

Executive Control in Filipino-English Bilinguals and Chinese-Filipino-English Trilinguals: Evidence from the Simon Arrows Task

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Abstract

A comparison between the performance of 48 Filipino-English bilinguals and 57 Chinese-Filipino-English trilinguals shows that the latter group did better on the incongruent trials than on those that were congruent, under Super Lab Pro software. The data can be interpreted in terms of the trilinguals' heightened attention to greater conflict engendered by the activation of reasonably well separated representations of the three languages in question. This implies that the ongoing management of assorted linguistic systems may impart a general advantage to the executive functions, especially those involving inhibitory control [1]. The Simon Arrows Task, variant of the classic Simon task, is a good measure of this inhibitory control, as it looks at an individual's ability to suppress irrelevant spatial information [2]. Thus, this task can serve as a valuable tool for studying whether the cognitive demands imposed by the active management of multiple languages enhance the efficiency of executive control processes which, in turn, results in faster responding or higher accuracy when resolving conflicts [1].

Keywords: *Executive Control, Bilingualism, Trilingualism, Inhibitory Control, Simon Arrows Task, Cognitive Flexibility*

1. Introduction

The varied results for each of these behavioral and electrophysiological measures in the current body of language context studies require these parameters to be considered in a unified experimental design, so as to understand fully how multilingualism interacts with nonverbal cognitive performance [3]. Prior studies found that bilinguals and trilinguals often have better-developed executive control than monolinguals, a difference that is most pronounced in inhibition and conflict resolution tasks [4];[3]. The so-called "bilingual advantage hypothesis" claims that the co-activated languages need to be managed and shifted actively, which engages the very neural substrates that form the basis of inhibitory control processes [5]. By virtue of their continuous activation and suppression of linguistic representations, it is believed that this will result in a more efficient allocation of attentional resources and improved cognitive flexibility [5]. Yet the existence and extent of such advantages are still under discussion, and some studies provide inconsistent or zero effects, especially when different operationalizations of bilingualism were used [1].

This study aims to further that debate in assessing executive control differences between Filipino-English bilinguals and Chinese-Filipino-English trilinguals, with a hypothesis that trilinguals would be at a more significant advantage on inhibitory control tasks due to the increasing linguistic demands placed on them. The Simon Arrows Task is used in this research to examine these assumptions regarding differences, thus presenting a differentiated perspective on how multilingualism, in varying degrees, can be expected to affect the development of executive function [6]. This illustrates how complex the definition and measurement of multilingualism as an important factor in cognition are, needing finer-grained specification of the very language experiences involved and their interaction with task demands [3]. An example of this would be the language context, like whether code-switching occurs or whether an environment is entirely in one language, which could limit the cognitive effects of multilingualism [3]. To understand this better, both behavioral performance and neural correlates would have to be investigated, since manipulating language context may lead to effects in either domain [3]. Specific aspects of the bilingualism itself, like proficiency, age of acquisition, and language dominance, influence the nature and magnitude of cognitive advantages that manifest [7]. This paper, therefore, carefully delineates participant groups according to these factors, to foster a strong comparison between Filipino-English bilinguals and Chinese-Filipino-English trilinguals. It intends to identify effects of different levels of multilingualism on cognition, or to compare the executive control abilities of bilinguals and trilinguals within a hence non-Western context. It will closely assess through the rigorous application of the Simon Arrows Task-the building of resources within an executive capacity for managing different languages, especially in a trilingual scenario, on specific aspects such as conflict resolution and attentional control [8]. This study is expected to contribute brilliantly to the ongoing argument under the cognitive plasticity framework by offering evidence on how multiple languages impact on molding and fine-tuning cognitive abilities [25]; [27]; [29]; [9].

