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Impact of Trilingual Efficiency on the Working Memory and Inhibitory Control in Undergraduates: A Case Study of Pakistan

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ABSTRACT

In recent years, the phenomenon of multilingualism has spread throughout the world. Pakistan offers an intriguing picture of multilingualism, yet little research has been done in this domain. The previous body of research in the multilingualism and cognition domain had produced inconsistent findings. This study aimed to investigate the positive impact of multilingualism on executive functions of inhibitory control and working memory in undergraduate students. Twenty participants were hired from a call center organization. A language history questionnaire (LHQ3) was administered along with the Simon and Corsi experimental tasks to measure inhibition and working memory. A simple linear regression analysis was run to find the impact of multilingualism. The data findings showed no impact of multilingualism on inhibitory control and working memory. The results showed insufficient statistical evidence to prove the multilingual advantage. Moreover, the results also projected the involvement of multiple confounding variables that may be the principal reason for inconsistent findings in this field of research. Hence, the bilingual advantage hypothesis is rejected because the findings could not predict the generalizability of the positive effect of multilingualism on the executive functions in the larger population of undergraduates. The study suggests that a multiple hierarchical regression model may be more productive, including multiple confounding variables.

Keywords: Memory; Inhibition Control; Multilingualism; Psychoanalysis

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1. Introduction

The research on multilingualism and cognition postulates the question for the present study: what potential impact may multilingualism have on the working memory and inhibitory control of young adults in the Pakistani context? The first hypothesis is based on the widespread notion that multilingualism favours executive functions, i.e., bilingual executive advantage, BEA^[1, 2]. In line with this, a hypothesis can be posited for the present study that the greater the number of spoken languages, the more significant the positive impact on inhibition control. Furthermore, a second hypothesis can be posited that the greater the number of spoken languages, the more significant the positive impact on working memory. The hypotheses are based on the findings that linguistic diversity is responsible for better working memory and inhibitory control because proficient multilingual speakers excessively manage and inhibit numerous irrelevant linguistic items for the production and retrieval of relevant items^[3-5].

The developmental trends of executive control functions suggest that the development of executive functions in children initiates from early childhood and reaches maturity till late adolescence; however, in some instances, inhibition, working memory, and cognitive flexibility may continue to improve during young adulthood^[6-10]. The trend in inhibitory control and working memory capacity showed improvement until age 35 and 30, respectively. Thus, the abovementioned trends in executive functions present an appropriate foundation for the present study to analyze the impact of multilingualism on inhibition control and working memory capacity in young adults between the ages of 18 to 25.

Multilingualism is a dynamic process in which a language user has command over more than two languages^[11]. So in a multilingual brain, numerous languages are operational at any given instant; therefore, a multilingual performs two primary executive functions repetitively^[12]. The multilingual individual must inhibit and control the interferences from unrelated linguistic items (inhibitory control). At the same time, inhibitory control requires the manipulation of momentary information (working memory) to produce and allocate related linguistic items^[13]. Working memory and inhibitory control are the essential executive functions discussed in the present study. Memory refers to the storage of information in the brain, while the executive function in

which the stored information is manipulated to perform various tasks is called working memory^[14]. On the other hand, inhibitory control refers to restraining irrelevant stimuli while maintaining focus on relevant stimuli. In multilingualism and cognition, working memory and inhibition perform a substantial role by constantly managing and retrieving the related lexical items, and simultaneously inhibiting the interference from irrelevant lexical stimuli^[15].

Pakistan is a developing country with a rich history of culture entwined with ancient Indus civilization, the Mughal dynasty, and British colonialism; hence, the country presents a captivating linguistic and cultural diversity^[16, 17]. In Pakistan, there is a clear demarcation among the national, provincial, minor, and foreign languages; and a sense of competitiveness is found among different speakers of the language^[18, 19]. A typical Pakistani child is exposed to multiple languages, such as English for higher education and official purposes, local and minor languages for primary and secondary education, and also for informal communication, while Arabic is used for religious instructions; however, the degree and nature of language interaction may vary, but the taxonomy remains the same^[20, 21].

Inclusive language policies must be developed to diffuse the competitiveness and marginalization of various languages. The goal can be achieved through efficient research that couples numerous languages and cognitive development with education by providing a knowledgeable stance on how various languages can improve or deteriorate higher cognitive functions that are quintessential for success in higher studies. So, it is pertinent to discover the factors involved in multilingual advantage in the Pakistani context. The present study has tried to discover the multilingual impact on working memory and inhibitory control. At the same time, the research attempted to predict the accurate indicator (the number of languages or linguistic proficiency) of multilingual impact on executive functions.

Significance of the Study

The status quo of Pakistan offers an intriguing illustration of a postcolonial multilingual developing nation setting, where the issue of multiple languages has generated significant debate over the years. According to Predominantly in postcolonial multilingual nations, language choice may be a potent cause of prejudice. Nevertheless, local, national, and

educational languages play a significant role in the country's development. Although Pakistan is a multilingual country, it is pertinent to dissolve the linguistic confusion by researching the benefits of multiple languages on executive functions as it is necessary to harmonize the linguistic overlap to improve cognitive processes.

