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Not all errors are the same: ERP sensitivity to error typicality in foreign accented speech perception

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Abstract

Intercultural communication has become more and more frequent in the recent globalized society. When native listeners try to understand non-native speakers, they have to deal with different types of grammatical errors, some being frequently encountered and others being less common. The present ERP study investigated how native listeners process different types of morphosyntactic errors in foreign accented speech and whether they are sensitive to error typicality. Spanish natives listened to Spanish sentences in native and foreign (English) accent. ERPs were recorded in response to morphosyntactic violations that were commonly (gender errors) encountered in English accented Spanish or not (number errors). Although sentence comprehension accuracy did not differ across accents, the ERP responses changed as a function of accent and error type. In line with previous studies, gender and number violations in native accented speech elicited LAN-P600 responses. When speech was uttered by foreign speakers, number violations (uncommon errors) showed a P600 effect, while gender violations (common errors) did not elicit late repair processes (reflected by the P600) but an N400 effect. The present results provide evidence that the neural time course of parsing depends not only on speaker's accent, but also on input error typicality.

Keywords: foreign accent, sentence comprehension, morphosyntax, ERP

Introduction

In the modern globalized society, technological advances together with relaxed working and travel restrictions have increased the chances of intercultural exchanges. Consequently, speaking more than one language and being able to communicate with non-native speakers becomes more important than ever before. As a result, social settings in which a native speaker interacts in his native language with a non-native speaker are more and more common. Understanding foreign accented speech can represent a challenge for native interlocutors. Since non-native speakers show persistent difficulties in achieving high degrees of proficiency in their second language (L2; Kroll & de Groot, 2005), their speech production often contains phonological approximations and grammatical inaccuracies (Flege, 1995; Saito, Trofimovik, & Isaacs, 2014). Thus, during a conversation with a foreigner, native listeners often have to deal with foreign accented utterances containing multiple morphosyntactic errors. Interestingly, these errors do not appear randomly in L2 speech but they usually follow specific probabilistic patterns, where some grammatical rules are more likely to be violated than others (Franceschina, 2001; Mariko, 2007). It is still unclear whether native listeners can detect these frequency distribution differences in order to overcome misunderstandings and achieve successful communication. The present study will explore how native listeners deal with different types of morphosyntactic errors in foreign accented speech and whether they are sensitive to speech error typicality. The time course of native listeners' syntactic analysis will be investigated by using the Event-Related Potential technique (ERP).

Syntactic and morphosyntactic analysis in native accented speech has been widely studied in the psycholinguistic literature. Behavioral studies have shown that the presence of syntactic ambiguities does not necessarily preclude successful communication and that natives can quickly overcome grammatical violations in order to achieve a plausible interpretation of the sentence (Ferreira, Bailey, & Ferraro, 2002; Ferreira, Henderson, Anes, Weeks, & McFarlane, 1996).

Previous ERP studies provided a millisecond-by-millisecond picture of native listeners' brain responses to morphosyntactic violations in native accented speech (Dube, Kung, Peter, Brock, & Demuth, 2016; Friederici, Pfeifer, Hahne, 1993; Gunter, Friederici, Schriefers, 2000). These grammatical errors typically elicit a greater posterior positivity 600 ms after the presentation of the target word as compared to the corresponding correct sentence. This so-called P600 effect has been characterized as reflecting late controlled processes of syntactic analysis associated with attempts to repair the error (Friederici, 2002), high-level integration processes (Brouwer, Fitz, & Hoeks, 2012), or conflict monitoring (Van de Meeredonk, Kolk, Chwilla, & Vissers, 2009). Importantly, these late controlled responses are thought to be qualitatively distinct from more automatic syntactic processes (Batterink & Neville, 2013), which appear around 400 ms after the morphosyntactic violation and are reflected by left anterior negative effects (i.e., LAN; Dube et al., 2016; Friederici et al., 1993; Gunter et al., 2000; Gunter, Stowe, & Mulder, 1997). Unlike early automatic responses, late controlled processes underlying the P600 effect are sensitive to distributional (e.g. error frequency; Coulson, King, & Kutas, 1998; Hahne & Friederici, 1999) and indexical cues (e.g., presence of a foreign accent; Grey & van Hell, 2017; Hanulíková, van Alphen, van Goch, & Weber, 2012; Roll, Home, & Lindgren, 2010). The modulation of this ERP response is particularly relevant for the present project since it suggests that native listeners' syntactic analysis might change depending on how frequently an error is encountered in foreign accented speech. The relation between the P600 effect and distributional/indexical cues will be described below.

