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The foreign-language effect on self-positivity bias: Behavioral and electrophysiological evidence

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Abstract

Previous research has shown that using foreign languages reduces cognitive biases. Here, we investigate whether this foreign-language effect extends to self-related cognition – in particular, the self-positivity bias, which refers to automatic association of oneself with positive information and has a facilitation role in maintaining mental health. We applied event-related brain potentials and oscillations in the implicit association test where Chinese–English bilinguals responded to category words (self vs. others) and attribute words (positive vs. negative) in either their native language Chinese or their foreign language English. In response to Chinese words, a self-positivity bias occurred, indexed by a positive *D*-score in reaction times as well as by smaller N200, larger P3-like/LPC responses, and lower alpha desynchronization when self words were associated with positive relative to negative traits. However, the bias was diminished in the English context. Overall, our findings provide important implications for language choices when self-protective mechanisms should be enhanced.

1. Introduction

Previous studies have shown that cognitive biases are reduced by using a foreign language and this foreign-language effect has been observed in various domains of cognition – notably, decision making including moral judgment (Circi, Gatti, Russo, & Vecchi, 2021; Costa, Vives, & Corey, 2017; Geipel, Hadjichristidis, & Surian, 2015; Keysar, Hayakawa, & An, 2012). Recently, Romero-Rivas, López-Benítez, and Rodríguez-Cuadrado (2020) examined whether the foreign-language effect on moral judgment would be modulated by self-distance and found that participants were more willing to sacrifice themselves (relative to doing nothing or sacrificing another person) when processing moral dilemmas in their foreign language. Indeed, there is behavioral evidence for the foreign-language effect on self-bias, which refers to the enhancement of the processing of self-related stimuli as compared to stimuli unrelated to the self (Ivaz, Costa, & Duñabeitia, 2016; Ivaz, Griffin, & Duñabeitia, 2019). van Hugten and van Witteloostuijn (2018) assessed the foreign-language effect on the self-serving bias, which describes individuals' tendency to attribute positive feedback to their own ability but attribute negative feedback to external factors. Against the foreign-language emotionality reduction hypothesis, the study found that teenage participants who processed feedback in their foreign language displayed greater self-serving bias than those who processed feedback in their mother tongue.

It seems that the foreign-language effect does interact with self-related cognition although the results are sometimes unexpected. In self-related cognition, one of the biases mentally healthy humans have is to think positively of themselves (Fields, Weber, Stillerman, Delaney-Busch, & Kuperberg, 2019), known as self-positivity bias (Mezulis, Abramson, Hyde, & Hankin, 2004). For example, people judge themselves in a more positive view (Watson, Dritschel, Jentzsch, & Obonsawin, 2008), attribute good things to themselves (Mezulis et al., 2004), and even believe that they can get rid of this bias more easily than others (Chen et al., 2014). This attributional preference is rooted in the need for humans to maintain mental health (Sharot & Garrett, 2015). Indeed, the self-positivity bias is a key form of, or motivated by, self-protective mechanisms, which prevents healthy human beings from harmful effects of negative self-views (Giacomin & Jordan, 2020). Therefore, it is of significance to know whether the bias would be modulated by language of operation.

Considering that self-views may be hidden from limited introspective accessibility or colored self-presentational orientation (Schnabel, Banse, & Asendorpf, 2006), the above question could be addressed by employing the implicit association test (IAT), which has been extensively applied to measure an individual's implicit attitude (Vianello & Bar-Anan, 2020). The test is implemented by having participants categorize stimuli from four types of

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words – two types of category words (e.g., *flower* and *insect*) and two types of attribute words (e.g., *lovely* and *ugly*) – by pressing one of two response keys. The IAT starts with practice blocks in which two category words are discriminated first and then two attribute words are discriminated. In the critical blocks of the test, each response key is paired with one category and one attribute. For example, in one of the test blocks, participants respond to flower category words and positive attribute words using one key and to insect category words and negative attribute words using the other key. In another test block, participants respond to flower words and negative words with the same key and to insect words and positive words with the other key. The IAT is based on the premise that stronger stimulus–affect associations result in faster response times when one key is paired with affectively congruent types of words (e.g., *flower* + *lovely*) than when the key is paired with affectively incongruent types of words (e.g., *flower* + *ugly*). Unlike explicit measures of self-report, the IAT relies on differentials in reaction times to index an individual's automatic attitudes. The behavioral IAT effect or implicit bias is measured by the *D*-score, determined mainly by the latency difference between two test blocks, which improves the sensitivity and power of the measure (Greenwald, Nosek, & Banaji, 2003).

Wu, Gu, Cai, and Zhang (2016), applying ERPs to the IAT, provided strong evidence for the existence of the self-positivity bias. In addition to the behavioral finding that participants responded faster when self was paired with positive traits and others were paired with negative traits, ERP results showed that the self-negative condition elicited a larger N200 and a smaller P3-like component as compared to the self-positive condition. Given that the N200 is linked to the suppression of habitual response biases (Gu et al., 2019; Williams & Themanson, 2011), greater N200 responses to the self-negative pairings suggest stronger inhibitory control over the automatic self-positive association. The P3-like response, also labeled as the late positive component (LPC; Polich, 2007; Lou et al., 2021), has been shown to be modulated by intrinsic psychological relevance even when the occurrence probability does not vary across different stimuli (Johnston, Miller, & Burleson, 1986), with augmented amplitudes for self-relevant stimuli relative to control stimuli (Gray, Ambady, Lowenthal, & Deldin, 2004). Moreover, previous electrophysiological studies using the IAT have found increased P3/LPC for efficient categorization in the congruent blocks, suggesting enhanced attentional allocation and stimulus evaluation associated with the implicit bias of individuals (Coates & Campbell, 2010; Lou et al., 2021; Williams & Themanson, 2011).

