Investigating Multilingualism and its Association with Executive Functioning: An Exploratory Study Comparing Bilingual, Trilingual and Quadrilingual College Students in India

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Abstract. Multilingualism has both advantages and disadvantages. Past research has highlighted this dichotomy by exploring the impact of linguistic ability on individuals' executive functioning. This study explores the relationship between individuals' linguistic ability (number of languages spoken) and their executive functioning, specifically, working memory – measured using the Corsi Block-Tapping task (Mueller, 2011a), inhibitory control – measured using the Go/No-Go task (Mueller, 2011b) and problem solving – measured using the Tower of London task (Mueller, 2011c) among a total of 91 bilingual, trilingual and quadrilingual Indian colleges students. Results from a Kruskal Wallis test indicated non-significant results for problem solving among the three groups. However, significant differences were found between groups for working memory (p = .050) (particularly between bilinguals and quadrilinguals, and trilinguals and quadrilinguals) and inhibitory control (p = .020) (particularly between trilinguals and quadrilinguals). The mixed results indicate a need for further research in this domain within the vast and diverse population of India.

Keywords: *bilingualism, trilingualism, quadrilingualism, working memory, inhibitory control, problem solving, Indian population.*

Раджан Ґаріма, Патіл Нянада. Вивчення багатомовності та її зв'язку з екзекутивною функцією: Експериментальне дослідження з порівняння двомовних, тримовних та чотиримовних студентів коледжів у Індії.

Анотація. Багатомовність має як переваги, так і недоліки. Попередні дослідження висвітлили цю дихотомію, вивчаючи вплив лінгвістичних здібностей на виконавчу діяльність людини. У цьому дослідженні вивчається зв'язок між мовною здатністю індивідів (кількістю мов, якими вони володіють) та їхньою екзекутивною функцією, зокрема, робочою пам'яттю, вимірюваною за допомогою тесту Corsi Block-Tapping (Mueller, 2011a), інгібіторним контролем, вимірюваним за допомогою тесту Go/No-Go (Mueller, 2011b), та вирішенням проблем, вимірюваним за допомогою тесту "Лондонський Тауер" (Mueller, 2011c), серед студентів індійських коледжів, які володіють двома, трьома, або чотирма мовами. Результати тесту Краскала Волліса засвідчили незначні відмінності у вирішенні проблем між трьома групами. Однак були виявлені значні відмінності між групами щодо робочої пам'яті (p = .050) (особливо між двомовними і чотиримовними, а також тримовними і чотиримовними) та інгібіторного контролю (p = .020) (особливо між тримовними і

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чотиримовними). Змішані результати вказують на потребу в подальших дослідженнях у цій галузі серед численного та розмаїтого населення Індії.

Ключові слова: *двомовність, тримовність, чотиримовність, робоча пам'ять, інгібіторний контроль, вирішення проблем, населення Індії.*

Introduction
Literature Review

Explaining Multilingualism

Multilingualism is having 'fluency in multiple languages'. Research on multilinguals has highlighted advantages and disadvantages of learning and speaking multiple languages (Anton et al., 2019; Bialystok & Craik, 2010; Dick et al., 2019: Espi-Sanchis, & Cockcroft, 2021: Lehtonen et al., 2019; Slot & Suchodoletz, 2018).

Effects of Multilingualism on Executive Functioning

An enhancement in executive functioning skills is the biggest advantage highlighted by researchers. The existing studies focus on understanding the relationship between number of languages spoken and executive functioning using two broad approaches – through linguistic and non-linguistic based tasks (Czapka et al., 2019). Multilinguals (those who speak more than one language) have been shown to perform better at various non-linguistic cognitive tasks which involve skills like attentional control (Bialystok, 2008), response inhibition (Poarch & Hell, 2012b), task switching (Barac & Bialystok, 2012) and working memory (Oschwald, et al., 2018). However, they perform at par or sometimes worse than their monolingual (those who speak one language) counterparts on linguistic tasks (Bialystok, 2009; Slot & Suchodoletz, 2018). Multilinguals also commit greater errors during rapid retrieval of lexical knowledge (Bialystok & Craik, 2010). Therefore, we can conclude that multilinguals experience both pros and cons.

