Reading Shakespearean tropes in a foreign tongue: Age of L2 acquisition modulates neural responses to functional shifts

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ABSTRACT

Functional shifts (FSs) – morphosyntactically marked words evoking coherent but novel meanings – are ubiquitous in English and, specially, in Shakespearean literature. While their neural signatures have been explored in native speakers, no study has targeted foreign-language users, let alone comparing early and late bilinguals. Here, we administered a validated FS paradigm to subjects from both populations and evaluated time-frequency modulations evoked by FS and control sentences. Early bilinguals exhibited greater sensitivity towards FSs, indexed by reduced fronto-posterior theta-band oscillations across semantic- and structural-integration windows. Such oscillatory modulations may represent a key marker of age-of-acquisition effects during foreign-language wordplay processing.

1. Introduction

Functional shifts (FSs) – detivationally or morphosyntactically marked words which evoke contextually coherent, novel meanings – not only prove common in English (Cannon, 1985), but are also ubiquitous in the works of its prime penman, William Shakespeare (Blake, 1983). For example, in the Shakespearean passage *To lip a wanton in a secure couch*, the word *lip*, though canonically used as a noun, acts as a verb retaining critical semantic features of its intended meaning (TO KISS) (Quirk et al., 1985). In native English users, FSs selectively modulate event-related potentials (ERPs) sensitive to syntactic anomalies (Thierry et al., 2008) and increase activity in brain regions associated with novel integration of meaning (Keidel et al., 2013). However, no study has yet explored how these tropes are processed by users of English as a foreign language (L2), who actually outnumber native speakers (Lewis et al., 2018) and prove numerous among the readership of Shakespeare's originals (Kennedy, 2001). In particular, the electrophysiological examination of FS processing in non-native users can constrain neurocognitive models of trope comprehension in L2 and its relationship with subject-level variables. To address this issue considering temporal and topographical brain signatures, we assessed evoked and oscillatory modulations of FS processing in early and late bilinguals (EBs and LBs, respectively).

Bilingualism research indicates that morphosyntactic integration processes in L2s are sensitive to age-of-acquisition (AoA) effects. Depending on whether the language was acquired after or before the age of six (Hull and Vaid, 2006, 2007; Long, 1990; Mahendra et al., 2003; Mayo et al., 1997; Perani et al., 2003; Waldron and Hernandez, 2013), bilinguals differ in their neural responses to morphosyntactic (Hernandez et al., 2007; Mahendra et al., 2003; Wartenburger et al., 2003; Weber-Fox and Neville, 2001) and word-level (Mahendra et al., 2003; Perani et al., 2003) manipulations. While neuroscientific results based on ERPs or neuroimaging techniques are not entirely consistent (e.g., see Ardal et al., 1990; Wartenburger et al., 2003), a promising yet unexploited approach to L2-processing effects consists in examining associated time-frequency modulations.

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Time-frequency measures offer better temporal resolution than fMRI (Kim et al., 1997). This attribute is crucial to tap rapid semantic and syntactic processes (e.g., Hahne and Friederici, 1999) like the ones related to FSs, which are separated by a window of roughly 200 ms (Münte et al., 1993). Moreover, unlike ERPs, time-frequency analyses can access neural information not phase-locked to the stimuli (Mouraux and Iannetti, 2008), often resulting in higher sensitivity to particular experimental conditions (e.g., Willems et al., 2008). In particular, implicit processing of morphosyntactic (Bastiaansen et al., 2002b; Bastiaansen et al., 2009; Roehm et al., 2004; Schneider et al., 2016) and semantic (Allefeld et al., 2005; Bastiaansen et al., 2005; Davidson and Indefrey, 2007; Hald et al., 2006; Willems et al., 2008) information in native languages has been related to modulations of the theta band (4–8 Hz), which thus represents a promising target to assess AoA effects during FS processing in non-native users.