Besides the ERP components, time-frequency decomposition of electroencephalographic (EEG) signals provides important non-phase-locked indices of cognition including event-related spectral perturbation (ERSP), which basically measures average dynamic changes in amplitude of the broadband EEG frequency spectrum as a function of time relative to an experimental event (Delorme & Makeig, 2004). The increase in power of a frequency is referred to as event-related synchronization (ERS), and event-related desynchronization (ERD) reflects a decrease of rhythmic activity. Previous research has shown that the theta (4–8 Hz) and alpha power (8–12 Hz) are sensitive to control processes and allocation of attention (Cavanagh & Frank, 2014; Klimesch, 2012). Frontal theta has been reported to serve as a marker for top-down cognitive control (Cavanagh & Frank, 2014; Nigbur, Ivanova, & Stürmer, 2011). For example, stereotype-incompatible conditions (e.g., male gender names paired with female gender traits) elicit an enhanced ERS in theta power (Jia et al., 2020). On the other side, ERD in alpha activity reflects general attention demand and active cognitive processing (Klimesch, 2012; Klimesch, Sauseng, & Hanslmayr, 2007; Zhu et al., 2018). For example, as compared to congruent conditions, incongruent conditions elicit larger alpha ERD, suggesting the suppression of attention for conflicting information (Compton, Arnstein, Freedman, Dainer-Best, & Liss, 2011; Gu et al., 2019; McDermott, Wiesman, Proskovec, Heinrichs-Graham, & Wilson, 2017).

In the present study, we applied both ERP and ERSP to the IAT to investigate whether the self-positivity bias would be reduced by the use of a foreign language as compared to a mother tongue. Based on the literature, we hypothesized that the "self + positive" association would be significantly decreased in the foreign relative to native language in terms of IAT-score. Moreover, we expected that in the native language, incompatible trials (e.g., self + negative) relative to compatible trials (e.g., self + positive) would elicit larger N200 amplitudes, increased theta ERS and alpha ERD due to increased inhibition, but such differences would be diminished or abolished in the foreign language. Also, we predicted larger P3-like responses in compatible trials than in incompatible trials in the native language, as a function of allocation of more attentional resources, and such differences would not be observed in the foreign language.

2. Methods

2.1 Participants

Twenty-eight Chinese–English bilinguals were recruited in the current study with the aim of retaining 24 datasets for analysis. The target sample size was determined using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) based on a medium effect size (0.25) and a minimum power of 0.8 at α level of 0.05. Four participants were excluded due to excessive artifacts in their EEG, leaving 24 bilinguals (nine males; age range, 19–24 years; $M \pm SD$, 21.54 ± 1.56 years) in the final analysis. All participants gave written informed agreement in accordance with the Declaration of Helsinki. All participants were right-handed and had no vision problems or language disabilities. They reported no history of neurological or psychiatric disorders. The study protocol was approved by the local ethics committee at the University of Electronic Science and Technology of China.

All participants had passed the College English Test Band 6 (CET-6), an advanced level of national English test for Chinese non-English-majors, with a mean score of 545.8 ± 34.5 out of 710 total points, indicating that participants had an intermediate level of proficiency in English (Jin, Jie, & Wang, 2022). They started learning English between the ages of 4 and 12 (8.75 ± 2.15 years). They rated their Chinese and English proficiency (on a scale of 1 = not literate, to 10 = very literate; $M_{\text{Chinese}} = 8.48 \pm 1.01$; $M_{\text{English}} = 5.86 \pm 1.26$) and frequency of use (1–not at all, to 10–always; $M_{\text{Chinese}} = 8.22 \pm 1.06$; $M_{\text{English}} = 4.63 \pm 1.54$). Paired *t*-tests showed that proficiency ($t_{23} = 9.3$, $p < 0.001$) and frequency of use ($t_{23} = 10.59$, $p < 0.001$) were significantly higher for Chinese than for English, indicating that participants here were unbalanced bilinguals.

2.2 Stimuli

Attribute words included 44 positive and 44 negative words in Chinese from a personality trait adjective pool (Wang &

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Table 1. Valence, arousal, and familiarity ($M \pm SD$) of Chinese and English adjectives

	Chinese		English	
	positive	negative	positive	negative
valence	7.38 ± 0.39	2.53 ± 0.63	7.25 ± 0.36	2.77 ± 0.44
arousal	7.09 ± 0.36	6.95 ± 0.48	6.98 ± 0.27	6.88 ± 0.53
familiarity	8.53 ± 0.17	8.51 ± 0.15	8.56 ± 0.39	8.40 ± 0.44

Cui, 2005) and we selected the English equivalents of the Chinese stimuli from a person-descriptive word list (Dumas, Johnson, & Lynch, 2002) (Table S1). The task also involved category words including self-related words (Chinese: "我", "自己"; English: "I", "me") and others-related words (Chinese: "他", "她"; English: "he", "she"). The valence, arousal, and familiarity of the words were controlled based on a pretest rating by an independent sample of 10 English majors using 9-point scales (Table 1). Affective valence was significantly different between positive and negative words in either Chinese or English (both $ps < 0.001$), but there was no cross-language difference for each valence (both $ps > 0.1$). Arousal and familiarity were not significantly different between positive and negative words in either Chinese or English (all $ps > 0.05$); nor were they between languages (all $ps > 0.1$).

