

Bilingualism and Executive Functions: A Review of Evidence Across the Lifespan



Qi Luo^{1, 2, *}, Hongxia Zhang¹

¹School of Foreign Languages and Literatures, Chongqing University of Education, Chongqing 400060, China

²School of English Studies, Sichuan International Studies University, Chongqing 400031, China

Abstract: The cognitive consequences of bilingualism have attracted sustained scholarly attention, particularly regarding whether regular use of two languages enhances executive functions (EF). While a substantial body of research reports a bilingual advantage in cognitive control, recent replication attempts and large-scale studies have produced inconsistent or null findings, giving rise to an ongoing debate. This review synthesizes influential empirical and neurocognitive studies examining bilingualism and executive functions across the lifespan, including children, young adults, and older adults. It first outlines theoretical accounts such as the Bilingual Executive Processing Advantage hypothesis, then reviews commonly employed experimental paradigms in non-verbal cognitive processing, including the Simon, Stroop, Flanker, and Attention Network Test, alongside neuroimaging approaches such as fMRI. The review demonstrates that evidence for bilingual cognitive advantages varies considerably by age group, task type, and methodological design, with effects more frequently observed in children and older adults than in young adults. Finally, the paper discusses key modulating factors that may account for conflicting findings, including individual differences, task sensitivity, sample size, and experimental variability. It is argued that the absence of consistent evidence does not negate bilingual advantages but instead highlights the need for more fine-grained, methodologically rigorous research. This review contributes to the ongoing debate by offering an integrative perspective on when, how, and under what conditions bilingualism may influence executive functioning.

Keywords: Bilingualism; Executive Functions; Cognitive Control; Bilingual Advantage; Lifespan

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1 Introduction

The prevalence of bilingualism has instigated ever-growing interest in the effects of using two languages regularly on cognitive development. While reams of studies have asserted better performance of bilingual populations in some cognitive tasks as compared to monolingual peers, doubts are raised recently as some researchers have found no difference between the groups. This has led to an intense debate ensuing over the cognitive effects of bilingualism. This review selects pertinent bilingualism research on the

cognitive consequences and suggests some possible reasons for conflict findings.

2 Bilingualism and Executive Functions

A large body of evidence on bilingualism research demonstrates that being bilingual is linked to enhanced cognitive control, which conveys a *bilingual advantage* in

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*Corresponding author: Qi Luo, luoqiforward@126.com

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cognition [1]. This view is based on the phenomenon that bilingual speakers exhibit persistent cross-linguistic competition and interaction during non-verbal processing. Specifically, bilinguals have to activate the target language while inhibiting the other. Hence, for context-appropriate communication, a cognitive control mechanism is urgently needed for bilinguals to resolve the conflict between two languages. This mechanism, namely the executive functions (EF), is innate in humans.

EF is a high-level cognitive mechanism associated with the frontal lobes. It is defined as the regulation, coordination and arrangements of actions in correspondence with goal-directed behaviours regardless of some irrelevant stimuli [2]. It includes selective attention, task-switching, conflict resolution and inhibitory control abilities. According to the *bilingual executive processing advantage* (BEP) hypothesis [3], bilinguals' repeated use of EF system in linguistic conflict management not only ensures effective communication but also enhances the efficacy of the system itself in a general way. In other words, managing attention in two simultaneously active languages, suppressing interference from non-target language and selecting language according to interlocutors repetitively train and consequently fine-tune bilingual speakers' cognitive control mechanism.

3 Experimental Paradigms in Non-verbal Cognitive Processing Research

Bilingualism studies have used several experimental paradigms to investigate cognitive processing. This review selects some most widely used paradigms. Concerning behavioural tasks, the Simon task [4] presents coloured squares in different positions to create stimulus-spatial incongruency. Participants are asked to respond to the square features regardless of the positions. In the Stroop paradigm [5], participants are instructed to name the font colour of a colour word without interference from the mismatching word meaning. The Flanker task [6] uses target-direction conflict by exhibiting arrays of arrows to the opposite response, and the Attention Network Test (ANT) [7] is a refined variant of the Flanker task. All of the paradigms measure response suppression, selective attention and inhibitory control by inducing cognitive conflict during the tasks. The efficiency of these tasks is examined by changes

in reaction time resulting from different signals.