The present study will help determine whether multilingualism impacts executive functions and what factors are involved in it, thus facilitating the authorities to reconsider the educational policies implemented at all levels of education to promote multilingual educational practices. Apart from this, multilingualism also facilitates cultural harmony by giving value to an individual's identity in the social sphere's hierarchy, strengthening the nation^[22]. However, the research concerning the multilingual impact on executive functions is negligible in the Pakistani context. Given the predominant nature of multilingualism, the present study will set a new trend in psycholinguistic research and pave the way for future researchers to further their research in this domain. To elevate cognitive, socio-cultural, and educational competence, systematic and detailed research is required in psycholinguistics. Because psycholinguistics combines cognition and language and provides an understanding of cognitive tendencies concerning language^[23], it can provide an informative stance toward dissolving linguistic turmoil while facilitating cognitive and cultural well-being. In addition, considering the low literacy rate and linguistic overlap in the Pakistani context, the present research will provide a novel outlook to diminish the concerns regarding multiple language use in education and social interaction.

2. Literature Review

2.1. Multilingualism and Executive Functions: A Brief Overview

The phenomenon of multilingualism soared from rapid globalization, growing corporate commercialism, and massive migration of people from one corner of the world to another; hence, these factors elevated the significance of learning multiple languages in modern-day society^[24-26]. The previous research was mainly concerned with the bilingual nature of this phenomenon. It is assumed that multilingualism is essentially cumulative bilingualism in the sense that more than two languages will have similar shifting effects

on cognition; however, despite the fact that the phenomenon of multilingualism has grown exponentially over the years, the research on the topic remained scarce^[27]. Though, research on bi/multilingualism mainly concerns its effects on executive function. Executive functions are domain-general and superior mental processes that involve inhibitory control, working memory, and cognitive flexibility. These functions regulate inhibiting, monitoring, learning, initiation, planning, and switching between tasks^[28].

Regarding the cognitive effects of bilingualism and multilingualism, the research on various concerns of cognition, switching, and working memory is now being renewed^[29]. The research on cognitive functions suggests a bilingual advantage to problem-solving aspects, abstract thinking skills, creative thinking skills, higher concept formation skills, and an inclusive advanced psychological flexibility. Multilingualism is important and states several gains in executive functions, meta-linguistic abilities, parallel activation, and controlled inhibition of languages^[30]. The prominent feature of multilingual cognition is controlled interference among the languages, i.e., inhibition control, the use of target language in a specific situation by preventing the following want for interference from the non-target language. Meanwhile, many studies also pointed out that bilingualism and multilingualism were correlated with cognitive reserve, delaying the inception of cognitive impairments^[31-36]. In a new investigation, the researchers found a constant effect of multiple languages on inhibitory control mechanisms; however, they were unable to find any impact on working memory capacity because of insufficient evidence and scant research.

However, the previous data also suggest that the findings of multiple language advantages on executive functions are unpredictable^[37]. Various studies refuted the correlation of multiple languages with cognition, stating that numerous languages had no notable effect on executive functions; however, the studies pointed out the involvement of other noteworthy factors which could be the cause of research complications, such as the age of acquisition, lifestyle, cultural differences, education status, frequency of language switching, immigration, language proficiency, and usage^[38-46]. Besides, the research also shows the positive, multilingual effect on executive functions in the immigrated individuals from different ethnic backgrounds. At the same time, some

researchers have linked this phenomenon to the “healthy immigrant effect,” which states that immigrants have high intelligence and educational status than non-immigrants^[47]. However, for credible data collection, the researcher must consider these influencing factors. In multilingual research, these factors are termed confounding variables^[48]. Moreover, it is suggested that bilingual and multilingual proficiency must be measured using a scale instead of crudely categorizing the participants into different categories. Hence, the present study will try to carefully control the confounding variables mentioned above and use a composite language score to perform credible data collection and analysis.

Multilingualism is not a simple linguistic phenomenon because various languages operate simultaneously in a single brain, which can also cause the adverse psychological effects of linguistic overloads, such as misperception, delayed retrieval, high cross-language intrusion, lower verbal fluency than monolinguals, and mental fatigue^[49]. Previous research was inclined toward finding out the impact of bilingualism or multilingualism on cognitive functions, primarily on school children and older adults, neglecting young adults. The present study tends to determine the effects of multilingualism on executive control functions in young adults. The focal population of the present study will be younger adults or undergraduate students in the Pakistani context.

Since learning and using multiple languages correspond to language experiences and concern the learner’s cognitive and linguistic characteristics; however, to understand the processing of various languages, it is pivotal to comprehend the subtleties of cognitive processes^[50]. Apart from the learner’s cognitive and linguistic characteristics, there are various factors such as the diversity of languages in the environment, i.e., sociolinguistic diversity, socioeconomic status. Age of acquisition, use of languages, and IQ also plays a vital role in the effective processing and use of multiple languages^[51, 52]. The executive control functions can be further classified into three chief constituents, inhibitory control, working memory capacity, and cognitive flexibility. Working memory capacity and inhibitory control are the principal components of the current study.