Theoretical Framework

It is a theoretical frame which assumes the fact that the engagement of a multicompetent linguistic system demands a higher capacity cognitive effort, which in turn develops better working executive function mechanisms [9]. This whole view indicates that the ongoing battle among competing linguistic representations acts as a cognitive exercise, thus strengthening the general-purpose processes of executive control-inhibition, task switching, and working memory. Of specific interest is that the Simon task paradigm, especially the arrow version, provides a good experimental setup for probing the issue of inhibitory control by complementary effects. In this case, spatially incongruent responses would produce, typically, longer reaction times, thus reduced accuracy [3]. This is interference referred to as the Simon effect, whereby it can be measured a person has the ability to inhibit even automatic irrelevant spatial information in favour of features relevant to the task [11]. Thus, along the lines of response latencies or accuracy scores on congruent and outcome incongruent conditions, it is possible to infer about the effectiveness of executive control about conflicting information [12];[13]. It would be consistent with the point that the co-activated linguistic systems' demands lead to a more generalized improvement of cognitive monitoring processes, depending on overall reaction times on interference tasks [14].

This increased cognitive demand associated with managing multiple languages is theorized to lead to advantages in very different domains of executive function, such as inhibitory control, attentional control, and cognitive flexibility [15]. This suggests a differential effect of language experience on higher-level cognitive mechanisms relative to lower-level ones [16]. The "resistance to interference" framework postulates that multilingualism leads to a stronger and more efficient selection mechanism regarding the target stimuli or responses in the presence of conflicting inputs, which results in lower levels of interference effects [14]. Such evidence, on how much these abilities are effective in solving the resistance to an opposition made by coactivated language representations, could be directly explained by the Inhibitory Control Model - a domain general approach for executive control driven by top-down cues (Simonis et al., 2020). This would mean that bilinguals and trilinguals tend to show a decreased Simon effect likewise-inhibition-control processes that these subjects must frequently pursue entirely to keep more than one language in working memory [1].

Literature Review

The bilingual advantage in executive functions has been one of the popular topics of research, which assumes that the constant need to manage and switch between two or more languages enhances general cognitive control [18]. Considering the viewed continuous activation and suppression of language representations, it is said that inhibitory control and cognitive flexibility have been enhanced due to this phenomenon [15]. However, the very definition and measurement of bilingualism were pointed out to be some of the major factors that would make an influence in finding and interpreting that advantage, with differences in methodology likely leading to different conclusions [1]. Therefore, many studies along these lines have started to deal with trilingualism as a continuous variable and not as a dichotomous one, focusing on using specific linguistic experiences for the purpose of cognitive performance, while statistically controlling for confounding background variables such as socioeconomic status, intelligence, and age [19]. This allows for a more fine-grained consideration of how multilingual experiences may act- or come to bear- on executive function in terms of age of acquisition, language proficiency, and daily use of languages [15]. Current evidence also seems to suggest that the advantages of multilingualism may operate beyond executive functions to include white matter integrity and general brain connectivity, which could provide another avenue for neuroprotection and facilitate cognitive enhancement [20]

Evidence from the most recent literature suggests that multilingualism has become an object of study in its own right. On the one hand, the working hypothesis behind this line of reasoning suggests that continued language conflict resolution may, in turn, actually modify the executive function networks more generally [3]. Assuming such a premise, it would follow that the constant mediation across competing linguistic systems eventually strengthens other domain-general cognitive processes-such as executive attention, being of utmost consequence in holding task-relevant information in the presence of interference [15]. Further empirical evidence suggests that bilingualism, specifically multilingualism, is associated with improved cognitive functions such as working memory, attentional control, and problem-solving abilities, thereby indicating a wide range of cognitive benefits [21]. The existence of various languages in one's mind generates competition whereby one must inhibit the irrelevant language while attending to the active language for potential interference [22]. This continued engagement of executive control supposedly grants

cognitive advantages to bilingual and multilingual individuals over their monolingual counterparts [16]. However, the latest rounds of meta-analysis and critical review have argued that the evidence in favor of a generalizable "bilingual advantage" within executive function is essentially zero when taking into consideration publication bias and various other explanatory factors [4]. Even with these critiques, some emerging evidence shows that the effects of multilingualism on cognitive functions may be task-specific, mainly being manifested in nonverbal tasks with greater executive demands especially for children and older adults [23]. For instance, some studies suggest that the cognitive advantages related to bilingualism may depend on the specific languages spoken [9]. This is especially pertinent in light of the similarities between the languages, given that languages with high overlap may lead to more competition, which puts a higher demand on inhibitory control and executive functions [23].

