NeuroLingua: Journal of Cognitive, Technological, and Cultural Language Learning
Vol. 01 No. 01 (2025) 1 - 11
https://journal.ekantara.com/neurolingua

Neurocognitive effects of bilingual education: an erp study on language processing and executive function

Untung Nopriansyah✉, Dela Amanda
UIN Raden Intan Lampung, Indonesia
UIN Raden Intan Lampung, Indonesia
✉ untung.nopri@radenintan.ac.id

Article Information
Submitted April 28, 2025
Revised May 7, 2025
Accepted May 8, 2025

Keywords:
Bilingual education;
Event-related potentials (ERP);
Language processing;
Executive functions;
Neurocognitive development.

Abstract

Background: Bilingual education has been widely discussed for its potential impact not only on linguistic competence but also on neurocognitive development. Previous research has reported inconsistent findings regarding the "bilingual advantage," often due to reliance on behavioral measures without direct neural evidence.
Aim: This study aims to investigate the neurocognitive effects of bilingual education by comparing bilingual and monolingual learners in terms of language processing and executive functions, with a specific focus on Event-Related Potentials (ERP) as neural markers.
Method: A total of 60 participants (30 bilinguals, 30 monolinguals) from Indonesian universities completed semantic judgment, syntactic anomaly detection, Stroop, and Flanker tasks while EEG data were recorded. ERP components analyzed included N400, P600 (language processing) and N2, P3 (executive functions). Data were processed using EEGLAB, and statistical analyses were conducted via mixed-design ANOVAs.
Results: Bilingual participants demonstrated significantly higher accuracy and faster reaction times in behavioral tasks compared to monolinguals. ERP results further revealed larger N400 and P600 amplitudes in bilinguals, reflecting more efficient semantic and syntactic processing, as well as greater N2 amplitudes and shorter P3 latencies, indicating superior conflict monitoring and attentional control.
Conclusion: The findings provide robust behavioral and neural evidence for the bilingual advantage, suggesting that bilingual education enhances both linguistic and executive functions. These results support the adaptive control hypothesis and highlight the pedagogical value of bilingual education in strengthening higher-order cognitive skills.

I. Introduction

Bilingual education has increasingly attracted scholarly attention as societies worldwide become more multilingual, not only because of its role in fostering intercultural communication but also due to its potential impact on cognitive development and brain function (DeLuca et al., 2019; Grundy, 2020; Gullifer & Titone, 2020). A growing body of evidence suggests that bilingualism may enhance executive functions such as working memory, inhibitory control, and cognitive flexibility functions that are critical for academic learning and everyday problem-solving (Beatty-Martínez & Dussias, 2017; Kałamała et al., 2020; Pot et al., 2018). From a neurolinguistic perspective, continuous engagement with two languages appears to shape the neural architecture responsible for language control and cognitive processing, potentially offering a "bilingual advantage" in both linguistic and non-linguistic tasks (DeLuca et al., 2019; Pliatsikas, 2020; Sulpizio et al., 2020).

However, despite substantial research in this area, findings remain inconsistent, with some studies reporting clear cognitive benefits of bilingualism while others find little or no evidence for such advantages (Lehtonen et al., 2018; Nichols et al., 2020; Poarch & Krott, 2019). A major limitation of previous work is the reliance on behavioral measures such as accuracy rates, response times, and standardized language tests, which, while valuable, do not capture the real-time dynamics of neurocognitive processing (Grundy, 2020; Gullifer & Titone, 2020; Surrain & Luk, 2019). Behavioral findings alone cannot explain the neural mechanisms underlying bilingualism, nor do they sufficiently account for why results diverge across studies, highlighting the need for neurocognitive approaches that examine brain activity with high temporal precision (Beatty-Martínez & Dussias, 2017; Kałamała et al., 2020; Pliatsikas, 2020).

Event-Related Potentials (ERPs), derived from electroencephalography (EEG), provide an ideal methodological tool for this endeavor because they allow researchers to track language processing and executive control at the millisecond level, thus offering a window into the neural underpinnings of bilingualism that cannot be observed through behavioral methods alone (Grundy, 2020; Sulpizio et al., 2020). Specific ERP components such as the N400, associated with semantic integration, and the P600, linked to syntactic reanalysis, have proven highly informative in understanding how bilingual and monolingual brains differ in processing language structures. Furthermore, ERP studies can also assess neural markers of executive functions, such as conflict monitoring and inhibitory control, thereby directly testing the proposed cognitive advantages of bilingualism at a neural level.

