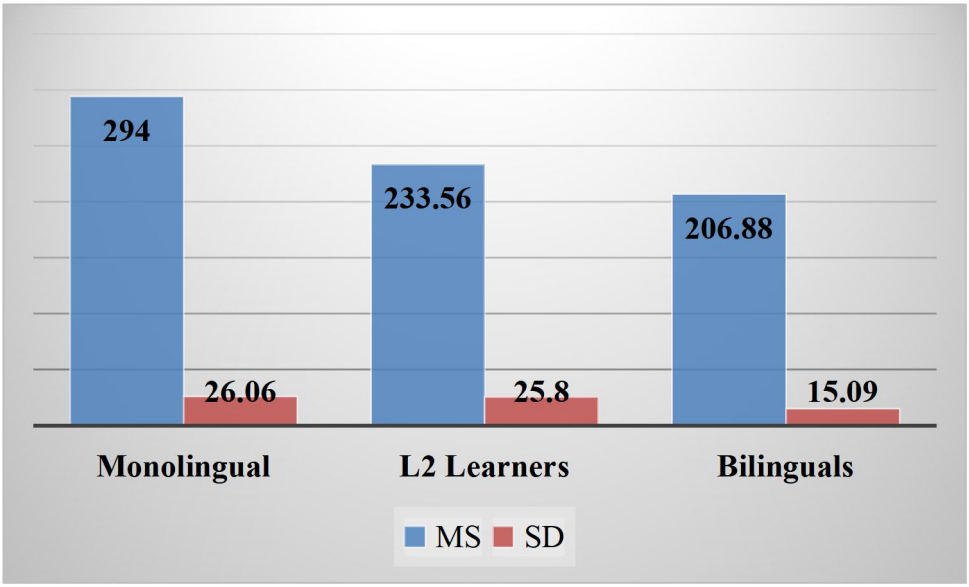

Figure 1

Shows the differences in the means in the DSF task

As Table 4 shows, there are statistically significant differences in the DSB between monolinguals, bilinguals, and L2 Learners. The calculated p value = 29.37, which is statistically significant when the significance level is less than 0.01.

Table 4

Descriptive statistics on verbal WM DSB task shows the differences between monolinguals, bilinguals and L2 Learners

Source of variance	Sum of squares	Df	Mean squares	P value	Sig level
between groups	192.08	2	96.04	29.37	<0.01
within groups	235.44	72	3.27		
Total	427.52	74			

DSB = Digit span backward

For the binary comparison between the means and to ensure that the differences favored any group, the post-test Tukey method was used, and the results were as follows:

Table 5

Shows the results of the two-way comparisons between groups' means using the Tukey post-test

The group	Groups	Difference in means	Statistical sig
Monolingual	L2 Learners	- 3.08	<0.01
	Bilingual	-3.64 *	<0.01
L2 Learners	Monolingual	3.08 *	<0.01
	Bilingual	-0.56	not significant
Bilingual	Monolingual	3.64*	<0.01
	L2 Learners	0.56	not significant

** Significance at level less than 0.01*

The binary comparison between the groups' means using the post-test Tukey showed that differences in averages were statistically significant at a level of less than 0.01 In favor of bilinguals and second language learners over monolinguals. The means in the three groups as shown in the following table:

Table 6

Shows the differences in the means in the DSB

Groups	Sample	MS	SD
Monolingual	25	6.68	1.52
L2 Learners	25	9.76	1.87
Bilingual	25	10.32	1.99

It was the largest mean for bilinguals, which was estimated at 10.32, followed by the means of L2 learners, which reached 9.76, and last was the smallest mean for monolinguals, which was estimated at 6.68. It can be said that there are statistically significant differences in the DSB between monolinguals, bilinguals, and L2 learners in favor of bilinguals and L2 learners.