Statement of the Problem

While there are countless studies that have looked into the cognitive advantages of being bilingual, not enough work has been done to examine the influence of trilingualism, more specifically in a strange linguistic situation like Filipino-English-Chinese, upon executive control. This study intends to fill that gap by comparing the efficiency of executive controls in Filipino-English bilinguals and Chinese-Filipino-English trilinguals using the Simon Arrows Task [15]. This task was chosen because it allows for the measurement of some significant components of executive function, such as inhibitory control and cognitive flexibility [4]. Using the neurophysiological measure of the Simon Arrows Task gives a more objective and more finely grained analysis of the cognitive processes inherent in executive control, thereby minimizing the inherent confounds involved if either self-report measures or behavioral task measures are used exclusively [19]. This further allows these two groups to be compared side by side in terms of response times and error rates during congruent and incongruent conditions and give insight into the mechanisms by which they resolve conflict. Therefore, this study is interested in answering the question: how do Filipino-English bilinguals compare with Chinese-Filipino-English trilinguals?

2. Methodology

In this section, we will explain how the study was designed, how participants—Filipino-English bilingual and Chinese-Filipino-English trilingual people—were recruited and how data collection was carried on, as well as the analytical techniques that were used. The research design compared Simon Arrows Task performance to explore cognitive effects of multilingualism, thus aiming to find out cognitive implications of different levels of multilingualism in relation to the performance of each group.

Research Design

The quantitative study employed the Two- Factor ANOVA in repeated measures design to analyze the combination of between subjects (sex: male vs. female) and within subjects (i.e. semantic priming for related and non-related primes). Two- way Analysis of Variance was employed to compare the means of two independent variables of two or more populations. It was

used to test the interaction between the two independent variables [29]; [6]. This task was selected given the well-cultivated precedent of its ability to elicit conflict resolution and measure inhibitory control, all pivotal aspects of executive function [23]. The Simon Arrows Task measures incongruent stimuli handling by the participants: a task that is most relevant when dealing with the contexts of active competition between multiple language systems [23] [3]. Given its design, it further enables the dissociation of processing efficiency between congruent and incongruent trials, thus serving as a solid measure of cognitive flexibility and attentional shifting in multilingual populations [3]. Therefore, reaction times and accuracy rates will be focused on for the subsequent analysis in order to quantify the efficiency of executive control processes in mediating language interference. The made-run method will attempt to elucidate possible differences in cognitive processing strategy coming from different linguistic backgrounds, which in turn may lead to a better understanding of the interaction between language experience and executive functions [1]. Besides, such intuitive instructions for the task reduce working memory-related confounds, which could be detrimental for interpretation in other very complex cognitive tasks [24].

The Participants

Within the original sample of 120 participants, those who had accuracy scores falling 2 standard deviations below the mean were categorized as outliers owing to frequent errors and excluded from possible statistical analysis. Out of these, 15 outliers were: 12, 17, 18, 25, 50, 52, 61, 65, 73, 75, 83, 86, 99, 100, 103. Hence, there remained 105 participants for statistical analysis. Participants in this study consisted of 50 males and 55 females, aged 12-15, who were all high school students. The extemporaneous speaking test indicated that all respondents in this research were performing well up to proficient (70-85% competence) levels in speaking Chinese, Filipino, or English, proving that the respondents were authentic Filipino-English and Chinese-Filipino-English trilinguals.