2.1.1. Working Memory

Memory was classified into two components, short-term memory (STM) and long-term memory (LTM); nevertheless, now a novel term, Working Memory, is being

conversed and hotly debated^[53]. Working memory is an integral brain system that offers momentary storage and manipulation of information, mandatory for intricate cognitive tasks such as comprehension, learning, and reasoning^[54]. In line with this, working memory is essentially a form of memory that facilitates the execution of complicated cognitive tasks and is referred to as “memory at work^[55]. It is not feasible to limit memory as a unitary system and proposed the multicomponent model of working memory. In the multicomponent model of working memory, three components were assigned to working memory, (i) the central executive, which processes the information and guides the response behavior accordingly; and the two slave systems, (ii) the phonological loop, which stores acoustic information and processes it further (iii) the Visio-spatial sketchpad, that stores and processes visual and spatial information. Later on, another fourth component of the episodic buffer was added; The episodic buffer as a mediator of the phonological loop and Visio-spatial sketchpad^[56]. The elements of the multicomponent model are essential for systematizing the learning and processing of languages and information, therefore establishing a solid connection of working memory with executive functions^[57], hence, proving to be a critical model in analyzing the impact of multiple languages on executive functions. Although the multicomponent model is widely accepted, the weaknesses of this model are also highlighted. There are three weak points of the model; firstly, the model is unable to specify and segregate the cognitive functions that are not part of working memory; secondly, the simplicity of the model, as it is difficult to explain the relationship of cognitive tasks beyond laboratory premises; lastly, the model fails to explain the detailed description and functioning of the central executive component.

Furthermore, recent research conducted provides a detailed account of the bilingual advantage hypothesis; a large sample of 180 Spanish adults (90 bilingual + 90 monolingual) was tested. The 90 bilinguals were proficient in Spanish and Basque. Researchers controlled and managed the possible influencing factors such as age, IQ, educational status, and socioeconomic status. The researchers found no significant impact of bilingualism on executive functions except working memory. It was concluded that while bilinguals were proficient and processing more than one language daily, the positive effect on working memory can be linked to the trans-

fer of training by constantly processing, manipulating, and retrieving extra-linguistic information. The study also highlights a critical aspect by separating the working memory from other executive functions, while many researchers have included the working memory in the executive functions due to strong interrelated neural links involved in both working memory and executive functions^[58–60].

On the opposite side, it was found that bilinguals had greater working memory capacity than their monolingual counterparts, and also remarked that it is not the case that only individuals with higher working memory can become bilinguals; instead, there is a positive effect on working memory when an individual learns a second language^[61]. Furthermore, the working memory is rather dynamic and complicated as it is presently understood, and urges to change the design of the studies to longitudinal ones because working memory is susceptible to change over time with different language experiences. For accurately measuring the working memory, operation span tasks, n-back tasks, Corsi tasks and digit span tasks are widely administered.

2.1.2. Inhibitory Control

Inhibitory control, or IC, is a superordinate construct related to cognitive psychology that describes the voluntary and involuntary suppression of the target stimuli and behavior responses^[62]. In the fields of psychopathology and cognitive psychology, IC is regarded as one of the vital constructs extending over numerous theoretical explanations^[63]. Two chief elements of IC are categorized as; (i) Response Inhibition (also called Behavioral and Motor Inhibition), (ii) Attention Inhibition (also called Interference Control, Interference suppression, or selective attention)^[64]. Attention inhibition allows selectively focusing on a target stimulus while suppressing the attention to non-target stimuli in an external environment; moreover, AI is crucial for executing a mentally demanding task and processing the visual, sensory, and auditory perceptions of a requisite stimulus^[65]. Multiple languages positively influence executive processes, primarily inhibitory control mechanisms^[66]. Because for the production of the right linguistic items at the right moment, multilinguals are constantly controlling and inhibiting their languages, hence contouring their verbal output according to the target situation by employing excessive inhibition of irrelevant linguistic items. Executive functions are closely interlinked for effective functioning and signify the importance

of working memory in processing language. Therefore, suggesting that inhibitory control mechanisms facilitate working memory, and in return, inhibitory control mechanisms are also reinforced by working memory.

The inhibitory control model pioneered the account of multiple language impact on executive control functions by showing the efficacy of stimuli inhibition by multiple language users^[67, 68]. A prolific account of the inhibitory control model was put forward; in this study, the multilinguals were shown to suppress the incongruent stimuli, while the triggers from the non-target language were stimulated at the same time. Later on, it was suggested that language proficiency eventually decides the intensity of the stimulus suppression; furthermore, the data indicated that if a language user is proficient in the first language (L1), then an intense suppression is required to suppress the L1 stimulus while using L2. Still, if a language user is proficient in the second (L2) or third language (L3), then an exaggerated suppression is needed to suppress the L2 and L3 stimuli while using L1. Some studies collect data on task-switching through the switch and non-switch trials. They reported unequal switch costs between L1 and L2 because when the task was switched from dominant L1 to weak L2, additional time was taken to inhibit the dominant L1^[69, 70].