To examine this possibility, we asked EBs and LBs to perform a previously validated FS paradigm (Keidel et al., 2013) and examined ERP and time-frequency modulations evoked by FS and control sentences, considering windows implicated in semantic (Kutas and Federmeier, 2000, 2011; Lau et al., 2008) and structural integration (Hagoort et al., 1993; Hahne and Friederici, 1999; Kaan et al., 2000; Osterhout et al., 1994; Osterhout and Mobley, 1995) processes. Guided by evidence of reduced or even absent electrophysiological responses to linguistic manipulations in LBs (Caffarra et al., 2015; Hahne, 2001; Hahne and Friederici, 2001; Pakulak and Neville, 2011; Weber-Fox and Neville, 1996), alongside works robustly showing these modulations in EBs (Molinaro et al., 2017; Weber-Fox and Neville, 1996), we hypothesized that only the latter would exhibit increased sensitivity towards the structural wordplay of FSs, as indexed by significant theta-band modulations across both windows (Allefeld et al., 2005; Bastiaansen et al., 2002b, 2005, 2009; Davidson and Indefrey, 2007; Hald et al., 2006; Roehm et al., 2004; Schneider et al., 2016; Willems et al., 2008). Also, to evaluate the specificity of the predicted theta effects, we also analyzed activity in response to FSs in other language-sensitive bands, namely, alpha (8–12 Hz) and beta (12–30 Hz) (Bastiaansen et al., 2009; Davidson and Indefrey, 2007; Kielar et al., 2014; Röhm et al., 2001; Willems et al., 2008). Briefly, by focusing on the neural signatures of FSs in L2 users, this study aims to offer new insights into the impact AoA on bilingual language processing.

2. Methods

2.1. Participants

The recruitment for this study comprised 44 Spanish-English bilinguals from Argentina. They all had normal or corrected-to-normal vision and no history of neurological or psychiatric disease. Ten subjects were removed from analysis: two because their performance was 3 *SD*s below or above the group's mean (e.g., Marian et al., 2007; Vega et al., 2016), three due to technical errors during signal recording, and five because they had fewer than 15 trials in at least one condition after data pre-processing (Fischer et al., 2017). Thus, the final sample consisted in 34 bilinguals (mean age = 32.35 ± 9; 29 females), divided into two groups according to their AoA. At a conventional cutoff of six (e.g., Hull and Vaid, 2006, 2007; Long, 1990; Mayo et al., 1997), 18 participants qualified as EBs while the remaining 16 were LBs. The groups were matched in sociodemographic variables and in self-assessed L2 competence, years of study, and exposure, as measured through a previously reported questionnaire (García et al., 2014; Santilli et al., 2018; see Table 1).

Of note, the power achieved by our design was tested following recommended guidelines (Gelman and Carlin, 2014), and it proved suitable to obtain robust estimates (see Supplementary material, Section 1). Of note, our final sample was similar to and even larger than those reported in previous research on FSs (Keidel et al., 2013) and other bilingual EEG paradigms (e.g., Hahne, 2001; Kielar et al., 2014;

Weber-Fox and Neville, 1996).

The study was approved by the institutional ethics' committee. All participants provided informed consent in accordance with the Declaration of Helsinki.

2.2. Stimuli

All stimuli for the FS and the control sentences were taken from Thierry et al. (2008), who extracted 40 excerpts from Shakespeare's works containing FSs, adapted them to modern English, and then generated identical sentences in which the FS item was replaced by another word. Each target sentence was preceded by another sentence, setting a semantic context. In FS sentences, the critical word was semantically congruent but syntactically marked (e.g., "I was not supposed to go there alone: you said you would *companion* me"). In control sentences, the critical word was both semantically and syntactically correct (e.g., "I was not supposed to go there alone: you said you would *accompany* me"). All critical words were matched in lexical frequency and familiarity, as well as orthographic, phonemic, and syllabic length (see Table S1 in Supplementary material, Section 2). Sentences had an average length of 13 ± 2 words, and the length of critical words varied from 3 to 11 letters.

2.3. Procedure

Participants read four blocks of stimuli in a Faraday cage within a soundproof room. Blocks were counterbalanced between subjects. To avoid learning effects, only one variant of the sentences was presented per block. After a fixation cross, the initial (context-setting) sentence was presented all at once. Subjects had to press the spacebar when they understood it. The target sentence was then immediately triggered, one word at a time (200 ms on screen, separated by 200/300 ms), with the critical word appearing between the second and seventh position. Following the final word, participants were allotted a maximum of 2–2.5 s to indicate whether or not they understood the meaning of the sentence (even if its structure was odd), by pressing pre-assigned keys (Fig. 1). Responses were considered correct in the former case and incorrect in the latter. Reaction times (RTs) were recorded by the computer. Before the study, participants completed eight practice trials and received feedback on their performance.

2.4. Behavioral data analysis

Behavioral data was analyzed with Jamovi software (v 0.7.5.1). Accuracy and RT data were analyzed via separate 2×2 mixed-effects ANOVAs, with group (EBs, LBs) as a between-subjects factor and condition (FS sentences, control sentences) as a within-subject factor. Effect sizes were calculated with partial eta squared.

