The Specificity of Bilingual Advantage: Enhanced Response Inhibition but Unchanged Interference Inhibition

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Abstract. Bilingual learning can have some positive effects on an individual's executive functions, particularly in terms of response inhibition and interference inhibition. However, most of the previous experiments mainly focused on the advantages brought by learning bilingualism and the macroscopic impact on the brain structure, lacking direct and behavioral-level comparative studies on how it specifically acts on different inhibitory sub-functions. This experiment takes a step forward by using the GO/NO-GO experiment and the Stroop experiment to precisely measure the behavioral performance of bilinguals and monolinguals in response inhibition and interference inhibition tasks, directly linking bilingual learning with these two key executive sub-functions, aiming to more precisely reveal their intrinsic relationship. Finally, the experimental results show that the advantages of bilingual learning are more evident in response inhibition, while they are less significant in interference inhibition. This finding provides new and important evidence for understanding the specific manifestations and boundaries of bilingual cognitive advantages.

Keywords: Bilingualism, executive function, response inhibition, interference inhibition.

1. Introduction

“A bilingual person” refers to a person who can simultaneously master and use two or more languages. In today's society, bilingualism has become a common social phenomenon. According to incomplete statistics, approximately 70% of the population belongs to the category of bilinguals. Research has found that the mastery and use of bilingualism not only facilitate interpersonal communication, expand the cultural background and activity space of bilinguals, but also have a significant impact on the psychology of bilinguals, especially their cognitive abilities. A large number of studies have shown that compared to monolinguals (individuals who only master and use one language), bilinguals exhibit certain advantages in cognitive control aspects such as attention search, inhibition control, and cognitive transformation, which is known as the bilingual cognitive advantage [1, 2].

Inhibition control is a core cognitive ability of humans and has a significant impact on an individual's survival and development. According to the specific operation mechanism of inhibition control, it can be divided into two sub-types: response inhibition and interference inhibition (conflict inhibition) [3]. Response inhibition mainly refers to the individual making a selective response among multiple responses and inhibiting irrelevant responses based on stimulus cues. The commonly used measurement task is the Go/No-go task, while interference inhibition mainly refers to the individual responding to certain stimuli based on cue instructions while ignoring or inhibiting other stimuli. The commonly used measurement tasks are the Stroop task and the Simon task. The two types of inhibition control not only have different behavioral manifestations but also have different neural physiological bases. The Go/No-go task creates a "dominant response" that needs to be inhibited. When the No-go stimulus is presented, the motor system of the subject is already in a preparatory state, making inhibition more difficult. When the No-go is successfully inhibited for about 300-500 milliseconds, a positive wave appears in the posterior parietal cortex, which is widely regarded as the physiological marker of the inhibition process itself, mainly involving the inferior frontal gyrus (IFG) and the supplementary motor area (SMA/preSMA) and other brain regions. In the Stroop task, the Stroop effect produced is evidence of the difficulty of interference inhibition. It indicates that even if the subject tries to ignore the word meaning, the automatic reading process still interferes with the

target response. This process mainly involves the anterior cingulate cortex (ACC) and the dorsolateral prefrontal cortex (dIPFC). Because the activation intensity of ACC is closely related to the intensity of the Stroop effect, the activation of dlPFC is related to the success of interference inhibition and the correctness of the task. If dlPFC is damaged, the Stroop effect will be significantly abnormal [4,5].

However, most of the existing studies on the combined influence of bilingual experience on inhibition control use a single task to explore a certain aspect or use multiple tasks to explore the impact on overall cognitive function. There are few studies comparing the influence of bilingual experience on the two types of inhibition control abilities. Therefore, this study aims to examine the influence of bilingual experience on the two cognitive control functions of individual response inhibition and interference inhibition, in order to further enrich the research on the impact of bilingual experience on individual cognition.

The acquisition of bilingual cognitive advantages is mainly due to the fact that bilingual individuals need to suppress the other language when processing the target language, or because they constantly switch between the two languages, thereby enabling the cognitive functions of the second language speakers to be continuously trained, and thus enhancing their cognitive executive functions [6].

In addition, whether the second language is activated simultaneously during the processing of the mother tongue is influenced by the proficiency of the second language. For low-proficiency L2 participants, the activation of the second language during the processing of the mother tongue is relatively weak, so the advantage effect of inhibitory control ability is not obvious. For high-proficiency L2 participants, the second language is simultaneously activated during the processing of the mother tongue, so high-proficiency bilinguals need to expend more cognitive resources to inhibit the non-target language, and thus the advantage effect of inhibitory control ability is more obvious.

2. Research Methods

2.1. Experimental Design

The experiment adopted a single-factor within-subjects design. The independent variable was the proficiency in the English language, which was divided into low proficiency L2 participants and high proficiency L2 participants. The experimental tasks included the STROOP task and the Go/No-go task. The dependent variables were the reaction time (RT) and the task response accuracy of the participants during the tasks.

2.2. Participants

The participants were recruited from the students of Qufu Normal University. There was a total of 85 undergraduate and graduate students, mainly from the School of Psychology and the School of Foreign Languages. Among them, there were 43 monolinguals and 42 bilinguals (who had passed the English proficiency test at the fourth level of the major).

2.3. Tasks

The GO/NO-GO experimental procedure and the Stroop experimental procedure were both written using the PsychoPy software. The experimenter guided the participants to complete the experiments using two laptops. Both experiments included a practice section, which was not included in the data collection to ensure more accurate data could be obtained.