Furthermore, multilinguals not only deal with the linguistic suppression of the distracting stimuli but their self-monitoring control system is also at work to maintain the balance between the intended production and actual production of the target language referred to as the auditory feedback mechanism^[3]. A few studies advocated the relation between auditory feedback mechanism and executive control functions, stating that the attentional load can adapt to any altercation in auditory feedback by pointing out the inclusion of similar systems that regulate the executive functions^[71–73]. On the other hand, there are not any substantive evidence to link executive control functions and auditory feedback regulation^[74]. For measuring the language interference and inhibition in bi/multilingual, Stroop, flanker, and Simon tasks are widely used^[75].

2.2. Research Gap

Executive functions are higher cognitive processes meticulously associated with language, everyday tasks, and crucial decisions. At the same time, language plays an in-

fluent role in executing these cognitive tasks successfully. Nevertheless, the research on the impact of multilingualism on executive functions offers contradictory findings. Abundant studies suggest that multiple languages positively influence administrative functions, while numerous also negate the positive influence of multilingualism on executive functions. Because of the prevalence of multilingualism and the intricate nature of the executive functions, it is pertinent to obviate the opposing views.

Nonetheless, bi/multilingual gains in inhibitory control and working memory capacity are reported on various accounts. However, the research is chiefly concerned with bilingualism, with negligible research on multilingualism. The multilingual advantage domain is nestled with confounding variables, making the study increasingly problematic. To precisely measure the nature of the relationship between multilingualism and executive functions, the researcher must consider all the possible factors, such as age difference, age of acquisition, language proficiency, lifestyle, intelligence level, educational level, immigration status, linguistic diversity, socioeconomic status, and individual differences. The internal linguistic factors such as phonetic and semantic similarity of languages and languages with different and same ancestral languages are overlooked.

The literature review suggests that extensive neurological research on executive functions is needed to comprehend the peculiarity of the effects of multilingualism on executive functions. Moreover, a large population sample is required for improved findings. At the same time, a diverse range of speakers and spoken languages are also crucial for enhancing the existing knowledge about cognitive consequences. Moreover, most of the studies were correlational cross-sectional studies, and perhaps a longitudinal study can find more substantive evidence and findings in this regard. Several researchers did not test the proficiency of multiple languages on a continuous scale; they used categorical classification instead. Thus, the results of their study were rejected by others. At the same time, the study participants were mostly school children due to the general notion that executive functions mature in late adolescence. Still, various findings suggest that higher cognitive processes continue to improve well during young adulthood. Hence, future researchers must acknowledge the abovementioned factors while contemplating their research in this domain.

3. Research Methodology

3.1. Research Design

The appropriate research design for investigating the effects of multilingualism on executive functions is the cross-sectional quantitative experimental research design. This study aimed to test the bilingual advantage hypothesis that multilingualism can predict a positive change in executive functions. The quantitative experimental research design was suitable for predicting the impact of multilingualism on executive functions. A quantitative non-experimental research design uses the scientific method to test a hypothesis; in this method, the data is organized in numbers, and statistical analysis is performed to yield the results^[76]. The present study used numerical data and performed Simon task^[77], and Corsi tasks^[78], to test the inhibition control and working memory of the participants. Later, the numerical data obtained from the questionnaire and the experiments were statistically analyzed.

3.2. Participants

It is stressed to obtain primary data in scientific and statistical analysis because primary data is more authentic and objective than secondary data^[79]. Due to the quantitative and statistical nature of the study, primary sources for data collection were preferred. The research population was undergraduate students. The selection of university undergraduate students was crucial because the linguistic diversity rate found in universities is relatively higher than in colleges and schools. The participants were hired for the data collection through a call center organization called Nexilinks and were enrolled in degree programs at the university level in morning. The criterion for selection was that a participant must be between the ages of 18 and 25 years and currently pursuing an undergraduate degree in any university. A total of 20 participants out of 32, including nine females (N = 9) and eleven males (N = 11), were selected based on their age and educational background (**Table 1**). The selected research participants were undergraduate students working part-time in the call center in the evening. The participants were adequately compensated for their participation in the experiment.

Rationale for choosing the participants from call centre

Organization:

Generally, in Pakistan students are fluent in two languages, one is their native language and the other is an official language, i.e, Urdu and English. In most cases, students are not fluent in English Language. Meanwhile, students working in call centre organizations are usually fluent in English language as well. As English language becomes a part of their daily professional life. Hence, the participants were chosen from call centre organization to ensure trilingual efficiency and solid result base.