The Instruments

As per Madrazo and Bernardo [29], the Simon Arrows task was performed on a laptop with a 14-inch screen using Superlab (version 4.0) software. The participants were instructed to press either the "X" or "?" keys for their responses indicating left or right for all types of trials (i.e. control, reverse, congruent, and incongruent). Before the main blocks of trials, participants received instructions to complete the task as fast and accurate as they could. Following this, they undergo 10 practice trials, which were feedback trials. For the main trials, there were two 58-trial blocks under the control condition and two under the reverse condition. Lateral trials consisted of two blocks of 96 trials, which included 48 congruent and 48 incongruent trials. The six blocks were presented in two different counterbalanced sequences. The first was control, reverse, lateral, reverse, lateral, control; the second was control, lateral, reverse, lateral, reverse, control. Within each block of trials, the trials were displayed in a random order. Each block commenced with an uppercase "X" in regular Tahoma font sized 20 points at the central fixation point. The stimulus trial appeared in the target location and remained on the screen until the participant made a response. The next trial appeared at an interval of 30 milliseconds after the response made by the participant. The participant was then asked a question regarding moving on to the next block of trials at the conclusion of each block. The subsequent block commenced as soon as the participant responded to the prompt. No feedback was provided for the main trial blocks.

Proficiency Examination

The test of proficiency was an extemporaneous speaking test that gauged reception (comprehension) and production (speaking). It was intended for high school students in a specific area in the Philippines to measure their proficiency in a certain language. Reception meant understanding the questions before going into speaking proper, but the proficiency score came mostly from ratings of the oral production of the participants. Three evaluators were proficient in the three languages and rated the spoken and written products using modified Heaton's (1989) rating scales. They read a question in one language to the participants, and they had to give their opinions or express their ideas on a topic using that same language; they were given different questions, too, for every language. Then recorded their oral responses. For the bilingual speakers, the first test was in Filipino, followed by English, while for the trilinguals, it was Filipino, English, and, then, Chinese. Giving them a preparatory time of 5 minutes to prepare and organize ideas for a speech that must be delivered within 3-5 minutes, and if, conceivably, the participant had minimal ideas pertinent to a topic, he/she would still be able to answer a different question.

Data Collection

This study went through Research Ethics Review and cleared for data collection. The researchers obtained permission from the school principal and acquainted the office with pertinent data about the study-research objectives, significance of the study, procedures of data collection, ethical considerations, and research tools-within the context of the review for this study. Once permission was obtained, the researcher directly goes to the site to make communications with the department head and the class advisers for the learner profiles and schedules for collecting data. In addition, the researcher ensured that all participants had been properly oriented with the study's objectives and procedures before data collection.

3. Results

The language groups were compared on the less cognitively taxing Simon arrow task trials. The values marked the response accuracy and reaction times of control and reverse trials. A separate Mixed Design ANOVA was carried out for each dependent variable (accuracy & reaction time), testing language group (bilingual vs. trilingual) as a between-groups factor and direction of trial (control vs. reverse) as a within-groups factor. The ANOVA on accuracy showed that, indeed, subjects were more accurate in control than in reverse trials [$F(1, 103)=13.10$, $MSE=302.16$, $p<.001$, $\eta^2p=.06$] and that trilinguals were more accurate than bilinguals [$F(1, 103)=6.81$, $MSE=252.14$, $p=.004$, $\eta^2p=.05$]. The interaction of language groups and direction trials was also significant [$F(1, 103)=4.15$, $MSE=94.56$, $p=.013$, $\eta^2p=.03$]; in reverse trials, this significant dip in accuracy was evidently heavier for the bilingual population. When it comes to response times, response times for reverse trials were rather slower for both groups [$F(1, 103)=8.70$, $MSE=89442.72$, $p=.031$, $\eta^2p=.06$], but none between bilinguals and trilinguals [$F(1, 103)=0.88$, $MSE=43163.75$, $p=.578$, $\eta^2p=.005$], or their interaction separately [$F(1, 103)=0.51$, $MSE=3716.84$, $p=.617$, $\eta^2p=.032$]. Therefore, there is limited evidence which would