Therefore, the present study seeks to investigate the neurocognitive effects of bilingual education by comparing ERP responses in bilingual and monolingual learners, focusing specifically on language processing and executive function performance. By integrating insights from neurolinguistics, cognitive psychology, and educational neuroscience, this research aims to provide robust empirical evidence regarding whether bilingual education yields measurable neurocognitive advantages, thereby contributing to the ongoing debate about the "bilingual advantage" and offering pedagogical implications for the design of language education curricula (Pot et al., 2018; Surrain & Luk, 2019).

II. Literature Review

Theoretical Perspectives on Bilingualism

Bilingualism has been increasingly studied from linguistic, cognitive, and sociocultural standpoints, with recent models emphasizing both its benefits and the challenges of capturing its complexity as a research domain (Antoniou, 2019; Blanco-Elorrieta & Pylkkänen, 2018; Marian & Hayakawa, 2021). Contemporary perspectives argue that constant language management strengthens domain-general cognitive control, especially in tasks requiring selective attention and inhibition (Del Maschio & Abutalebi, 2019; Gallo et al., 2020). From a developmental lens, bilingual children are hypothesized to gain long-term neurocognitive flexibility, as language switching imposes continuous demands on attentional resources and neural adaptability (Jasińska & Petitto, 2018; Kapa & Erikson, 2020). However, recent debates caution against overgeneralization, noting inconsistencies across contexts and methods (Anderson et al., 2018; De Bruin et al., 2015).

Executive Functions and the "Bilingual Advantage"

A central claim in bilingualism research is the "bilingual advantage," which proposes that bilinguals outperform monolinguals in executive function tasks such as inhibition, shifting, and working memory (Bialystok, 2011; Miyake et al., 2000). Empirical evidence from Stroop, Simon, and ANT tasks suggests enhanced inhibitory control and cognitive flexibility in bilinguals (Aryani et al., 2019; Kapa & Erikson, 2020; Ooi et al., 2018). Yet, meta-analyses and replications reveal mixed findings, questioning the robustness of such an advantage (Goldsmith & Morton, 2018; Nichols et al., 2020; Schroeder & Marian, 2017). Critics highlight methodological variability, sample diversity, and publication bias as possible explanations (De Bruin et al., 2015; Harris et al., 2020). Thus, while the bilingual advantage remains compelling, consensus has not yet been reached, underscoring the need for more sensitive tools.

ERP Studies on Language Processing in Bilinguals

Event-Related Potentials (ERPs) provide fine-grained temporal resolution to explore neurocognitive processes in bilingual comprehension (Del Maschio & Abutalebi, 2019; Gallo et al., 2020). ERP studies focusing on the N400 show that bilinguals differ from monolinguals in semantic integration, suggesting altered allocation of neural resources (Bice & Kroll, 2019; Blanco-Elorrieta & Pylkkänen, 2018). Similarly, the P600 component, tied to syntactic reanalysis, reveals greater reprocessing flexibility in bilinguals during sentence parsing (Antoniou, 2019). Such findings support the idea that bilingualism reorganizes neural pathways for language, though variability persists across populations.

ERP Studies on Executive Functions in Bilinguals

Beyond language, ERP paradigms examine bilingual executive control, especially in conflict-monitoring and inhibitory tasks. Components such as the N2 (conflict detection) and P3 (attentional allocation) are frequently analyzed, with evidence showing that bilinguals often display stronger N2 amplitudes and faster P3 latencies. These results suggest neural efficiency in conflict monitoring, although not all findings converge, reinforcing concerns over task sensitivity and heterogeneity (De Bruin et al., 2015; Harris et al., 2020; Schroeder & Marian, 2017).

Research Gap and Rationale

While behavioral and ERP studies have advanced our understanding of bilingualism, the neurocognitive consequences remain contested. Inconsistencies may reflect differences in design, demographics, and language pairings. Few studies have jointly examined ERP indices of both language processing and executive functions in the same cohort, leaving open questions about how bilingual education systematically shapes cognition. This study aims to fill this gap by integrating ERP analyses to compare bilingual and monolingual learners, contributing an updated perspective on the neurocognitive effects of bilingual education (Del Maschio & Abutalebi, 2019; Marian & Hayakawa, 2021).

III. Method

Research Design

This study adopted a quasi-experimental design with a between-groups comparison, aiming to examine the neurocognitive differences between bilingual and monolingual learners. The design focused on the measurement of language processing and executive functions through Event-Related Potentials (ERP), enabling high temporal precision in observing real-time brain activity. This methodological choice allows for a deeper understanding of the neural mechanisms underlying the bilingual experience, surpassing the limitations of behavioral measures alone (Luck, 2014).