All demographic, behavioral, and preprocessed EEG data is publicly available on the Open Science Framework (Vilas et al., 2018).

2.5. EEG recording and pre-processing

High-density EEG activity was recorded during task performance. Signals were originally sampled at 1024 Hz with a Biosemi Active Two 128-channel system, referenced to link mastoids and re-referenced to the grand average. Data were down-sampled to 512 Hz and bandpass-filtered between 0.1 Hz (high-pass) and 50 Hz (low-pass). Continuous EEG data were segmented in epochs of −0.4 to 2 s, locked to critical-word onset. A baseline correction (−200–0) was applied in each trial. Epochs without participant response were excluded from analysis. Oculomotor artifacts were removed by independent component analysis. Further artifacts were discarded through visual inspection and noisy channels were interpolated. The final percentage of trials included in the analyses was high for both control (EBs = 85.14%, LBs = 85%) and FS (EBs = 86.67%, LBs = 85.94%) sentences. These

Table 1
Participants' demographic and linguistic profile.

	EBs	LBs	EBs vs. LBs	
	n = 18	n = 16	p-value[*]	partial η2
Demographic data				
Gender (F: M)	(17:1)	(12:4)	0.110	–
Age (years)	33.06 (11.20)	31.56 (6.44)	0.643	0.007
Language background				
Age of L2 learning (years)	**4.22 (1.96)**	**9.19 (2.81)**	**< .001**	**0.523**
Years of study of L2	19.44 (9.27)	15.19 (7.94)	0.163	0.060
L1 competence[a]	6.72 (0.46)	6.75 (0.45)	0.860	0.001
L2 competence[a]	6.11 (0.96)	6.13 (0.96)	0.967	0.000
Weekly exposure to L1 media[b]	2.61 (1.38)	2.81 (1.42)	0.678	0.005
Weekly exposure to L2 media[b]	2.94 (1.52)	3.94 (1.84)	0.099	0.085
Weekly reading in L1[b]	3.24 (1.56)	3.63 (1.78)	0.509	0.014
Weekly reading in L2[b]	3.47 (1.62)	3.69 (1.78)	0.717	0.004

Data presented as mean (*SD*) with the exception of gender. EBs: early bilinguals; LBs: late bilinguals; L1: native language; L2: foreign language.

[a] Data from a self-rating scale ranging from 1 (null) to 7 (optimal).

[b] Data from a self-rating scale with the following ranks: 0 = null, 1 = little (from 1 to 3 h), 2 = considerable (from 4 to 6 h), 3 = intense (from 7 to 9 h), 4 = very intense (from 10 to 12 h), 5 = extremely intense (from 13 to 15 h), 6 = excessive (more than 15 h).

[*] *p*-values calculated with one-way ANOVAs (except for gender results, which were analyzed via a chi-square test).

percentages yielded no significant main effect of condition ($F(1, 32) = 0.591$, $p = .448$, partial η2 = 0.018), group ($F(1, 32) = 0.017$, $p = .896$, partial η2 = 0.001), or group-by-condition interaction ($F(1, 32) = 0.034$, $p = .855$, partial η2 = 0.001). Pre-processing steps were performed on EEGLAB (v11.0.4.3b) in MATLAB (vR2012a).

2.6. ERP and time-frequency analysis

Analyses were implemented on FieldTrip (Oostenveld et al., 2011). Mean ERP amplitudes were calculated for each subject and condition. A correction was performed by subtracting the baseline (−200 to 0 ms) mean from the waveform following the critical word. Data from each trial was transformed to the time-frequency domain using the Fast Fourier Transform with a hanning taper (window length = 500 ms,

steps = 9 ms) and zero padding (Gross, 2014). Trials from each individual and condition were averaged. Results were baseline-normalized with decibel conversion (Cohen, 2014).

To identify FS-specific modulations, we subtracted control sentences charts from FS sentences matrices at the subject level. Then, subtracted matrices for EBs and LBs were compared through a cluster-based permutation test (3000 permutations), using two-tailed *t*-tests. This method controls for the multiple comparisons problem and has been successfully applied in previous works (Davidson and Indefrey, 2007; Kielar et al., 2014).