Researchers have proposed a theory to explain this dichotomy, known as the cross-language interference hypothesis. The theory argues that multilinguals have to ignore interferences from one language while speaking in another. These cross-language interference demands provide life-long training for executive functioning tasks (Oschwald, et al., 2018). The learning and actively speaking multiple languages provides individuals with sustained training resulting in enhanced executive functioning. Therefore, one could say that the number of languages spoken by an individual is directly proportionate to their executive functioning skills. By this logic, one would expect to find higher cognitive skills among trilinguals than bilinguals; among quadrilinguals than trilinguals and so on. However, research has shown that such is not the case (Schroeder & Marian, 2016). A study found that trilinguals (those who speak three languages) share the similar advantages as bilinguals (those who speak two languages) (Poarch & Hell,

2012a). Hence, many more factors impact the relationship between multilingualism and executive functioning.

Factors Affecting the Impact of Multilingualism on Executive Functioning

Research into other factors such as cultural background (Bialystok and Barac, 2012; Treffers-Daller et al., 2020), age at which the languages were learned (Boumeester et al., 2019), socioeconomic status (Bialystok and Calvo, 2014), educational level, similarity and dissimilarity of the languages learned and proficiency in each language (Poarch, 2018; Espi-Sanchis, & Cockcroft, 2021) show that impact the relationship between multilingualism and executive functions.

Effect of Similarity of Languages. Researchers investigating the effects of similarity or dissimilarity of the languages spoken are yet to find a clear answer. Barac & Bialystok (2012) found that similar languages allow for better performance in lexical tasks. It seems to enhance rapid recall abilities of the individuals (Oschwald et. al., 2018) but not always (Polczynska et. al., 2016).

Proficiency in the Language. Similar to most data presented previously, there is ambiguity present in the existing literature (Achaa-Amankwaa et al., 2023; Filippi et al., 2021). Certain studies have found that proficiency in the second language does not have influence the relationship (Matilda, Selin & James, 2021; Oschwald et al., 2018), while other research have found contrary results (Antoniuo et al., 2016; Bialystok & Majumder, 1998; Fernandez et al., 2013). Some studies also say that the relationship is moderated by proficiency (Poarch & Hell, 2012). Furthermore, studies examining the neural networks of language too have found activation in different areas across different proficiency levels (Briellmann et al., 2004; Chung-Fat-Yim et al., n.d.). Thus, most studies attempt to control this variable (Mehrani & Zabihi, 2017) in order to make generalized conclusions.

Bilingualism vs Trilingualism

Many studied have attempted to show the differences between trilinguals and bilinguals. Some studies report that bilinguals and trilinguals share the same advantages (Poarch & Hell, 2012a), while other suggest several differences (Schroeder and Marian, 2016). A study suggested that certain cognitive skills are better for bilinguals, while trilinguals exceed in others (Schroeder & Marian, 2016). Thus, having separate frameworks to understand the two populations will be beneficial in understanding the similarities and differences between them.

Quadrilingualism

Most of the research examining this relationship has been conducted in Western countries. Studies on quadrilinguals are very few and tend to combine trilinguals and quadrilinguals into one group – labelled as multilinguals (those who speak multiple languages) (Antoniuo et al.,2016; Cockcroft et al., 2019; Czapka & Festman, 2021;

Limber & Buchweitz, 2014; Reyes, 2013; Simonis, 2018). This failure to distinguish between the two as separate groups pose a problem when analysing and generalizing the data collected due to within group variations.

Although, a bilingual and trilingual advantage has been seen in most studies, the same cannot be seen among quadrilinguals in the existing literature. Quadrilinguals perform poorly on symmetry span tasks (King, 2020) and inhibitory control (Matilda et al., 2021). Therefore, we cannot use the same framework for bilinguals, trilinguals and quadrilinguals. We also cannot conclude that speaking multiple languages is better than speaking one or vice-a-versa.

Understanding Executive Functioning

Executive functions are top-down mental processes essential in carrying out automatic processing and instinctual behaviour. They play a vital role in physical and mental health, cognitive skills and social behaviour. Task-switching, working memory and inhibitory control are the three key elements of executive functioning (Diamond, 2013). Other higher-order executive functions – problem-solving, logical reasoning and decision making – are built from these core components (Diamond, 2013).

Executive functioning develops throughout one's lifespan. It develops rapidly among children and slows down with age. The components of executive functioning are stable and grow simultaneously (at different rates) (Miyake & Friedman, 2013). They can be enhanced through training and practice. Individual experiences makes studying these variables extremely difficult. Stress, physical health, emotional state, social and environmental factors all affect an individuals' executive functions (Diamond, 2013).