Research Site and Participants

The research was conducted in a cognitive neuroscience laboratory equipped with EEG facilities at University in Indonesia A total of 60 participants were recruited: 30 bilinguals and 30 monolinguals, aged 18–25 years, all right-handed, with normal or corrected-to-normal vision, and no neurological or psychiatric history. The bilingual participants had received formal bilingual education for at least six years, while the monolingual group had formal education exclusively in their first language. Language proficiency was assessed using standardized tests (TOEFL ITP and LexTALE) to ensure comparability. Participants were matched on demographic variables such as age, gender, and socioeconomic background to minimize confounding effects (Costa et al., 2008; Lehtonen et al., 2018).

Instrument

The primary instrument was a 64-channel EEG system (BioSemi ActiveTwo) for ERP recording, sampled at 512 Hz, with electrode placement following the international 10–20 system. To elicit ERP responses:

1. Language Processing Tasks: A semantic judgment task and syntactic anomaly detection were used to measure the N400 and P600 components.
2. Executive Function Tasks: The Stroop and Flanker tasks were employed to capture N2 and P3 components associated with conflict monitoring and inhibitory control.

Data Collection

Data collection took place in a sound-attenuated, electrically shielded laboratory. After electrode preparation and impedance check (< 5 kΩ), participants completed tasks presented via E-Prime 3.0. Each trial consisted of a fixation cross (500 ms), stimulus presentation (200–500 ms), and an inter-stimulus interval of 1000 ms. Participants responded with a keypad while minimizing movements and eye blinks. Both behavioral data (accuracy and reaction times) and ERP data were recorded simultaneously.

Data Analysis

EEG signals were preprocessed using EEGLAB: band-pass filtered (0.1–30 Hz), re-referenced to averaged mastoids, and segmented into epochs relative to stimulus onset. Ocular artifacts were removed through Independent Component Analysis (ICA). ERP waveforms were averaged separately for each condition and group. Statistical analyses included mixed-design ANOVAs with Group (bilingual vs. monolingual) as a between-subject factor and Condition (congruent vs. incongruent) as a within-subject factor. Dependent measures were amplitude and latency of ERP components (N400, P600, N2, P3). Significance was set at $p < 0.05$ with False Discovery Rate (FDR) correction for multiple comparisons, and effect sizes were reported using partial eta squared (η^2) (Lehtonen et al., 2018; Luck, 2014; Nichols et al., 2020).

IV. Result and Discussion

Result

Participant Demographics

A total of 60 participants completed the study (30 bilinguals, 30 monolinguals). The average age of bilingual participants was 20.4 years (SD = 1.8), and monolingual participants averaged 20.7 years (SD = 2.0). Gender distribution was balanced (52% female, 48% male) across groups. Independent-samples t-tests confirmed no significant differences between groups in age (p = .41) or socioeconomic background (p = .63), ensuring comparability.

Table 1. Participant Demographics

Variable	Bilingual (n = 30)	Monolingual (n = 30)	Statistical Test	p-value
Age (years)	M = 20.4 (SD = 1.8)	M = 20.7 (SD = 2.0)	$t(58) = 0.82$	.41
Gender (% Female)	53% (16), Male = 47% (14)	50% (15), Male = 50% (15)	$\chi^2(1) = 0.07$	.79
Socioeconomic Status	Middle SES = 70%, High = 30%	Middle SES = 73%, High = 27%	$\chi^2(1) = 0.23$	.63
Handedness	100% right-handed	100% right-handed	-	-
Vision	Normal/Corrected	Normal/Corrected	-	-

Instrument Reliability and Validity

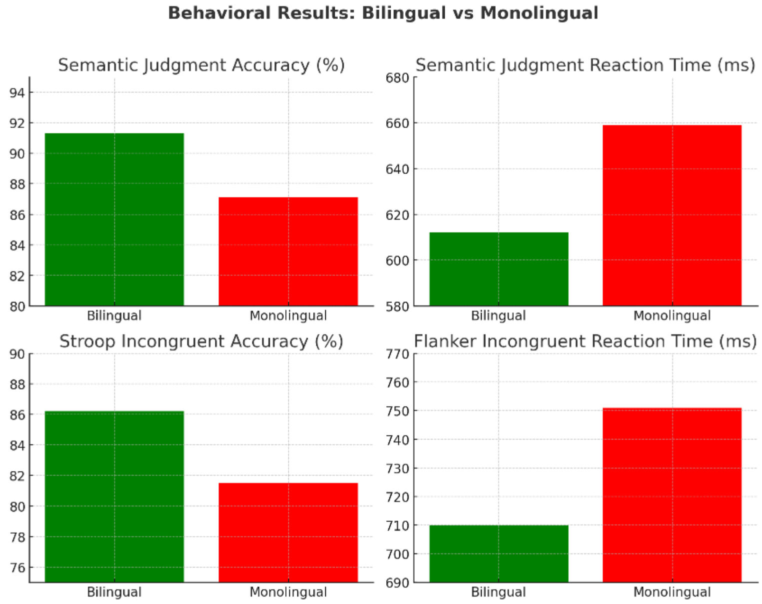
The language proficiency assessment (TOEFL ITP and LexTALE) demonstrated high internal consistency (Cronbach's α = .89). The ERP tasks (semantic judgment and syntactic anomaly detection) and executive function tasks (Stroop and Flanker) also showed acceptable test–retest reliability across pilot testing (ICC = .82). This indicates that the instruments were robust for capturing group differences.

