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Interpreting experience enhances early attentional processing, conflict monitoring and interference suppression along the time course of processing

Yanping Dong*, Fei Zhong

Bilingual Cognition and Development Lab, Center for Linguistics and Applied Linguistics, Guangdong University of Foreign Studies, China

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ABSTRACT

To explore how interpreting experience may modulate young adults' executive functioning, the present study conducted two ERP studies using the Flanker task, and recruited university students of more or less interpreting experience. Experiment 1 revealed that participants of more interpreting experience exhibited larger N1 and N2 amplitudes in both congruent and incongruent conditions, which, according to previous research, are respectively evidence for advantages in early attentional processing and monitoring. As for the response time (RT) data, a smaller interference effect for the group of more interpreting experience was obtained, showing an advantage in inhibition. The P3 results were quite mixed, with the results of the first half P3 time window mainly supporting a monitoring advantage, and the results of the second half mainly supporting an inhibition advantage. Experiment 2 replicated Experiment 1 with two participant groups more closely matched in age and L2 AoA. The pattern of the results was similar to that in Experiment 1, except that the inhibition advantage from the P3 component appeared earlier, and that the inhibition advantage in RT data was only marginally significant. Both experiments have produced results that can be integrated into a coherent whole along the time course of processing, indicating that interpreting experience may enhance early attentional processing, conflict monitoring and interference suppression, with the latter two as parts of inhibitory control.

1. Introduction

Cognitive control, also known as executive functions or executive functioning/control, is an umbrella term containing cognitive processes that are related to the self-regulation and self-control of daily behaviors (Miyake and Friedman, 2012). Such processes include flexibility of thinking, ability to sustain attention, goal maintenance, conflict monitoring, inhibition, interference suppression, switching, (working memory) updating, etc. (Alvarez and Emory, 2006; Chan et al., 2008; Green and Abutalebi, 2013; Salthouse et al., 2003). There is research suggesting that language-specific experiences such as interpreting and public speaking may contribute to the enhancement of cognitive control (Dong and Xie, 2014; Xie and Dong, 2015; Yudes et al., 2011). The rationale behind it is that the exercise of a certain function in the language domain may help enhance its corresponding executive function in the nonlinguistic domain. It seems that this line of research has been stimulated by research on bilingual advantages, which has been a hot topic for the past decade (e.g., Bialystok et al., 2004). It is postulated that bilinguals may be better at cognitive functions such as inhibition (Bialystok et al., 2004; but see Kirk et al., 2014), mental set shifting/switching (e.g., Prior and Macwhinney, 2010; but see Hernández et al., 2013) and monitoring (e.g., Barac and Bialystok, 2012; but see Paap and Greenberg, 2013), probably because bilinguals have to select the right language at the right moment since the two languages are generally non-selectively activated (e.g., Dijkstra and van Heuven, 2002). Since the research on bilingual advantages has become controversial, and the presence or absence of bilingual advantages has become elusive (e.g., Paap et al., 2015; Valian, 2015), it may be helpful to turn our attention to a related question, i.e., what specific language experience enhances which aspect of cognitive control.

Taking the intensity and other unique features of the interpreting task into consideration, we believe that exploring how interpreting experience enhances which aspect of cognitive control will probably offer some help in the study of the mind and brain. Interpreting is a complex and cognitively demanding language task that requires the coordination of several processes under strong time pressure, and thus control over the whole process of interpreting (De Groot and Christoffels, 2006). The two languages are simultaneously activated in interpreting (e.g., Dong and Lin, 2013), certainly more activated

* Correspondence to: Center for Linguistics and Applied Linguistics, Guangdong University of Foreign Studies, Baiyun Avenue North 2#, Guangzhou 510420, China.
E-mail address: ypdong@gdufs.edu.cn (Y. Dong).

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than when a bilingual is in a monolingual mode. Interpreters have to switch swiftly between languages, inhibiting the interference of the language not wanted at that instant, and updating contents in the working memory system. The functions of switching/shifting, inhibitory control, and updating in the language domain are thus exercised, which may help improve their corresponding functions in the nonlinguistic domain. What's more, interpreters have to keep alert to the task at the moment, comprehending the coming information and/or producing the target language (in simultaneous or consecutive interpreting). Attentional control is therefore an essential skill in interpreting (Cowan, 2000; De Groot and Christoffels, 2006; Timarová et al., 2014), and the exercise of such a skill may contribute to a nonlinguistic advantage. Interpreting experience, therefore, may produce domain-general advantages in the executive functions of inhibition, switching/shifting, updating and attentional processing.

There have been a few empirical studies on interpreter advantages in executive functions. Three of the studies (Dong and Liu, 2016; Dong and Xie, 2014; Yudes et al., 2011) suggest that interpreting experience enhances switching ability (as measured in the Wisconsin Cart Sorting Test, or as indexed by the switch costs in a color-shape task), but not inhibition (as measured respectively in the Simon, Flanker and Stroop tasks). Babcock and Vallesi (2015) and Becker et al. (2016), however, found an interpreter advantage in monitoring ability (indexed by mixing costs in a color-shape task), but not in switching ability (indexed by switch costs in the color-shape task). Woumans et al. (2015) found that interpreters outperformed unbalanced bilinguals in the Simon and ANT (a more complex form of Flanker) tasks (i.e., higher accuracy in both tasks and smaller error congruency effect in the ANT), but the interpreters did not outperform balanced bilinguals, suggesting that the interpreter advantage in inhibitory control and attentional processing cannot be uniquely ascribed to interpreting experience. Morales et al. (2015a, 2015b) reported higher updating skills from simultaneous interpreters than from general bilinguals and a modulating effect of interpreting experience on the interaction between attentional networks in the ANT, suggesting an interpreter advantage in updating and in attentional processing. To sum up, it seems that in the few existing studies, there was always a certain cognitive control advantage for professional interpreters or students with more interpreting experience. But the results were not necessarily consistent.

Among the three functions of inhibition, switching and updating (Miyake and Friedman, 2012), there seems to be more research on bilingual advantages in inhibition, and the results were quite mixed (Dong and Li, 2015). The situation is more or less the same for research on interpreter advantages, as can be seen in the few studies described above. Tasks such as the Flanker, the Simon, the Stroop and the ANT are assumed to be typical tests of inhibition; and the word "inhibition" may include quite different processes, especially when tested by different tasks. Timarová et al. (2014), for example, conducted a series of experiments to explore the relationship between simultaneous interpreting experience and executive control ability. Two of the tasks were related to inhibitory control. One was the Flanker task, and it revealed that the interference effect, defined as the ratio of incongruent RT to neutral RT, was negatively correlated to interpreting experience. The other was the antisaccade task, but no such correlation was found. The question of an interpreter advantage in inhibitory control is therefore not so straightforward.

To summarize, more research is needed for the role of interpreting experience in the enhancement of cognitive control. Among all the components of cognitive control, we are more interested in inhibition, which seems the most explored component in the literature. And among all the tasks related to inhibition, the Flanker, together with its more complex form of the ANT, seems the most frequently used task (in studies such as Dong and Xie, 2014; Morales et al., 2015a, 2015b; Timarová et al., 2014; Woumans et al., 2015). With the Flanker task, *an advantage in inhibition* means stronger ability to inhibit the interference from surrounding flankers. Statistically speaking, this advantage is generally reflected in the significant interaction between participant groups and congruency conditions (congruent: '> > > > >', neutral: '< > < > > < > < >', incongruent: '> > < > >'). When that interaction is not significant, there is a possibility that the main effect of participant groups is significant, which means that one group, faster in both congruent and incongruent conditions, is more efficient at going back and forth between mixed trials that require conflict resolution (e.g., Hilchey and Klein, 2011). The group that is faster at the task is said to possess *an advantage in monitoring*. In the present study, we intended to use the Flanker task and record participants' electrophysiological responses with the ERP technique.

The ERP technique, with its high temporal resolution, may offer further insights. Previous research indicates that the components of N2, P3 and N1 are related to cognitive control, although the exact processes reflected by these components are still being determined. Specifically, N2 is a typical negative-going component related to the inhibition process (see Folstein and van Petten, 2008, for a review). This component has been analyzed in Flanker tasks to explore inhibitory control (Blackburn, 2013; Johnstone et al., 2009; Kousaie and Phillips, 2012). The Flanker task in Blackburn (2013), for example, revealed a group-congruency interaction in the N2 component. Further analysis showed that only non-switchers (those who do not code-switch between languages during conversation) exhibited larger N2 amplitudes for the incongruent condition than the congruent condition. This congruency effect was not significant for switchers or monolinguals. The results indicate that the non-switchers, with larger N2 effect, exhibited superior inhibitory control due to their frequent suppression of the other language. In the present study, similar to behavioral data, if the group-congruency interaction is significant, we may claim that the group showing larger N2 amplitudes in the incongruent condition possesses better inhibition ability (with no group difference in the congruent condition). If the interaction is not significant but the main effect of group was significant, N2 reflects conflict monitoring, with the advantageous group exhibiting larger N2 amplitudes in both congruent and incongruent conditions.