Theories of Executive Functioning

Executive functioning as a whole has been attempted to be studied under various theoretical frameworks. Early theories attempted to study the various components of executive functioning individually (Broadbent, 1958; Posner & Snyder, 1975), as a whole (Baddeley et al., 1996) and through the lens of neuropsychology (Garcia-Madruga et al., 2016). However, modern day theories combine the two approaches and view executive functioning as a whole, still divide and study the various components as separate yet correlated elements (Diamond, 2013; Miyake & Friedman, 2013).

Relevance of Executive Functioning

Executive functioning are skills that individuals are constantly using in their everyday life. For example, when in a crowded space, one is able to focus on the video on their phone because they are exercising inhibitory control, which is they are not only focusing on the video but also ignoring interfering information coming in the form of noise from their surroundings. Executive functioning is very useful and acts

as an important predictor of multiple things, such as several psychological disorders (Diamond, 2005), poor health (Miller et al., 2011), decreased productivity (Bailey, 2007), lack of socio-emotional regulation (Denson et al., 2011) and academics (Borella et al., 2010). Thus, executive functioning plays a crucial role in the lives of both school and university students.

Gaps in Literature

Past research has shown multiple advantages as well as disadvantages of being multilingual (used collectively for all bilinguals, trilinguals, quadrilinguals and so on) (Antoniou, 2018; Bialystok, 2008; Dick et al., 2019: Espi-Sanchis, & Cockcroft, 2021; Lehtonen et al., 2019; Oschwald et al., 2018; Poarch & Hell, 2012a; Slot & Suchodoletz, 2018 and more). Although such studies have been replicated in various cultures, it is still unclear as to what pro and cons multilinguals experience and why they experience them. Moreover, very few studies have been conducted in an Indian context (Bialystok & Majumder, 1998; Chan & Rao, 2022; Daga & Rajan, 2023; Iyer & Venkatesan, 2021; Rafeekh et al., 2021). Additionally, the differences in group size, language groups, populations, and methodologies have resulted in inconclusive and contradictory findings. This raises the question that maybe factors other than individuals' linguistic ability may impact the executive functioning of multilingual individuals.

Rationale for the Current Study

The current study attempts to study one such factor – number of languages spoken. The study follows the rationale that a higher number of languages spoken and its cross-language interference demands provide life-long training resulting in differences in executive functioning. According to the 2021 India Census, there is a total of over 19,500 languages and dialects spoken in India. The report further states that over 31 crore Indians are bilinguals and over eight and a half crore are trilinguals. With such a vast variety of languages as well as a large population, the Indian population is an understudied group with a lot to offer.

Current Study

The current study aims to add onto existing literature by exploring the relationship between executive functioning and bilingual, trilingual and quadrilingual college students in India. The study explores executive functioning skills of individuals through non-linguistic tasks only.

Research Question. Does the number of languages an individual speaks have an effect on an individual's executive functioning, particularly inhibitory control, working memory and problem solving?

Hypothesis. There would be significant differences between bilingual, trilingual and quadrilinguals individuals on executive functioning tasks.

Methodology

Participants

The sample size consisted of 91 participants (Bilinguals = 30, Trilinguals = 31, Quadrilinguals = 30). The sample was composed of more females than males (Females = 66 (72.5%), Males = 24 (27.5%)). The sample consisted of individuals aged between 18 to 22 years. The mean age of participants was 19.7 years (Bilinguals Mean $_{age}$ = 19.8, Trilinguals Mean $_{age}$ = 19.5 and Quadrilingual Mean $_{age}$ = 19.8). Participants were recruited using a google form (circulated via email across all batches within FLAME University, and through posters placed across the university campus), thus a convenience sampling method was employed. The participants were informed about the true purpose of the study to ensure for informed consent. The participants had the option to withdraw their consent at any time during the study without any consequences.

Table 1
Descriptive Statistics

Group	Bilingual		Trilingual		Quadrilingual	
	N	%	N	%	N	%
Male	6	20	6	19.35	11	36.67
Female	24	80	24	77.42	18	60
Other	0	0	0	0	1	3.33
Total	30	32.97	31	34.07	30	32.97

Note. N = 91 (N =/> 30 participants in each language group)

Anonymity of the participants was maintained. The minimum criteria for inclusion included a minimum age limit of 18 years old and a basic high school education (completed 10th Grade). No participant was excluded on the basis of their race, gender, caste, socio-economic status or a particular language spoken by them. No compensation, monetary or otherwise, was given to the participants.