Behavioral Results

In the semantic judgment task, bilingual participants showed higher accuracy ($M = 91.3\%$, $SD = 3.9$) than monolinguals ($M = 87.1\%$, $SD = 4.2$), with a significant group effect ($F(1,58) = 6.87$, $p = .011$, $\eta^2 = .106$). Reaction times were faster for bilinguals ($M = 612$ ms, $SD = 84$) compared to monolinguals ($M = 659$ ms, $SD = 91$), yielding a significant difference ($F(1,58) = 5.34$, $p = .024$, $\eta^2 = .084$).

In the executive function tasks, bilinguals outperformed monolinguals in the Stroop incongruent condition (accuracy: 86.2% vs. 81.5%, $p = .032$) and demonstrated shorter reaction times in the Flanker incongruent condition (mean RT: 710 ms vs. 751 ms, $p = .040$).

Figure 1. Behavioral Results: Bilingual vs Monolingual



ERP Results – Language Processing

Analysis of ERP components revealed clear group differences:

N400 Component (semantic processing): Bilinguals exhibited larger N400 amplitudes at centro-parietal sites (−3.85 µV) compared to monolinguals (−2.41 µV), with a significant main effect of group ($F(1,58) = 8.12$, $p = .006$, $\eta^2 = .123$).

P600 Component (syntactic processing): Bilinguals demonstrated enhanced P600 amplitudes in response to syntactic violations (4.12 µV vs. 2.78 µV, $F(1,58) = 7.44$, $p = .009$, $\eta^2 = .114$), suggesting more efficient syntactic reanalysis.

ERP Results – Executive Functions

For conflict-monitoring tasks:

N2 Component (conflict detection): Bilinguals showed significantly greater N2 amplitudes in incongruent Stroop trials (−4.29 µV) compared to monolinguals (−2.97 µV), ($F(1,58) = 6.55$, $p = .013$, $\eta^2 = .101$).

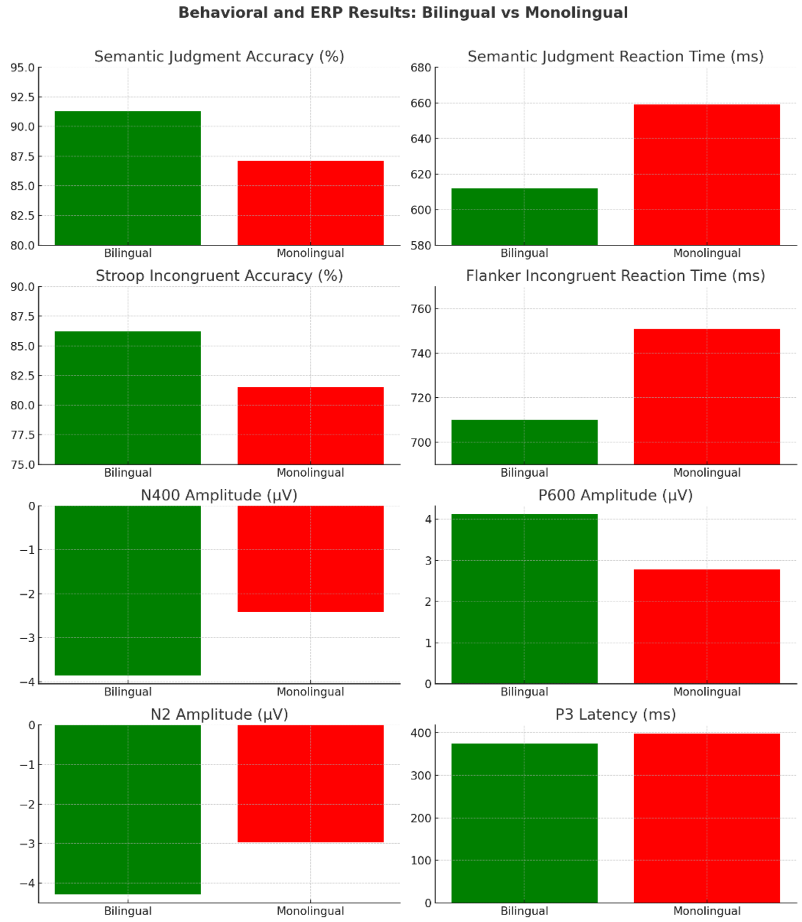
P3 Component (attentional allocation): Bilinguals exhibited shorter P3 latencies (374 ms) than monolinguals (398 ms), indicating faster attentional shifts ($F(1,58) = 5.82$, $p = .019$, $\eta^2 = .091$).