3.3. Confounding Variables

Measuring trilingual efficiency is an intricate task. As described earlier, the overlap of psychological factors in language efficiency can modify the results. It was observed in the testing phase that one of the participants was extremely shy and could not execute the tasks properly. It took a significant proportion of time to make her comfortable with the testing. Psychological factors, such as personality, anxiety and IQ play a crucial role in the multilingual domain. These factors may modify the results. Furthermore, socioeconomic background also plays a pivotal role in determining the language efficiency. Participants with linguistically diverse and resourceful backgrounds scored higher on language proficiency.

3.4. Task

The data for the present study was collected from 20 participants. The language history and usage data were collected through an online questionnaire of LHQ 3^[80], and experiments were performed with the help of computer-generated Simon and Corsi tasks provided by Psytoolkit^[81]. LHQ 3 is an innovative web-based tool designed for assessing the degree of multilingualism. LHQ 3 was selected because it can assess up to four languages based on different modules of proficiency and usage. An online and modified version of the Language history questionnaire, LHQ3, was administered. Participants were asked about the number of spoken languages, the ages at which they learned the languages, the frequency of language mixing, and language proficiency in the questionnaire. Multilingual scoring in LHQ3 uses Shannon entropy (H) to produce multilingual scores, ranging from 0 to 2. In extreme cases, the monolingual participants will be

scored 0. While participants with scores ranging between 0 and 1 will be considered bilinguals, participants with scores ranging between 1 and 2 will be considered multilinguals. All the participants were multilinguals scoring one or above one on the multilingual language diversity score (MLS). Later on, Simon and Corsi's tasks were administered.

In Simon's task^[77], the inhibition control was tested using two blocks containing the words "Left" and "Right." The sequence of the block words was chosen randomly but keeping in mind that the participant had to press the 'A' button for the word 'Left' and 'L' button for the word 'Right,' regardless of the position of the word presented on the screen. The position of the words "Right" and "Left" acted as a distracting stimulus, and the participants were to focus on the words, not on the position of the words. At first, a cue was presented, and after a 300 ms delay, the blocks were shown on the screen. If the participant answered the trial correctly, the task would move on to the subsequent trial, and if the trial was answered incorrectly, an error message showed for 500 ms. The result of the 30 trial tasks was presented after the experiment was completed, in the form of compatible and incompatible RT trial scores. The Simon effect was concluded from these scores by subtracting incompatible RT from the compatible RT.

The Corsi or "Corsi block-tapping test" is a working memory task analogous to the digit span test^[78]. The Corsi test administered in the study was non-verbal. In the test, a set of nine blocks were presented on the computer screen; in each trial, a specific sequence of blocks was highlighted for 500 ms. A total of nine trials were used, and after every trial, the number of highlighted blocks was increased by one block until nine blocks were highlighted at once. In the first trial, the highlighted blocks were two; in the second trial, the highlighted blocks were three; in the third trial, the highlighted blocks were four, and so on. Then after each trial, the sequence of highlighted blocks was to be memorized and drawn again by the participant after the voice signaling "go." In the meantime, the Corsi span measurement was recorded based on correct responses.

3.5. Data Analysis Tool

The data were analyzed using IBM SPSS version 25. Firstly, Correlation analysis was run using Pearson's correlation for the multilingual diversity score (MLS), Simon

Table 1. The biodata of the research participants indicating the criterion for selection.

	Age	Gender	Educational Background (Under Graduate)	Language Usage
Participant 1	24	Male	B.S. English Linguistics	Urdu, Punjabi, English
Participant 2	23	Male	B.S. Computer Sciences	Urdu, Punjabi, English
Participant 3	22	Male	B.S. English Linguistics	Urdu, Punjabi, English
Participant 4	22	Female	B.S. Computer Sciences	Urdu, Saraiki, English
Participant 5	24	Male	B.S. English Linguistics	Urdu, Pashto, English
Participant 6	23	Male	B.S. Economics	Urdu, Saraiki, English
Participant 7	19	Male	B.S. English Linguistics	Urdu, Punjabi, English
Participant 8	25	Female	B.S. Software Engineering	Urdu, Punjabi, English
Participant 9	22	Male	B.S. Software Engineering	Urdu, Saraiki, English
Participant 10	24	Male	B.S. Computer Sciences	Urdu, Punjabi, English
Participant 11	23	Female	B.S. Software Engineering	Urdu, Punjabi, English
Participant 12	25	Female	B.S. Computer Sciences	Urdu, Pashto, English
Participant 13	25	Male	B.S. Computer Sciences	Urdu, Punjabi, English
Participant 14	25	Female	B.S. Environmental Sciences	Urdu, Punjabi, English
Participant 15	22	Male	B.S. Computer Sciences	Urdu, Punjabi, English
Participant 16	24	Female	B.S. Chemistry	Urdu, Punjabi, English
Participant 17	22	Female	B.S. English Linguistics	Urdu, Saraiki, English
Participant 18	18	Male	B.S. Chemistry	Urdu, Punjabi, English
Participant 19	25	Female	B.S. Biotechnology	Urdu, Pashto, English
Participant 20	22	Female	B.S. English Linguistics	Urdu, Punjabi, English

task scores, and Corsi task scores. All assumptions were checked, and one outlier was flagged using a scatterplot graph, which scored way below average in the Simon task. After that, a simple linear regression analysis was carried out separately for each executive function component, i.e., working memory (Corsi task) and inhibitory control (Simon task), to ascertain if these variables predict the impact of multilingualism.