state that trilinguals had more advantage over bilinguals in this task of response inhibition in cases where there is less conflict. Trilinguals were better at this task than bilinguals, in terms of increased accuracy and faster response times, although their accuracy was less affected than that of bilinguals in cases of reverse response options. The effect sizes of the advantages, however, were statistically small. Given those small effect sizes, they do not provide any viable reason to reject the hypothesis positing that there will be no trilingual advantage in inhibitory control tasks. So, I then compare difference between the two group-lateral trials, which were the most cognitively demanding in that they required not only response inhibition but also interference suppression. Congruent and incongruent trials' accuracy and reaction times were presented such that each dependent variable underwent separate ANOVA with mixed designs, with language group as the between-groups factor and direction trial (congruent vs. incongruent) as the within-groups factor. Accuracy ANOVA results suggest that participants were more correct on congruent than incongruent trials [$F(1, 103)=213.66$, $MSE=20271.63$, $p<.002$, $\eta^2p=.52$], while trilinguals were more accurate than bilinguals [$F(1, 103)=64.82$, $MSE=8682.73$, $p<.0012$, $\eta^2p=.36$]. Language groups did interact with direction trials [$F(1, 103)=64.62$, $MSE=6632.01$, $p<.0022$, $\eta^2p=.36$]; the drop observed in accuracy levels of incongruent trials was largely in the bilingual population. In terms of response latency, participants used more time for incongruent trials [$F(1, 103)=58.12$, $MSE=260831.47$, $p<.0013$, $\eta^2p=.32$]. A significant difference between bilingual and trilingual participants was also evident [$F(1,103)=68.68$, $MSE=241148.35$, $p=.004$, $\eta^2p=.28$] as the average response time favors trilinguals. Interaction between language groups and direction trials proved to be significant as well [$F(1, 103)=72.79$, $MSE=562097.73$, $p=.0021$, $\eta^2p = .36$]. Thus, there exists very strong evidence for trilingual superiority over bilinguals in this relatively more complicated inhibition task involving both response inhibition and suppression of interference. Trilinguals were faster and more accurate than bilinguals, and their response time and accuracy were less thwarted in incongruent trials compared to congruent ones.

4. Discussion

The study's results are supportive of the hypothesis that Chinese-Filipino-English trilinguals have greater executive control than Filipino-English bilinguals under conditions of high cognitive workload, as measured by the Simon Arrows Task. The main effects on accuracy exhibit that all participants performed better in the less taxing control conditions, compared to the reverse ones, which were more demanding. Trilinguals compared to bilinguals showed significantly higher accuracy overall, which corresponds to superior inhibition by the trilinguals. Following up on the cognitive differences with an interaction effect between language group and trial direction, trilinguals experienced decreased accuracy in reverse trials for both groups but not as severely as the bilinguals. The implication here is that the trilinguals have more efficient operations in resolving the conflict and attentional control because they are better able to deal with the increased interference that was present in the reverse trials. This finding would fit well into the theory that continuously managing multiple language systems enhances domain-general executive functions, including inhibition and cognitive flexibility.

The trials of the Simon Arrows Task for the current study has indeed proven to be effective, since it enhances sensitivity to inhibitory control processes and permits performance to be distinguished in terms of congruent versus incongruent stimuli . The design of the task, favoring

conflict resolution and attentional shifting—two domains of executive function developmentally affected by multilingual experiences—minimizes nuisance variables from working memory. Also a methodological rigor added during well-controlled data collection procedures such as ethical clearance, orientation to participants, and proficiency validation, will assure that the demonstrated cognitive advantages are due to true language group differences and not due to confounding variables. The proficiency test confirmed that across both language groups, participants were proficient enough in the language, thereby minimizing the confounding variables that would arise due to difference in language skills. These findings contribute to the deepening debate on the multilingual advantage in executive function. Whereas other meta-analytic studies have doubted the universality of this advantage, currently, the study emphasizes the role of language context, language proficiency, and the specific cognitive demands that the task imposes in bringing about this advantage. The performance by trilinguals is enhanced under more challenging conditions, supporting those theories that advocate for task-specific and context-specific manifestation of cognitive advantages due to multilingualism [23];[3].