P3 is a positive-going component related to inhibition and attentional resources (see Polich, 2007, for a review). According to Polich (2007), P3 can be a reflection of inhibition, and the amount of attentional resources allocated to the inhibition process is negatively related to the P3 amplitude. For example, in Kousaie and Phillips (2012), the Stroop task exhibited smaller P3 amplitudes for the incongruent condition than the congruent and neutral conditions, suggesting that *smaller P3 amplitudes meant more attentional resources allocated to the incongruent condition* (since it generally requires more resources to make a decision and respond in the incongruent condition than in the two other conditions). Statistical analysis and its interpretations for P3 are the same as those for N2.

N1 is an ERP component related to early attentional processing (Beste et al., 2008). Beste et al. (2008) found that patients with Huntington's disease and presymptomatic Huntington's disease exhibited reduced N1 amplitudes than their healthy controls when performing the Flanker task, indicating deficient attentional processes. Based on participants' performance in a Flanker task, Johnstone et al. (2009) further suggested that N1 was sensitive to the presence of flankers and was a reflection of automatic attention oriented to the flankers. In short, N1 is considered an index of early attentional processing (especially in a task containing flankers), with larger N1 amplitudes signifying better attentional processing.

The present study was intended to explore the modulation effect of interpreting experience on interpreters' abilities of inhibitory control and early attentional processing, with the employment of the ERP technique. To achieve this goal, groups of university students with different amount of interpreting training were recruited to perform a Flanker task, and the ERP components of N1, N2 and P3, together with RT, were recorded and analyzed. It was hypothesized that participants with more interpreting training would be better in early attentional processing and inhibitory control.

Experiment 1 recruited two groups of university students majoring in Translation and Interpreting, with one group as graduate students receiving more interpreting training, and the other group as junior students receiving less such training. The strength of this design is that both participant groups had been trained in the same program in the same university, while the weakness lies in that the two groups may differ a little in their age. To overcome this weakness in Experiment 1, Experiment 2 recruited a new group of participants that were comparable in age with the more-IE group in Experiment 1.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Forty-eight students from Guangdong University of Foreign Studies participated for monetary compensation. Twenty-six (1 male, 25 female) of them, labeled as the "more-IE" group in the present study, were first-year graduates majoring in Translation and Interpreting (T & I). Twenty-two students (4 male, 18 female), labeled as the "less-IE" group, were juniors majoring in T & I. The more-IE and the less-IE groups received respectively 2.3 and 0.5 years of interpreting training on average. For the less-IE group, they had received two courses of translation and two of interpreting, with 32 h of classroom instruction in each course. For the more-IE group, they had received an average of six courses of translation and eight courses of interpreting, with 32 h of classroom instruction in each course. Each course of interpreting required students to do at least 32 h of practice after class. Since all the students were unbalanced bilinguals learning English as a foreign language, interpreting training was demanding for all of them.

Data of eight participants were excluded due to excessive artifacts in their EEG (criteria will be explained in Section 2.1.3). Therefore, there were twenty participants (1 male, 19 female) in the "more-IE" group, and twenty participants (4 male, 16 female) in the "less-IE" group. All these remaining participants had normal or corrected-to-normal vision, and were right-handed as measured by a Chinese version of Coren's (1992) handedness questionnaire. They were also matched on L2 proficiency (English proficiency) assessed by Syndicate's (2001) quick placement test. Other background information was collected by a short version of the language history questionnaire (Li et al., 2013). Participants signed a written consent after the nature of the experiment had been fully explained. Critical background information[1] is presented in Table 1.

As Table 1 shows, the two groups of participants differed in the amount of interpreting training as designed ($t=8.01$, $p < .001$). They were matched in L2 proficiency, frequency of L2 use and L2 learning history, as expected. As for age, the more-IE group was about two years older than the less-IE group, but both groups were "young adults" with all participants aged from 20 to 25, and we therefore considered the two groups comparable. As for L2 AoA, the less-IE group started about two years earlier, which could be a problem. However, in the research on bilingual cognitive control advantages, the factor of L2 AoA, if it plays a role, is negatively correlated with cognitive control ability (see

[1] Apart from the factors reported in Table 1, intelligence is generally considered an important factor in studies of executive functions, but we did not measure this factor in the present study for two reasons. First, it was found that although working memory updating was correlated with intelligence measures, inhibition and shifting were not (Benedek et al., 2014). Second, two of our previous studies (Dong and Liu, 2016; Xie and Dong, 2015) that measured participants' intelligence (with Raven's Advanced Progressive Matrices Set) found no difference between groups of university students, probably because students in the same university in China did not differ much from each other in intelligence. And yet, we do encourage future researchers of similar topics to measure participants' intelligence, and we consider the lack of such information a weakness in the present study.

Table 1
Summary of participants' background information (means with SDs in brackets).

	More-IE group N =20	Less-IE group N =20	*t* value
Interpreting training (years)	2.30 (1.01)	0.50 (0)	8.01***
L2 proficiency[a]	50.10 (2.75)	49.60 (2.87)	.56
Frequency of L2 use (%)	50.37 (1.56)	49.34 (18.27)	.22
L2 learning history (years)	12.75 (1.62)	12.95 (1.80)	−.37
L2 AoA[b]	1.50 (2.01)	8.20 (1.88)	3.37**
age (years)	23.40 (.94)	21.20 (.62)	8.75***

[a] The total score of L2 proficiency is 60, tested by Oxford Quick Placement test (Syndicate, 2001)
[b] AoA: age of acquisition
*** $p < .001$
** $p < .01$

Dong and Li, 2015, for a brief review), and would probably diminish cognitive control advantages supposedly brought by interpreting experience to the more-IE group in the present study. If it turned out that the more-IE group was better than the less-IE group as we had predicted, it means that the factor of interpreting training did play a significant role.

2.1.2. Stimuli and procedure

Participants were asked to complete a short version of language history questionnaire (Li et al., 2013) and a handedness questionnaire (Coren, 1992) when they came to the lab for the experiment.

After the questionnaires, the Flanker task started. Participants were seated in a sofa 130 cm away from a 17" LCD (Lenovo L1710D, 60-Hz refresh rate). Each stimulus consisted of five horizontally arranged chevrons (" < " or " > "), with the central one pointing to either the same or opposite direction of the remaining four, and thus creating congruent (" > > > > > ", " < < < < < ") and incongruent conditions (" > > < > > ", " < < > < < "). For each trial, a fixation was presented at the center of screen for 300 ms, followed by a blank screen for another 300 ms. A stimulus then appeared for 800 ms during which the participants were required to make a response to the direction of the central chevron correctly and quickly. Then a blank screen would appear for 900, 1000, or 1100 ms (to reduce potential expectancy effects). Altogether, the experiment consisted of four blocks of 72 trials (36 for each condition) preceded by a practice block of 12 trials. Trials were presented pseudo-randomly in the task where the same stimulus did not appear in five consecutive trials.

After the Flanker task, participants were asked to finish an Oxford Quick Placement test (Syndicate, 2001) that was intended to measure their L2 proficiency.

2.1.3. EEG recording and offline processing

The Electroencephalogram (EEG) was continuously recorded by elastic electrode caps with 64 Ag/AgCl electrodes placed in line with the International 10/20 system, using NeuroScan Synamps2 (Compumedics, El Paso, TX, USA) with a sampling rate of 1000 Hz and a bandpass of .05–100 Hz. The veridical electrooculogram (VEOG) were recorded by two electrodes placed above and below the left eye. The horizontal electrooculogram (HEOG) were placed at the outer canthi of the eyes. The EEG recording was referenced online to the left mastoid. Impedances were kept below 10KΩ.

In offline analysis, the EEG was firstly re-referenced to the M2 channel. Then, incorrect responses and artifacts such as myoelectricity, drifting, and HEOG were manually rejected. VEOG was corrected by a function in the Neuroscan 4.5. Then, a digital low pass filter of 30 Hz (24 dB/octave) was applied to the ERP signals. The filtered EEG signals were segmented into epochs of 800 ms, which was time-locked to the onset of each stimuli and which included a 100 ms pre-stimulus baseline. Epochs were then baseline corrected, and bad epochs with amplitudes over ± 70μV were automatically rejected. To maintain a relatively high signal-to-noise ratio, if the remaining trials of any stimulus type were less than 80% of the total trials, the data of the corresponding participant were excluded.[2] The loss of data during the whole offline processing was 10.30%.