4. Results

The result of descriptive statistics of age, multilingual diversity scores (MLS), Simon effect score, and Corsi score are presented below.

The first simple linear regression analysis was done using MLS and Simon effect. The MLS was placed as an independent variable while the Simon effect was dependent (see **Table 2**). The standardized coefficient beta or Pearson’s correlation of -0.131 showed a significantly weak negative correlation between multilingual diversity score (MLS) and the Simon effect, indicating an inverse relationship between MLS and Simon effect. Moreover, the r-squared value of 0.017 indicated that the regression model described only 1.7 percent of the data. At the same time, the p-value was greater than 0.05 ($p > 0.05$), which indicated that the model is not statistically significant enough to provide evidence for

rejecting the null hypothesis.

The second simple linear regression was done using MLS as an independent variable while Corsi scores as a dependent variable (see **Table 3**). The standardized coefficient beta or Pearson’s correlation of 0.151 showed a significantly weak positive correlation between the multilingual diversity score (MLS) and the Corsi scores, indicating a positive relationship between MLS and Corsi scores. Furthermore, the r-squared value of 0.023 directed that the regression model defined only 2.3 percent of the data. Simultaneously, the p-value was greater than 0.05 ($p > 0.05$), which specified a lack of statistical evidence to reject the null hypothesis.

The objective of this experimental study was to find evidence that proves multilingualism has a positive impact on executive functions of working memory and inhibitory control. Pakistan is a postcolonial developing state, and the inhabitants speak multiple languages; consequently, the national, official, and local languages differ^[20]. The preferred languages by the government in education are different from the local languages. Under these circumstances, students are struck with linguistic turmoil at higher levels of education, which causes emotional distress^[21]. A comprehensive research framework in the psycholinguistic domain is required to alleviate the linguistic turmoil and lessen emotional distress. The objective of the present study was to discover scientific evidence that multilingualism benefits executive

Table 2. Descriptive Statistics.

	N	Min.	Max.	Mean	Std. Deviation
MLS	20	1.01	1.98	1.6725	0.24391
Simon Effect	20	-3323	278	-177.30	750.742
Corsi Score	20	4	8	5.45	1.432
Age	20	19	25	22.95	1.676
Valid N (listwise)	20				

functions, so an agreement can be developed to dissolve the situation on scientific grounds.

In this experimental study, twenty participants were hired. Assumptions were checked, and one outlier was flagged. The outlier scored way below average in the Simon task. At first, a language history assessing questionnaire of LHQ 3 was administered. Then experiments on the Simon task and Corsi task were performed. The research results are as follows: the data showed a weak negative correlation between Simon task score and MLS, which indicates that an increase in MLS negatively affects the inhibition control (**Table 4; Figure 1**). However, the correlation is significantly weak at -0.131 . The simple linear regression analysis results for the Simon task score depicted a higher p-value ($p > 0.05$) which proposed that there is insufficient statistical evidence to accept the alternative hypothesis; in addition, the r-squared value proposed that only 1.7 percent of data fitted the regression model. On the other hand, Corsi scores were positively and weakly correlated at 0.151 with MLS, which specified that using multiple languages can slightly increase the user’s working memory (**Figure 2**). The simple linear regression results of Corsi scores also showed a higher p-value ($p > 0.05$) (**Tables 5 and 6**), which implied that the data was insufficient to reject the null hypothesis. The null hypothesis cannot be rejected considering the outcome, thus proving that multilingualism does not positively impact executive functions of working memory and inhibition control.

Given the results of the linear regression model, multilingualism does not have a positive influence on inhibitory control or rather any influence at all. As stated previously, according to the developmental trends of executive functions, inhibition control can develop even through young adulthood^[9, 10]. However, the results showed a lack of evidence to support the multilingual impact on the inhibitory control of the chosen sample, although all the participants were active multilinguals. Nevertheless, it can be assumed that after a certain age, it could be possible that only a slight inhibition is required at a high

level of linguistic proficiency^[82]. The contrastive findings in the inhibitory control research may stem from the failure to separate the different aspects of inhibitory control, such as attention and response inhibition^[62]. In addition, the unpredicted findings of inhibition control may be subject to the administration of irrelevant tasks, and it is preferred to use various tasks to measure inhibitory control or any other executive function^[31]. Hence considering the intricacy and overlap in the multiple aspects of inhibition control, it is recommended to perform the experimental tasks with respect to the desired measuring aspect of the inhibition control and the number of administered tasks must be increased.