Measures

The recruitment form collected other demographic data such as age, gender, educational background and number of languages spoken proficiency (reading and writing) and fluency (speaking) in each language. The study measured three variables of executive functioning. All participants completed three cognitive tasks; 1. The Corsi Block task – Working memory, 2. The Go/No-Go task – Inhibitory control, and 3. The Tower of London task – Problem solving. All three tasks were run on PEBL – Psychology Experiment Building Language.

The Corsi Block Taping Task (Corsi, 1972). The Corsi Block Tapping Task is used to measure visuospatial working memory (Orsini, 1994). Participants are presented with nine squares that appear in randomized positions on the screen at each trial that sequentially light up. The participant is expected to replicate the sequence. Being a power test, it increases in difficulty. The trials begin with a sequence of two blocks and go on till a sequence of nine blocks. A correct trial is one wherein the participant correctly replicates the sequence. After every two correct trials, the number of blocks in the sequence increase. However, after two failed trials, the task ends. The task has high test-retest reliability (Paula, Malloy-Diniz & Romano-Silva, 2016). Furthermore, a study found that results between a traditional and digital version of the test were also consistent (Siddi et al., 2020).

The Go/No-Go Task (Gordon & Caramazza, 1982). The Go/No-Go task measure inhibitory control. Participants are presented with a target stimulus and a distractor stimulus. They must click a button whenever they see the target stimulus and avoid pressing it when the distractor stimulus is shown. A correct trial occurs every time the participant correctly clicks the button for the target stimulus and correctly avoids clicking the button for the distractor stimulus. However, if the participant fails to do so, an incorrect trial occurs. There are two rounds in the task. In the second round, the distractor stimulus and the target stimulus are swapped, further increasing the test difficulty. The test has strong test-retest reliability and a modest convergent validity when compared to other measures of inhibitory control (Langencker et al., 2007).

The Tower of London Task (Berg & Byrd, 2002). The Tower of London task measures problem solving. In the task participants are presented with a diagram that shows 3 columns and up to 3 coloured discs. The participants are required to replicate the position of the discs shown by moving the discs in a fixed number of moves. This requires the participants to plan their moves ahead of time. A correct trial occurs when the participant is able to replicate the given diagram correctly. The participant gets only one chance per trial. The task has great internal validity and a satisfactory split-half reliability (Kaller, Unterrainer & Stahl, 2012; Kostering et al., 2015).

Procedure

Following development of a research design, approval from the FLAME University IRB was sought. After attaining the approval for the study, participants were recruited and called to the Computer Lab at the FLAME University campus. Participants were then quickly re-briefed about the study and asked if they had any questions. The researcher clarified and answered all question before administrating the tasks. A small debriefing was also carried out after the completion of the three tasks. Following this, the participants were also asked if they would like to know the results of the study. If they said yes, they were asked to leave their contact details with the researcher. No compulsion was made for the same. The participants were free to leave after this.

Results and Analysis

Data analysis

The data collected was quantitative in nature. Three different tasks were administered using PEBL, a digital software, – The Corsi-Block Tapping task for working memory (Mueller, 2011a), the Go/No Go task (Mueller, 2011b) for Inhibitory control, and the Tower of London task (Mueller, 2011c) for problem-solving were selected as measures. Only the PI and the Co-PI had access to the Google drive wherein data was stored. The collected data was then analysed using SPSS version 25.0.

After checking for normality and descriptive statistics, the data was found to be not normally distributed.

Results

The Kolmogorov-Smirnov Lilliefors (K-S Lilliefors) test indicated that the data collected deviated significantly from normal. Hence, non-parametric equivalents of One way ANOVA and Tukey's Post Hoc Test, which were the Kruskal Wallis test and the Dunn-Bonferroni post hoc test analysis, were conducted. Levene's test revealed homogeneity of variance between the three groups across all variables.

Corsi Block-Taping Task (Mueller, 2011a) – Working Memory

The K-S Lilliefors test indicated that the data for memory span deviated significantly from normal ($D(91) = .163$, $p > .01$). Although, Levene's test of homogeneity of variance was not significant ($F(2.88), = .363$, $p = .697$) indicating equality of variance across the three language groups for all the selected variable (Correctness or Total Correct Trials and Memory span).

There was a statistically significant difference between the total number of correct trials between the three language groups ($H(2) = 6.163$, $p = .046$), with a mean rank of 41.18 for Bilinguals, 41.37 for Trilinguals and 55.60 for Quadrilinguals. Post hoc tests indicated significant differences between Bilinguals and Quadrilinguals ($p = .031$) and Trilinguals and Quadrilinguals ($p = .032$). Differences between Trilinguals and Bilinguals were not statistically significant.