2.3 Procedure

The IAT was administered using E-prime 3.0 software (Psychology Software Tools, Pittsburgh, PA). There were compatible (self + positive and others + negative) and incompatible (self + negative and others + positive) tasks operated in both Chinese and English. The order of the tasks was randomized within a language session and the order of the language sessions was counterbalanced across participants. Each task included three practice blocks and one test block. In the first 12-trial practice block, participants learned to discriminate category words (self vs. others) by pressing two keys ("f" and "j") on a keyboard. In the second 12-trial practice block, they learned to discriminate attribute words (positive vs. negative) by pressing the same keys. In the third 24-trial practice block, discrimination of category and attribute words was combined such that one category-attribute pair was assigned to one key while the other category-attribute pair was assigned to the other. The practice blocks were followed by the test block where the response assignments were identical to those in the third practice block. There were four test blocks (Chinese-compatible, Chinese-incompatible, English-compatible, English-incompatible). Each test block consisted of 88 trials. Each trial started with a fixation of a random duration between 500 and 800 ms. Then, a stimulus word was presented for 1000 ms. Upon seeing the word, participants were required to respond as quickly as possible by pressing "f" or "j" according to the block-specific instructions. The assignment of key responses was counterbalanced across participants. That is, half of the participants used the "f" and "j" keys to indicate respectively self and other category words in the compatible blocks while in the incompatible blocks they pressed "f" for other category words and "j" for self category words. The other half of the participants followed the reversed assignment.

2.4 Acquisition and analysis of data

Behavioral data collection and analysis

Reaction times and accuracy were collected using E-prime 3.0. IAT scores were computed by using the improved D-score algorithm for IAT data in Chinese and English context respectively (Greenwald et al., 2003, 2021). Responses longer than 10,000 ms or shorter than 300 ms were eliminated and error responses were replaced with the block mean of correct latencies plus an error penalty of 600 ms, which is an error treatment recommended and widely applied in previous IAT research (e.g., Weber, Viehmann, Ziegele, & Schemer, 2020). Such treatment of IAT data showed higher implicit-explicit correlations than simply retaining or discarding error latencies (Greenwald et al., 2003). The average response times of compatible blocks (e.g., self + positive) were subtracted from the average response times of incompatible blocks (e.g., self + negative). This difference was divided by the standard deviation of all correct response times within the compatible and the incompatible blocks. A one-sample t-test was conducted respectively for the Chinese and the English condition to compare the D-score with zero. A positive D-score represents faster reaction to compatible pairings than to incompatible pairings. We then used a paired t-test (two-tailed) to measure the cross-language differences in D-scores. Cohen's d was calculated as a measure of effect size.

EEG data recording and pre-processing

EEG signals were recorded using a 64-channel actiCHamp system (Brain Products, Gilching, Germany) with a 0.05–100 Hz band pass and a 500 Hz sampling rate. Each channel was referenced online to the Fz electrode. All interelectrode impedances were maintained below 5 kΩ. The off-line analysis was performed using Brain Vision Analyzer 2.1.2. The EEG data were re-referenced to the global average reference (Dien, 2017) and further filtered with a 0.1-35 Hz band pass using the second-order Infinite Impulse Response (IIR) Filter. Ocular artifacts were corrected using independent component analysis (Makeig, Jung, Bell, Ghahremani, & Sejnowski, 1997), with the mean number of rejected components being 2 ± 0.7. The continuous EEG data were segmented into epochs of 1200 ms including a 200-ms pre-stimulus baseline. EEG epochs containing artifacts exceeding ±100 μV were discarded. The epochs were averaged for each condition and baseline correction was applied. There was a minimum of 30 valid trials per condition in every participant (see Table S2 for more details).

ERP analysis

Given that previous studies using the IAT have suggested that implicit attitudes are activated by the presentation of category words instead of attribute words (Banfield, van der Lugt, & Münte, 2006; van der Lugt, Banfield, Osinsky, & Munte, 2011) and indeed no significant effects were found when we analyzed the ERPs elicited by attribute words (see *SI Text* in Supplementary Materials for details), we finally focused on the ERPs time-locked to the onset of category words across different conditions. Moreover, previous evidence has suggested that the self-positivity bias does not necessarily lead to negative evaluation of others (Fields et al., 2019; Xia et al., 2021). In fact, healthy human beings generally view others positively, albeit with viewing themselves even more positively (Alicke, Klotz, Breitenbecher, Yurak & Vredenburg, 1995). In any case, it seems unlikely that participants here would have any motivation to view others

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negatively, given that the task did not require any comparison between self and others. Therefore, the present study included evaluative associations with others as fillers and focused only on self words in our analyses (but see *SI Text* in Supplementary Materials for additional analysis of other category words), which is indeed consistent with previous research investigating self-attitude using the IAT (e.g., Baccus, Baldwin, & Packer, 2004). Based on previous electrophysiological evidence on self-relevant information processing (Coates & Campbell, 2010; Fleischhauer, Strobel, Diers, & Enge, 2014; Wu et al., 2016), our analysis focused on the N200 and P3-like components. Peak latencies were automatically detected between 250 and 350 ms for the N200 and between 350 and 600 ms for the P3. The latency windows were determined based on the literature (Gao, Zika, Rogers, & Thierry, 2015; Ludyga, Mücke, Andrä, Gerber, & Pühse, 2021; Wu et al., 2016) and inspection of individual waveforms and grand-averaged ERPs in each condition. Similarly, counting on both the literature and left lateralized grand-averaged waveforms in this study (Figure S1), the N200 was calculated as the mean amplitude in a 100 ms time-window centered at the peak latency over nine electrodes (F3, F1, Fz, FC3, FC1, FCz, C3, C1, Cz) showing the N200 maximal sensitivity. The P3 was defined as the mean amplitude in a 100 ms time-window centered at the peak over six electrodes (FC1, C1, CP1, FCz, Cz, CPz). The time-windows and electrodes selected here were also confirmed by the Mass Univariate Analysis (Groppe, Urbach, & Kutas, 2011; Figure S2). Differences between conditions in peak latency were analyzed using repeated-measures ANOVAs with Language and Compatibility as within-subject variables. Mean amplitudes were subjected to Language × Compatibility × Electrode ANOVAs. Regarding electrode-related effects, given our primary interest in compatibility variations between different languages, we focused on the three-way interaction to examine the compatibility by language interplay on different electrodes (see *SI Text* in Supplementary Materials for all other interactions of Electrode with Language and Compatibility).