Averaged ERP components N1, N2 and P3 were determined via visual inspection and with reference to previous studies. N1 was defined as the most negative peaks between 30–130 ms, N2 was defined as the most negative peaks between 240–380 ms, and P3 was defined as the most positive peaks between 320–520 ms. Selection of the electrodes reported was based on a whole-head analysis.

2.1.4. Data analysis

For the indexes of RT and accuracy rate (ACC), a 2 (congruency: congruent, incongruent) ×2 (group: more-IE, less-IE) ANOVA would be conducted and a univariate test would be employed for the analysis of interference effect (i.e. the incongruent-minus-congruent value).

For N1, N2 and P3 mean amplitudes, each electrode was first analyzed through a 2 (congruency: congruent, incongruent) ×2 (group: more-IE, less-IE) ANOVA, and those electrodes that showed neither a significant group-congruency interaction nor a significant main effect of group were excluded from further analysis. A 2 (congruency: congruent, incongruent) ×2 (group: more-IE, less-IE) × n (electrode) ANOVA would be then conducted respectively for those electrodes with a significant group-congruency interaction, and those without such an interaction but with a significant main effect of group. Other remaining electrodes such as those that showed a marginally significant group-congruency interaction were analyzed so that areas with smaller effects were also mapped onto the time course of processing.

2.2. Results

2.2.1. Behavioral results

Outliers of 3 SDs beyond the mean RT, accounting for 1.10% of the total data, were excluded. Table 2 summarizes the remaining data in each condition of the task across the two groups.

Table 2
Mean RT or accuracy rate (with SD in bracket) for each condition in the Flanker task across groups.

	More-IE group N =20	Less-IE group N =20	F value
Congruent RT (ms)	447.16 (41.44)	434.58 (38.67)	.99
Incongruent RT (ms)	502.92 (40.99)	513.04 (42.56)	.59
Interference effect RT (ms)	55.76 (26.39)	78.45 (23.17)	8.35**
Congruent ACC (%)	98.85 (1.88)	98.58 (2.78)	.08
Incongruent ACC (%)	94.65 (3.34)	93.37 (3.83)	1.64
Interference effect ACC (%)	4.20 (2.77)	5.21 (3.71)	.95

** : $p < .01$

With regard to RT, a 2 (congruency: congruent, incongruent) ×2 (group: more-IE, less-IE) ANOVA analysis revealed an interaction of congruency and group, $F(1, 38) = 8.35$, $p = .006$, $\eta_p^2 = .180$, and a main effect of congruency, $F(1, 38) = 292.06$, $p < .001$, $\eta_p^2 = .885$, but not a main effect of group, $F(1, 38) = .01$, $p = .921$, $\eta_p^2 < .001$. Simple effect analyses revealed that both groups of participants responded faster in the congruent than the incongruent condition (ps < .001), but the two groups did not differ from each other in RT in either condition (ps > .1). *The interference effect (i.e. the incongruent-minus-congruent value), however, was significantly smaller for the more-IE than the less-IE group* ($F(1, 38) = 8.35$, $p = .006$, $\eta_p^2 = .180$), *which means the more-IE group was better at inhibitory control*, as predicted.

With regard to ACC, none of the above comparisons reached significance (Fs < 1, ps > .1, $\eta_p^2 = .024$), except for the congruency effect ($F(1, 38) = 82.67$, $p < .001$, $\eta_p^2 = .685$).

2.2.2. Event-related potentials

The ERP waveforms revealed the expected components, i.e. N1, N2 and P3. Fig. 1 depicts the grand average waveforms for both congruency conditions from both participant groups. Fig. 2 represents the topographic maps of the components.

2.2.2.1. N1 Results. A whole-head analysis showed that 21 electrodes exhibited significant group differences (with the group-congruency interactions not significant). A 2 (congruency: congruent, incongruent) ×2 (group: more-IE, less-IE) ×21 (electrode: FP1, FPZ, FP2, AF3, AF4, F7, F5, F3, F1, Fz, F2, F4, F6, FT7, FC5, FC3, FC1, FCz, FC2, C5, C3) ANOVA analysis revealed a main effect of group, $F(1, 38) = 7.98$, $p = .007$, $\eta_p^2 = .174$, and a main effect of electrodes, $F(20, 760) = 63.80$, $p < .001$, $\eta_p^2 = .627$. None of the other indexes including all interactions was significant (Fs < 2, ps > .1). The main effect of group, together with the absence of interactions, and the values of amplitude indicates that the *more-IE group exhibited consistently larger N1 amplitudes across the 21 electrodes than the less-IE group in both congruent and incongruent conditions, which is consistent with the hypothesis of an interpreter advantage in early attentional processing*.

2.2.2.2. N2 Results. A whole-head analysis showed that 16 electrodes exhibited significant group differences (with the group-congruency interactions not significant). A 2 (congruency: congruent, incongruent) ×2 (group: more-IE, less-IE) ×16 (electrode: FPZ, AF4, AF3, F7, F5, F3, F1, Fz, F2, F4, FC5, FC3, FC1, FCz, FC2, FC4) ANOVA revealed a main effect of group, $F(1, 38) = 9.83$, $p = .003$, $\eta_p^2 = .205$, a main effect of congruency, $F(1, 38) = 65.28$, $p < .001$, $\eta_p^2 = .632$ and a marginal main effect of electrode, $F(15, 570) = 2.76$, $p = .059$, $\eta_p^2 = .068$. Except for the congruency-electrode interaction ($F(15, 570) = 19.82$, $p < .001$, $\eta_p^2 = .343$), other interactions were not significant, Fs < 1, ps > .1, including the group-congruency interaction. The results revealed that *the more-IE group exhibited consistently larger N2 amplitudes across the 16 electrodes than the less-IE group, which is consistent with the hypothesis of an interpreter advantage in monitoring*.

Apart from these 16 electrodes, 13 other electrodes (FP1, FP2, F7, FT7, FC6, T7, C5, C3, Cz, C2, C4, C6 and T8) revealed results approaching a monitoring advantage, i.e. no group-congruency interaction (ps > .1) but a marginal main effect of group (.05 < ps < .1) was observed.

2.2.2.3. P3 Results. The P3 results were quite complex. On the one hand, some of the electrodes exhibited results similar to the monitoring advantage results in N2 (i.e., insignificant group-congruency interaction but significant main effect of group). On the other hand, some other electrodes exhibited results consistent with an inhibition advantage interpretation (i.e., significant group-congruency interaction, with simple effect analysis revealing significant group difference in the incongruent condition but not in the congruent condition). Since the time window of P3 overlaps with that of N2 and RT data, dividing the time window into two may reveal a gradual change and better explain P3 results. The following analyses were thus conducted first on the whole P3 time window and then on different parts of the P3 window.

2.2.2.3.1. P3 results in the whole time window. A whole-head analysis indicated that 11 electrodes exhibited a monitoring advantage or an inhibition advantage. For the ten electrodes of F5, F3, F1, F2, FC3, FC1, FCz. FC2, FC4 and FC6, a 2 (congruency: congruent,

[2] Moreno et al. (2014) kept a higher criterion of 90%, but did not exclude more participants, probably because their EEG signals were more stable than ours. In our study, some of the participants got nervous easily in the ERP study and made small head movements that contaminated the EEG.