Similarly, a statistically significant difference between the memory spans of the three language groups was found ($H(2) = 5.976$, $p = .050$), with a mean rank of 41.4 for Bilinguals, 41.29 for Trilinguals and 55.47 for Quadrilinguals. Post hoc tests indicated significant differences between Bilinguals and Quadrilinguals ($p = .035$) and Trilinguals and Quadrilinguals ($p = .033$). Differences between Trilinguals and Bilinguals were not statistically significant. Lastly, the effect size for both total number of correct trails and memory span is medium highlighting the significance of the difference between the two variables has practical implications.

Table 2
Chi-square Values for Corsi Block-Taping Task (Mueller, 2011a)

Variable	Language Group	N	Mean	SD	Mean Rank	Kruskal-Wallis Chi-square	Sig.	Eta Squared (η2)
Block Span	Bilingual	0	6.10	1.47	45.12	4.378	.112	.027
	Trilingual	1	5.81	1.23	39.85			
	Quadrilingual	0	6.37	1.56	53.23			
	Total	1	6.09	1.43				
Total Score	Bilingual	0	54.37	24.54	43.05	5.231	.073	.068
	Trilingual	1	51.39	21.44	40.32			
	Quadrilingual	0	61.80	24.05	54.82			
	Total	1	55.80	23.52				
Total Correct Trials	Bilingual	0	8.50	1.87	41.18	6.163	.046	.079
	Trilingual	1	8.55	1.67	41.37			
	Quadrilingual	0	9.20	2.37	55.60			
	Total	1	8.75	1.99				
Memory Span	Bilingual	0	5.23	0.98	41.4	5.976	.050	.077
	Trilingual	1	5.27	0.84	41.29			
	Quadrilingual	0	5.60	1.18	55.47			
	Total	1	5.37	1.01				

Note. ***p* <.05, η2 = .01 indicates a small effect; η2 = .06 indicates a medium effect; η2 = .14 indicates a large effect size

The Go/No-Go Task (Mueller, 2011b) – Inhibitory Control

Similar to the data for memory span, the K-S Lilliefors test indicated that the correctness (total correct trials) data deviated significantly from normal (D(91) = .180, $p > .01$). Although, data for commission error did not deviate from normal (D(91) = .101, p = .022). Additionally, Levene's test of homogeneity of variance was not significant (F(2.88), = 2.900, $p = .060$) indicating equality of variance across the three language groups for all the selected variable (Correctness or Total Correct trials, Total Error). Levene's test of homogeneity of variance was significant (F(2.88), = 5.121, $p = .008$) indicating inequality of variance across the three language groups for omission error.

There was a statistically significant difference between the number of total correct trials and total error between the three language groups (H(2) = 7.874, $p = .020$), with a mean rank of 45.48 for Bilinguals, 36.94 for Trilinguals and 55.88 for Quadrilinguals for total correct trials and 46.52 for Bilinguals, 55.06 for Trilinguals and 36.12 for Quadrilinguals for total errors. Post hoc tests indicated significant differences between Trilinguals and Quadrilinguals ($p = .005$). Differences between Trilinguals and Bilinguals and Bilinguals and Quadrilinguals were not statistically significant.

Similarly, a statistically significant difference between the omission errors of the three language groups was found (H(2) = 9.970, $p = .007$), with a mean rank of 53.22 for Bilinguals, 50.60 for Trilinguals and 36.12 for Quadrilinguals. Post hoc tests indicated significant differences between Bilinguals and Quadrilinguals ($p = .011$) and Trilinguals and Quadrilinguals ($p = .004$). Differences between Trilinguals and Bilinguals were not statistically significant. Additionally, there was no statistically significant difference between the commission errors of the three language groups was found. Lastly, the effect size for all variable is large indicating a high validity and showcasing the practical importance of the findings.