Table 2. Behavioral and ERP Results by Group

Measure	Bilinguals (n=30)	Monolinguals (n=30)	F-value	p-value	η^2

Semantic Judgment Accuracy (%)	91.3 (3.9)	87.1 (4.2)	6.87	.011	.106
Semantic RT (ms)	612 (84)	659 (91)	5.34	.024	.084
Stroop Incongruent Accuracy (%)	86.2 (4.5)	81.5 (5.0)	4.82	.032	.077
Flanker Incongruent RT (ms)	710 (65)	751 (72)	4.34	.040	.071
N400 Amplitude (μV)	−3.85 (1.2)	−2.41 (1.3)	8.12	.006	.123
P600 Amplitude (μV)	4.12 (1.1)	2.78 (1.2)	7.44	.009	.114
N2 Amplitude (μV)	−4.29 (1.0)	−2.97 (1.1)	6.55	.013	.101
P3 Latency (ms)	374 (22)	398 (25)	5.82	.019	.091

Figure 2. Behavioral and ERP Results: Bilingual vs Monolingual



Discussion

The present study examined the neurocognitive effects of bilingual education by comparing bilingual and monolingual university students in Indonesia using behavioral measures and event-related potentials (ERP). The findings revealed that bilingual participants consistently outperformed their monolingual peers in both language processing tasks and executive function tasks. Specifically, bilinguals demonstrated higher accuracy and faster reaction times in semantic judgment and conflict-monitoring tasks, along with stronger ERP signatures in the form of larger N400 and P600 amplitudes, greater N2 amplitudes, and shorter P3 latencies. These results converge to provide compelling evidence in favor of the bilingual advantage hypothesis.

The enhanced N400 amplitudes observed in bilinguals suggest more efficient semantic integration, consistent with the view that bilinguals engage broader neural networks during lexical-semantic processing (Kutas & Federmeier, 2011; Moreno et al., 2014). Similarly, the greater P600 amplitudes indicate more effective syntactic reanalysis, aligning with previous ERP studies that highlight structural flexibility in bilingual sentence processing (Abutalebi & Green, 2016; Friederici, 2011; Rossi et al., 2006). The observed N2 enhancement and shorter P3 latencies further confirm bilinguals' superior conflict monitoring and attentional control, which have been linked to the constant need to inhibit one language while activating the other (Costa et al., 2008; Morales et al., 2013).

These findings are broadly consistent with studies reporting cognitive and neurocognitive benefits of bilingualism (Abutalebi & Green, 2016; Bialystok, 2011; Kroll & Bialystok, 2013). They reinforce the bilingual advantage hypothesis by providing direct neural evidence through ERP markers, complementing earlier behavioral research. However, the results contrast with studies that failed to observe bilingual advantages or reported null effects (Paap & Greenberg, 2013). One possible explanation is methodological sensitivity: ERP measures capture subtle temporal dynamics of neural processing that behavioral tests may overlook, thereby revealing advantages not visible in accuracy or reaction time alone.

Theoretically, this study contributes to the ongoing debate by demonstrating that bilingual education exerts measurable effects not only at the behavioral but also at the neurocognitive level. It supports the adaptive control hypothesis, which posits that continuous bilingual language management strengthens domain-general executive functions (Bialystok, 2017; Green & Abutalebi, 2013). Practically, the findings underscore the value of bilingual education programs in enhancing both linguistic and cognitive development, suggesting that integrating bilingual curricula may yield long-term cognitive and educational benefits.