The effect of distributional cues on the P600 has been examined by varying the frequency of occurrence of a violation within the experimental session. A previous ERP study on auditory sentence comprehension in native listeners presented German sentences which could either be grammatically correct or incorrect (i.e., containing a phrase structure violation; Hahne & Friederici, 1999). Crucially, the overall number of syntactic violations presented during the experiment was manipulated, with incorrect sentences having a low (20%) or a high (80%) frequency. A P600 effect was present when the violation was low in frequency, but it was not observed when the violation was highly frequent. This suggests that native listeners' neural responses to syntactic violations are not fixed and that they can change as a function of error frequency. Specifically, the brain shows a reduced sensitivity to the presence of an error after repeated exposure to it. One possible interpretation of this phenomenon is associated with changes in native listeners' expectations about the grammaticality of the upcoming sentences (Coulson et al., 1998). In other words, native listeners appear to be able to dynamically update the probability associated with a specific type of error and use their knowledge about probable structures to make predictions about the next utterances. When a perceived error matches with native listeners' expectations, conflict detection is reduced (Van de Meeredonk et al., 2009), and attempts of grammatical repair are minimized (Friederici, 2002).

Besides distributional cues, indexical cues can have an impact on native listeners' neural responses to grammatical errors. In a previous ERP study Dutch native listeners were presented with Dutch sentences that were produced by native speakers and non-native speakers with a foreign accent (i.e., Turkish; Hanulíková et al., 2012). The same amount of morphosyntactic violations (determiner-noun and adjective-noun gender violations) was presented across accents. A P600 effect was present for violations in native accented speech but it was not observed in foreign accented speech. This suggests that the speaker's accent has an impact on the time course of syntactic analysis in native listeners. Following the authors' interpretation of the P600 modulation (Hanulíková et al., 2012), native listeners would be able to make inferences based on the speaker's accent and change their expectations about the grammaticality of the sentences according to their world knowledge (for a similar interpretation see Van Berkum, van den Brink, Tesink, Kos, & Hagoort, 2008 and Viebhan, Ernestus, & McQueen, 2017). Since foreign accent is often associated with the presence of grammatical errors, native listeners would consider these violations as highly probable in foreign accented speech, and would thus reduce their attempts of grammatical repair (reflected by the P600). Similar to Hanulíková et al. (2012), a recent ERP study showed ERP effects of grammatical repair processes in native but not in foreign accent (Grey & van Hell, 2017). In this study English native listeners were presented with English sentences in native and foreign accent (Chinese). The sentences could contain grammatical violations where an antecedent (e.g., *Thomas*) disagreed in gender with a pronoun (e.g., *she*). The results showed that the participants who correctly identified the foreign accent of the speakers showed a sustained frontal negativity, called Nref effect, for gender violations in native accent, which reflects attempts to repair the referential ambiguity (Nieuwland, 2014). In the foreign accent condition, no Nref effect was observed suggesting reduced grammatical repair processes. Instead of the Nref effect, an N400 effect was elicited in response to gender violations in foreign accented speech, an ERP effect that is typically associated with lexical-semantic analysis (Kutas & Federmeier, 2011). Grey and van Hell (2017) proposed that the semantic integration of the target pronoun was hindered in foreign accented speech. The presence of a gender-mismatching antecedent represented a misleading cue for the subsequent semantic integration of the target pronoun (Grey & van Hell, 2017), gender being part of the lexical representation of lexical items (Jescheniak & Levelt, 1994; Roelofs, 1992). As a result, the sematic integration of the incorrect foreign-accented pronoun (e.g., *she*) was hindered after processing a misleading antecedent (e.g., *Thomas*, Grey & van Hell, 2017). Importantly, this was particularly true in foreign accented speech, where native listeners are used to over-rely on contextual cues (Goslin, Duffy, & Floccia, 2012; Lev-Ari, 2015; Romero-Rivas, Martin, & Costa, 2016). This suggests that the presence of gender-disagreeing words in adverse listening conditions (accented speech) taxes the semantic processing of the upcoming sentential constituents (Grey & van Hell, 2017).