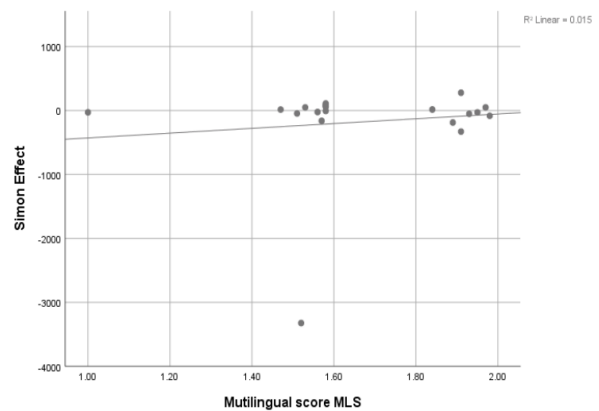


Figure 1. Simple Scatter with Fit Line of Simon Effect by Multilingual Score MLS.

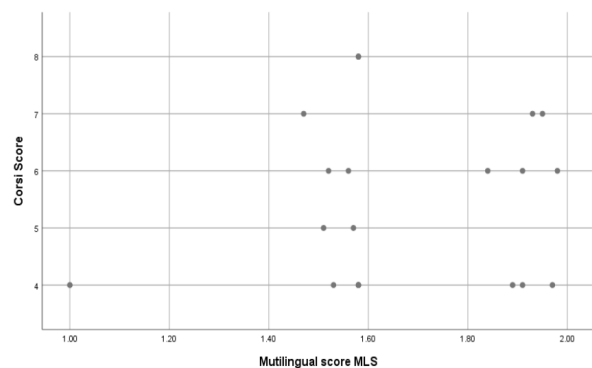


Figure 2. Simple Scatter with Fit Line of Corsi Score by Multilingual Score MLS.

Table 3. Model Summary.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.131 ^a	0.017	-0.041	130.029

a. Predictors: (Constant), Multilingual Language Diversity Score (N = 19).

Table 4. Coefficients^a.

Model	Model	Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
1	(Constant)	100.448	208.613		0.482	0.636
	MLS	-66.777	122.898	-0.131	-0.543	0.594

a. Dependent Variable: Simon Effect.

Table 5. Standard error of the Estimate.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.151 ^a	0.023	-0.035	1.490

a. Predictors: (Constant), Multilingual Language Diversity Score (N = 20).

Table 6. Coefficients^a.

Model	Model	Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
1	(Constant)	3.935	2.391		1.646	0.118
	Multilingual Language Diversity	0.884	1.409	0.151	0.628	0.538

a. Dependent Variable: Corsi Score.

The results also depicted a lack of statistical evidence to support the advantageous effect of multiple languages on working memory. A positive relationship was shown between bilingual older adults, children, and working memory^[83]. Moreover, a beneficial effect on the working memory of older adults was also found^[48]. Pearson’s correlation from the present study suggests a significantly weak positive correlation between working memory and multilingual score, which is in line with the previously mentioned studies. Still, the results lacked enough evidence to show a positive effect in the sample. A significant enhancement in the visuospatial working memory measure was seen in a larger sample size^[13]; moreover, these significant results were reported when the variables of second language proficiency and frequency of second language mixing were analyzed. It suggests the involvement of multiple influencing variables. In addition, the usage of non-verbal working memory tasks was highlighted in the study, which is in line with the importance of non-verbal tasks^[83]. On this account, the phenomenon of bilingualism may have an impact on a few specific sub-components of working memory, and using verbal working memory tasks of an auditory nature may prove detrimental

for bilinguals^[84]. These findings were also reported as significant evidence of multilingual advantage in non-verbal working memory tasks^[85]. However, the significance of the model drastically decreased after socio-economic status (SES) and IQ variables were co-varied. This points to the intricate relationship of the findings of multilingual research with influencing variables.

5. Discussion

The objective of this experimental study was to find evidence that proves that multilingualism has a positive impact on executive functions of working memory and inhibitory control. Pakistan is a postcolonial developing state, and the inhabitants speak multiple languages; consequently, the national, official, and local languages differ^[20]. The preferred languages by the government in education are different from local languages. Under these circumstances, students are struck with linguistic turmoil at the higher levels of education, which causes emotional distress^[21]. A comprehensive research framework in the psycholinguistic domain is required to alleviate the linguistic turmoil and lessen emotional

distress. The objective of the present study was to discover scientific evidence that multilingualism benefits executive functions, so an agreement can be developed to dissolve the situation on scientific grounds.