ERSP analysis

Preprocessed EEG data were imported to EEGLAB toolbox (Delorme & Makeig, 2004) running under Matlab R2014b (MathWorks, Natick, MA, USA) and segmented into 2000 ms epochs time-locked to the onset of category words including a prestimulus period of 500 ms. The trial-by-trial time-frequency analysis was conducted by Morlet wavelet decomposition implemented in EEGLAB's newtimef() function between 3 and 30 Hz, with linearly increasing number of cycles (frequency step of 0.5 Hz) from 2 cycles for the lowest frequency (3 Hz) to 10 cycles for the highest frequency (30 Hz). Power values were normalized with respect to a 200 ms pre-stimulus baseline (Jia et al., 2020; Zhu et al., 2018) and transformed into decibel scale (10_log10 of the signal).

According to the maximal strength of ERS and ERD in the theta and alpha bands averaged across all channels, the time-frequency windows of interest (300–600 ms and 200–400 ms) were taken into statistical analysis respectively for the theta (4–8 Hz) and alpha (8–12 Hz) bands (Mu & Han, 2010). Alpha activity was analysed respectively over the fronto-central (F3, F1, Fz, FC3, FC1, FCz,) and parieto-occipital (P1, Pz, P2, PO3, POz, PO4) sites where pronounced power has been found (Wu, Liu, Yao, Li, & Peng, 2020). Theta activity was analysed at six electrodes (FC1, FCz, FC2, C1, Cz, and C2) where the maximal power has been identified (Keute et al., 2020).

Given that participants learned English later and had lower levels in English proficiency and frequency of use than Chinese, which might contribute to the enhancement of deliberative thinking (Costa, Foucart, Arnon, Aparici, & Apesteguia, 2014), and the language status of bilinguals could also contribute to cross-language emotionality differences and thus lead to reduction of cognitive biases in a foreign language context (Caldwell-Harris, 2015), we examined whether language-dependent variations in self-positivity bias (indexed by compatible-incompatible differences in D-score, N200 and P3 amplitude, and alpha power) correlated with cross-language differences in language status (proficiency, frequency of use, and age of acquisition). Also, we calculated the correlations between dependent measures – namely, the cross-language differences in D-score, N200, P3, and alpha power.

3. Results

3.1 Behavioral results

The one-sample t-tests showed that the D-score was significantly higher than zero in the Chinese context ($M = 0.39$, $SD = 0.36$; $t_{23} = 5.33$, $p < 0.001$, Cohen's $d = 1.09$), but not in the English context ($M = 0.14$, $SD = 0.38$; $t_{23} = 1.82$, $p = 0.082$, Cohen's $d = 0.37$). The paired t-test showed that the D-score in the Chinese context was significantly higher than that in the English context ($t_{23} = 2.48$, $p = 0.021$, Cohen's $d = 0.51$).

3.2 ERP results

We found a significant main effect of Language ($F_{1,23} = 5.806$, $p = 0.024$, $\eta_p^2 = 0.202$) on the N200, with more negative responses to English category words than to Chinese equivalents (Figure 1). While the main effect of Compatibility was not significant ($p = 0.19$), there was a significant interaction between Language and Compatibility ($F_{1,23} = 4.583$, $p = 0.043$, $\eta_p^2 = 0.166$). Pairwise comparisons showed that Chinese words in the incompatible relative to compatible condition evoked significantly larger N200 ($F_{1,23} = 7.379$, $p = 0.012$, $\eta_p^2 = 0.243$). With English words, however, the N200 amplitudes did not differ between the compatible and incompatible conditions ($p = 0.743$). The Language × Compatibility × Electrode interaction was not significant ($p = 0.531$). In terms of peak latency, we found a significant effect of Language ($F_{1,23} = 23.789$, $p < 0.001$, $\eta_p^2 = 0.508$), with shorter latency in response to Chinese as compared to English words. There was no significant main effect of Compatibility ($p = 0.251$) or interaction between Language and Compatibility ($p = 0.558$).