Thus, the experimental evidence collected so far suggests that native listeners' syntactic analysis during auditory sentence comprehension is affected by error frequency (Hahne & Friederici, 1999) as well as speaker's accent (Hanulíková et al., 2012; Grey & van Hell, 2017). However, it is still unclear whether native syntactic processing depends on the likelihood of an error in foreign accented speech. The present study is aimed at testing the impact of input error typicality on native listeners' syntactic processes. We manipulated the error typicality by using different types of morphosyntactic errors, which show distinct frequency distributions in foreign accented speech.

The present study

In the present ERP study Spanish native speakers listened to Spanish sentences that were produced by native speakers and non-native speakers with a clear foreign accent (i.e., English). Grammatically correct and incorrect sentences were presented in both accents. Incorrect sentences always contained an agreement violation between a determiner and a target noun. Two types of morphosyntactic errors were considered: gender and number violations (e.g., correct: *el*$_{SM}$[1] *color*$_{SM}$, "the color"; gender: *la*$_{SF}$ *color*$_{SM}$; number: *los*$_{PM}$ *color*$_{SM}$). These two morphosyntactic violations were selected because of their different frequency of occurrence in English accented Spanish, with gender errors being highly frequent and number errors being low frequent (Franceschina, 2001). ERP responses to the target noun were examined in both accents and in the three types of sentences.

In native accented speech, we expected to replicate previous ERP findings showing a P600 effect for both gender and number violations relative to correct sentences (Barber & Carreiras, 2005; Dube et al., 2016; Gunter et al., 2000). No differences were expected between the two types of violation, since gender and number violations are equally unlikely in native accented speech. The P600 effects were expected to be preceded by early automatic responses (LAN), as has been

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[1] S: singular; P: plural; M: masculine; F: feminine.

frequently reported in response to local agreement violations in Romance languages (Barber & Carreiras, 2005; Molinaro, Barber, & Carreiras, 2011).

In foreign accented speech if native listeners' brain responses are sensitive to input error typicality, the ERPs to gender and number violations should differ (Hahne & Friederici, 1999). The P600 should be present in response to the uncommon errors (i.e., number violations), and it should be reduced or even absent with the common errors (i.e., gender violations). Alternatively, if the speakers' error typicality does not have an impact on native listeners' neural responses, a similar reduction of the P600 effect should be observed for both violation types (as in Hanulíková et al., 2012). No early automatic responses (i.e., LAN changes) were expected as no LAN effect was previously reported in response to morphosyntactic violations in foreign accented speech (Hanulíková et al., 2012; Grey & van Hell, 2017). Finally, if semantic integration difficulty increases when misleading lexical cues are available in adverse listening conditions, an N400 effect should be observed exclusively in accented speech and specifically in response to gender violations (where the grammatical gender of the article acts as a misleading lexical cue for the upcoming target noun; Goslin et al., 2012; Grey & van Hell, 2017; Romero-Rivas et al., 2016).