The behavioural tasks are increasingly complemented with neuroimaging paradigms for more accurate analysis of neuronal correlates in EF. The most common one is functional magnetic resonance imaging (fMRI) [8]. It helps detect neuronal activation in the brain and examines which brain regions are active during control processing.

Implementations of these paradigms can be found in Section 4, below.

4 Pertinent Research Across the Lifespan

To present the lifespan trajectory of bilingualism impact on cognition, this review presents research findings by age groups, namely by children, young adults, and the elderly.

4.1 Research with Children

The approach that *bilingualism results in cognitive enhancement* originated from studies with children [9]. Early in the 2000s, there was a widespread belief that bilingualism is detrimental to intelligence development in children [10] until a study conducted by Peal and Lambert [11] reported a reverse pattern of results: bilingual children outperformed monolinguals in both verbal and non-verbal tasks.

Since then, similar studies in favour of the bilingual cognitive benefits have mushroomed. Bialystok *et al.* [12] tested 56 bilingual children on four EF tasks and found evidence of the *bilingual advantage* in cognitive control. Poarch and van Hell [13] used the Simon task and ANT to compare 5- to 8-year old bilingual and trilingual children with monolingual peers. Their results revealed improved cognitive inhibition in bilingual and trilingual children. Mohades *et al.* [14] used fMRI with the Simon task and compared the brain activity between bilinguals and monolinguals. Better conflict resolution was found in bilinguals as they have more efficient brain control. Likewise, positive results were found with bilingual children performing better on cognitive tasks in ANT [15] and the Flanker task [16].

Nevertheless, a handful of attempts which replicated previous experiments failed to find a similar link between bilingualism and better cognitive mechanisms [17], coining the *replication crisis* [18]. Among those studies, the one conducted by Poarch [19] was notable, because the author

replicated his previous co-authored research [13] but found different results. Specifically, bilingual children presented no Simon effect but better inhibitory control in the Flanker task in comparison to monolinguals. Likewise, Duñabeitia et al. [20] used the classic Stroop task and found no evidence for better inhibitory performance in bilingual children.

4.2 Research with Young Adults

Comparable conflicting evidence was also found in the research with young adults, which has been the focus of most research.

In terms of positive results, Bialystok et al. [21] used the Simon task to compare the control processing abilities of young and older bilinguals with monolinguals. They reported that bilinguals carry out control processing with more efficiency than monolinguals. Bialystok [22] tested bilinguals and video-game monolingual players with the Simon task and reported faster responses in bilingual adults than in monolingual players under the most control-demanding condition of the task. Subsequent studies also found cognitive benefits in young adults in the Flanker task [23] and the Simon task and ANT [24]. The involvement of some neuroimaging paradigms also presented evidence in favour of the *bilingual advantage*. Abutalebi [25] used fMRI and found enhanced conflict monitoring in young adults. They showed that being bilingual has helped to improve the nature of prefrontal cortex with more efficiency in conflicting non-verbal processing.

However, other studies have shown negative evidence. The *replication crisis* occurred when Paap and Greenberg [26] replicated the experiments in [21] and conducted three studies, involving four mental control tasks to compare the cognitive abilities of bilinguals versus monolinguals. Surprisingly, they reported no *bilingual advantage* in executive processing. Coderre and van Heuven [27] used the Simon and Stroop tasks to test 58 young adults but found absent enhanced cognitive control. The controversy was also shown in fMRI results [28].

4.3 Research with Older Adults

The pioneering research to find the *bilingual advantage* in the elderly was conducted by Bialystok et al. [21]. Besides the findings presented in Section 4.1, the researchers reported that bilingualism might enhance the control system in prefrontal parts of the brain and protect against some age-related cognitive decline losses. Likewise, several

studies in the elderly patients have shown that being bilingual might postpone the onset of dementia as compared to monolinguals [29] including Alzheimer's [30-32]. However, it is worth noting that most studies investigating the cognitive consequence on neurological diseases are retrospective studies, which might have the limitations of unrestrained variables in the experiments, strong selection biases towards information, and non-exhaustive statistics measurement [33].