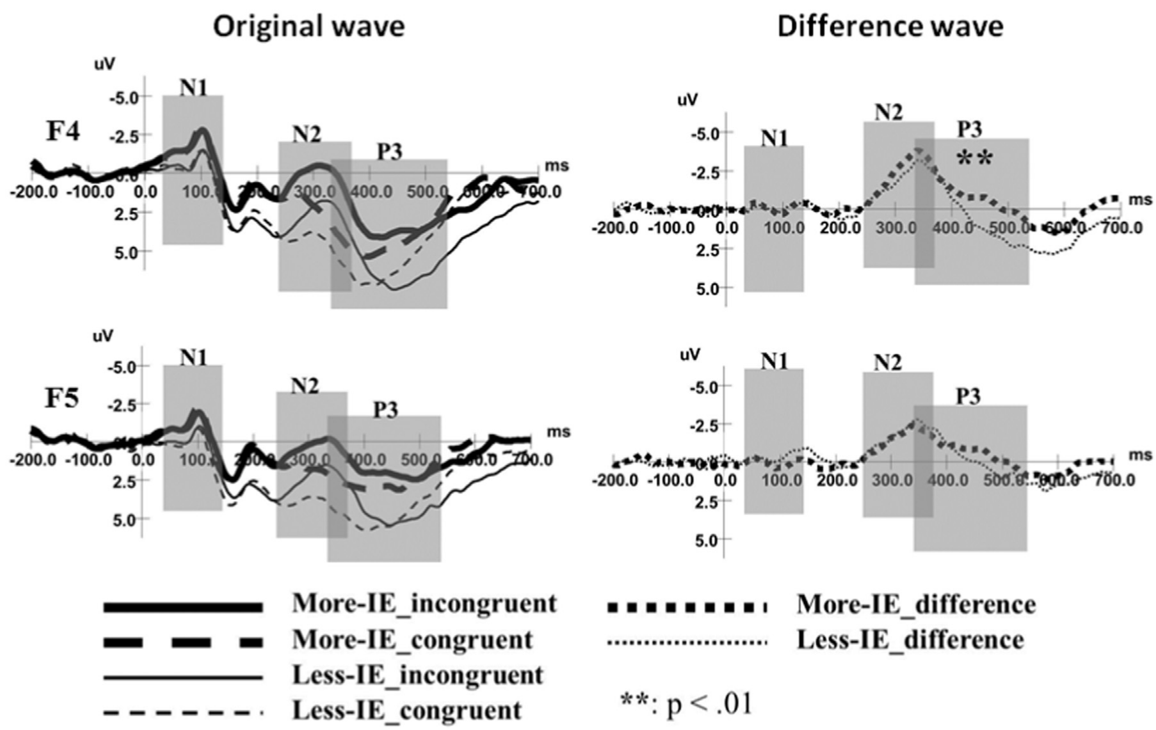

Fig. 1. Left panel: grand average waveforms for participant groups with more or less interpreting experience (more-IE and less-IE) in incongruent and congruent conditions in two example electrodes F4 and F5. Right panel: difference waves between two congruency conditions for each group (with F4 illustrating significant difference between the two groups).

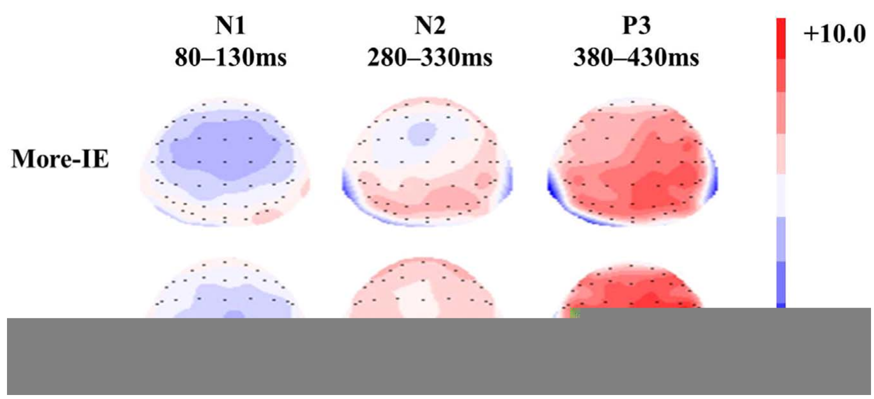

Fig. 2. Topographic maps of N1, N2 and P3 from the incongruent condition for the two participant groups. Each picture represents 50 ms around the peak of the corresponding component.

incongruent) ×2 (group: more-IE, less-IE) ×10 (electrodes) ANOVA revealed a main effect of group (F(1, 38) =6.57, p=.014, η_p^2 =.147), of congruency (F(1, 38) =12.64, p=.001, η_p^2 =.250), and of electrode (F(9, 342) =15.61, p < .001, η_p^2 =.291). Except for the marginal congruency-electrode interaction (F(9, 342) =2.46, p < .055, η_p^2 =.061), no other interactions were significant (Fs < 2, ps > .1), including the group-congruency interaction. The P3 results of these ten electrodes thus indicated a monitoring advantage for the more-IE group.

For the electrode F4, A 2 (congruency: congruent, incongruent) ×2 (group: more-IE, less-IE) ANOVA showed a main effect of congruency (F(1, 38) =13.34, p=.003, η_p^2 =.214), and of group (F(1, 38) =4.99, p=.031, η_p^2 =.116). Their interaction was significant (F(1, 38) =5.50, p=.024, η_p^2 =.127). Simple effect analysis showed that the more-IE group exhibited smaller P3 amplitudes than the less-IE group in the incongruent condition (F(1, 38) =8.21, p=.007), but not in the congruent condition (F(1, 38) =2.24, p=.143). Thus, for the electrode F4, the statistical results revealed an inhibition advantage for the more-IE group.

Apart from the above 11 electrodes, 6 electrodes (F6, FT7, FC5, C2, C6, T8) revealed statistical results approaching an interpretation of either a monitoring advantage or an inhibition advantage. Some of them showed a marginally significant group-congruency interaction (F6, FT7, FC5, T8 and C6, .05 < ps < .1), and some of them exhibited no such interaction with a marginally significant main effect of group (C2 and T8, .05 < ps < .1).

2.2.2.3.2. P3 analysis in different time windows. To further explore how P3 bridges the monitoring advantage revealed by N2 amplitudes and the inhibition advantage revealed by RT data, we divided the time window of P3 into two at 440 ms, which was around the peak of the averaged wave in the incongruent condition.

In the first half time window, i.e. 320 – 440 ms, a whole head analysis showed that 12 electrodes exhibited significant group differences (with the group-congruency interactions not significant). A 2 (congruency: congruent, incongruent) ×2 (group: more-IE, less-IE) ×12 (electrode: AF4, F5, F3, F1, Fz, F2, FC3, FC1, FCz, FC2, FC4, T8) ANOVA revealed a main effect of congruency (F(1, 38) =39.80, p

$< .001$, $\eta_p^2 = .512$), of group ($F(1, 38) = 6.64$, $p = .014$, $\eta_p^2 = .149$) and of electrode ($F(11, 418) = 9.93$, $p < .001$, $\eta_p^2 = .207$). Although the congruency- electrode interaction was obtained ($F(11, 418) = 8.92$, $p < .001$, $\eta_p^2 = .190$), other interactions including the group-congruency interaction were not significant (Fs < 1, ps $> .1$). *Statistical results from these 12 electrodes at the first half of the P3 time window were thus consistent with those from N2, indicating a monitoring advantage for the more-IE group.*

Besides, two electrodes (FC5 and T8) showed results approaching a monitoring advantage interpretation, i.e., no group-congruency interaction (ps $> .1$) was observed but the main effect of group was marginally significant ($.05 <$ ps $< .1$).

In the second half, i.e. the 440–520 ms time window, a whole-head analysis showed that 13 electrodes exhibited a monitoring advantage or an inhibition advantage. Among them, *10 electrodes revealed evidence for an inhibition advantage for the more-IE group*. A 2 (congruency: congruent, incongruent) ×2 (group: more-IE, less-IE) ×10 (electrode: AF4, Fz, F4, F6, FCz, FC2, FC4, C4, C6, T8) ANOVA exhibited a main effect of group ($F(1, 38) = 6.01$, $p = .019$, $\eta_p^2 = .137$), of congruency ($F(1, 38) = 4.32$, $p = .045$, $\eta_p^2 = .102$), and of electrode ($F(9, 342) = 14.11$, $p < .001$, $\eta_p^2 = .271$). The group-congruency interaction was significant ($F(1, 38) = 6.89$, $p = .012$, $\eta_p^2 = .153$), while no other interactions were significant (Fs < 2, ps $> .1$). Simple effect analyses indicated that the more-IE group exhibited smaller P3 amplitudes than the less-IE group in the incongruent condition (ps $< .05$), but not in the congruent condition (ps $> .1$).

The remaining 3 electrodes of F5, F3 and FC3 revealed evidence for a monitoring advantage for the more-IE group. A 2 (congruency: congruent, incongruent) ×2 (group: more-IE, less-IE) ×3 (electrode: F5, F3, FC3) ANOVA exhibited a main effect of group ($F(1,38) = 5.41$, $p = .025$, $\eta_p^2 = .125$), and of electrode ($F(2, 76) = 10.02$, $p = .001$, $\eta_p^2 = .209$). None of the others were significant, including the group-congruency interaction.

Apart from the above electrodes, 17 electrodes revealed statistical results approaching an interpretation of either a monitoring advantage or an inhibition advantage. Some of them exhibited no group-congruency interaction with a marginally significant main effect of group (F8, FT7 and FC5, $.05 <$ ps $< .1$), and some of them showed a marginal group-congruency interaction (FP1, AF3, FC1, FC6, FT8, CP2, CP6, TP8, P2, P4, CB1 and O1, $.05 < p < .1$). Some others (C2 and CP4) showed a significant group-congruency interaction (ps $< .05$), but the simple effect analyses did not reveal the pattern of an inhibition advantage.