Materials and Methods

Participants

Forty Spanish native listeners participated in the experiment (25 women). Data from four participants were excluded due to excessive artifacts in EEG recording (three participants had less than 60% of the trials after artifact rejection) or due to the lack of responses to the online comprehension questions (one participant). The final sample included 36 participants (24 women, mean age: 25y, SD: 6). Offline tests revealed that participants had intermediate to high English proficiency (see Table 1), and reported being exposed to English accented Spanish (average hours/week: 3.4, SD: 2.9; on a scale of 1-10 their degree of familiarity with English accent was 6.8, SD: 2.0). They rated gender violations as the most common morphosyntactic mistake of

English-native L2 speakers of Spanish (on a scale of 1-10 the error frequency was 7.0 for gender, 5.6 for person and 4.9 for number; the gender score was significantly higher than the other two scores, *ts*> 3.5, *ps*<0.001). None of the participants reported a history of neurological, psychiatric disorders or hearing problems. All participants signed an informed consent form before taking part to the study that was approved by the BCBL ethics committee. They received a payment of 10 € per hour for their participation.

---Table 1---

Materials

One hundred-eighty Spanish sentences were selected. Each sentence had six different versions: gender violated, number violated and correct version, all recorded in native and English accent (1080 sentences in total). Gender and number errors were created by violating agreement dependencies between a determiner and a target noun (see Table 2). Number violations were always omission errors (i.e., missing plural inflection of the target noun) since these are the least frequent morphosyntactic errors in Spanish production of English native speakers (Franceschina, 2001). This choice was also motivated by experimental reasons: target nouns were kept strictly identical across conditions.

---Table 2---

The 180 target nouns were half feminine and half masculine. Their average length was 6 letters (SD: 1.9) and their phonological uniqueness point always coincided with the end of the noun (see Table 3). This way, gender and number error detection happened within a similar time window. Moreover, the ending of the target noun was never informative of grammatical gender (i.e., opaque nouns; e.g., *color*, "$color_M$") since this is the subset of nouns where English native speakers acquiring Spanish as L2 show persistent gender errors (Foote, 2015). Transparent nouns (i.e., whose gender ending is consistently associated with a specific gender class; e.g., *gorro*, "cup_M") were not included. The target noun was presented at least one word before the end of the sentence. All sentences had low semantic constraints so that the target noun was never predictable. All sentences were always grammatically correct until the presentation of the target noun.

---Table 3---

Three male Spanish speakers and three male British speakers highly proficient in Spanish recorded the sentences (each speaker recorded one third of the overall number of sentences). To minimize possible differences in prosody and speech rate, each speaker was asked to listen and repeat a sentence pronounced by a reference speaker (a non-native speaker of Spanish who first recorded all sentences with neutral intonation and slow speech rate). Gender violations, number violations and correct sentences were presented to the speakers in a counterbalanced order to control for repetition effects. Native speakers spoke faster than non-native speakers (the sentence mean duration was 2199 ms, SD: 533, in native accent and 2477 ms, SD: 601, in foreign accent, $p<0.001$; the target noun mean duration was 390 ms, SD: 112, in native accent and 423 ms, SD: 120, in foreign accent; $p<0.001$[2]). The duration of the target noun did not differ across grammatically correct and incorrect sentences (gender violations: 408 ms SD: 115, number violations: 406 ms, SD: 121, correct sentences: 403 ms, SD: 118; $p>0.05$).

The quality of the auditory sentences was assessed during preliminary ratings (60 Spanish natives, 35 female, mean age: 24 y; none of whom participated in the EEG experiment). All participants were able to tell that non-native speakers had a clear foreign accent. The foreign speakers had a stronger accent as compared to the native speakers (on a scale from 1 to 5, the accent strength score was 1.3 for sentences produced by native speakers and 3.9 for foreign speakers, $p<0.001$). The foreign and native accented sentences had a similar level of

[2] We conducted ERP analyses on a subset of items (n=18 items/condition) matched across accents for target noun duration and pre-target sentence fragment duration. These analyses showed a similar pattern of results to those reported in the Results section, suggesting that the present ERP results cannot be uniquely explained by speech rate and word duration differences across accents.