The analysis of P3-like/LPC responses identified a significant main effect of Compatibility ($F_{1,23} = 5.898$, $p = 0.023$, $\eta_p^2 = 0.204$), showing enhanced amplitudes in the compatible relative to incompatible condition. While the main effect of Language was not significant ($p = 0.32$), there was a significant interaction between Language and Compatibility ($F_{1,23} = 4.378$, $p = 0.048$, $\eta_p^2 = 0.16$). The compatible as compared to incompatible pairings produced increased amplitudes in the Chinese context ($F_{1,23} = 9.023$, $p = 0.006$, $\eta_p^2 = 0.282$), but not in English ($p = 0.223$). The Language × Compatibility × Electrode interaction was not significant ($p = 0.132$). We also observed a main effect of Language in latency with earlier peaks for Chinese words than for English words ($F_{1,23} = 9.132$, $p = 0.006$, $\eta_p^2 = 0.284$). The main effect of Compatibility ($p = 0.631$) and the interaction

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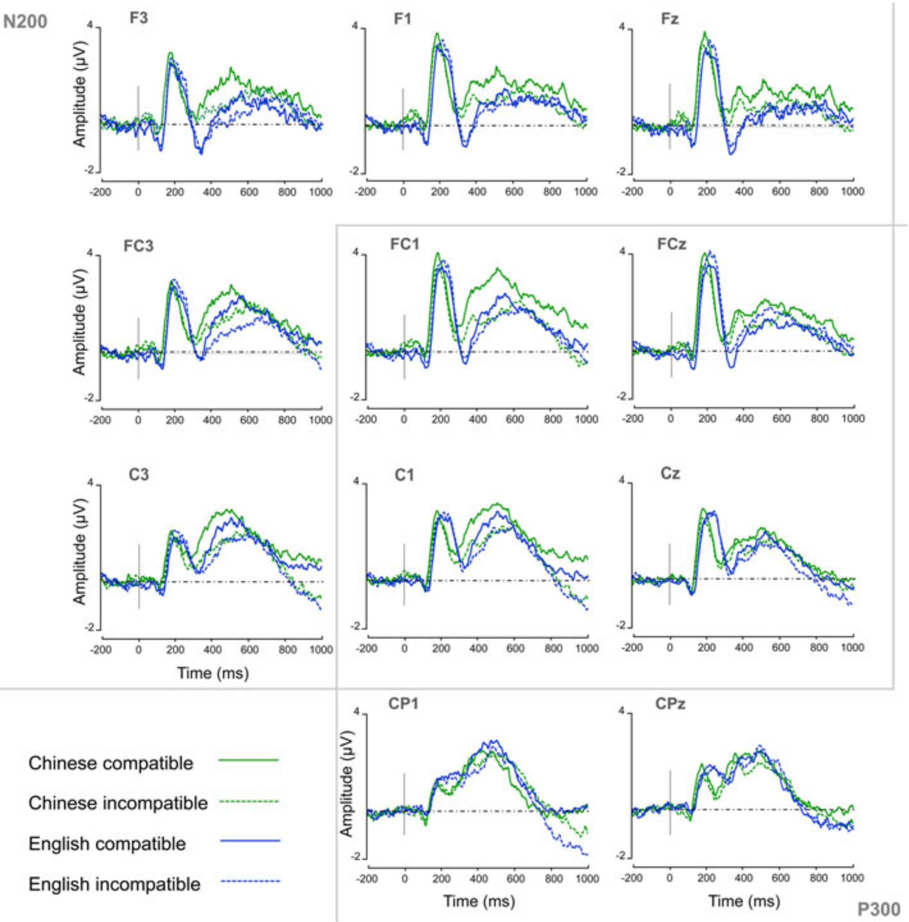

Figure 1. ERPs elicited by Chinese and English self words in the compatible and incompatible conditions. Waveforms depict brain potential variations over nine electrodes showing the maximum sensitivity of the N200 (F3, F1, Fz, FC3, FC1, FCz, C3, C1, and Cz) and over six electrodes showing the maximum sensitivity of the P3 (FC1, FCz, C1, Cz, CP1, and CPz).

between Compatibility and Language ($p = 0.775$) were not significant.

3.3 ERSP results

In terms of ERSP, theta activity showed a significant main effect of Compatibility ($F_{1,23} = 8.72$, $p = 0.007$, $\eta_p^2 = 0.28$; Figure 2a), with incompatible word pairings eliciting stronger theta ERS than compatible ones. Neither the main effect of Language ($p = 0.108$) nor the interaction between Language and Compatibility ($p = 0.798$) was significant. The Language × Compatibility × Electrode interaction was not significant ($p = 0.716$).

In the time range of 200–400 ms, the analysis of alpha band in the frontal-central region showed no significant main effect of Language ($p = 0.1$) or Compatibility ($p = 0.34$). Critically, we found a significant Language × Compatibility interaction ($F_{1,23} = 4.92$, $p = 0.037$, $\eta_p^2 = 0.19$; Figure 2b). Incompatible pairings in Chinese elicited greater alpha ERD than those in English ($F_{1,23} = 7.14$, $p = 0.014$, $\eta_p^2 = 0.24$). Moreover, in Chinese, alpha ERD in the incompatible relative to compatible condition tended to be stronger ($F_{1,23} = 4.04$, $p = 0.056$, $\eta_p^2 = 0.15$), and however, this difference was not observed for English words ($p = 0.581$). The Language × Compatibility × Electrode interaction was not significant ($p = 0.117$). With regards to alpha power over the parieto-occipital region, we found no significant main effect of Compatibility ($p = 0.773$) or Language ($p = 0.31$) or interaction between Compatibility and Language ($p = 0.228$). The interaction between Language, Compatibility, and Electrode was not significant ($p = 0.303$).

We also examined brain potentials and oscillations for attribute words as we did with self-category words. The results showed neither a significant main effect of Compatibility ($ps > 0.1$) nor an interaction between Language and Compatibility ($ps > 0.1$) (see *SI Text* in Supplementary Materials for details).