To increase statistical power, the cluster test was performed on constrained and averaged hypothesis-driven windows and frequencies. We considered an earlier window, associated to semantic processes (200–500 ms) (Kutas and Federmeier, 2000, 2011; Lau et al., 2008),
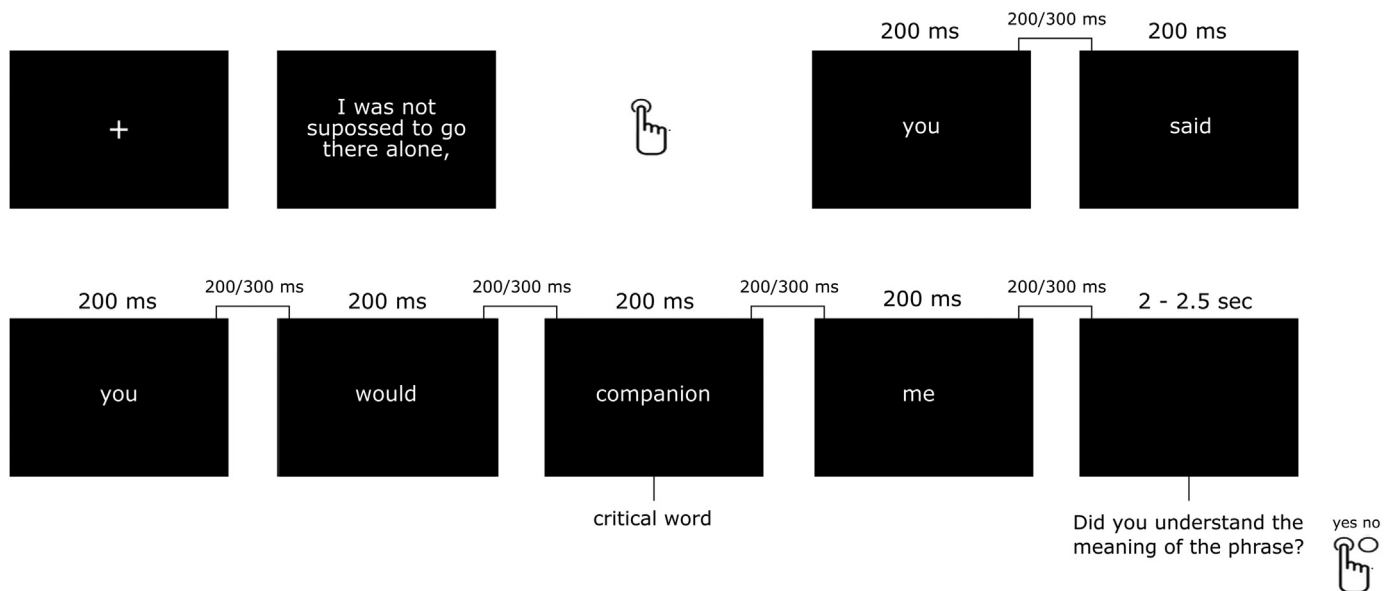
A) Experimental paradigm

Fig. 1. Experimental paradigm. A. Each trial began with a fixation cross, followed by an initial sentence that introduced a semantic context (this sentence was presented all at once, and subjects were instructed to press the spacebar as soon as they understood its meaning). The target sentence appeared immediately afterwards, one word at a time. Words appeared on the center of the screen and remained there for 200 ms. The interval time between words was variable (between 200 and 300 ms). The critical word appeared between the second and last position of the sentence. The final word was followed by a blank screen (lasting between 2 and 2.5 s), during which participants indicated whether they understood the meaning of the sentence stimulus or not, by pressing pre-assigned keys.

and a later window, related to structural integration efforts (500–800 ms) (Hagoort et al., 1993; Hahne and Friederici, 1999; Kaan et al., 2000; Osterhout et al., 1994; Osterhout and Mobley, 1995). Each time a significant cluster was obtained, separately for each group, FS charts were tested against control-sentence matrices to further explore how each group processed FSs relative to unmarked sentences. Additionally, mixed-effects ANOVAs were performed over significant clusters to test for interaction effects. The same analysis was performed on alpha (8–12 Hz) and beta (12–30 Hz) brain signals, to test the specificity of the hypothesized theta effects. Also, to examine the relationship between theta power and AoA as a continuous variable (by combining data from both groups), a simple linear regression was computed predicting neural responses to FSs (averaged over significant channels) based on participants' AoA.