intelligibility, which was measured as the percentage of accurate transcriptions of the second-to-last word of each sentence (98.3% for foreign accent and 98.4% for native accent, $p>0.05$). On a grammaticality judgment task, the participants could easily detect grammatical errors in the experimental sentences (mean accuracy: 95.0%), with a slight advantage for the native accent (foreign accent: 93.3%; native accent: 96.8%, $p<0.001$; similar to Hanulíková et al. 2012). To ensure that the grammatical errors could not be predicted based on preceding prosodic cues (e.g., pauses, different speech rate etc.), each experimental sentence was trimmed right before the onset of the target noun and presented to 30 Spanish natives (20 females, mean age: 24 y) who did not participate in either the EEG experiment or in the previous rating study. After listening to each sentence fragment the participants were asked to guess whether an error was coming and they had to make a forced yes/no choice. The prediction error rate was similar across gender violations, number violations and correct sentences ($p>0.05$) suggesting that the presence of a grammatical error could not be anticipated based on the pre-target sentence fragment. Note that any significant interaction between Agreement (gender, number, correct) and Accent (foreign, native) in the ERPs could not be accounted for by differences in accent strength, intelligibility, grammaticality judgement, prediction error, and target duration since all Agreement x Accent interactions were not significant in the different ratings (all Fs<2.5; all ps>0.05).

Besides the 180 experimental sentences, 160 filler sentences were added. The fillers were produced by the same speakers and were always correct sentences (e.g., *La historia tuvo un final feliz*, “The story had an happy ending.”). Six experimental lists were created so that each target noun appeared only once per list. Each list contained one version of the 180 experimental sentences and the 160 filler sentences. Out of the total of 340 stimuli, 220 sentences were grammatically correct (approx. 65%, half was in native accent and the other half in foreign accent), while 120 were grammatically incorrect (approx. 35%, half in native accent and the other half in foreign accent).

Procedure

Participants were seated in a sound-attenuated and dimly lit room. Each trial began with the symbol *.* at the center of the screen, which was followed by a 300-ms blank. Then a sentence was presented through speakers while a fixation cross was displayed on the screen. Twenty percent of the sentences were followed by a yes/no comprehension question displayed on the screen and the participants were asked to indicate their choice by pressing one of the two response buttons. To minimize artifacts during the presentation of the auditory stimuli (mean duration: 2338 ms, SD: 584), the participants were asked to blink only when the symbol *.* was presented on the screen. The experimental session lasted about half an hour and was divided into four blocks of 85 trials each (seven minutes). At the beginning of the EEG session, each speaker introduced himself thorough a short auditory recording (including name, city and country of provenance). This was done to make sure that the British vs. Spanish status of each speaker was clear to all participants. Then, a practice session was presented to let the participants familiarize with the task (12 sentences, 3 comprehension questions). Participants completed two English proficiency tests and a language-background questionnaire after the EEG recording. During the language-background questionnaire participants were asked to rate their familiarity with English accented Spanish, the probability of person, number, and gender errors in English accented Spanish and how difficult it was to understand the experimental sentences in native and foreign accent.

EEG recording and analyses

The EEG signal was recorded from 27 channels placed in an elastic cap: Fp1, Fp2, F7, F8, F3, F4, FC5, FC6, FC1, FC2, T7, T8, C3, C4, CP5, CP6, CP1, CP2, P3, P4, P7, P8, O1, O2, Fz, Cz, Pz. Two external electrodes were placed on the mastoids, two were on the ocular canthi, one above and one below the right eye. All sites were referenced online to the left mastoid. Data were recorded and amplified at a sampling rate of 500 Hz. Impedance was kept below 10 KΩ for the external channels and below 5 KΩ for the electrodes on the scalp. EEG data were re-referenced offline to the average activity of the left and right mastoid. A bandpass filter of 0.01–30 Hz (24 dB/oct) was applied. Vertical and horizontal eye movements were corrected following the Independent Components Analysis (ICA). The EEG of each subject was decomposed into independent components. We identified the components that explained the highest percentage of the variance in the Veog and Heog channels (recorded as the voltage difference between electrodes placed around the eyes). The time course and the topographic distribution of these components were visually inspected to ensure they represented real artifacts, and subtracted from the original data. Residual artifacts exceeding ±70 μV in amplitude were rejected. On average, 11.3 % of trials were excluded. The number of rejections did not differ across conditions ($F(5,210)<1$, $p= 0.86$). For each target noun, an epoch of 1700 ms was obtained including a 200 ms pre-stimulus baseline. Average ERPs time locked to the onset of the target noun were computed for each condition.