2.3. Discussion

The present study aimed to explore how interpreting experience would help enhance young adults' ability in executive functioning. Briefly, the results from Experiment 1 showed that, compared with the less-IE group (participants with less interpreting experience), the more-IE group exhibited a smaller interference effect in RT, larger N1 and N2 amplitudes in both congruent and incongruent conditions (with the group-congruency interactions not significant), and smaller P3 amplitudes in the incongruent but not in the congruent condition (with significant group-congruency interactions). According to the interpretation of the ERP components of N1, N2 and P3 in the introduction part, the N1 results reported above are evidence of an advantage in early attentional processing for the more-IE group, and the N2 and RT results are respectively evidence of monitoring and inhibition advantages for the more-IE group. Some electrodes in P3 revealed data supporting a monitoring advantage while others revealed data supporting an inhibition advantage. This "bridging" effect of P3 was more apparent when the time window of P3 was cut into two, with the data from the first half time window mainly supporting a monitoring advantage, and the data from the second half mainly supporting an inhibition advantage. Fig. 3 depicts the dynamics of the interpreter advantage along the time course of processing.

As far as we know, Fig. 3 illustrates the dynamics of the interpreter advantage for the first time in the literature. And yet, as described in Experiment 1, the two participant groups (university students with more or less interpreting experience) differed in age and L2 AOA (see Table 1 for details). Although we reasoned earlier that these differences may not change the findings of advantages for the more-IE group, it would be better if these findings could be replicated with participant groups that matched more closely in age and L2 AOA, which is the task of Experiment 2.

3. Experiment 2

Experiment 2 was mainly intended as a replication of Experiment 1.

3.1. Methods

Apart from adding a new group of participants, this section of Methods is the same as that in Experiment 1. That is, sections such as "stimuli and procedure", "EEG recording and offline processing", and "data analysis" are omitted in this section.

A new group of students were recruited from the same university (as in Experiment 1). There were altogether 23 first-year graduate students (3 male, 20 female) majoring in Linguistics. They were labeled as the less-IE group because they had received on average .78 years of interpreting training during their undergraduate years as English majors.

Data of three participants from this less-IE group were excluded for the same reason as described in Experiment 1. Twenty participants (2 male, 18 female) thus remained in the less-IE group, all being right-handed and enjoying normal or corrected-to-normal vision. Table 3 is a comparison of this less-IE group with the more-IE group in Experiment 1. As the table shows, the two participant groups differed in interpreting training as designed ($t = 6.21$, $p < .001$), but they were statistically equal in L2 proficiency, frequency of L2 use and L2 learning history, age and L2 AoA, as expected.

3.2. Results

3.2.1. Behavioral results

The data trimming process, which deleted outliers of 3 SDs beyond the mean RT, excluded .92% of the total data. Table 4 is a summary of the remaining data for each condition of the task across the two participant groups.

With regard to RT, a 2 (congruency: congruent, incongruent) ×2 (group: more-IE, less-IE) ANOVA analysis revealed a marginal interaction of congruency and group ($F(1, 38) = 3.52$, $p = .068$, $\eta_p^2 = .085$), and a main effect of congruency($F(1, 38) = 253.65$, $p < .001$, $\eta_p^2 = .870$), but not a main effect of group ($F(1, 38) = .24$, $p = .630$, $\eta_p^2 = .006$). *The interference effect (i.e., the incongruent-minus-congruent value), was marginally significantly smaller for the more-IE than the less-IE group ($F(1, 38) = 3.52$, $p = .068$, $\eta_P^2 = .085$), which means that the more-IE group tended to be better at inhibitory control.*

With regard to ACC, none of the above comparisons reached significance (all Fs < 1, ps $> .1$), except for the congruency effect ($F(1, 38) = 53.608$, $p < .001$, $\eta_p^2 = .585$).

3.2.2. Event-related potentials

The ERP waveforms revealed the expected components, i.e. N1, N2 and P3. Fig. 4 depicts the grand average waveforms for both congruency conditions and for both participant groups. Fig. 5 represents the topographic maps of the components.

3.2.2.1. N1 results. A whole-head analysis showed that 16 electrodes exhibited significant group differences (with the group-congruency interaction not significant). A 2 (congruency: congruent, incongruent)

Fig. 3. Interpretation of the ERP results along the time course of processing, with marked electrodes indicating that, students with more interpreting experience showed an advantage in early attentional processing at N1, a monitoring advantage at N2, and an inhibition advantage at the 2nd half time window of P3.

Table 3
Summary of participants' background information (means with SDs in brackets) in Experiment 2.

	More-IE group N =20	Less-IE group N =20	*t* value
Interpreting training (years)	2.30 (1.01)	.78 (.43)	6.21[***]
L2 proficiency[a]	50.10 (2.75)	49.00 (2.62)	1.27
Frequency of L2 use (%)	50.37 (10.56)	47.63 (13.76)	.71
L2 learning history (years)	12.75 (1.62)	12.40 (1.54)	.70
L2 AoA[b]	10.50 (2.01)	10.95(1.67)	−.77
age (years)	23.40 (.94)	23.40 (.50)	.00

[a] The total score of L2 proficiency is 60, tested by Oxford Quick Placement test (Syndicate, 2001)
[b] AoA: age of acquisition
[***] 1) p < .001

Table 4
Mean RT or accuracy rate (with SD in bracket) for each condition in the Flanker task across groups.

	More-IE group N =20	Less-IE group N =20	F value
Congruent RT (ms)	447.16 (41.44)	445.87 (40.65)	.01
Incongruent RT (ms)	502.92 (40.99)	516.51 (44.47)	1.01
Interference effect RT (ms)	55.76 (26.39)	70.64 (23.73)	3.52△
Congruent ACC (%)	98.85 (1.88)	99.20 (.82)	.58
Incongruent ACC (%)	94.65 (3.34)	94.83 (4.56)	1.64
Interference effect ACC (%)	4.20 (2.77)	4.38 (4.44)	.95

△: .05 < *p* < .1.

×2 (group: more-IE, less-IE) ×16 (electrode: FC2, FC4, C3, C1, CZ, C2, C4, C6, CP3, CP1, CPZ, CP2, CP4, CP6, TP8, P8) ANOVA analysis revealed a main effect of group, F(1, 38) =7.48, p=.009, η_p^2 =.164, and a main effect of electrodes (F(15, 570) =27.95, p < .001, η_p^2 =.424). None of the other indexes including all the interactions was significant (Fs < .1, ps > .1). *The N1 results of Experiment 1 were thus replicated here, with specifically 16 electrodes in Experiment 2 supporting an advantage in early attentional processing for the more-IE group.*

3.2.2.2. N2 Results. A whole-head analysis indicated that 11 electrodes showed significant group differences (with the group-congruency interaction not significant). A 2 (congruency: congruent, incongruent) ×2 (group: more-IE, less-IE) ×11 (electrode: Fz, F2, FC2, FC6, FT8, C4, C6, T8, CP6, TP8, P8) ANOVA showed a main effect of congruency (F(1, 38) =64.26, p < .001, η_p^2 =.628), of group (F(1, 38) =9.78, p=.003, η_p^2 =.205), and of electrode (F(10, 380) =9.01, p < .001, η_p^2 =.192). Except for the congruency-electrode interaction (F(10, 380) =10.16, p < .001, η_p^2 =.211), no other interactions were significant (Fs < 2, ps > 2), including the group-congruency interaction. Again, *the N2 results of Experiment 1 were replicated, with specifically 11 electrodes in Experiment 2 supporting a monitoring advantage for the more-IE group.*

Apart from the 11 electrodes, 19 electrodes exhibited results approaching an interpretation of either a monitoring advantage or an inhibition advantage. Among them, seven electrodes (F3, F8, FC3, CP2, P4 PO8, PO6) showed no group-congruency interactions with a marginal main effect of group (.05 < ps < .1), while 12 electrodes (F4, FC1, FCz, FC4, C1, Cz, C2, CPz, P6, C5, C3 and CP3) revealed a marginally significant group-congruency interaction (.05 < ps < .1).

3.2.2.3. P3 results. Similar to the P3 component analysis in Experiment 1, we first analyzed the whole time window, and then divided the time window into two halves at 440 ms in order to see if there was a similar transition from a monitoring advantage to an inhibition advantage as in Experiment 1.

3.2.2.3.1. P3 results in the whole time window. A whole-head analysis indicated that 5 electrodes showed significant group-congruency interactions. A 2 (congruency: congruent, incongruent) ×2 (group: more-IE, less-IE) ×5 (electrodes: FZ, F4, FC4, C4 and T8) ANOVA showed a main effect of congruency (F(1, 38) =6.15, p=.18, η_p^2 =.139), and a marginally significant main effect of group (F(1, 38) =3.09, p=.087, η_p^2 =.075). The group-congruency interaction was significant (F(1, 38) =6.59, p=.014, η_p^2 =.148). Simple effect analyses revealed that the more-IE group exhibited smaller P3 amplitudes than the less-IE group in the incongruent condition (ps < .05), but not in the congruent condition (ps > .1). The results on the 5 electrodes revealed an inhibition advantage for the more-IE group.