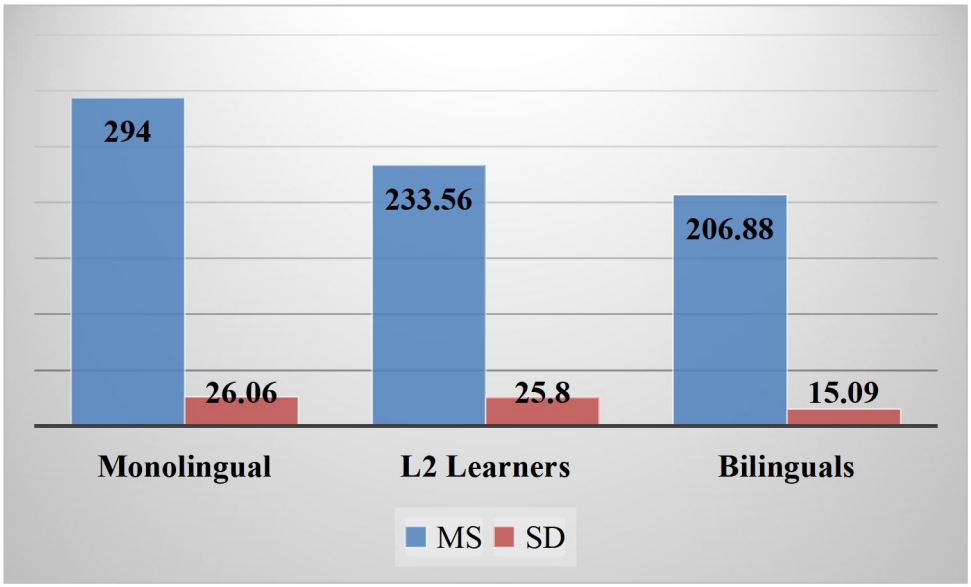

Figure 2

Shows the differences in the means in the DSB task

3.2. Visuospatial WM

As Table 7 shows, there are statistically significant differences in visuospatial WM between monolinguals, bilinguals, and L2 Learners. The calculated p-value = 5.33, which is statistically significant at the significance level less than 0.01.

Table 7

Descriptive statistics on visuospatial WM task shows the differences between monolinguals, bilinguals and L2 Learners

Source of variance	Sum of squares	Df	Mean squares	P value	Sig level
between groups	36.82	2	18.41	5.33	<0.01
within groups	248.32	72	3.44		
Total	284.14	74			

For the binary comparison between the means and to ensure that the differences favored any group, the post-test Tukey method was used, and the results were as follows:

Table 8

Shows the results of the two-way comparisons between groups' means using the Tukey post-test

The group	Groups	Difference in mean	Statistical significance
Monolingual	L2 Learners	0.16	no sig
	Bilingual	-1.40 *	< 0.05
L2 Learners	Monolingual	0.16	no sig
	Bilingual	-1.56 *	< 0.05
Bilıngual	Monolıngual	1,4 *	< 0,,05
	L2 Leaĥners	-1,56 *	< 0,,05

** Significance less than 0.05*

The binary comparison between groups' means using the post-test Tukey showed that the differences in the means were statistically significant at the significance level of less than 0.05 between monolinguals and bilinguals in favor of bilinguals, and between L2 Learners and bilinguals in favor of bilinguals. The means in the three groups as shown in the following table:

Table 9

Shows the differences in the means in the. visuospatial WM task

Groups	Sample	MS	SD
Monolingual	25	14.36	0.43
L2 Learners	25	14.20	0.27
Bilingual	25	15.76	3.38

It was the largest mean among bilinguals, which was estimated at 15.76, then followed by both the means of monolinguals and L2 Learners, who reached approximately equal values, which are 14.36 and 14.20. It can be said that there are statistically significant differences in visuospatial WM between monolinguals, bilinguals, and L2 Learners, and this is in favor of bilinguals.