When a bilingual speaker communicates with a diverse range of speakers in a linguistically dense environment, it enhances the executive load of the bilingual speaker, increasing the working memory performance^[86]. As for the present study, all the participants were actively involved in a diverse atmosphere where they frequently used multiple languages still; the linear regression model results for working memory projected no beneficial impact of multilingualism. Furthermore, the insignificance of the regression model results when the variables of second language proficiency and frequency of second language mixing were not included^[13]. Hence, the results projected the involvement of various confounding variables. As the results became substantial after the inclusion of two variables of proficiency and mixing, the results may also become significant if different modules of proficiency, domination, usage, and mixing of LHQ 3, were used along with the number of languages spoken. Multilingualism and cognition domain has multiple influencing factors, often producing inaccurate findings^[87]. Involvement of the multiple influencing variables and unfitting inclusion of various modules of language questionnaires can be the chief reason for inconsistent findings in the multilingualism and cognition domain.

In the present research, a few influencing factors were controlled using LHQ 3, such as age, educational background, linguistic proficiency, and the number of languages spoken. However, pinpointing the exact influencing factors is a complicated task that necessitates thorough research on the interrelation of the executive functions^[13, 87]. In addition, another prevailing variable that was not accounted for was the IQ of the participants. Executive functions are highly interrelated and strongly connected with IQ^[88]. So, it is suggested that future researchers administer an IQ test along with the language history questionnaire for more reliable results. Due to numerous confounding variables, a multiple hierarchical regression model might be a better fit for the data and produce a more productive outcome. A multiple hierarchical regression model may better define the data because of the several influencing factors involved in this domain^[48].

As previously discussed, positive effects on executive functions when non-verbal tasks were administered and negative impact on verbal tasks involving rigorous information processing was reported^[83]. In line with this, the researcher tried to keep the experimental Simon and Corsi tasks as non-verbal as possible. However, only two words, “Right” and “Left,” were incorporated into the Simon task because the non-verbal Simon task provided by the Psytoolkit website^[81], uses a pointing device. As discussed earlier, the Simon task score (Simon effect) is calculated by subtracting the reaction time of incompatible trials from compatible trials. Hence, a pointing device, i.e., a mouse, if used for this task, may have altered the correct measurement of the reaction times due to the latency or delay in pointing, which might have produced fallible reaction times in the result. However, the Corsi tasks were non-verbal, and only the number of correct responses was reported.

The results also proposed a lack of a sufficient sample size for productive results. A sample size of about 300 participants is suggested for future researchers. According to the studies with relatively large sample sizes, an advantage in executive functions was found^[34, 61]. A significantly large sample size is preferred in the multilingualism and cognition domain. Furthermore, multilingualism was quantified as a composite score on a continuous scale^[5]. Regardless, most participants found it challenging to recall when they started learning or using a second or third language and how many hours they spent talking in each language. It was challenging to answer these questions accurately, which may have caused the participants to answer the questions inaccurately. Moreover, it is also recommended that future researchers increase the number of administered tasks. As executive functions are complex and interrelated to test efficiently, and one task per executive function can yield incomplete results, it is suggested that at least three tasks per executive function should be administered for more refined and productive results.

Another significant factor that plays a role can be a dormant Arabic language lexicon that resides in almost every Muslim Pakistani individual’s brain. Most Muslims can read, memorize and pronounce Arabic words flawlessly, but they cannot comprehend the meaning. Knowing an additional language may not produce beneficial effects on executive functions; however, using an additional language consistently can enhance executive functions. So a separate module must

be included in the questionnaire to account for the dormant languages and how they can influence the accurate scoring of multilingualism.

Learning and using multiple languages is a complex experience, while higher cognitive functions are similarly complicated and intricate to measure and comprehend^[83]. The present experimental study could not find a significant effect of multilingualism on inhibitory control and working memory. The study introduced a new measure of categorizing multiple languages based on a composite score (MLS). Correlations were found between executive functions and multilingualism; nonetheless, the findings of the linear regression model were not statistically significant enough to generalize the predictability of the executive advantages of multilingualism in a larger population. The findings from the present study can be added to the body of literature that suggests no significant impact of multilingualism on inhibition control and working memory. However, the study was conducted because, in the Pakistani context, little to no research is done on the topic of multilingualism and cognition, and there is an imminent need to research the topic in the multilingual Pakistani context.

6. Conclusions

Multilingualism benefits inhibition control, and working memory were the two hypotheses raised by the present study. The objective of the study was to find evidence of executive gains through multilingualism. The findings exposed significantly weak correlations, but the regression models did not project adequate evidence to consider these correlations. Hence, the null hypothesis was accepted that multilingualism does not benefit executive functions of working memory and inhibition control. The study proved the prior findings of no influence of multilingualism on cognition. The strength of the present study was that it included the composite language score (MLS), and some of the confounding variables were controlled. As described earlier, the number of confounding variables is staggering in the multilingual and cognition domain, and rigorous research is required to segregate the influencing variables. This approach can lower the inconsistencies of the results of multilingual research on executive functions.

Author Contributions

M.S.K. collected and compiled the data. H.S., A.H. and N.H.: contributing to completing the literature, discussion and conclusions. H.S. also supervised this article.

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Data Availability Statement

We could not provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study due to privacy or ethical restrictions. Authors can consider providing the data set if contacted by email.

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Conflicts of Interest

There is no conflict of interest.

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