That has, therefore, been criticised by some prospective studies which support the notion that *bilingualism does not have a positive impact on dementia*. Crane et al. [34] analysed 2,520 older bilinguals with dementia and found no evidence for enhanced cognitive control. Besides, Kousaie and Phillips [35] used the set of Stroop, Simon and Flanker tasks to analyse 22 older adults. They reported mixed results among the groups, as the *bilingual advantage* only presented in the Stroop task. Similar studies have also found no or insignificant evidence towards the beneficial bilingual effects on delaying dementia [36-38].

4.4 Research Summary

Overall, the above-mentioned evidence is inconclusive across age groups. While some researchers support the *bilingual advantage*, others do not report the effect. At the same time, cognitive effects are the hardest to detect in young adults. This might be explained by young adults' peaked EF abilities as compared to other groups, which result in the likely ceiling effects and thus made the *bilingual advantage* imperceptible [33]. This also clarifies why the cognitive benefits are often found in children or vulnerable patients. Their performance does not reach the maximum, which helps manifest the *bilingual advantage*.

It is also intriguing that, while a forest of studies has found the *bilingual advantage* or shown equal performance between bilinguals and monolinguals, no research yet has found a *bilingual disadvantage* in cognitive control aspect. If relevant bilingualism papers reporting cognitive benefits were false negatives, we might expect some opposite patterns of results, such as monolinguals outperforming bilinguals in some cognitive tasks. While no such notion was proposed, it might be the case that there are some unapprehended research fields in terms of the EF performance between monolinguals and bilinguals. Specifically, the two groups of populations might have overlapping EF abilities which have not been found due to some modulating factors in the experiments.

5 Modulating Factors That Might Influence the Research Findings

The existence or nonexistence of the *bilingual advantage* might largely depend on the individual and experimental variables during cognitive testing [33].

The individual differences derive from the diverse life experiences of each participant. With the variant combinations of socioeconomic status, ethnicity, cultural backgrounds, language proficiencies, and even pre-existing cognitive abilities, every participant tested in the experiment might differ a lot from their counterparts [39]. For instance, those with initial better-developed cognitive control would get a higher score in cognitive tasks. Thus, participants with the pre-existing computer or musical skills are more likely to perform better than their counterparts, because both computer games [40] and musical training [41] can enhance cognitive development. Moreover, it would be more and more challenging to find a monolingual speaker in nowadays' global village. The participants who filled in the language background questionnaire and claimed to be a monolingual might have slightly been exposed to a foreign language in a TV show or at school. To summarise, if researchers investigate the cognition based self-reported bilingual or monolingual populations with neglected individual differences, inaccurate results might appear.

Possible differences in the experimental designs could also alter the conclusions. First, the possibility of revealing the cognitive effects seems to vary with different paradigms involved. For example, almost all studies with the Stroop task, the majority of the Flanker task and ANT revealed the *bilingual advantage*, while the results of the Simon task were less clear, especially in children and young adults. Costa *et al.* [23] demonstrated that participants' performance may be altered due to small discrepancy in the experiment paradigms, including ways of stimuli presentation and choices of diverse tasks. Besides, the sample size of an experiment can also make differences. Paap and Greenberg [26] showed that the mixed results in the research community might result from the Type-1 errors due to small sample sizes in most studies.

6 Conclusion

The debate over cognitive benefits of bilingualism is still ongoing, and whether there is a *bilingual advantage* in gen-

eral cognition requires more rigorous and fine-grained research. It is notable, though, that the conflicting evidence is not a threat to the reliability of research but an opportunity for the advancement of science. We should appreciate the contribution made from diverse approaches that address cognitive control development in the bilingualism research community.

ORCID

0009-0001-7846-2411 (Qi Luo)

Author Contributions

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Competing Interests

The authors declare that they have no competing interests.

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