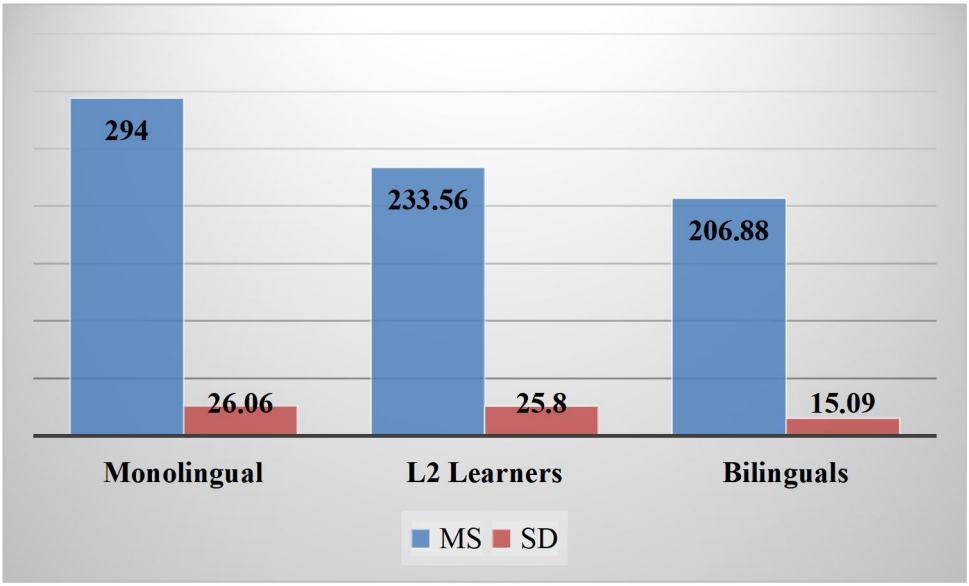

Figure 3

Shows the differences in the means in the visuospatial WM task

3.3. Inhibition

Accuracy:

As Table 10 shows, there are statistically significant differences in visual selective attention accuracy between monolinguals, bilinguals, and L2 Learners. The calculated p-value = 160.06, which is statistically significant at the significance level less than 0.01.

Table 10

Descriptive statistics on Accuracy of visual selective attention task shows the differences between monolinguals, bilinguals and L2 Learners

Source of variance	Sum of squares	Df	Mean squares	P value	Significance level
between groups	192.08	2	96.04	9.37	< 0.01
within groups	235.44	72	3.27		
Total	427.52	74			

For the binary comparison between the means and to ensure that the differences favored any group, the post-test Tukey method was used, and the results were as follows:

Table 11

Shows the results of the two-way comparisons between groups' means using theTukey post-test

The group	Groups	Difference in means	Statistical significance
Monolingual	L2 Learners	- 9.24 *	< 0.01
	Bilingual	-14.88 *	< 0.01
L2 Learners	Monolingual	- 9.24 *	< 0.01
	Bilingual	- 5.64 *	< 0.01
Bilingual	Monolingual	-14.88 *	< 0.01
	L2 Learners	- 5.64 *	< 0.01

** Significance at level less than 0.01*

It showed that the differences in the means were statistically significant at a level of less than 0.01 between monolinguals and L2 learners in favor of L2 in the accuracy of visual selective attention, and both monolinguals and bilinguals in favor of bilinguals. In addition, L2 learners in the accuracy of visual selective attention in favor of bilinguals.

Table 12

Shows the differences in the means in the. Accuracy of visual selective attention task

Groups	Sample	MS	SD
Monolingual	25	22.64	3.09
L2 Learners	25	31.88	3.46
Bilingual	25	37.52	2.20

The highest mean was for bilinguals, which was estimated at 37.52, followed by the mean for the L2 Learners, which was estimated at 31.88, and then the monolinguals with a mean of 22.64. From it, it can be said that there are statistically significant differences in the accuracy of visual selective attention between monolinguals, bilinguals, and L2 Learners, and this is in favor of bilinguals, then L2 Learners, and then monolinguals.