We found no significant correlations of cross-language differences in *D*-score, N200, P3, and alpha desynchronization with those in language proficiency, frequency of use, and age of acquisition ($ps > 0.05$). With regards to the correlations between cross-language differences in dependent measures, we found that the cross-language difference of the compatibility effect in N200 was significantly correlated with that in P3 ($r = 0.51$, $p = 0.011$). Other correlations between dependent measures were not significant ($ps > 0.1$).

4. Discussion

Applying ERP and ERSP to the IAT operated in Chinese and English, the present study investigated whether the foreign-language effect extends to self-related cognition. First of all, both behavioral and electrophysiological results showed significant effects of compatibility in Chinese, with a positive *D*-score as well as smaller N200, larger P3-like/LPC response, and lower alpha desynchronization in the compatible relative to incompatible condition, consistently indicating an implicit self-positivity bias in the native language context. In line with previous findings (Greenwald & Farnham, 2000; Lou et al., 2021; Wu et al., 2016), participants here automatically associated themselves with positive personality traits.

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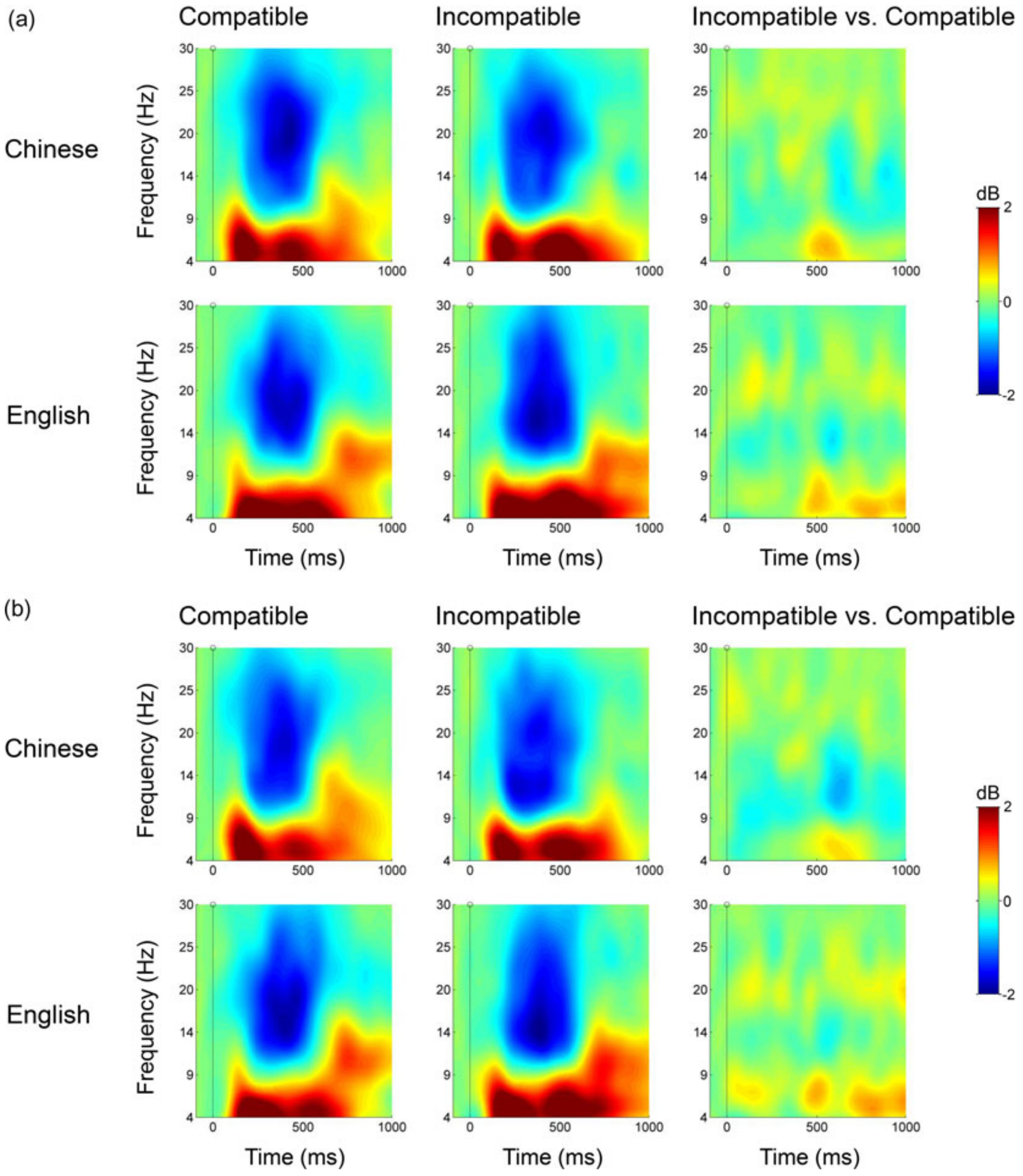

Figure 2. The grand-averaged time-frequency representations for Chinese and English self words in the compatible and incompatible conditions. (a) Grand average time-frequency distributions measured from FC1, FCz, FC2, C1, Cz, and C2 electrodes where theta power was measured. (b) Grand-averaged time-frequency distributions measured from F3, F1, Fz, FC3, FC1, and FCz electrodes where alpha power was measured.

Moreover, this self-positivity bias was reduced in English. Regarding the behavioral IAT effect, the *D*-score in the Chinese context was significantly higher than zero, indicating a stronger association between self and positive traits as compared to that between self and negative traits. In contrast, the *D*-score in the English context was not significantly higher than zero, indicating that the self-positivity bias observed in the native language was diminished when words were provided in the foreign language. The comparison between languages showed a smaller *D*-score in English relative to Chinese, confirming a reduced self-positivity bias in the foreign language as compared to the native language.