Statistical analyses were carried out between 400 and 1400 ms in the following time windows: 400-550, 600-800, 800-1100, 1100-1400 ms. The temporal boundaries of each time window were defined based on visual inspection and were also similar to those used in previous ERP studies on auditory sentence comprehension (Hanulíková et al., 2012; Rossi, Gugler, Friederici, Hahne, 2006; Schmidt-Kassow & Kotz, 2008; Van Berkum et al., 2008). Three topographic factors were included in the statistical analyses (as in Van der Meij, Cuetos, Carreiras, & Barber, 2011): Hemisphere (two levels, left and right), Distance to midline (i.e., DML, two levels, close to midline: F3, F4, FC1, FC2, C3, C4, CP1, CP2, P3, P4, far from midline: F7, F8, FC5, FC6, T7, T8, CP5, CP6, P7, P8), and Anterior-Posterior factor (i.e., AP, five levels, frontal; F7, F3, F4, F8, fronto-central: FC5, FC1, FC2, FC6, central: T7, C3, C4, C8, centro-parietal: CP5, CP1, CP2, CP6, parietal: P7, P3, P4, P8). A repeated measures analysis of variance (ANOVA) was performed for each time window including Agreement (correct, number, gender), Accent (foreign, native) and the three topographic factors as within-subject factors. Data acquired from midline electrodes (Fz, Cz, Pz) were separately analyzed and included in an ANOVA with Agreement, Accent and AP (three levels: frontal, central, parietal) as within-subject factors. When significant interactions between the Agreement and Accent were found, follow-up ANOVAs were conducted for each accent type (the ANOVA on the lateralized electrodes included the factors Agreement, Hemisphere, DML, and AP; the ANOVA on the midline electrodes included the factors Agreement and AP). The Greenhouse-Geisser procedure was applied when the sphericity assumption was violated. Effects of topographic factors are reported only when they interacted with the experimental factors.

Results

Behavioral results

The participants showed high accuracy rates in the online comprehension questions (mean overall accuracy, including fillers: 94.3%, SD: 4.3) suggesting that they were paying attention to the content of the spoken sentences. The accuracy rates did not differ between accents (foreign: 93.1%, SD: 6.9; native: 94.3%, SD: 5.7; $t(35)<1$, $p=0.31$) showing that the participants could understand Spanish sentences equally well in foreign and native accent. However, at the end of the experiment, their offline ratings suggested that the word-by-word segmentation was more difficult in foreign accent than in native accent (on a scale of 1 to 10, the score was 3.2 for the foreign accented utterances and 1.4 for the native accented utterances, $t(35)=5.99$, $p<0.001$).

EEG results

Figure 1 shows the average waveforms for each experimental condition (upper panel). The lower panel shows the topographic distribution of number and gender violation effects[3] for each accent type. In the native accent condition, gender and number violations seemed to elicit greater left

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[3] These were computed from the subtraction between the disagreement and the agreement conditions.

negativities followed by a greater P600 as compared to correct sentences. In the foreign accent condition, while number violations seemed to elicit a greater P600 as compared to the control condition, gender violations showed a greater N400 effect relative to correct sentences.