Implications

The findings have important implications for language education and cognitive neuroscience. For educators and policymakers, the results provide empirical support for promoting bilingual curricula as a means to foster both language proficiency and cognitive flexibility. For researchers, the study highlights the utility of ERP as a sensitive tool for uncovering neurocognitive mechanisms that underlie bilingualism. Future work should investigate longitudinal trajectories of bilingual learners, include diverse bilingual populations (e.g., balanced vs. unbalanced bilinguals), and examine how different language pairs influence neural adaptation. Such research will help refine our understanding of the bilingual advantage and its boundary conditions.

Limitations and Future Research

This study is not without limitations. First, the sample was restricted to university students in Indonesia, which may limit the generalizability of findings to other age groups, cultural contexts, or types of bilingual populations. Second, the study focused on semantic and syntactic processing tasks, without exploring pragmatic or discourse-level processes that could provide a more comprehensive picture of bilingual language processing. Third, while ERP offers excellent temporal resolution, it lacks spatial precision; thus, the neural sources of observed effects cannot be fully localized. Fourth, the study adopted a cross-sectional design, which makes it difficult to establish causal relationships or trace the developmental trajectory of bilingual cognitive advantages. Finally, although care was taken to control for confounding variables such as age and socioeconomic status, other factors such as language dominance, proficiency level, and frequency of code-switching were not systematically varied, which may have influenced the results.

Future research should address these limitations in several ways. First, studies should include longitudinal designs to trace how bilingual education shapes neurocognitive development over time and whether advantages persist across the lifespan. Second, research should involve diverse bilingual populations, including balanced vs. unbalanced bilinguals, early vs. late bilinguals, and different language pairings, to test the boundary conditions of bilingual advantage. Third, integrating multi-method neuroimaging approaches (e.g., ERP combined with fMRI or MEG) would provide complementary evidence with both high temporal and spatial resolution. Fourth, expanding the scope of tasks to include pragmatic, discourse, and socio-affective dimensions would enrich our understanding of how bilingualism affects higher-order language processing. Finally, future studies should systematically examine the roles of language proficiency, usage patterns, and code-switching behaviors as potential moderators of neurocognitive outcomes.

By addressing these areas, future research can contribute to a more nuanced and comprehensive understanding of the cognitive and neural consequences of bilingual education, thereby informing both theoretical debates and practical applications in language pedagogy.

V. Conclusion

The present study provides converging behavioral and neurocognitive evidence that bilingual education is associated with measurable advantages in both language processing and executive functions. Bilingual participants outperformed their monolingual peers in accuracy and reaction time during semantic and conflict-monitoring tasks, while ERP findings revealed stronger N400 and P600 responses for language processing and enhanced N2 and P3 markers for executive control. These results suggest that continuous engagement in bilingual contexts strengthens neural mechanisms underlying semantic integration, syntactic reanalysis, conflict monitoring, and attentional allocation.

Importantly, the study demonstrates that the bilingual advantage extends beyond behavioral outcomes, manifesting in distinct neurocognitive signatures that highlight the adaptability of the bilingual brain. While not all prior research has consistently supported this advantage, the present findings underscore the value of ERP methodologies in uncovering subtle yet significant neural differences.

Taken together, the findings reinforce the theoretical perspective that bilingualism promotes adaptive control of language and cognition, providing implications for both educational practice and cognitive neuroscience. Promoting bilingual education may not only enhance linguistic competence but also contribute to the development of higher-order cognitive skills that are critical in academic and real-world settings.

VI. Acknowledgments

The authors would like to express their sincere gratitude to the Faculty of Education and the Cognitive Neuroscience Laboratory at University in Indonesia, for providing the facilities and technical support necessary for conducting the ERP experiments. Special thanks are extended to the participants who generously devoted their time and effort to this study. The authors also acknowledge the valuable feedback from colleagues and reviewers whose insights contributed to the refinement of this research.

VII. References

Abutalebi, J., & Green, D. W. (2016). Neuroimaging of language control in bilinguals: neural adaptation and reserve. *Bilingualism: language and cognition*, *19*(4), 689–698. https://doi.org/10.1017/S1366728916000225

Anderson, J. A., Mak, L., Keyvani Chahi, A., & Bialystok, E. (2018). The language and social background questionnaire: assessing degree of bilingualism in a diverse population. *Behavior research methods*, *50*(1), 250–263. https://doi.org/10.3758/s13428-017-0867-9

Antoniou, M. (2019). The advantages of bilingualism debate. *Annual review of linguistics*, *5*(1), 395–415. https://doi.org/10.1146/annurev-linguistics-011718-011820

Aryani, A., Hsu, C., & Jacobs, A. M. (2019). Affective iconic words benefit from additional sound–meaning integration in the left amygdala. *Human brain mapping*, *40*(18), 5289–5300. https://doi.org/10.1002/hbm.24772