3. Results

3.1. Behavioral performance

Accuracy analyses revealed a main effect of condition ($F(1, 32) = 141.163$, $p < .001$, partial $\eta2 = 0.815$), with FS sentences eliciting more errors than control sentences. However, the main effect of group ($F(1, 32) = 0.801$, $p = .377$, partial $\eta2 = 0.024$) and the group-by-condition interaction ($F(1, 32) = 0.386$, $p = .539$, partial $\eta2 = 0.012$) were not significant.

A significant main effect of condition also emerged in RTs ($F(1, 32) = 29.326$, $p < .001$, partial $\eta2 = 0.478$), showing slower responses to FS than control sentences. This variable did not differ between groups ($F(1, 32) = 2.58$, $p = .118$, partial $\eta2 = 0.075$) and it exhibited a non-significant group-by-condition interaction ($F(1, 32) = .316$, $p = .578$, partial $\eta2 = 0.010$). Results remained the same even when removing trials 3 SDs above the RT mean (see Supplementary materials, Section 3).

3.2. ERP results

Between-group comparisons of ERP correlates during FS processing revealed no significant cluster in either time window ($p > .025$; see Fig. S1 in Supplementary material, Section 4).

3.3. Time-frequency results

Relative to LBs, EBs exhibited less theta power for FS sentences (Fig. 2.1.A-B). Two significant theta-band clusters were observed in the semantic window: one comprising frontal electrodes ($p < .01$) and another over left posterior electrodes ($p < .025$; Fig. 2.1.A). In the structural integration window, a significant theta-band cluster emerged over frontal electrodes ($p < .025$; Fig. 2.1.A). Also, FS sentences elicited less theta power than control sentences in EBs (Fig. 2.2.A-B), with a significant frontal cluster in the semantic window ($p < .025$; Fig. 2.2.A) and another one in the structural integration window ($p < .025$; Fig. 2.2.A). Contrariwise, the comparison between FS and control sentences revealed no significant clusters in LBs ($p > .025$; Fig. 2.3.A-B). Similar patterns of results emerged when performing ANOVAs, with the additional finding of a group-by-window interaction in posterior sites (see Supplementary material, Section 5). No significant clusters were found in the alpha or beta bands (see Supplementary material, Section 6).

Also, when predicting theta power in response to FSs as a function of AoA, a significant regression equation was found in the semantic ($t(32) = 3.54$, $p < .01$, $R^2 = 0.28$) and structural integration ($t(32) = 2.63$, $p < .01$, $R^2 = 0.18$) windows (see Fig. S2 in Supplementary material, Section 7).

Finally, to ensure that the time-frequency results demonstrate patterns not already present in the ERPs, we time-locked the activity of channels belonging to the significant theta-clusters and replicated the time-frequency analysis on the average activity of each subject and condition. No differences between groups emerged from the ERP plots and no significant cluster was obtained in the ERP-based time-frequency analysis (see Supplementary material, Section 8).

4. Discussion

Time-frequency results revealed distinct sensitivity to Shakespearean FSs in EBs, but not in LBs. Notably, this pattern emerged in the absence of between-group differences in accuracy, RTs, or ERP modulations. Such null effects likely reflect both groups' high L2 proficiency, an attribute that can overcome AoA effects on behavioral measures (e.g., Perani et al., 1998) and evoked neural responses (Perani et al., 1998; Rossi et al., 2006).

Specifically, in the semantic integration window, processing of FSs elicited less theta power in EBs than in LBs over mid frontal, right frontal, and left posterior electrodes. Also, whereas EBs showed significant theta decreases for FSs compared to control sentences in frontal regions, LBs exhibited no differential modulations between conditions. This suggests that responses to FSs are distinctively modulated by the age of first exposure to the L2, as reported in previous lexical tasks (Mahendra et al., 2003; Perani et al., 2003). In fact, the regression analysis showed that as AoA decreased, theta power in response to FSs decreased as well.

In this sense, note that theta modulations have been consistently implicated in semantic processes and proposed to index retrieval of lexical information (Allefeld et al., 2005; Bastiaansen et al., 2005; Braunstein et al., 2012; Davidson and Indefrey, 2007; Hald et al., 2006; Willems et al., 2008). In particular, decreases in theta have been linked to processing of novel, unfamiliar words (Bakker-Marshall et al., 2018; Bakker et al., 2015). Accordingly, frontal differences could be interpreted as EBs having greater sensitivity in distinguishing the semantic novelty introduced by FSs. In fact, in native speakers, FSs recruit mostly right hemisphere regions (Keidel et al., 2013) associated with semantic-novelty integration efforts (Diaz et al., 2011; Mashal et al., 2007; Seger et al., 2000). More generally, given that AoA can affect brain responses during particular word-processing tasks (Nichols and Joanisse, 2016; Perani et al., 2003), between-group differences over posterior sites could reflect a broader impact of AoA on lexico-semantic accessibility.