Apart from the above electrodes, 11 electrodes revealed results approaching an interpretation of either a monitoring advantage or an inhibition advantage. Eight of them (AF3, F5, F2, FCz, FC2, Cz, C6, CP3) showed a marginal group-congruency interaction (.05 < ps < .1). Some others (C2, CP1, CPz) showed a significant group-congruency interaction (ps < .05) but the simple effect analyses did not reveal the pattern of an inhibition advantage.

3.2.2.3.2. P3 analysis in different time windows. Similar to the P3 component analysis in Experiment 1, we divided the P3 time window into two at 440 ms. From the first time window (320–440 ms) to the second one (440–520 ms), the number of electrodes revealing a monitoring advantage decreased from two to zero, while that revealing an inhibition advantage increased from three to ten. To be more specific, *in the first time window, analyses on FT8 and T8 showed a monitoring advantage for the more-IE group*, with no group-congruency interaction (F(1, 38) =1.38, p=.247, η_p^2 =.035) but a

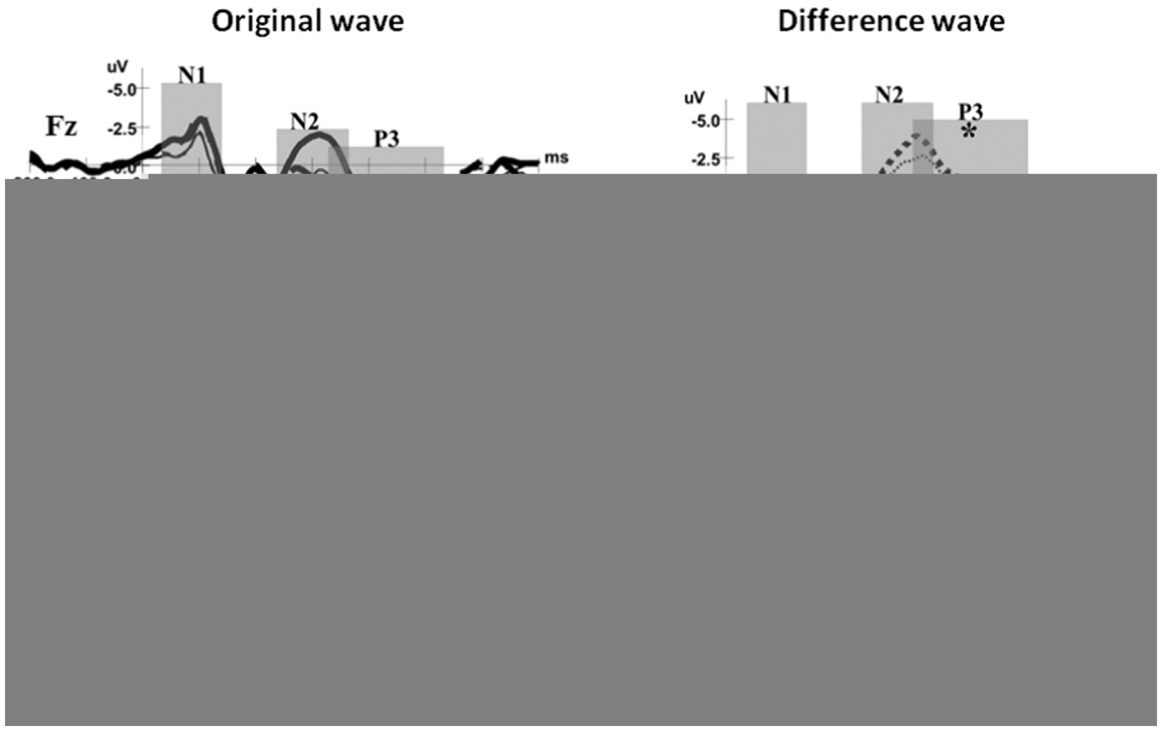

Fig. 4. Left panel: grand average waveforms for participant groups with more or less interpreting experience (more-IE and less-IE) in incongruent and congruent conditions in two example electrodes Fz and Cz. Right panel: difference waves between two congruency conditions for each group (with Fz illustrating significant difference between the two groups).

main effect of group (F(1, 38) =5.45, p=.025, η_p^2 =.125). *Analyses on F4, F6 and CP4 exhibited an inhibition advantage for the more-IE group*, with a significant group-congruency interaction (F(1, 38) =5.27, p=.027, η_p^2 =.122), and significant group differences in the incongruent condition (ps < .05) but not in the congruent condition (ps > .1).

However, *in the second time window, none of the electrodes revealed a monitoring advantage but analyses on the 10 electrodes of FP1, FP2, AF4, Fz, F2, F4, F8, FC4, FT8 and T8 exhibited an inhibition advantage for the more-IE group,* with a significant group-congruency interaction (F(1, 38) =7.32, p=.010, η_p^2 =.162), and significant group differences in the incongruent condition (ps < .05) but not in the congruent condition (ps > .1).

3.3. Discussion

With two groups of students more matched in age and L2 AoA, Experiment 2 replicated the general results of Experiment 1. To be more specific, the N1 results showed the same pattern as those in Experiment 1, revealing an advantage of early attentional processing for the more-IE group than for the less-IE group. Similarly, the N2 and P3 results respectively exhibited evidence for a monitoring advantage and an inhibition advantage for the more-IE group.

There were differences in the results of the two experiments. First, for the RT data in Experiment 2, an inhibition advantage for the more-IE group was only marginally significant, while it was significant in Experiment 1. Second, for the P3 component, the inhibition advantage for the more-IE group appeared in the 1st half time window in Experiment 2, while it only appeared in the 2nd half time window in Experiment 1. The next section of "General Discussion" will try to give an explanation.

4. General discussion

The present study aimed to explore the contributions of interpret-

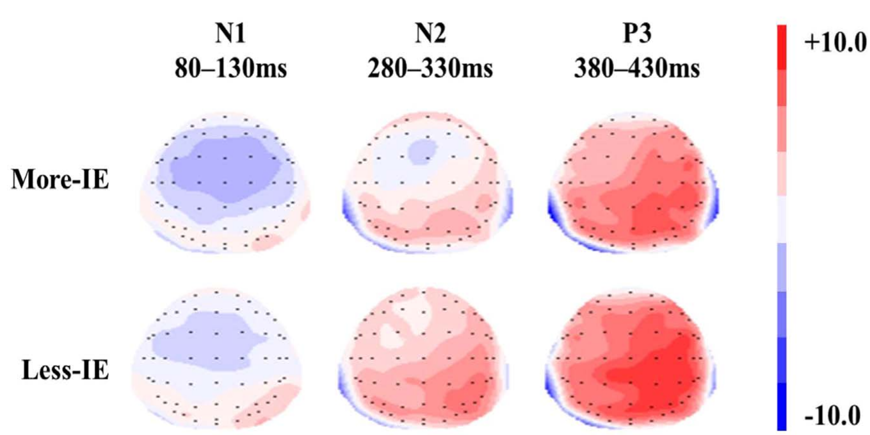

Fig. 5. Topographic maps of N1, N2 and P3 from the incongruent condition for the two participant groups. Each picture represents 50 ms around the peak of the corresponding component.

ing experience to the enhancement of young adults' ability in inhibitory control and attentional processing. Experiment 1 recruited two groups of students majoring in Translation and Interpreting, and found that students with more interpreting experience (i.e., the more-IE group) were more alert at early attentional processing (as revealed in N1 amplitude) and inhibitory control (i.e., monitoring as revealed in N2 amplitudes, and inhibition as revealed in P3 amplitudes and RT). Intended as a replication of Experiment 1, Experiment 2 recruited a new control group of participants matched more closely (in AOA and age) with the more-IE group in Experiment 1, and found similar evidence for advantages in early attentional processing and inhibitory control for students with more interpreting experience. The most important difference between the results of the two experiments is that Experiment 1 found a significant inhibition advantage for the more-IE group in the RT data, while that effect was only marginally significant in Experiment 2.

To be more specific, for the N1 time window, compared with participants with less interpreting experience, participants with more interpreting experience showed larger N1 amplitudes in both congruent and incongruent conditions (in 21 electrodes in Experiment 1, and in 16 electrodes in Experiment 2, with no significant group-congruency interaction and with no main effect of electrodes). According to previous research comparing Flanker performance by healthy and patient participants (Beste et al., 2008), N1 reflects participants' early attentional processing (with patients suffering from insufficient attentional resources). The N1 results in both experiments in the present study thus suggest that interpreting experience enhances early attentional processing (especially in a task containing interfering flankers). Although we are not aware of any other research on bilingual or interpreter advantages that has analyzed the N1 component or has reached a similar conclusion, this conclusion seems consistent with findings from the N2 and P3 components along the time course of processing in the present study.