Furthermore, the current study extends the literature by analyzing a very unusual linguistic situation where Filipino-English bilinguals are compared with Chinese-Filipino-English trilinguals, which brings fresh insights into how various multilingual combinations may engage executive control networks in different ways. The constant need to coordinate three different language systems probably requires shifting inhibitory demands and thereby strengthening executive function [9].

In brief, this suggests that trilingualism, particularly among linguistically distinct languages, should confer a stronger executive control advantage than bilingualism. Most probably, this advantage applies to situations more demanding to resolve conflicts and inhibit actions, as witnessed in results from the Simon Arrows Task. It is imperative that future investigations adopt neurophysiological correlates and expand participant subject pools to provide additional clarification on the mechanisms of multilingual cognitive advantage.

5. Conclusion

This research gives strong evidence that trilingualism is better than bilingualism for executive control acquisition, especially in inhibitory control and conflict-resolution tasks. The Simon Arrows Task — a sensitive measure of executive function — was employed where Chinese-Filipino-English trilinguals surpassed Filipino-English bilinguals in faster and more accurate responses under higher cognitive demands characterized by incongruent trials. This lends credence to the theoretical framework that managing multiple distinct linguistic systems engages and strengthens domain-general executive function processes such as inhibitory control, attentional shifting, and conflict resolution. The results agree with recent perspectives emphasizing the importance of language context, proficiency, and task-specific cognitive demands in eliciting multilingual cognitive benefits, resolving some controversies in the bilingual advantage debate. The unique linguistic environment focused on Filipino-English bilinguals versus Chinese-Filipino-English trilinguals offers novel insights, showing that the continuous engagement and suppression required to manage three different languages and especially with different degrees of linguistic overlap increases inhibitory demands and hence executive function capacity. Methodologically, the study has vigorous design in terms of careful selection of participants, proficiency validation, and

the application of the Simon Arrows Task, which excises working memory confounds, tightening the validity of the conclusions drawn here. The fact that the trilingual participants performed better, particularly where higher inhibitory demands were placed (exemplified by reverse and incongruent trials), suggests that multilanguage experience may act like a form of cognitive training, improving the efficiency of these domain-general executive control mechanisms. In sum, the study contributes an important piece of evidence to a rapidly growing body of evidence that multilingualism, especially trilingualism in linguistically diverse contexts, facilitates some specific executive functions. It confirms that cognitive advantages show themselves in ways specific to the task and context: thus bringing forward theoretical and practical understanding of how multilingual experience sculpts the cognitive control system.