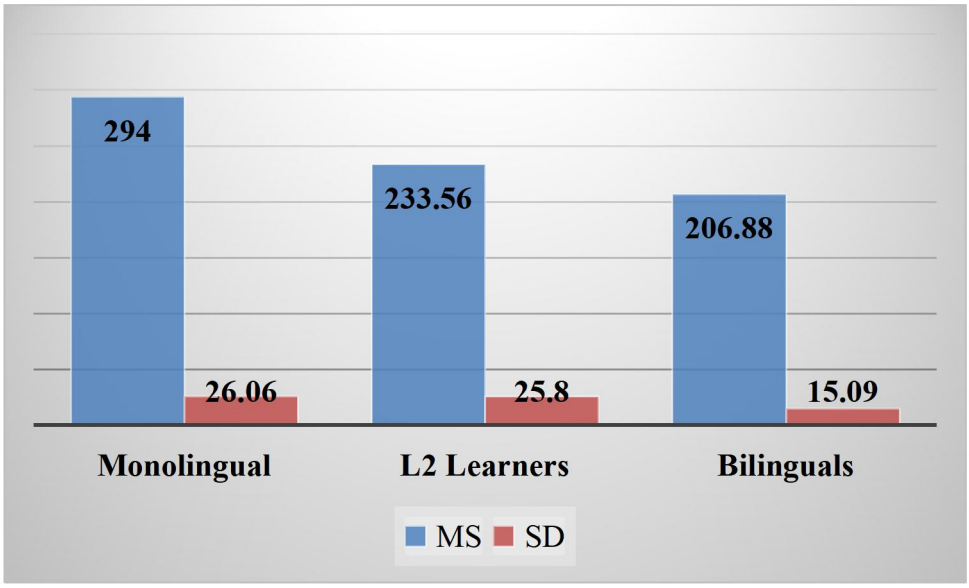

Figure 4

Shows the differences in the means in the accuracy of visual selective attention task Time:

As Table 13 shows, there are statistically significant differences in the time of visual attention between monolinguals, bilinguals, and L2 Learners. The calculated p-value = 95.00, which is statistically significant at the significance level less than 0.01.

Table 13

Descriptive statistics on Time of visual selective attention task shows the differences between monolinguals, bilinguals and L2 Learners

Source of variance	Sum of squares	Df	Mean squares	P value	Significance level
between groups	99622.58	2	49811.29	95.00	< 0.01
within groups	37748.80	72	524.28		
Total	137371.38	74			

For the binary comparison between means and make sure that the differences were in favor of any group, the post-test Tukey was used, and the results were as follows:

Table 14

Shows the results of the two-way comparisons between groups' means using the Tukey post-test

The group	Groups	Difference in means	Statistical significance
Monolingual	L2 Learners	60.44 *	< 0.05
	Bilingual	78.12 *	< 0.05
L2 Learners	Monolingual	- 60.44*	< 0.05
	Bilingual	26.68 *	< 0.05
Bilingual	Monolingual	- 87.12 *	< 0,05
	L2 Learners	- 26.68 *	< 0.05

**significant at a level of less than 0,05*

The differences in means in visual selective attention time were statistically significant at a level of less than 0,05 between monolinguals and L2 learners in favor of L2 learners, monolinguals and bilinguals in favor of L2 learners, and both monolinguals and L2 learners. Moreover, bilinguals were fastest, then L2 learners, then monolinguals.

Table 15

Shows the differences in the means in the. Accuracy of visual selective attention task

Groups	Sample	MS	SD
Monolingual	25	294.00	26.06
L2 Learners	25	233.56	25.80
Bilingual	25	206.88	15.09

It was the lowest average for bilinguals, estimated at 206.88 seconds, followed by the mean of L2 learners with 233.56 seconds, and then the monolinguals with 294.00 seconds. We conclude that there are statistically significant differences in the time of visual selective attention between monolinguals, bilinguals, and L2 learners, this is in favor of bilinguals, then both L2 learners and monolinguals.