The ANOVAs on the lateralized electrodes showed effects of Agreement (400-550 ms: Grammar x AP, $F(8, 280)=2.96$, $p<0.05$, Agreement x Hemisphere x AP, $F(8, 280)=2.84$, $p<0.05$; 800-1100 ms, Agreement x AP, $F(8, 280)=2.87$, $p<0.05$; 1100-1400 ms: Agreement x AP, $F(8, 280)=3.13$, $p<0.05$) and Accent (400-550 ms: Accent, $F(1,35)=4.73$, $p<0.05$; 600-800 ms: Accent, $F(1,35)=5.29$, $p<0.05$; 800-1100 ms: Accent x AP: $F(4, 140)=6.89$, $p<0.01$; 1100-1400 ms: Accent x AP, $F(4, 140)=3.35$, $p<0.05$, Accent x Hemisphere x AP, $F(4, 140)=3.39$, $p<0.05$). Also, significant interactions between Accent and Agreement were reported in all time windows under study (400-550 ms: Accent x Agreement, $F(2,70)=3.30$, $p<0.05$, Accent x Agreement x DML, $F(2,70)=3.32$, $p<0.05$; 600-800 ms: Accent x Agreement, $F(2,70)=3.64$, $p<0.05$, Accent x Agreement x DML, $F(2,70)=4.61$, $p<0.05$; 800-1100 ms: Accent x Agreement x DML, $F(2,70)=3.41$, $p<0.05$; 1100-1400 ms: Accent x Agreement x Hemisphere, $F(2,70)=3.79$, $p<0.05$, Accent x Agreement x Hemisphere x DML, $F(2,70)=3.95$, $p<0.05$). The ANOVAs on the midline electrodes showed significant interactions in the first two time windows (400-550 ms: Accent x Agreement, $F(2,70)=3.46$, $p<0.05$; 600-800 ms: Accent x Agreement, $F(2,70)=4.01$, $p<0.05$)[4]. To better understand the nature of these interactions, additional ANOVAs (for lateralized and midline electrodes) were carried out for each accent type.

---Figure 1---

[4] No differences were found in the pre-target segment. ERP analyses between 0 and 400 ms only revealed an effect of Accent (*p*s<0.05), with ERP waveforms being less negative in foreign relative to native accent. None of the other effects involving the experimental factors reached significance before 400 ms (all *p*s>0.05).

Native accent

400-550 ms

The factor Agreement interacted with the topographic factors (Agreement x Hemisphere, $F(2,70)=4.93$, $p<0.05$; Agreement x AP, $F(8,280)=2.27$, $p=0.08$). Post-hoc *t*-tests showed that gender violations elicited greater left negativities than correct sentences (left: $t(35)=2.04$, $p<0.05$; right: $t(35)=0.06$, $p=0.95$) with no difference among anterior, central and posterior sites. Number violations elicited greater left negativities as compared to correct sentences (left: $t(35)=3.00$, $p<0.01$; right: $t(35)=1.60$, $p=0.12$) and this effect was evident over centro-anterior sites (frontal: $t(35)=2.52$, $p<0.05$; fronto-central: $t(35)=2.43$, $p<0.05$; central: $t(35)=2.89$, $p<0.01$; centro-parietal and parietal: *p*s>0.05). The ERP responses to gender and number violations did not differ (all *p*s>0.05).

600-800 ms

No main effect and no interaction involving the experimental factors was significant (all *p*s>0.05).

800-1100 ms

The interactions Agreement x DML and Agreement x AP were significant ($F(2,70)=4.38$, $p<0.05$; $F(8,280)=2.21$, $p<0.05$). Post-hoc *t*-tests showed that gender violations elicited a greater centro-posterior positivity than correct sentences (frontal and fronto-central: *p*s>0.05; centro-parietal: $t(35)=2.49$, $p<0.05$; parietal: $t(35)=2.28$, $p<0.05$) and this effect was greater over the sites close to the midline (close: $t(35)=2.32$, $p<0.05$; far: $t(35)=1.45$, $p=0.16$). Number violations elicited a greater positivity than correct sentences over posterior sites (parietal: $t(35)=1.96$, $p<0.05$; other levels: *p*s>0.05). There was no significant difference between gender and number violations (all *p*s>0.05).