For the N2 component, participants with more interpreting experience exhibited larger N2 amplitudes in both congruency conditions (in 16 electrodes in Experiment 1, and in 11 electrodes in Experiment 2, with no significant group-congruency interaction).[3] This pattern is consistent with "the bilingual executive processing advantage (BEPA hypothesis)", which suggests the bilingual advantage is not restricted to processing conflict conditions but operates as an overall cognitive monitoring advantage, extending to non-conflict conditions (Coderre and van Heuven, 2014; Hilchey and Klein, 2011). The N2 results, therefore, indicate that interpreting experience can bring interpreters a domain-general advantage in conflict processing, leading to a more efficient monitoring of a conflict environment (Coderre and van Heuven, 2014).

The inhibition advantage, on the other hand, mainly occurred during the P3 time window, which is consistent with the inhibition hypothesis of P3 (Polich, 2007). What's more, the inhibition advantage appeared in the second half P3 time window in Experiment 1(in 10 electrodes), while in Experiment 2, this advantage appeared earlier in the first half P3 window (in 3 electrodes which increased to 10 in the second half P3 window). The P3 results thus indicate that interpreting experience may enhance one's inhibitory ability. This conclusion about the interpreting experience is consistent with some previous studies (Morales et al., 2015a, 2015b; the Flanker task in Timarová et al., 2014), and contradictory with some others (Dong and Liu, 2016; Dong and Xie, 2014; the antisaccade task in Timarová et al., 2014; Yudes et al., 2011), but all these previous studies were conducted with behavioral methods, and their conclusions were based on analyses of RT data.

As for the behavioral data, Experiment 1 did not reveal any group difference in either the congruent or incongruent condition, but the participants with more interpreting experience showed a significantly smaller interference effect, while in Experiment 2, the effect was only marginally significant. Since a smaller interference effect reflects smaller influence imposed by the conflict condition and thus smaller costs to suppress the distracters of the flankers, the results of Experiment 1 indicated that the participants with more interpreting experience exhibited a superior ability (or performance) of interference suppression, i.e., interference suppression advantage. For Experiment 2, however, such an advantage was not fully supported. The difference of the RT data in the two experiments partly reflects the controversy over the existence of bilingual advantages in the literature (e.g., Paap et al., 2015; Valian, 2015).

The difference in the behavioral RT results in the two experiments was probably related to the difference in time when an inhibition advantage started to appear in the two experiments. As reported earlier, the inhibition advantage appeared in the 2nd half time window of P3 in Experiment 1, while it started to appear in the 1st half window of P3 in Experiment 2. To be sure of the earliest appearance of the inhibition advantage, we did similar analyses for the N2 components, dividing the N2 time window into halves. Fig. 6 depicts the changes of the number of electrodes showing a significant monitoring or inhibition advantage. If we take into account those electrodes that showed intermediary results (with some close to a monitoring advantage and others to an inhibition one), the dynamics seems intensified as presented in Table 5.

With Fig. 6 and Table 5, we postulate that the marginal/reduced significance of the inhibition advantage in the RT results in Experiment 2 was probably a result of the earlier appearance of this advantage in Experiment 2 (than in Experiment 1). In Experiment 1, the inhibition advantage appeared only in the second half P3 time window which overlapped in time with participants' response, and therefore, an inhibition advantage was found in the index of RT. However, in Experiment 2, the inhibition advantage appeared much earlier (second half time window of N2), but did not last long enough until participants' behavioral responses. In other words, when the conflict was resolved, the less-IE group caught up with the more-IE group. Blackburn (2013) made a similar claim. In his Flanker experiment, non-switchers manifested an inhibition advantage in the N2 component over switchers and monolinguals, but not in the P3 component and RT data. It was claimed that when the conflict was resolved during the N2 time window, switchers and monolinguals "caught up" with the non-switchers.

Fig. 6 and Table 5 illustrate a *temporal* relationship between the monitoring advantage and the inhibition advantage in a task containing interference. An obvious pattern shared in the dynamics of the two experiments is that a monitoring advantage appeared, then became "weaker" (fewer electrodes), and was gradually replaced by an inhibition advantage which may or may not last until participants' behavioral responses. This temporal relationship is reasonable in that for an inhibition advantage to occur (i.e., better at suppressing interference), the participant must be better at monitoring the context containing interference (around the N2 time window). For a task containing interfering flankers, the better-performing participant may be more alert to the incoming stimuli at the earliest possible time around the N1 time window (although there is not enough time to perceive the stimuli as indicated by the absence of a significant main effect of congruency in N1 results). By the P3 time window, the better-performing participant must have successfully allotted more attention to the stimuli with conflict (i.e., the incongruent condition) and be more efficient at suppressing interferences. The performance of the better-performing participant is thus consistent throughout the whole time course of processing. Measuring participants' responses at a single stage (such as

[3] According to Luck (2005), the voltage of ERP waveforms can be influenced by factors such as the skull, the scalp, the holes of eyes, etc., and it is therefore possible that the overall larger amplitudes for the more-IE group were elicited by some unrelated factors. However, at a later stage of the time course (P3), group differences were only obtained in the incongruent but not in the congruent condition. This reduces the possibility that some unrelated factors had contributed to the group differences.

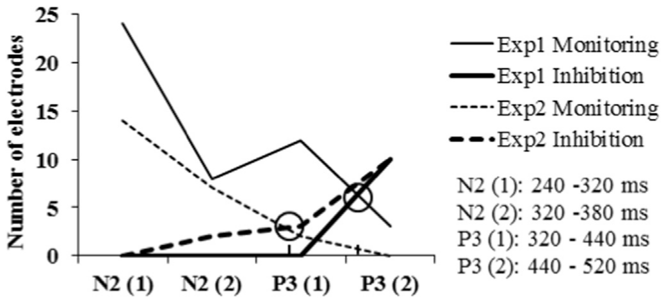

Fig. 6. Number of electrodes exhibiting monitoring and inhibition advantages for the more-IE group in Experiment 1 and 2 along the time course of N2 and P3 time windows, with the two circles identifying the turning points from which the inhibition advantage became more apparent than the monitoring advantage.

Table 5
Number of electrodes exhibiting monitoring and inhibition advantages (with number of electrodes showing such tendency in brackets) in Experiment 1 and 2 along the time course of N2 and P3 time windows.

		N2	N2 (1)	N2 (2)	P3	P3 (1)	P3 (2)
Exp1	Monitoring (tendency)	16 (13)	24 (8)	8 (2)	10 (5)	12 (2)	3(3)
	Inhibition (tendency)	0 (0)	0 (0)	0 (0)	1 (2)	0 (0)	10 (10)
Exp2	Monitoring (tendency)	11 (7)	14 (8)	7 (7)	0 (0)	2 (10)	0 (0)
	Inhibition (tendency)	0 (13)	0 (11)	2 (6)	5 (11)	3 (5)	10 (20)

Note: N2 (1) and (2) or P3 (1) and (2) respectively refer to the 1st and 2nd half of the N2 or P3 time window.

RT) may not reach consistent conclusions, as shown by the vast literature in bilingual advantage research (e.g., Paap et al., 2015; Valian, 2015), or by the few studies in interpreter advantage research (e.g., Babcock and Vallesi, 2015; Becker et al., 2016; Dong and Liu, 2016; Dong and Xie, 2014; Morales et al., 2015a, 2015b; Timarová et al., 2014; Woumans et al., 2015; Yudes et al., 2011).

The difference between the two experiments suggests that larger AoA or age may delay the onset of an inhibition advantage. As Table 1 shows, the more-IE group was about two years older (23.40 vs. 21.20) and started to learn English about two years later (10.50 vs. 8.20). As reasoned earlier in the paper, if it turned out that the more-IE group was better than the less-IE group, it means that the factor of interpreting training did play a significant role. Since we did obtain results as predicted, it means that probably because of the more-IE group's larger AOA (and age), their advantage at inhibition was delayed (mainly in the second half P3 window, and in RT). More research is definitely needed to verify this claim.

To sum up, the most critical finding in the present study is that students with more interpreting experience were better at processes needed to perform a task containing interfering flankers. These processes are (early) attentional processing in the N1 time window, conflict monitoring in the N2 window, and inhibition/interference suppression in the P3 window (and in the behavioral response phase). These processes are needed to perform not only the Flanker task, but also an interpreting task. Interpreting between languages requires interpreters to keep alert to the incoming information, to monitor the context constantly, and to inhibit one of the two highly activated languages not wanted at that instant when producing the output. Intensive practice in interpreting, therefore, may help enhance domain-general functions, notably the supervisory attentional system. In other words, participants with more interpreting experience may be more engaged in a task that requires suppression of interfering flankers, and they may be more efficient at monitoring the context and suppressing interference.