Table 3
Chi-square values for The Go/No-Go task (Mueller, 2011b)

Variable	Language Group	N	Mean	SD	Mean Rank	Kruskal-Wallis Chi-square	Sig.	Eta Squared ($\eta 2$)
Total Correct	Bilingual	0	298.40	11.60	45.48	7.874	.020	.067
	Trilingual	1	288.03	31.91	36.94			
	Quadrilingual	0	301.93	13.32	55.88			
	Total	1	296.03	21.80				

	Bilingual	0	21.60	11.60	46.52			
Total Errors	Trilingual	1	31.97	31.91	55.06	7.874	.020	.098
	Quadrilingual	0	18.07	13.32	36.12			
	Total	1	23.97	21.80				
	Bilingual	0	4.07	5.82	53.22			
Omission Error	Trilingual	1	10.23	27.01	50.60	9.970	.007	.121
	Quadrilingual	0	1.83	3.98	36.12			
	Total	1	5.43	16.49				
	Bilingual	0	17.53	8.13	44.72			
Commission Error	Trilingual	1	21.74	10.70	54.37	5.528	.063	.072
	Quadrilingual	0	16.17	10.70	38.63			
	Total	1	18.52	10.10				

Note. ***p* <.05, η2 = .01 indicates a small effect; η2 =.06 indicates a medium effect; η2 = .14 indicates a large effect size

The Tower of London Task (Mueller, 2011c) – Problem Solving

Lastly, similar to the data for the previous two tasks, the K-S Lilliefors test indicated that the correctness (success out of 12 trials) data deviated significantly from normal (D(91) = .124, *p* > .01). Additionally, Levene's test of homogeneity of variance was also not significant (F(2.88), = .347, *p* = .708) indicating equality of variance across the three language groups for all the selected variables (Correctness or Success out of 12 trials).

There was no statistically significant difference between any of the measures of problem-solving as measured by the Tower of London task (Mueller, 2011c) between the three language groups. The effect size across variable is small indicating low practical implications and replicability of the results in similar future studies.

Table 4
Chi-square Values for The Tower of London Task (Mueller, 2011c)

Variable	Language Group	N	Mean	SD	Mean Rank	Kruskal-Wallis Chi-square	Sig.	Eta Squared (η2)
Success: Out of 12 Trials	Bilingual	30	7.10	2.38	44.17	2.104	.349	.001
	Trilingual	31	6.87	2.93	42.37			
	Quadrilingual	30	7.73	2.48	51.58			
	Total	91	7.23	2.61				
Total Score: Out of 36	Bilingual	30	21.00	7.09	43.18	2.415	.299	.038
	Trilingual	31	20.61	8.79	42.84			
	Quadrilingual	30	23.30	7.43	52.08			
	Total	91	21.59	7.81				
Total Time	Bilingual	30	262.77	105.90	43.08	.562	.755	.017
	Trilingual	31	288.18	131.97	47.02			
	Quadrilingual	30	278.01	106.43	47.87			
	Total	91	276.45	114.80				

Note. ***p* <.05, η2 = .01 indicates a small effect; η2 = .06 indicates a medium effect; η2 = .14 indicates a large effect size.

Discussion

Results from earlier studies examining the relationship between language and executive functioning have been ambiguous. It is still unclear as to what extent does linguistic ability influence their executive functions. By examining the relationship between number of languages spoken and executive functioning, specifically working memory, inhibitory control and problem solving in the context of Indian bilinguals, trilinguals, and quadrilinguals, this study aimed to close gaps in the existing literature.

The results from Kruskal Wallis test demonstrated a significant difference in working memory (p = .050) and inhibitory control (p = .020) between the three language groups. Differences were found particularly between quadrilinguals and the other two language groups and not among bilinguals and trilinguals. Interestingly, there were no significant findings for problem solving amongst the three language groups. Therefore, the findings reflect the dichotomy as found in past literature. It shows that multilingualism has significant effects, especially among an Indian population. Although the extent to which it influences executive functioning still

remain ambiguous, as does the reasoning behind the same, the findings of this research help us to understand this complex relationship and the role of culture a little bit better.

Results of the Corsi Block Tapping task (Mueller, 2011a)

The results indicated that Quadrilinguals outperformed both bilinguals and trilinguals. Additionally, a statistically significant difference was not obtained between bilinguals and trilinguals. Past literature comparing the results of bilinguals and trilinguals on working memory have also found insignificant differences between the two groups (Bialystok, 2008; Poarch & Hell, 2012). The current data, on the contrary, suggests that bilinguals may have outperformed trilinguals (Mean Rank $_{\text{Bilingual}}$ = 41.40, Mean Rank $_{\text{Trilingual}}$ = 41.29). This corroborates the findings of the study done by Iyer and Venkatesan (2021) on Indian Children. Therefore, we can infer that while a bilingual advantage has been seen in the past, trilinguals do not experience an enhancement in working memory as a result to the third language. However, quadrilinguals do exercise this advantage and outperform both bilinguals and trilinguals in working memory tasks.