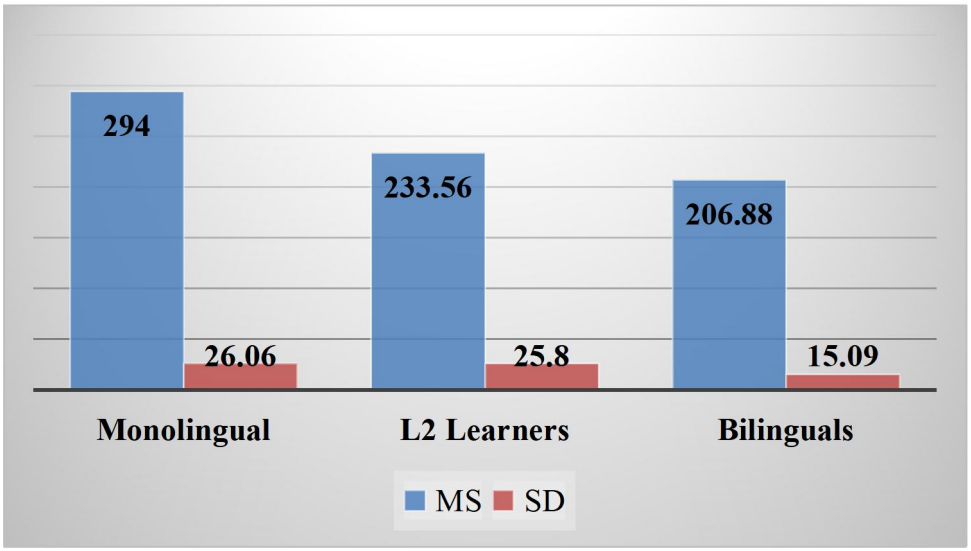

Figure 5

Shows the differences in the means in the accuracy of visual selective attention task

4. Discussion

This study aimed to examine the impact of bilingualism on children's performance on executive function tasks, including verbal WM, visuospatial WM, and inhibition. Statistical analyses revealed performance advantages for both bilinguals and second language learners compared to monolinguals, particularly on tasks requiring high-level cognitive control and attentional processing.

In verbal WM, bilinguals performed better than L2 learners and monolinguals in DSF & DSB tasks; especially in the DSB task, where bilingual children and L2 learners outperform monolinguals, the task requires greater attentional resources and executive control than the digit-forward span task. The verbal WM task involved repeating verbal stimuli in a sequential forward and backward manner and required storing, processing, and retrieving strings of numbers. These tasks involved phonological processing of verbal stimuli, with attentional control playing an essential role in focusing attention to store and retrieve the stimuli.

The statistical treatment showed that bilingual children and second language learners, respectively, outperformed monolingual children in performance on study tasks. Referring to the differences in the means and the statistical data between monolinguals (MS= 9.48, SD= 2.36), bilinguals (MS= 11.04, SD= 1.79), and second language learners (MS= 9.64, SD= 2.36) on the DSF task that requires storage, there was not a strong difference. This is consistent with the less positive results in phonological WM and evidence (Bonifacci et al., 2011; Engel de Abreau, 2011) that found no significant differences in phonological WM capacity between bilinguals and monolinguals. In the DSB task, which involves storage and processing, there is a clear difference in favor of bilinguals (MS = 10.32, SD = 1.99) and then second language learners (MS = 9.76, SD = 1.87), monolinguals (MS = 6.68, SD = 1.52), especially in the backward digit span, which requires cognitive effort and high concentration. This result is consistent with the idea of the positive effect of bilingualism on tasks that require high attention and concentration, and because of different linguistic representations, in addition to the transfer of the effect of inhibition and attentional and visuospatial skills, since the task includes numbers that the child processes visually and tries to remember. (Mehrani & Zabihi, 2017; Bialystok, 2001; Engle, 2002; Kane, Bleckley, Conway, Engle, 2001). This is consistent with evidence demonstrating the positive effects of bilingual experience and second-language learning.

In tasks involving attentional control, bilinguals perform better on WM tasks. Some evidence suggests that bilingualism enhances the processing and storage of stimuli in WM. Brain imaging and neural activity evidence from cognitive neuroscience suggest a positive effect of bilingualism, and language learning on cognitive tasks involving phonological processing. Brain activity recordings indicate that bilingualism provides greater processing capacity for completing tasks requiring higher cognitive demands (Bialystok et al., 2004; Morales, Calvo, & Bialystok, 2013; Luo et al., 2013; Abutalebi et al., 2012). Although the results support the positive effect of bilingualism on phonological WM tasks involving attentional processing, they should be interpreted without generalization. Socioeconomic status, educational environment, or familiarity with cognitive tasks may have contributed to differences in performance. Indeed, individual differences, specific spoken languages, age of acquisition, and proficiency levels may all influence the extent of cognitive benefits. These findings should be viewed in a broader context. Future studies should consider potential confounding factors such as socioeconomic status, cultural background, and previous exposure to tasks. They should also explore variation between groups of second language learners and bilinguals to better understand the mechanisms underlying any observed cognitive benefits.