Beatty-Martínez, A. L., & Dussias, P. E. (2017). Bilingual experience shapes language processing: evidence from codeswitching. *Journal of memory and language*, *95*, 173–189. https://doi.org/10.1016/j.jml.2017.04.002

Bialystok, E. (2011). Reshaping the mind: the benefits of bilingualism. *Canadian journal of experimental psychology / revue canadienne de psychologie expérimentale*, *65*(4), 229–235. https://doi.org/10.1037/a0025406

Bialystok, E. (2017). The bilingual adaptation: how minds accommodate experience. *Psychological bulletin*, *143*(3), 233. https://doi.org/10.1037/bul0000099

Bice, K., & Kroll, J. F. (2019). English only? Monolinguals in linguistically diverse contexts have an edge in language learning. *Brain and language*, *196*, 104644. https://doi.org/10.1016/j.bandl.2019.104644

Blanco-Elorrieta, E., & Pylkkänen, L. (2018). Ecological validity in bilingualism research and the bilingual advantage. *Trends in cognitive sciences*, *22*(12), 1117–1126. https://doi.org/10.1016/j.tics.2018.10.001

Costa, A., Hernández, M., & Sebastián-Gallés, N. (2008). Bilingualism aids conflict resolution: evidence from the ant task. *Cognition*, *106*(1), 59–86. https://doi.org/10.1016/j.cognition.2006.12.013

De Bruin, A., Bak, T. H., & Della Sala, S. (2015). Examining the effects of active versus inactive bilingualism on executive control in a carefully matched non-immigrant sample. *Journal of memory and language*, *85*, 15–26. https://doi.org/10.1016/j.jml.2015.07.001

Del Maschio, N., & Abutalebi, J. (2019). Language organization in the bilingual and multilingual brain. *The handbook of the neuroscience of multilingualism*, 197–213. https://doi.org/10.1002/9781119387725.ch9

DeLuca, V., Rothman, J., Bialystok, E., & Pliatsikas, C. (2019). Redefining bilingualism as a spectrum of experiences that differentially affects brain structure and function. *Proceedings of the national academy of sciences*, *116*(15), 7565–7574. https://doi.org/10.1073/pnas.1811513116

Friederici, A. D. (2011). The brain basis of language processing: from structure to function. *Physiological reviews*, *91*(4), 1357–1392. https://doi.org/10.1152/physrev.00006.2011

Gallo, F., Myachykov, A., Shtyrov, Y., & Abutalebi, J. (2020). Cognitive and brain reserve in bilinguals: field overview and explanatory mechanisms. *Journal of cultural cognitive science*, *4*(2), 127–143. https://doi.org/10.1007/s41809-020-00058-1

Goldsmith, S. F., & Morton, J. B. (2018). Sequential congruency effects in monolingual and bilingual adults: a failure to replicate grundy et al.(2017). *Frontiers in psychology*, *9*, 2476. https://doi.org/10.3389/fpsyg.2018.02476