Results of the Go/No-Go Task (Mueller, 2011b)

The results of the Go/No-Go task (Mueller, 2011b), too showed that Quadrilinguals outperformed the other two groups. Similarly, differences in the scores between bilinguals and trilinguals were not statistically significant. These findings corroborate the findings of two past studies (Poarch & Hell, 2012; Schroeder & Marian, 2016). On the other hand, contrary information was presented by Hsu (2014) stating that trilinguals and bilinguals were indeed different from each other. These variations are hypothesized to be attributed to task difficulty or overload of demand in the attentional control areas of the mind.

Results of the Tower of London Task (Mueller, 2011c)

Unlike the other two tasks, the Tower of London task (Mueller, 2011c), results revealed that there were no statistically significant differences between the three language groups. This indicates that the number of languages spoken by an individual did not have much influence over the individuals' problem-solving skills. Research about the relationship between an individual's linguistic ability and non-linguistic problem solving skills has not been explored in depth as most studies tend to focus on the primary measures of executive functioning, such as working memory (Antoniuo et al., 2016; Iyer & Venkatesan, 2021; King, 2020; Mehrani & Zabihi, 2017; Reyes, 2013), attentional control (Bialystok, 2008; Bialystok, Barac, Blaye & Poulin-Dubois, 2010; Hsu, 2014; Limber & Buchweitz, 2014; Poarch & Hell, 2012a), inhibition (Bialystok & Craik, 2010; Hsu, 2014; Matilda et al., 2021; Mehrani &

Zabihi, 2017; Miyake et al., 2000; Oschwald, et al., 2018; Poarch & Hell, 2012; Poarch et al., 2018) as well as linguistic tasks (Barac & Bialystok, 2012; Bialystok & Craik, 2010; Limber & Buchweitz, 2014; Oschwald et.al., 2018), and not on complex measures of executive functioning, such as problem solving. Although, the few studies that have been done, state that the bilinguals are better at problem solving than their monolingual peers (Bialystok & Majumder, 1998).

Furthermore, being a secondary measure of executive functioning, problem solving is a combination of working memory and inhibitory control. It is, therefore surprising to see that although differences were observed for both its primary variables, and yet differences were not found for problem solving. This indicates one of two things, first, problem solving is a much more complex task and factors beyond the number of languages an individual speaks affect it; or second, the Tower of London task lacks criterion validity (Phillips, 1999).

Overall Discussion

Past literature studying the effects of quadrilingualism, are limited in many ways. Firstly, studies that have been able to find and conduct experiments on quadrilingual participants are very few in number (Catalano, 2018). Furthermore, most papers that discuss multilingualism tend to group trilinguals and quadrilinguals together in order to create a large enough sample size (Kown, et al., 2021; Pfenninger, 2014). These corrections make the conclusions made by such studies not generalizable to either of the two groups – trilinguals or quadrilinguals. The current study not just makes a clear distinction between the two language groups but also reveals that while the difference between bilinguals and trilinguals is not that vast, knowing a fourth language might result in a significant difference.

Moreover, emphasis on the kind of tasks used and the demands of the particular task must also be taken into account. The Go/No-Go task has been used by several studies to understand the relationship between language and executive functioning (Fernandez et al, 2013). However, working memory has usually been explored through linguistic tasks, such as word recall tasks. As the current study wanted to see the influence of language on non-linguistic tasks, the Corsi-Block Tapping task (Mueller, 2011a) was used. Different tasks, although they measure the same variable, have varying demands in the amount of cognitive control required to finish the task (Poarch, 2018). Therefore, while the current study's results were not significant for the Tower of London task (Mueller, 2011c), using another task of problems solving, such as Remote Associates task (Mednick, 1968) may have yielded different results.

As one of the rationales behind the relationship of language and executive functioning is that learning multiple languages results in an increased cognitive load providing training opportunities for the executive functioning, the kind of task used to measure the said executive function plays a crucial role. Two tasks, although measuring the same variable, having two different demands from the individuals is an

internal variable that should be accounted for. The study done by Poarch (2018) found significant results for the Flanker task present across different language groups, but not for the Stroop task or Go/No-Go Task. Similarly, although the Go/No-Go task (Gordon & Caramazza, 1982) is used to measure the same variable, it partially also measures task switching, as in the second set of the 180 trials, the target and foiled stimulus are swapped, thereby resulting in an increased demand of cognitive control from the participants.