In visuospatial WM, bilinguals performed better than L2 learners and monolinguals on a visuospatial WM task, with bilinguals outperforming L2 learners and monolinguals. The task required attentional resources, executive control, and spatial reasoning. The visuospatial WM task involved repeating visual stimuli or completing a figure drawing and required storing, processing, and retrieving sequences of shapes and lines. These tasks involved visual attentional processing of visuospatial stimuli, with attentional control playing a role in focusing attention to store and retrieve stimuli. Statistical treatment showed that bilinguals outperformed L2 learners and monolinguals on the study task.

Based on the differences in means and statistical data between bilinguals (MS= 15.76, SD= 3.83), second language learners (MS= 14.20, SD = 0.27), and monolinguals (MS= 14.36, SD= 0.43) in the lines and shapes task that requires visual and attentional storage and processing, there was a significant difference in favor of bilinguals. This means that the performance of monolinguals and second language learners was consistent, unlike bilinguals, whose performance varied from that of monolinguals and second language learners. This result aligns with the idea that bilingualism positively influences executive functions. Specifically, it suggests that executive functions can improve in one context through the transfer of cognitive control, with inhibition being the most influential factor. The task in this study involved visual stimuli, such as shapes and lines, which the child processes and remembers. This requires the use of visuospatial attentional skills, which are part of executive functions, to process and store visuospatial information.

Several explanations exist for the superiority of bilinguals in visuospatial WM, supported by evidence highlighting the role of attentional control and executive control in enhancing visuospatial processing and storage. Paap and Greenberg (2013) discuss how bilingualism improves these cognitive abilities. Additionally, Bialystok (2001) proposed that bilingualism enhances the ability to process, store, and retrieve visuospatial stimuli. Another key factor is cognitive flexibility, a comprehensive executive function that bilingualism helps strengthen. Dijkstra et al. (2017) suggested that cognitive flexibility contributes to the more efficient storage and processing of visuospatial stimuli. Furthermore, Morales et al. (2013) found that visuospatial attention enhances the efficiency of processing visuospatial stimuli. Alternative explanations should be considered, including differences in language proficiency, age of acquisition, frequency of language switching, and the influence of family cultural and socioeconomic background. Cultural or educational differences in how visuospatial skills are practiced or taught may also have contributed to the performance differences. Bilingual children may be more exposed to stimuli that promote diverse forms of cognitive stimulation or problem-solving strategies, regardless of their language experience per see. Furthermore, the similar performance of monolinguals and second-language learners suggests that mere exposure to a second language without frequent active use or sufficient proficiency may not be enough to yield measurable cognitive benefits.

Although the results point to a potential bilingual advantage in visuospatial WM, it is important to consider the impact of uncontrolled variables in this study. Future research should aim to control for mediating factors that influence both bilingualism and cognitive performance. Greater emphasis should be placed on adopting a critical perspective, interpreting the findings within a broader context, and exercising caution when generalizing the results.

In inhibition, bilinguals performed better than second language learners, and monolinguals and second language learners performed better than monolinguals on visual selective attention task. Bilinguals performed more accurately and faster in inhibiting unrelated stimuli and selecting the target stimulus, then second language learners and finally

monolinguals. Selective attention task requires executive attentional and visual processing under accuracy and speed for visually similar stimuli. Task performance involves high attentional accuracy, cognitive control, and speed of stimuli processing. Statistical treatment showed that bilingual children and second language learners, respectively, outperformed monolingual children in performance on visual selective attention tasks, with bilinguals performing better. The differences in means and statistical data between bilinguals (Accuracy: MS= 37.52, SD= 2.20; Time: MS= 37.52, SD= 2.20), second language learners (Accuracy: MS= 31.88, SD= 3.46; Time: MS= 206.88, SD= 15.09), and monolinguals (Accuracy: MS= 22.64, SD= 3.09; Time: MS= 294.00, SD= 26.06) in the accuracy and speed of the selective attention task showed a significant difference in favor of bilinguals, and better performance for second language learners than monolinguals. These results are consistent with the positive findings of bilingualism's advantages over inhibition.