A compatible pattern emerged in the morphosyntactic integration window, with EBs exhibiting less theta power than LBs over frontal electrodes. Once more, EBs displayed significantly less theta power for FS than control sentences, while no difference was observed for LBs. This general pattern aligns with previous works showing a significant effect of AoA on neural markers of morphosyntactic processing (Hernandez et al., 2007; Mahendra et al., 2003; Wartenburger et al., 2003; Weber-Fox and Neville, 2001), while offering the first demonstration of this phenomenon in the time-frequency domain. In fact, in the morphosyntactic integration window, lower AoA was also associated with decreased theta power.

Importantly, theta-band modulations have been implicated in syntactic anomaly detection (Bastiaansen et al., 2002b, 2009; Roehm et al., 2004; Schneider et al., 2016; Vignali et al., 2016), mostly on frontal regions (Bastiaansen et al., 2002a, 2009; Schneider et al., 2016). While theta power may increase in response to ungrammaticalities (Bastiaansen et al., 2002a; Roehm et al., 2004) and in proportion to sentential incrementality (Bastiaansen et al., 2002b; Röhm et al., 2001), syntactically incorrect words have also been linked to theta power decreases (Bastiaansen et al., 2009; Schneider et al., 2016). The latter effect, in particular, has been proposed to index the detrimental impact of grammatical incongruences on semantic integration processes (Bastiaansen et al., 2009). Compatibly, theta decreases for EBs in the morphosyntactic integration window might reflect their distinctive sensitivity to the interplay between syntactic markedness and semantic novelty in FSs, leading to a temporal disruption in the construal of a meaningful sentence.
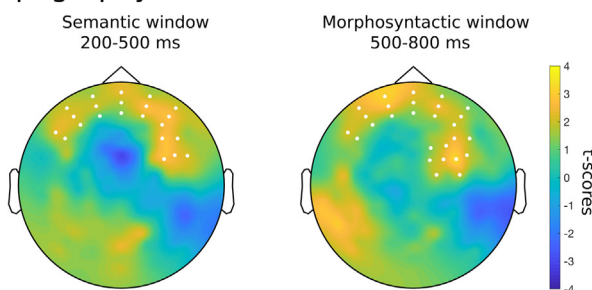
1) Group comparison

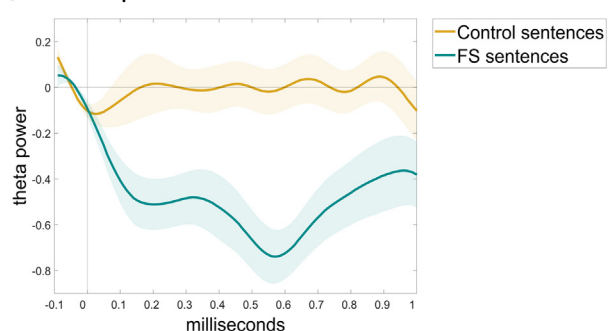### A) Topography differences
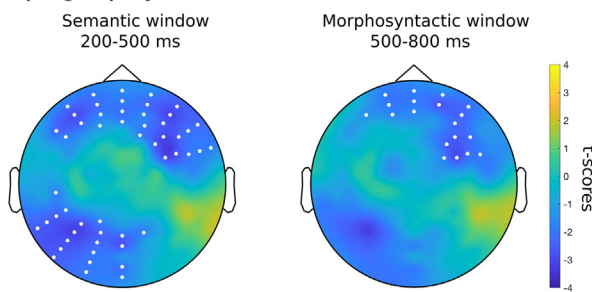
B) Theta power in time
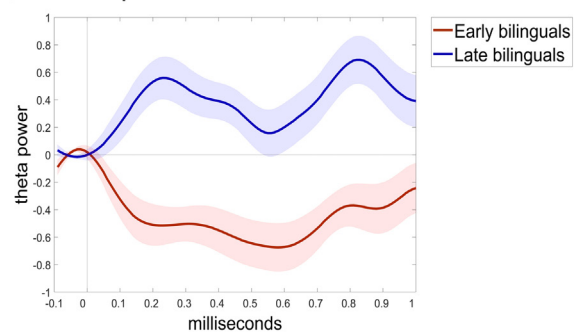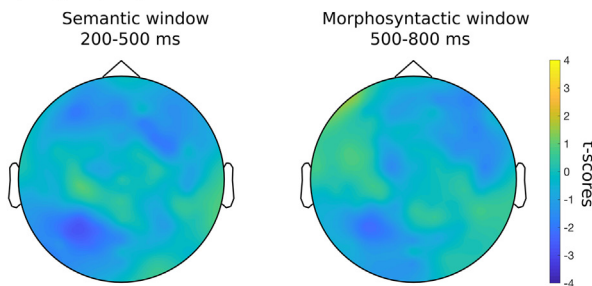