Past studies have also found that being a fluent speaker versus a learner of a language too has varying effects on one's cognitive capabilities (Chung-Fat-Yim et al., n.d; Pfenninger, 2014; Poarch & Hell, 2012a; Schroeder & Marian, 2016). Thus, distinguishing between learners versus fluent speakers of a language should also be accounted for through proficiency checks. Additionally, the rationale that cross-language interferences enhance task-switching and attentional control requires the individual to have good proficiency within the languages. If these cross-language interference are not enough, there would lesser training and hence lesser cognitive advantages experienced.

Although, the current study did record proficiency levels, it was unable to control for the same due to time restrictions. Furthermore, FLAME University (from where the participants were recruited from) makes it compulsory to take two language courses for all students in their first-year of study. This could be another factor that might have influenced the results of the study.

Other factors, such as different individual upbringings, early experiences with the language, patterns of language use, and other lifestyle elements also play a vital role in the development of executive functioning skills among people (Poarch, 2018). Environmental factors such as individual stress levels, sleep deprivation, loneliness are all confounding variables that influence an individual's executive functioning (Diamond, 2013). The current study was not able to control for these, due to lack of time and resources, which may have affected the results.

Implications of the Study

Despite the restrictions, the results of the study were able to highlight a significant benefit experienced by quadrilingual individuals. The results can be used to encourage school students to learn more languages. As the study was done amongst an Indian population, students should be motivated to not just take up the foreign language classes offered but to also familiarize themselves with their own regional languages. This encouragement from an early age will help them gain a more balanced proficiency in all the languages that they speak, which may translate into higher executive functioning in their adult life.

Furthermore, schools could introduce a multilingual education system in the classroom. Such a system can be an effective approach to foster academic success and intellectual development in addition to promoting language diversity. However, it

is also vital to take into account practical factors like the accessibility of resources (well-trained teachers, and resource materials), student's choices and demands as well as future economic value of the languages.

Strengths and Limitations of the Study

Most of the studies that have been previously conducted studies have sampled participants from European or American populations. Very few studies have been done on Indian populations (Iyer & Venkatesan, 2021; Daga & Rajan, 2023). The current study is one among a handful to explore the relationship of language and executive functioning using Indian languages as well as on a sample recruited from an Indian population. This study adds onto the existing literature by expanding on previous research. Moreover, very few studies have studied quadrilingual populations. Given the prevalence of multiple languages in India, the present research was able to investigate on quadrilingual individuals as well. While the study was able to yield a few significant results, there are a few limitations to the research as well.

Data Collection for Number of Languages Spoken. The data concerning number of languages spoken as well as the proficiency in each of the language spoken was collect using a self-report survey. No other scales or tests, were used to recheck this information. This ambiguity in level of proficiency could be one of the variables that may have led to the observed results. Future research studies should focus on checking these values using language proficiency tests.

Unable to Control for Similarity of Languages, Proficiency in Language, as well as Age of Language Acquisition. There was vast variation in the different languages the participants reported. These language differences as well as the age at which they were acquired may have impacted the results. Past research has shown that similarity of languages and age of acquisition play an important role. Therefore, ensuring that all participants speak the same languages as well as ensuring that they were learned around the same age will help avoid ambiguity within the results. Due to the lack of time and resources the present study was unable to check for the same.

Future Directions

Choosing a More Random and Diverse Sample

The current study recruited participants from only one university due to lack of resources and time. Future studies should, hence, try to get a diverse sample with individuals from all age groups. India is a large country with a population of over one million people (Worldometer, 2023) that come from various cultural backgrounds. With such a large population, researchers should aim to gain a diverse and large sample size to be able to generalize the results. Moreover, studies involving quadrilinguals should be emphasized, wherein they are not being clubbed together with trilinguals.

Understanding and Exploring the Various Measures of One Variable

Lastly, although various tasks claim to measure the same variable, literature has reported differences in the results found when two different tasks are used to measure the same variable (Barac & Bialystok, 2012; Calva & Bialystok, 2014). Thus, future studies should account for such differences.

Conclusions

In conclusion, although assessing multilingualism can be difficult due to the wide range of environmental and situational (house, education, work environment, neighbourhood and locality) and, individual (proficiency of languages spoken, utilization of languages in everyday life, age at which the language was learned etc.) factors, such differences in language experiences are the reasons that necessitates for more focused research on how multilinguals not only differ from monolinguals but also from other multilinguals.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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