Consistent with the behavioral IAT effect, the ERP amplitudes also showed the foreign-language effect on the self-positivity bias. The N200 was larger in response to Chinese words in the incompatible condition as compared to those in the compatible condition. This indicates that under the incompatible condition (self + negative) operated in Chinese, participants were required to classify self words and negative traits together and this contradicted habitual, automatic self-positive association (i.e., positive self-attitude). To respond correctly, participants had to inhibit the response driven by positive self-attitude, thus eliciting a pronounced N200 (Folstein & Van Petten, 2008; Wu et al., 2016). In response to English words, however, the N200 amplitude did not differ between the compatible and incompatible conditions, indicating the absence of the self-positivity bias in the foreign language context. This language-dependent modulation was also observed in the P3-like component. The compatible relative to incompatible pairings produced larger amplitudes in the Chinese context, but not in English, suggesting that more attentional resources were allocated to the targets of inherent

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significance when participants classified self and positive attributes together using their mother tongue (Gray et al., 2004; Tacikowski & Nowicka, 2010) and this effect was attenuated by the use of the second language. The cross-language difference of self-positivity bias in N200 positively associated with that in P3, suggesting that N200 and P3 activity may share mechanisms underlying cognitive processes of stimulus evaluation (Patel & Azzam, 2005). This is in line with previous research reporting overlapping cortical generators involving the left temporal, insular, cingulate, medial frontal and parietal cortex of IAT-sensitive ERPs in the N200 and P3 analysis time windows (Healy, Boran, & Smeaton, 2015). There may be differentiated but cooperative functions of N200 and P3 in that N200 signals cognitive control during tasks taxing response inhibition (Folstein & Van Petten, 2008; Gu et al., 2019) while the P3-like component reflects the allocation of attentional resources mediated by self-relevance and stimulus evaluation (Coates & Campbell, 2010; Wu et al., 2016). The changes in the two components coherently suggest the self-positivity bias observed in the native language is reduced when the foreign language is used.

In addition to ERPs, enhanced theta synchronization was observed in the incompatible relative to compatible condition, which is consistent with previous stereotype-related studies reporting that stereotype inconsistent trials elicited stronger frontal theta oscillation synchronization than stereotype consistent trials (Jia et al., 2020; Wang et al., 2022). Previous research has suggested that in the IAT the suppression of an implicit bias (e.g., stereotype) in the incompatible condition shares an underlying mechanism similar to domain-general cognitive control supported by prefrontal cortical activity (Cattaneo, Mattavelli, Platania, & Papagno, 2011; Knutson, Mah, Manly, & Grafman, 2007) including frontal theta oscillations (Cavanagh & Frank, 2014; Nigbur et al., 2011). In the incompatible trials in the current study, an implicit self-positivity bias needed to be suppressed, leading to increased theta synchronization. However, this change in theta oscillations seems insensitive to language context.

On the other hand, alpha oscillations in the frontal area displayed the language-dependent modulation of the self-positivity bias, which is consistent with behavioral and ERP findings. In particular, alpha desynchronization was greater in response to incompatible relative to compatible word pairings in Chinese, but not in English. It is well established that alpha oscillations display a negative association with cortical activation (Carp & Compton, 2009; Klimesch, 2012). Prior studies have shown decreased alpha power in task trials with conflict as compared to those without conflict, suggesting that conflict engages greater cerebral activity for mental adjustment (Compton et al., 2011; Gu et al., 2019; Wang & Sha, 2018). Consistent with previous studies, our task requirement for incompatible association contradicted the implicit positive self-evaluation bias, and due to this conflict, cognitive processes and mental effort increased, leading to attenuation of alpha power and excitation of task-related cortical activity to resolve the conflict (see Knyazev, 2007, for a review). When words were presented in English, however, alpha power did not differ between compatible and incompatible conditions, confirming the foreign-language effect on the self-positivity bias.

In the literature, a few studies have associated foreign language use with self-related processing. Ivaz et al. (2016) examined the foreign-language effect in a self-bias paradigm which has been used to show favorable responses to stimuli related to self as compared to those related to others. They found that participants responded faster and more accurately to neutral geometric shapes previously assigned to a label of self than to shapes assigned to a label indicating others when these labels were presented in a native language and this self-bias was significantly reduced when the label were provided in a foreign language. Ivaz et al. (2019) further investigated the driving force of such effect by applying the self-bias paradigm to a native, non-native local, and non-native foreign language. The results showed that the self-bias observed in the native language was diminished in the non-native foreign language but not in the non-native local language, suggesting that it is foreignness (not non-nativeness) that produces a psychological/emotional distance and thus leads to the self-bias reduction. While the above-mentioned two studies provide behavioral evidence supporting that using a foreign language weakens the salience of stimuli linked with self, our findings extend the foreign-language effect to the self-positivity association at both behavioral and electrophysiological levels though the effects we observed need confirmation in future research with an enlarged sample and improved statistical power.

A recent study (Liu, Schwieter, Wang, & Liu, 2022) modified the self-bias paradigm by adding an emotional component to the bilingual task and combined the task with ERPs to measure the neural correlates of self-positivity bias in the native and foreign languages. Bilinguals were first asked to build an association between geometry and identity and then the geometry was presented together with positive, negative, and neutral words in the subsequent testing session requiring participants to judge whether the words were real words or not. The study found a self-positivity bias indexed by N400 and LPC changes in the second but not the first language, which is opposite to the scenario of the foreign-language effect (i.e., reduction of cognitive biases) and our finding that a self-positivity bias occurred in the native but not the foreign language. The authors posited that more attention was allocated to valenced words in the second language, reversing the second-language emotionality disadvantage and leading to the self-positivity bias in the second language. However, this interpretation cannot explain the absence of self-positivity bias in the native language. They proposed another explanation for the self-positivity bias in the second language – that is, second-language processing recruits more cognitive resources and thus elicits more deliberative thinking. But, in this case, cognitive biases should be reduced due to deliberative consideration in the second relative to first language (Costa et al., 2014; Díaz-Lago & Matute, 2019; see below for more information), which contradicts with the occurrence of the self-positivity bias in the second but not the first language.