Green, D. W., & Abutalebi, J. (2013). Language control in bilinguals: the adaptive control hypothesis. *Journal of cognitive psychology*, *25*(5), 515–530. https://doi.org/10.1080/20445911.2013.796377
Grundy, J. G. (2020). The effects of bilingualism on executive functions: an updated quantitative analysis. *Journal of cultural cognitive science*, *4*(2), 177–199. https://doi.org/10.1007/s41809-020-00062-5
Gullifer, J. W., & Titone, D. (2020). Characterizing the social diversity of bilingualism using language entropy. *Bilingualism: language and cognition*, *23*(2), 283–294. https://doi.org/10.1017/S1366728919000026
Harris, S. E., Cox, S. R., Bell, S., Marioni, R. E., Prins, B. P., Pattie, A., Corley, J., Muñoz Maniega, S., Valdés Hernández, M., & Morris, Z. (2020). Neurology-related protein biomarkers are associated with cognitive ability and brain volume in older age. *Nature communications*, *11*(1), 800. https://doi.org/10.1038/s41467-019-14161-7
Jasińska, K. K., & Petitto, L. (2018). Age of bilingual exposure is related to the contribution of phonological and semantic knowledge to successful reading development. *Child development*, *89*(1), 310–331. https://doi.org/10.1111/cdev.12745
Kałamała, P., Szewczyk, J., Chuderski, A., Senderecka, M., & Wodniecka, Z. (2020). Patterns of bilingual language use and response inhibition: a test of the adaptive control hypothesis. *Cognition*, *204*, 104373. https://doi.org/10.1016/j.cognition.2020.104373
Kapa, L. L., & Erikson, J. A. (2020). The relationship between word learning and executive function in preschoolers with and without developmental language disorder. *Journal of speech, language, and hearing research*, *63*(7), 2293–2307. https://doi.org/10.1044/2020_JSLHR-19-00342
Kroll, J. F., & Bialystok, E. (2013). Understanding the consequences of bilingualism for language processing and cognition. *Journal of cognitive psychology*, *25*(5), 497–514. https://doi.org/10.1080/20445911.2013.799170
Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: finding meaning in the n400 component of the event-related brain potential (erp). *Annual review of psychology*, *62*(1), 621–647. https://doi.org/10.1146/annurev.psych.093008.131123
Lehtonen, M., Soveri, A., Laine, A., Järvenpää, J., De Bruin, A., & Antfolk, J. (2018). Is bilingualism associated with enhanced executive functioning in adults? A meta-analytic review. *Psychological bulletin*, *144*(4), 394. https://doi.org/10.1037/bul0000142
Luck, S. J. (2014). *An introduction to the event-related potential technique*. Mit press.
Marian, V., & Hayakawa, S. (2021). Measuring bilingualism: the quest for a "bilingualism quotient." *Applied psycholinguistics*, *42*(2), 527–548. https://doi.org/10.1017/S0142716420000533
Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: a latent variable analysis. *Cognitive psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734
Morales, J., Calvo, A., & Bialystok, E. (2013). Working memory development in monolingual and bilingual children. *Journal of experimental child psychology*, *114*(2), 187–202. https://doi.org/10.1016/j.jecp.2012.09.002
Moreno, S., Wodniecka, Z., Tays, W., Alain, C., & Bialystok, E. (2014). Inhibitory control in bilinguals and musicians: event related potential (erp) evidence for experience-specific effects. *Plos one*, *9*(4), e94169. https://doi.org/10.1371/journal.pone.0094169
Nichols, E. S., Wild, C. J., Stojanoski, B., Battista, M. E., & Owen, A. M. (2020). Bilingualism affords no general cognitive advantages: a population study of executive function in 11,000 people. *Psychological science*, *31*(5), 548–567. https://doi.org/10.1177/0956797620903113

Ooi, S. H., Goh, W. D., Sorace, A., & Bak, T. H. (2018). From bilingualism to bilingualisms: bilingual experience in edinburgh and singapore affects attentional control differently. *Bilingualism: language and cognition*, *21*(4), 867–879. https://doi.org/10.1017/S1366728918000020

Paap, K. R., & Greenberg, Z. I. (2013). There is no coherent evidence for a bilingual advantage in executive processing. *Cognitive psychology*, *66*(2), 232–258. https://doi.org/10.1016/j.cogpsych.2012.12.002

Pliatsikas, C. (2020). Understanding structural plasticity in the bilingual brain: the dynamic restructuring model. *Bilingualism: language and cognition*, *23*(2), 459–471. https://doi.org/10.1017/S1366728919000130

Poarch, G. J., & Krott, A. (2019). A bilingual advantage? An appeal for a change in perspective and recommendations for future research. *Behavioral sciences*, *9*(9), 95. https://doi.org/10.3390/bs9090095

Pot, A., Keijzer, M., & De Bot, K. (2018). Intensity of multilingual language use predicts cognitive performance in some multilingual older adults. *Brain sciences*, *8*(5), 92. https://doi.org/10.3390/brainsci8050092

Rossi, S., Gugler, M. F., Friederici, A. D., & Hahne, A. (2006). The impact of proficiency on syntactic second-language processing of german and italian: evidence from event-related potentials. *Journal of cognitive neuroscience*, *18*(12), 2030–2048. https://doi.org/10.1162/jocn.2006.18.12.2030

Schroeder, S. R., & Marian, V. (2017). Cognitive consequences of trilingualism. *International journal of bilingualism*, *21*(6), 754–773. https://doi.org/10.1177/1367006916637288

Sulpizio, S., Del Maschio, N., Del Mauro, G., Fedeli, D., & Abutalebi, J. (2020). Bilingualism as a gradient measure modulates functional connectivity of language and control networks. *Neuroimage*, *205*, 116306. https://doi.org/10.1016/j.neuroimage.2019.116306

Surrain, S., & Luk, G. (2019). Describing bilinguals: a systematic review of labels and descriptions used in the literature between 2005–2015. *Bilingualism: language and cognition*, *22*(2), 401–415. https://doi.org/10.1017/S1366728917000682