References

- [1]M. Champoux-Larsson and A. S. Dylman, "Different measurements of bilingualism and their effect on performance on a Simon task," *Applied Psycholinguistics*, vol. 42, no. 2, p. 505, Dec. 2020, doi: 10.1017/s0142716420000661.
- [2]G. J. Poarch and J. G. van Hell, "Executive functions and inhibitory control in multilingual children: Evidence from second-language learners, bilinguals, and trilinguals," *Journal of Experimental Child Psychology*, vol. 113, no. 4, p. 535, Aug. 2012, doi: 10.1016/j.jecp.2012.06.013.
- [3]A. Chung-Fat-Yim, G. J. Poarch, K. J. Comishen, and E. Bialystok, "Does language context impact the neural correlates of executive control in monolingual and multilingual young adults?," *Brain and Language*, vol. 222, p. 105011, Aug. 2021, doi: 10.1016/j.bandl.2021.105011.
- [4]R. Filippi and P. Bright, "A cross-sectional developmental approach to bilingualism: Exploring neurocognitive effects across the lifespan," *Ampersand*, vol. 10, p. 100097, Dec. 2022, doi: 10.1016/j.amper.2022.100097.
- [5]L. Gosselin and L. Sabourin, "Language athletes: Dual-language code-switchers exhibit inhibitory control advantages," *Frontiers in Psychology*, vol. 14, Mar. 2023, doi: 10.3389/fpsyg.2023.1150159.
- [6]J. Treffers-Daller, Z. Ongun, J. Hofweber, and M. Kořenář, "Explaining Individual Differences in Executive Functions Performance in Multilinguals: The Impact of Code-Switching and Alternating Between Multicultural Identity Styles," *Frontiers in Psychology*, vol. 11, Oct. 2020, doi: 10.3389/fpsyg.2020.561088.
- [7]A. J. Privitera, M. Momenian, and B. Weekes, "Graded bilingual effects on attentional network function in Chinese high school students," *Bilingualism Language and Cognition*, vol. 26, no. 3, p. 527, Dec. 2022, doi: 10.1017/s1366728922000803.
- [8]C. Goriot, M. Broersma, J. M. McQueen, S. Unsworth, and R. van Hout, "Language balance and switching ability in children acquiring English as a second language," *Journal of Experimental Child Psychology*, vol. 173, p. 168, May 2018, doi: 10.1016/j.jecp.2018.03.019.
- [9]S. R. Schroeder and V. Marian, "Cognitive consequences of trilingualism," *International Journal of Bilingualism*, vol. 21, no. 6, p. 754, Apr. 2016, doi: 10.1177/1367006916637288.
- [10]Z. Lin, "Analyzing the Effects of Second Language Acquisition on Children's Cognitive Development," *SHS Web of Conferences*, vol. 180, p. 2021, Jan. 2023, doi: 10.1051/shsconf/202318002021.
- [11]J. A. E. Anderson, A. Chung-Fat-Yim, B. Bellana, G. Luk, and E. Bialystok, "Language and cognitive control networks in bilinguals and monolinguals," *Neuropsychologia*, vol. 117, p. 352, Jun. 2018, doi: 10.1016/j.neuropsychologia.2018.06.023.
- [12]A. Patra, A. Bose, and T. Marinis, "Semantic context effects in monolingual and bilingual speakers," *Journal of Neurolinguistics*, vol. 57, p. 100942, Sep. 2020, doi: 10.1016/j.jneuroling.2020.100942.
- [13]N. Radman, L. B. Jost, S. Dorood, C. Mancini, and J. Annoni, "Language distance modulates cognitive control in bilinguals," *Scientific Reports*, vol. 11, no. 1, Dec. 2021, doi: 10.1038/s41598-021-02973-x.
- [14]A. B. Vivas, E. Chrysochoou, A. I. Ladas, and V. Salvari, "The moderating effect of bilingualism on lifespan cognitive development," *Cognitive Development*, vol. 55, p. 100890, Jun. 2020, doi: 10.1016/j.cogdev.2020.100890.