A major hypothesis about cognitive mechanisms underlying the foreign-language effect points to increased psychological distance and reduced emotional resonance with the use of a foreign relative to native language (Gao et al., 2015; Hayakawa, Costa, Foucart, & Keysar, 2016; Keysar et al., 2012). Foreign languages are usually acquired in a classroom setting with an emotionally neutral context and later than the time when orthographic and semantic aspects of vocabulary learning are specifically associated with corresponding self-related concepts and emotions (Circi et al., 2021; Sheikh & Titone, 2016). Therefore, the use of a foreign language could limit the access to autobiographical memories established in a native language context where self-representations have formed and thus lead to reduced activation of positive self-views.

Another possible explanation is that more costly and less fluent processing in a foreign relative to native language leads to less intuitive and/or more deliberative decisions (Costa et al., 2014;

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Díaz-Lago & Matute, 2019). In order to accomplish goal-directed behavior, cognitive control may be enhanced when bilinguals are functioning in a foreign language, resulting in increased systematicity and reduced bias. Given longer ERP latencies in the English as compared to Chinese conditions in the present study, bilinguals appeared to process foreign-language words less automatically, which might engage them in more controlled cognitive processes and reduce intuitive positive self-evaluations. One may even argue that participants did not have a proficiency of English high enough to be sensitive to experimental manipulation operated in English, or in an extreme case, participants' English proficiency was too low to understand English words in the task. But, it is noteworthy that participants in the present study had an intermediate level of English proficiency and should be able to access the meaning of English words here which were of high familiarity based on the pretest. Although our study did not provide direct evidence for participants' sensitivity to manipulations in English, a prior study (Liang & Chen, 2014) observed a semantic inhibiting effect in participants with a lower English proficiency as compared to our participants, suggesting that less proficient English learners were sensitive to English word meaning. Therefore, it is unlikely that reduced self-positivity bias in the foreign language here was due to participants' insensitivity to the semantic meaning of English words. Moreover, we did not observe significant correlations of cross-language differences in self-positivity biases (at either behavioral or neural level) with differences in language status (proficiency, frequency of use, and age of acquisition), indicating that the foreign-language effects on self-positivity biases might not be associated with English disfluency, at least not English disfluency alone. Our findings are in line with recent meta-analyses showing that foreign language experience such as proficiency and age of acquisition does not alter the foreign-language effect (Circi et al., 2021; Del Maschio, Crespi, Peressotti, Abutalebi, & Sulpizio, 2022) though some studies have argued for the opposite (Costa et al., 2014; Ivaz et al., 2019; Oganian, Heekeren, & Korn, 2019). However, the insignificant correlation may be due to the fact that the range of English proficiency among the bilingual participants was narrow in this study. Thus, our correlational analysis may not completely rule out the potential contribution of language-related factors. Future research should examine it using more delicate designs manipulating language variables instead of computing correlations alone. Also, it should be noted that previous research has suggested, with reduced self-bias in a foreign relative to native language context, that the foreign-language effects are pervasive enough to affect automatic emotional processing (Ivaz et al., 2016) whereas a subsequent study failed in identifying the association between the questionnaire indices of emotional distance toward the foreign language and the modulation of self-bias by the foreign language (Ivaz et al., 2019).

5. Conclusion

Taken together, both behavioral and electrophysiological results in the current study support our hypothesis that using a foreign language reduces the self-positivity bias although how the effect originates needs further investigation. The findings not only add to the growing body of evidence for the foreign-language effect but also have important implications for self-related information processing in an increasingly globalized world. This is particularly true for those who are immersed in a work or study environment where a foreign language is spoken. Using a foreign language has been suggested as a way to reduce bias in decision-making (Hayakawa et al., 2016) and thus has an advantage over using a native language in facilitating rational and deliberative decisions. When self-evaluation is involved, however, language choice should be made with caution. On the one hand, self-positivity bias has great significance for healthy psychological functioning (Fields et al., 2019). The reduction of positive self-evaluation by using a foreign language may lead to lowered self-esteem, which has been shown to associate with mental disorders such as depression and anxiety (Sowislo & Orth, 2013). In this case, a native language seems to have an advantage over a foreign language in protecting individuals' mental health. On the other hand, self-evaluation in a foreign language may prevent individuals from being over positive. Therefore, whether self-evaluation in a foreign language leads to favorable or unfavorable consequences may interact with individual differences in personality traits. Future research could investigate the interaction between person (e.g., different personality) and context (e.g., language of operation).

Competing interests. The authors declare none.

Data availability statement. MATLAB code used for data analysis in this study is available at Open Science Framework (OSF), https://osf.io/nqbc5/.

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SI Text Analyses of attribute words and other category words.

Table S1 Word stimuli used in the implicit association task.

Table S2 Means and standard derivations of trial number per condition.

Figure S1 Topographical distribution of the voltage amplitudes differences between the compatible and incompatible conditions in Chinese and English.

Figure S2 Results of the Mass Univariate Analysis.

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