Most evidence reported that bilinguals have an advantage over executive attention tasks. The positive role of bilingual activation in bilingualism and training control and inhibition skills. (Kroll, Bobb, and Hoshino; 2014). Distribution and balance of attentional processing capacity between two languages. (Bialystok & Craik, 2010; Byers-Heinlein, Burns, & Werker, 2010; and Kroll et al. 2012). Bilingualism enhances brain network development, executive function, and cognitive control training due to bilingual activation and language-to-language switching. (Morales, Calvo, and Bialystok; 2013). Both the inhibition and visuospatial WM tasks involved visual processing and visual selection to process the stimuli and required focused attentional processing to complete the task. This is what gave bilinguals an advantage and superiority due to their enhanced visual attentional abilities and better inhibition than monolinguals. This is a result of controlling the conflict between the two languages activating one language and ignoring the other while speaking at the same time. furthermore, Bilinguals' experience in managing two languages that compete for selection leads to greater WM capacity over time, according to a meta-analysis by Grundy and Timmer (2017), indicating that rivalry across languages increases WM capacity over time. Thus, cognitive processing of linguistic interference in the social context includes the intervention of cognitive resources in WM. This ensures that WM develops processing over time and uses the two languages through switching and shifting.

These findings support the idea that bilingualism influences the development of attention and cognition across different sociolinguistic settings. The specific nature of the linguistic reality in Algeria has a unique impact on cognitive development compared to other regions due to the presence of a set of factors related to languages on the social and cultural side from an evolutionary perspective. Given the existence of oral and written linguistic diversity in classical Arabic, Arabic dialect, Berber and its varieties, French and English, this provides a wide linguistic transfer, exchanges, and linguistic interactions. Exposure to more than one language and constant switching between languages according to the social and educational context enhances the cognitive effects and confirms their implications. Continuous exposure to Arabic, French, and English, orally and in writing, and the constant change in the Algerian educational setting enhances the cognitive and linguistic flexibility and executive functions of the Algerian child. Exposure to different written texts such as Arabic and Latin enhances visual attentional and phonological processing and is evident in literacy skills such as reading and writing. In addition, it enhances linguistic representations, metalinguistic awareness, awareness of language structures, and symbolic and logical thinking. This linguistic diversity used in the social and educational context ensures lexical richness, reinforcement of executive functions, and efficiency of cognitive processing capacity phonologically, visually, and attentional. Switching between the Arabic and Latin

alphabets enhances visuospatial processing, and spoken language enhances phonological processing.

Unlike bilingual contexts in foreign countries where two languages often share structural similarities (e.g., English and French), Algerian bilingualism spans diverse language families (Semitic, Berber, Romance) and involves spoken and formal varieties of the same language (Dialect vs. Standard Arabic). This requires higher levels of cognitive flexibility and sustained attentional engagement, shaping cognitive development in uniquely challenging ways. This context and linguistic diversity are challenges for Algerian children and cognitive training that contribute to improving cognitive processing, but they are negative factors if they do not conform to the developmental standards of children.

From our findings and with the advantage of the experience of second language learning in visuospatial and executive and verbal WM, and with the advantage of bilingualism in inhibition, suppression, shifting, and switching from one language to another, we support the hypothesis of the contribution of the executive component and the transfer of influence to the two sub-components. Through this, it becomes clear to us the role of language learning, especially in childhood, with the effective and positive influence and role in cognitive abilities and the positive interaction between language and cognitive functioning, and each aspect is complementary to the other. On the other hand, the advantage of bilingualism was less pronounced in phonological WM compared to visuospatial WM and inhibition. This may be due to linguistic stimuli, which may be affected by linguistic competence, phonological processing, and phonological fluency deficits. In addition, the cognitive load in phonological processing of the two languages may affect performance in phonological WM.