The present study has a few implications for research on cognitive control advantages, particularly research on bilingual advantage. First, interpreting experience provides a good perspective to investigate how language experience influences domain-general cognitive functions. Kousaie and Phillips (2012), for example, did not reveal any N2 or P3 differences between the bilingual and the monolingual groups in the Flanker task, indicating an absence of a bilingual advantage in inhibitory control. The difference between this study and the present study suggests that interpreting may be a more intense experience than general bilingual experience, with interpreting experience producing N2 and P3 advantages, and the latter failing to.

Second, analyzing EEG responses along the time course of processing (probably as early as from the N1 time window, especially in a Flanker task) may provide a more comprehensive and integrative view of cognitive control advantages. The finding that participants with more interpreting experience were better at early attentional processing, conflict monitoring and interference suppression along the entire time course of processing illustrates well the temporal relationship of these functions. It is hard to discover this relationship by the index of RT alone in typical behavioral studies. Moreover, the difference between the two experiments in the present study indicates that the absence of a cognitive control advantage in the index of RT in behavioral studies (e.g., Dong and Xie, 2014) does not mean the absence of such an advantage in EEG data.

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References

Alvarez, J.A., Emory, E., 2006. Executive function and the frontal lobes: a meta-analytic review. Neuropsychol. Rev. 16, 17–42.
Babcock, L., Vallesi, A., 2015. Are simultaneous interpreters expert bilinguals, unique bilinguals, or both? Biling. Lang. Cogn., 1–15.
Barac, R., Bialystok, E., 2012. Bilingual effects on cognitive and linguistic development: role of language, cultural background, and education. Child Dev. 83, 413–422.
Becker, M., Schubert, T., Strobach, T., Gallinat, J., Kühn, S., 2016. Simultaneous interpreters vs. professional multilingual controls: group differences in cognitive control as well as brain structure and function. Neuroimage 134, 250–260.
Benedek, M., Jauk, E., Sommer, M., Arendasy, M., Neubauer, A.C., 2014. Intelligence, creativity, and cognitive control: the common and differential involvement of executive functions in intelligence and creativity. Intelligence 46, 73–83.
Beste, C., Saft, C., Andrich, J., Gold, R., Falkenstein, M., 2008. Stimulus-response compatibility in Huntington's disease: a cognitive-neurophysiological analysis. J. Neurophysiol. 99, 1213–1223.
Bialystok, E., Craik, F.I., Klein, R., Viswanathan, M., 2004. Bilingualism, aging, and cognitive control: evidence from the Simon task. Psychol. Aging 19, 290–303.
Blackburn, A.M., 2013. A Study of the Relationship between Code Switching and the Bilingual Advantage: Evidence That Language Use Modulates Neural Indices of Language Processing and Cognitive Control. THE UNIVERSITY OF TEXAS AT SAN ANTONIO.
Chan, R.C., Shum, D., Toulopoulou, T., Chen, E.Y., 2008. Assessment of executive functions: review of instruments and identification of critical issues. Arch. Clin. Neuropsychol. 23, 201–216.
Coderre, E.L., van Heuven, W.J., 2014. Electrophysiological explorations of the bilingual advantage: evidence from a Stroop task. PLoS One 9, e103424.
Coren, S., 1992. The left-hander syndrome: The causes and consequences of left-handedness.
Cowan, N., 2000. Processing limits of selective attention and working memory: potential implications for interpreting. Interpreting 5, 117–146.
De Groot, A.M.B., Christoffels, I.K., 2006. Language control in bilinguals: monolingual tasks and simultaneous interpreting. Bilingualism 9, 189.
Dijkstra, T., van Heuven, W.J.B., 2002. The architecture of the bilingual word recognition system: from identification to decision. Biling. Lang. Cogn. 5.
Dong, Y., Li, P., 2015. The cognitive science of bilingualsm. Lang. Linguist. Compass 9, 1–13.
Dong, Y., Lin, J., 2013. Parallel processing of the target language during source language comprehension in interpreting. Biling. Lang. Cogn. 16, 682–692.
Dong, Y., Liu, Y., 2016. Classes in Translating and Interpreting Produce Differential Gains in Switching and Updating. Front Psychol. 7, 1297.

Dong, Y., Xie, Z., 2014. Contributions of second language proficiency and interpreting experience to cognitive control differences among young adult bilinguals. J. Cogn. Psychol. (Hove) 26, 506–519.
Folstein, J., van Petten, C., 2008. Influence of cognitive control and mismatch on the N2 component of the ERP: a review. Psychophysiology 45.
Green, D.W., Abutalebi, J., 2013. Language control in bilinguals: the adaptive control hypothesis. J. Cogn. Psychol. (Hove) 25, 515–530.
Hernández, M., Martin, C.D., Barceló, F., Costa, A., 2013. Where is the bilingual advantage in task-switching? J. Mem. Lang. 69, 257–276.
Hilchey, M.D., Klein, R.M., 2011. Are there bilingual advantages on nonlinguistic interference tasks? Implications for the plasticity of executive control processes. Psychon. Bull. Rev. 18, 625–658.
Johnstone, S.J., Barry, R.J., Markovska, V., Dimoska, A., Clarke, A.R., 2009. Response inhibition and interference control in children with AD/HD: a visual ERP investigation. Int J. Psychophysiol. 72, 145–153.
Kirk, N.W., Fiala, L., Scott-Brown, K.C., Kempe, V., 2014. No evidence for reduced Simon cost in elderly bilinguals and bidialectals. J. Cogn. Psychol. (Hove) 26, 640–648.
Kousaie, S., Phillips, N.A., 2012. Conflict monitoring and resolution: are two languages better than one? Evidence from reaction time and event-related brain potentials. Brain Res. 1446, 71–90.
Li, P., Zhang, F.A.N., Tsai, E., Puls, B., 2013. Language history questionnaire (LHQ 2.0): a new dynamic web-based research tool. Biling. Lang. Cogn. 17, 673–680.
Miyake, A., Friedman, N.P., 2012. The nature and organization of individual differences in executive functions: four general conclusions. Curr. Dir. Psychol. Sci. 21, 8–14.
Morales, J., Padilla, F., Gomez-Ariza, C.J., Bajo, M.T., 2015a. Simultaneous interpretation selectively influences working memory and attentional networks. Acta Psychol. (Amst.) 155, 82–91.
Morales, J., Yudes, C., Gomez-Ariza, C.J., Bajo, M.T., 2015b. Bilingualism modulates dual mechanisms of cognitive control: evidence from ERPs. Neuropsychologia 66, 157–169.
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, e94169.
Paap, K.R., Greenberg, Z.I., 2013. There is no coherent evidence for a bilingual advantage in executive processing. Cogn. Psychol. 66, 232–258.
Paap, K.R., Johnson, H.A., Sawi, O., 2015. Bilingual advantages in executive functioning either do not exist or are restricted to very specific and undetermined circumstances. Cortex 69, 265–278.
Polich, J., 2007. Updating P300: an integrative theory of P3a and P3b. Clin. Neurophysiol. 118, 2128–2148.
Prior, A., Macwhinney, B., 2010. A bilingual advantage in task switching. Biling.: Lang. Cogn. 13, 253.
Salthouse, T.A., Atkinson, T.M., Berish, D.E., 2003. Executive functioning as a potential mediator of age-related cognitive decline in normal adults. J. Exp. Psychol. Gen. 132, 566–594.
Syndicate, L.E., 2001. Quick PlacementTest 2. Oxford University Press and University of Cambridge Local Examinations Syndicate, 1–15.
Timarová, Š., Čeňková, I., Meylaerts, R., Hertog, E., Szmalec, A., Duyck, W., 2014. Simultaneous interpreting and working memory executive control. Interpreting 16, 139–168.
Valian, V., 2015. Bilingualism and cognition. Biling. Lang. Cogn. 18, 3–24.
Woumans, E., Ceuleers, E., Van, d.L.L., Szmalec, A., Duyck, W., 2015. Verbal and nonverbal cognitive control in bilinguals and interpreters. J. Exp. Psychol. Learn. Mem. Cogn. 41.
Xie, Z., Dong, Y., 2015. Contributions of bilingualism and public speaking training to cognitive control differences among young adults. Biling. Lang. Cogn., 1–14.
Yudes, C., Macizo, P., Bajo, T., 2011. The influence of expertise in simultaneous interpreting on non-verbal executive processes. Front Psychol. 2, 309.