2) EBs

A) Topography differences

B) Theta power in time

3) LBs

A) Topography differences

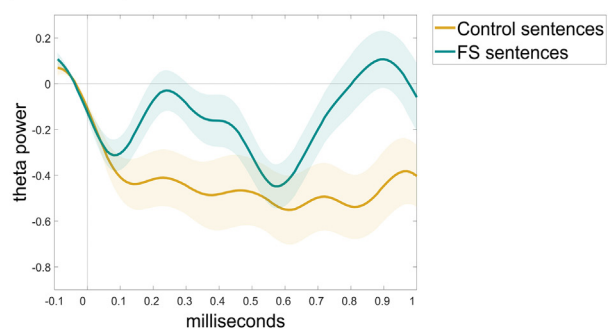### B) Theta power in time

Fig. 2. Theta-band modulations (4–8 Hz) underlying functional-shift (FS) processing. 1.A. Results from the cluster-based permutation test, obtained when comparing subtracted FS-sentence matrices (minus control-sentence matrices) of early bilinguals with those of late bilinguals. The color-bar represents *t*-values. Significant electrodes are highlighted using white dots. **1.B.** Theta power in time (-0.1–1 s), averaged across electrodes with significant differences and plotted separately for each group. The lines represent the mean value in each time-point, while the shades represent the 95% CI. **2.A.** Results from the cluster-based permutation test, obtained when comparing FS sentences with control sentences in early bilinguals. The color-bar represents *t*-values. Significant electrodes are highlighted using white dots. **2.B.** Theta power in time (-0.1–1 s) of early bilinguals, averaged across electrodes with significant differences and plotted separately for each condition. The lines represent the mean value in each time-point, while the shades represent the 95% CI. **3.A.** Same as 2.A, but for late bilinguals. **3.B.** Same as 2.B, but for late bilinguals. Since no electrodes displayed significant differences, theta power was averaged across electrodes with significant differences for early bilinguals.

The key role of the theta band in these effects is underscored by results from other frequency ranges. In contrast to the results above, no significant clusters were found in the alpha and beta bands when comparing the groups' responses to FSs (Supplementary material, Section 6). This lack of significant differentiations might partially be influenced by the more critical involvement of these frequencies in non-linguistic processes shared by both conditions, such as sensory processing of visual information, as shown in previous works (e.g., Bastiaansen and Brunia, 2001; Bastiaansen et al., 2005; Weiss and Mueller, 2012). Though tentatively, these findings highlight the

potential specificity of theta modulations as a signature of AoA effects during L2 processing.

Finally, beyond our time-frequency results, the lack of ERP effects might seem to be at odds with previous results from Thierry et al. (2008) with native English speakers. However, this discrepancy may reflect general differences in the processing of English as an L1 or as an L2. In fact, systematic ERP effects in L1 are often altered in L2s, and they are not necessarily present in EBs (Moreno and Kutas, 2005; Moreno et al., 2008; Pakulak and Neville, 2011; Weber-Fox and Neville, 1996). Be that as it may, the detection of clear AoA results in our time-

frequency analysis, together with the absence of ERP patterns associated to them (see Supplementary material, Section 8), suggests that this approach captures neurocognitive dynamics different from those tapped by ERPs, as shown in previous research on bilinguals (Braunstein et al., 2012). More generally, these speculations pave the way for further investigations on the sensitivity of different EEG techniques in the study of neural correlates of AoA during L2 processing.

In sum, theta modulations might constitute a key marker of AoA effects during foreign-language wordplay processing. More specifically, our results suggest that only EBs, as opposed to LBs, exhibit differential semantic and structural integration dynamics in this frequency band during reading of Shakespearean FSs. Given that condition-specific neural signatures have been reported for FS sentences in native speakers (Keidel et al., 2013; Thierry et al., 2008), our findings support the claim that EBs process linguistic information in a more native-like fashion than LBs (e.g., Berken et al., 2015; Mayo et al., 1997; Ullman, 2001). Of note, the detection of these patterns via time-frequency analysis underscores the relevance of this method to assess the impact of subject-level variables on trope comprehension, opening fruitful opportunities for the investigation of bilingualism.