5. Conclusion

This research focuses on the advantage of bilingualism and second language learning on cognitive abilities in schoolchildren in Algeria. The results of the study showed that bilinguals and second language learners outperformed monolinguals in executive function tasks. The findings indicated that bilingualism enhances performance in verbal WM tasks, visual spatiality, and inhibition. These findings can be interpreted in the context of active cognitive training resulting from switching between languages and transferring skills between executive functions, and that cognitive flexibility and inhibition direct executive functions. The linguistic diversity and frequent switching between distinct languages, both orally and orthographically, play a positive role in enhancing the executive functions of Algerian children.

The implications of the study suggest that bilingual education can improve children's cognitive functions, especially in linguistically diverse populations. The advantage of bilingualism on cognitive functions supports bilingual and multilingual education in Algerian schools to enhance cognitive and educational outcomes and design educational curricula that support language learning. Training teachers on effective bilingual learning strategies, understanding the cognitive advantages associated with linguistic diversity, and providing resources and support for second language learners. This study had several limitations, including a small sample size and limited demographic representation. The absence of a longitudinal design restricted analysis of changes over time, age, and language proficiency. Additionally, the selected tasks may not have been optimal, and the inability to fully control for language proficiency may have affected the statistical outcomes.

The topic of bilingualism and cognitive abilities requires further research and exploration within the Algerian context. Examining the relationship between linguistic diversity and cognitive development across different age groups and regions in Algeria can

lead to deeper understanding and the identification of best educational practices. The study recommends promoting bilingual education, integrating early language learning, training teachers on bilingualism, supporting second-language learners, and bilingual teacher training programs, early intervention language programs, and curriculum revisions, and encouraging the use of the mother tongue. Additionally, fostering multilingual settings at home by incorporating different languages in daily interactions can further enhance children's cognitive development.

Limitations

The sample size was relatively small, which may limit the ability to generalize the results to larger populations or diverse demographic groups. Additionally, the cross-sectional design of the study prevents concluding cause-and-effect relationships between bilingualism and cognitive performance. The study also relied on a limited set of tasks (digit span, Stroop, and visuospatial tasks) to assess executive functions. These tasks may not fully capture the range of executive functions or WM abilities, and using different tasks could yield varying results. Lastly, the study did not measure language proficiency with a standardized test, meaning differences in proficiency levels could have influenced the performance of bilingual and second-language learners. Future research should address these limitations by using longitudinal designs, expanding sample diversity, incorporating standardized measures of language proficiency to better understand the long-term cognitive impact of bilingualism, and including standardized tests in assessment.

Recommendations

Increasing Sample Size and Diversity

Future studies should include larger and more diverse samples to enhance the generalizability of findings across different age groups, socioeconomic backgrounds, and linguistic environments in Algeria.

Longitudinal Studies and Designs

Conducting longitudinal studies to better investigate the causal relationships between bilingualism and the development of executive functions over time allows for a more accurate assessment of the long-term cognitive effects of bilingualism.

Incorporating Standardized Measures of Language Proficiency

Using standardized and reliable assessments of language proficiency to control for variability in language proficiency and its potential impact on cognitive performance ensures a clearer interpretation of the effects of bilingualism.

Expanding the Study to Other Cognitive Domains

Future research could explore how bilingualism affects other cognitive domains, such as problem-solving, cognitive flexibility, and planning, to assess potential transfer effects beyond working memory and attentional control.

Controlling Sociocultural Factors

Investigating the impact of cultural and educational level, socioeconomicstatus, and native language environment on the cognitive advantages of bilingualism, as these contextual factors may modify the observed effects among Algerian schoolchildren.

Ethical Statements

Ethical Approval: This study received institutional approval from the University of Blida 2 and the Directorate of Education and Schools.

Informed Consent: Written informed consent was obtained from all parents of the participants.

Confidentiality: All data was anonymized and handled with strict confidentiality to protect the privacy of the participants.

AI statement

Artificial intelligence tools were carefully used to improve clarity, correct grammatical errors, enhance language and writing fluency, proofread, and rewrite, under the author's supervision. All scientific content, study design, data analysis, interpretation, and study conclusions were carried out solely by the authors.

Conflict of interest

The authors declare that they have no conflict of interest.

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