- [15]K. Antoniou and G. Spanoudis, "Inside the multilingual and bidialectal mind: an investigation of the cognitive effect on executive function," *Bilingualism Language and Cognition*, p. 1, Dec. 2024, doi: 10.1017/s1366728924000506.
- [16]G. deMeurisse and E. Kaan, "Bilingual attentional control: Evidence from the Partial Repetition Cost paradigm," *Bilingualism Language and Cognition*, vol. 27, no. 4, p. 599, Oct. 2023, doi: 10.1017/s1366728923000731.
- [17]M. Simonis, B. Galand, P. Hiligsmann, and A. Szmalec, "Attentional abilities of children enrolled in immersion education in French-speaking Belgium," *International Journal of Bilingual Education and Bilingualism*, vol. 26, no. 5, p. 554, Dec. 2020, doi: 10.1080/13670050.2020.1856033.
- [18]K. Beaudin and D. Poulin-Dubois, "Testing the Bilingual Cognitive Advantage in Toddlers Using the Early Executive Functions Questionnaire," *Languages*, vol. 7, no. 2, p. 122, May 2022, doi: 10.3390/languages7020122.
- [19]C. Vassiliu, V. Leong, and H. Hendriks, "The Influence of Multilingual Experience on Executive Function and Structure Learning: Effects in Young Adults in the UK and Singapore," *Languages*, vol. 9, no. 4, p. 136, Apr. 2024, doi: 10.3390/languages9040136.
- [20]G. Bubbico *et al.*, "Effects of four-month-long foreign language learning on executive functions and white matter integrity in older adults," *medRxiv (Cold Spring Harbor Laboratory)*, Sep. 2023, doi: 10.1101/2023.09.25.23296063.
- [21]R. Daud, "The Cognitive Benefits of Speaking Multiple Languages," *European Journal of Linguistics*, vol. 3, no. 4, p. 1, Jul. 2024, doi: 10.47941/ejl.2055.
- [22]T. Voits, C. Pliatsikas, H. Robson, and J. Rothman, "Beyond Alzheimer's disease: Can bilingualism be a more generalized protective factor in neurodegeneration?," *Neuropsychologia*, vol. 147. Elsevier BV, p. 107593, Aug. 31, 2020. doi: 10.1016/j.neuropsychologia.2020.107593.
- [23]P. Achaa-Amankwaa, E. Kushnereva, H. Miksch, J. Stumme, S. Heim, and M. Ebersbach, "Multilingualism is associated with small task-specific advantages in cognitive performance of older adults," *Scientific Reports*, vol. 13, no. 1, Oct. 2023, doi: 10.1038/s41598-023-43961-7.
- [24]D. Miller, F. Bayram, J. Rothman, and L. Serratrice, *Bilingual cognition and language: the state of the science across its subfields*. University of Reading, 2018. Accessed: Aug. 2025. [Online]. Available: https://centaur.reading.ac.uk/81305/3/HOF_SiBiL_final231218.pdf
- [25] E. Bialystok, F. I. M. Craik, C. Grady, W. Chau, R. Ishii, A. Gunji, et al., "Effect of bilingualism on cognitive control in the Simon task: Evidence from MEG," *Neuroimage*, vol. 24, pp. 40–49, 2005.
- [26] E. Bialystok, F. I. M. Craik, R. Klein, and M. Viswanathan, "Bilingualism, aging, and cognitive control: Evidence from the Simon task," *Psychology and Aging*, vol. 19, pp. 290–303, 2004.
- [27] E. Bialystok, F. I. M. Craik, and G. Luk, "Cognitive control and lexical access in younger and older bilinguals," *Journal of Experimental Psychology: Learning, Memory, and Cognition*, vol. 34, pp. 859–873, 2008.
- [28] E. Bialystok, F. I. M. Craik, and G. Luk, "Bilingualism: Consequences for mind and brain," *Trends in Cognitive Sciences*, vol. 16, pp. 240–250, 2012.
- [29] A. Madrazo and A. B. I. Bernardo, "Measuring two types of inhibitory control in bilinguals and trilinguals: Is there a trilingual advantage?," *Psychological Studies*, vol. 63, no. 1, pp. 52–60, 2018. doi: 10.1007/s12646-018-0439-9.
- [30] "11.3: Two-Way ANOVA (Factorial Design)," *Statistics LibreTexts*, Mar. 12, 2023. [Online]. Available: [https://stats.libretexts.org/Bookshelves/Introductory_Statistics/Mostly_Harmless_Statistics_\(Webb\)/11%3A_Analysis_of_Variance/11.03%3A_Two-Way_ANOVA_\(Factorial_Design\)](https://stats.libretexts.org/Bookshelves/Introductory_Statistics/Mostly_Harmless_Statistics_(Webb)/11%3A_Analysis_of_Variance/11.03%3A_Two-Way_ANOVA_(Factorial_Design)). [Accessed: Date].