In the GO/NO-GO experiment, a total of ten Arabic numerals from 0 to 9 were set, divided into two parts. In the first part, the participants were required to respond to odd numbers and not respond to even numbers. After a short break, they moved to the second part, where they were required to respond to even numbers and not respond to odd numbers. Then, reaction times were collected for both monolingual and bilingual participants separately.

In the Stroop experiment, four variables were set: the red Chinese character "red", the red Chinese character "blue", the blue Chinese character "red", and the blue Chinese character "blue". The participants were required to respond based on the color rather than the meaning.

3. Result Analysis

3.1. Analysis of Stroop Task Results

The results of the repeated measures analysis of variance (MANOVA) showed that the main effect of English proficiency was not significant, $F(1, 41) = 2.07$, $p = 0.16$. This result indicates that there was no significant difference in the conflict inhibition control ability between high-proficient English L2 learners ($M = 0.47$, $SD = 0.07$) and low-proficient English L2 learners ($M = 0.49$, $SD = 0.07$). Therefore, this study concludes that the influence effect of bilingual experience on the conflict inhibition (or interference inhibition) of bilinguals is not obvious. However, from the reaction times of the high and low proficient L2 participants, the reaction of the high-proficient L2 learners was faster than that of the low-proficient L2 learners. The main effect of the conflict condition was significant, $F(1, 41) = 99.66$, $p < 0.001$, $\eta 2 = 0.71$. The reaction of the participants in the consistent condition ($M = 0.46$, $SD = 0.06$) was significantly faster than that in the conflict condition ($M = 0.50$, $SD = 0.07$).

3.2. Analysis of Go/No-go Task Results

The results of the independent sample T-test showed that the main effect of English (L2) proficiency was significant, $t(83) = 3.07$, $p = 0.003$, 95% CI = [0.0079, 0.0399]. This result indicates that the reaction of the high-proficient English L2 learners ($M = 0.42$, $SD = 0.02$) was significantly faster than that of the low-proficient English L2 learners ($M = 0.45$, $SD = 0.05$). Therefore, this study concludes that compared to the low-proficient L2 learners, the high-proficient English L2 learners have a significant advantage in reaction inhibition. It indicates that bilingual experience has a good training effect on the reaction inhibition ability of L2 learners.

4. Discussion

Why do highly proficient bilinguals exhibit different performances on the Stroop task and the Go/No-go task? Since the Stroop task reflects the ability to inhibit interference, while the Go/No-go task reflects the ability to inhibit responses. According to the bilingual parallel activation theory in language processing and the language correction hierarchical representation theory whether the L2 is activated during the processing of the native language depends on the degree of L2 proficiency [7,8] . When the proficiency of L2 is low, the L2 is rarely activated or has a weak activation intensity during the processing of the native language. People do not need to consciously inhibit the L2, so the inhibitory control ability of low-proficiency bilinguals is weak. As the proficiency of the L2 increases, the representation mode of the L2 increasingly approaches that of the native language, so in the processing of the native language, the L2 naturally acquires parallel activation. This is because people need to consciously inhibit the influence of the L2, so highly proficient bilinguals have better response inhibition ability. At the same time, the results of this study also indicate that in language processing, the inhibition control of the L2 by people does not occur at the activation stage, but at the stage of language response selection.

Another possible reason is that there is a ceiling effect in the task [9]. The participants in this study were all young adults in the peak stage of cognitive development, with strong overall cognitive flexibility and inhibitory control abilities. The Stroop task paradigm used in this study was relatively traditional and of low difficulty, which might not be sufficient to fully stimulate high executive load, resulting in all participants, including the monolingual control group, performing at close to the upper limit level [10]. In this case, even if bilinguals have potential advantages in interference inhibition, it may be difficult for them to manifest these advantages due to the limited variability space of

behavioral indicators. Therefore, the current results failed to detect significant differences and do not completely rule out the subtle regulatory role of bilingual experience on the conflict monitoring system.

In future experiments, more challenging variations can be adopted, such as the emotional Stroop task and the quantity Stroop task. In the Stroop task, dual tasks can be imposed to increase the cognitive load of the participants. Additionally, more sensitive indicators can be used, such as electroencephalography (EEG) technology to record the N2/N450 components related to conflict monitoring and the P3 components related to inhibition control. Even if there are no differences in behavioral data, neurophysiological data may still reveal potential processing differences.

In the study, a language-switching task was incorporated to directly measure the language inhibition and switching costs of the participants. Using functional near-infrared spectroscopy or electroencephalography, the brain activities of the participants were simultaneously recorded as they performed non-linguistic inhibition tasks (such as Go/No-go) and language tasks, to test whether they shared the same neural basis (such as the right inferior frontal gyrus and anterior cingulate cortex).

5. Conclusion

This study compared the performance of high and low proficiency bilinguals in the Go/No-go and Stroop tasks, revealing that the bilingual cognitive advantage has significant specificity: it mainly manifests in the enhancement of response inhibition, while there is no significant advantage in interference inhibition.

At the theoretical level, it strongly supports the "specific transfer" hypothesis of bilingual cognitive advantage rather than the "overall improvement" hypothesis. The results show that bilingual experience precisely refines the crucial response selection and inhibition mechanisms in the language production process, and this strengthened neural cognitive mechanism (mainly involving the prefrontal- motor control circuit) can effectively transfer to non-linguistic response inhibition tasks. In contrast, the interference inhibition mechanism involved in early perceptual conflict resolution has not received the same level of training.

At the practical level, this study reminds us that we should avoid making general statements about "bilingual advantages". Future research should use neuroimaging techniques to directly verify this mechanism and explore its value in a wider population and application scenarios. This study ultimately establishes that the essence of "bilingual advantage" lies in its precise shaping of the cognitive control system, rather than a comprehensive revolution.

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