5. Limitations and avenues for further research

Our work features a number of limitations calling for further research. First, guided by previous works and hypotheses, we averaged brain activity over two pre-defined temporal windows. Future studies could replicate our experiment employing an unrestricted temporal analysis framework, to explore how the neural processing of FSs unfolds over time. In addition, future investigations could manipulate the position of FSs across sentences to investigate the potential influence of carryover effects and thus further assess the robustness of our present results.

Second, rather than literal renditions of FSs in Shakespeare's works, our paradigm employed previously validated modern-English variants (Thierry et al., 2008). While this allowed controlling for relevant linguistic confounds while ensuring comparability with previous studies, it could also undermine ecological validity. It would thus be interesting to extend our research with relevant naturalistic texts, as done in recent investigations (Desai et al., 2016; Dmochowski et al., 2012; Kuhl et al., 2016; Trevisan et al., 2017).

Third, data on AoA and L1/L2 competence levels was acquired through self-report assessments. Since such instruments are susceptible to social desirability and self-image biases, it would be useful to replicate our experiment in samples whose linguistic profile was established using objective measures. However, in spite of their limitations, self-assessments of AoA are a standard approach in the field (Ardal et al., 1990; Berken et al., 2015; Hernandez et al., 2007; Mahendra et al., 2003; Moreno and Kutas, 2005; Nichols and Joanisse, 2016; Pakulak and Neville, 2011; Santilli et al., 2018; Waldron and Hernandez, 2013; Weber-Fox and Neville, 2001, 1996) and our findings replicate a general pattern of results in AoA research, whereby neural responses are more discriminant of linguistic manipulations in EBs than LBs (Caffarra et al., 2015; Hahne, 2001; Hahne and Friederici, 2001; Pakulak and Neville, 2011; Weber-Fox and Neville, 1996). Similarly, self-reports are widely used to assess L2 competence (Hulstijn, 2014) and their outcomes can reliably predict language ability (Marian et al., 2007), accurately reproduce RT results (Langdon et al., 2005), and successfully replicate scores in multilingual naming tests (Gollan et al., 2012). Note, too, that the L2 competence levels reported by subjects in our samples are very similar to those documented in previous studies on subjects with comparable language histories (Marian et al., 2007), including works using the very questionnaire employed herein (García et al., 2014; Santilli et al., 2018). Although these considerations attest to the pertinence of our sampling methods, future research should aim to replicate this study with groups separated and matched via objective assessments of AoA and proficiency, respectively.

Fourth, future studies could compare the processing of FSs to that of other manipulated conditions (e.g., semantically incongruent sentences) to assess whether the observed patterns are specific to this trope or general to lexico-semantic or syntactic manipulations. This would give information on the extension of AoA effects across different linguistic dimensions. Additionally, incorporating conditions with semantic violations in future work would be advisable to avoid inflation of error rates and RTs. Nonetheless, our present findings stand on their own as evidence that AoA modulates neurocognitive activity during processing of L2 tropes.

Finally, although our findings are based on relatively common analysis procedures, recent works suggest that standard statistical practice may lead to misleading conclusions (Benjamin et al., 2018; Button et al., 2013; Gelman and Carlin, 2014; Greenland et al., 2016; Lakens et al., 2018; Lorca-Puls et al., 2018; Vasishth et al., 2018; Wasserstein and Lazar, 2016). Therefore, present findings should be taken as a heuristic contribution rather than definite demonstrations.

6. Conclusion

Focused on Shakespearean FSs, this is the first study examining how AoA impacts oscillatory correlates of L2 processing. We found that EBs, but not LBs, are implicitly sensitive to the structural anomaly and semantic novelty characterizing FSs, as previously observed in native English speakers through other neuroscientific methods (Keidel et al., 2013; Thierry et al., 2008). This finding aligns with previous studies showing that, relative to LBs, EBs process linguistic information in a more native-like fashion (Berken et al., 2015; Mayo et al., 1997; Pakulak and Neville, 2011; Ullman, 2001). More broadly, our study indicates that AoA effects on semantic and morphosyntactic integration efforts also extend to the processing of highly frequent tropes in English literature.

Acknowledgments

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.neuropsychologia.2019.01.007

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