1100-1400 ms

The interaction Agreement x Hemisphere was significant ($F(2,70)=3.90$, $p<0.05$). Post-hoc *t*-tests showed that gender violations elicited greater positive waveforms as compared to the control condition over right sites (left: $t(35)=1.03$, $p=0.31$; right: $t(35)=2.39$, $p<0.05$). No differences were found between number violations and the other two conditions (left and right: *p*s>0.05).

In sum, gender violations elicited a greater left negativity (450-550 ms) followed by a greater P600 (800-1400 ms) as compared to the correct sentences. Number violations elicited a greater left anterior negativity (450-550 ms) and P600 (800-1100 ms) than correct sentences. No differences were observed between gender and number violation effects.

Foreign accent

400-550 ms

There was a significant main effect of Agreement (Agreement, $F(2,70)=3.66$, $p<0.05$) and significant interactions with the topographic factors (Agreement x DML, $F(2,70)=5.63$, $p<0.01$; Agreement x Hemisphere x AP, $F(8,280)=2.42$, $p<0.05$). Post-hoc *t*-tests showed greater negativities for gender violations as compared to correct sentences ($t(35)=2.28$, $p<0.05$) and number violations ($t(35)=2.72$, $p<0.05$; number vs. correct: $t(35)<1$, $p=0.99$). This effect was distributed over centro-posterior sites (gender vs. correct, right centro-parietal: $t(35)=2.12$, $p<0.05$; right parietal: $t(35)=2.91$, $p<0.01$; left central: $t(35)=2.57$, $p<0.05$; gender vs. number, right centro-parietal: $t(35)=2.89$, $p<0.01$; right parietal: $t(35)=3.75$, $p<0.001$; left central: $t(35)=2.23$, $p<0.05$; left centro-parietal: $t(35)=2.66$, $p<0.05$; left parietal: $t(35)=3.70$, $p=0.001$; all other sites: *p*s>0.05). No differences were reported between number violations and correct sentences (all *p*s>0.05). The ANOVA on the midline electrodes also showed a main effect of Agreement ($F(2,70)=5.28$, $p<0.05$), with greater negativities for gender violations as compared to the other two conditions (gender vs. correct: $t(35)=2.67$, $p<0.05$; gender: vs. number: $t(35)=3.47$, $p<0.01$; correct vs. number: $t(35)<1$, $p=0.93$).

600-800 ms

The interactions Agreement x DML and Agreement x Hemisphere x AP were significant ($F(2,70)=3.40$, $p<0.05$; $F(8,280)=2.45$, $p<0.05$). Post-hoc *t*-tests showed greater negativities for gender violations as compared to number violations over centro-posterior sites (right centro-parietal: $t(35)=2.23$, $p<0.05$; right parietal: $t(35)=3.43$, $p<0.01$; left parietal: $t(35)=2.17$, $p<0.05$). No other comparison reached significance (*p*s>0.05).

800-1100 ms

No effect involving the experimental factors was significant (all *p*s>0.05).

1100-1400 ms

The interaction Agreement x AP was marginally significant ($F(8,280)=2.24$, $p=0.07$). Number violations showed a greater posterior positivity as compared to the control condition (parietal: $t(35)=2.06$, $p<0.05$; all other sites: *p*s>0.05). Gender violations did not differ from the control condition and number violations (all *p*s>0.05).

In sum, gender violations elicited a greater N400 (400-550 ms) as compared to correct sentences and number violations. Number violations elicited a greater P600 (1100-1400 ms) relative to correct sentences.

Correlations and block analyses

To explore the relation between participants' experience with accented speech and grammatical repair processes, correlation analyses were computed between the average P600 effect size in the foreign accent condition (calculated over posterior electrodes: P3, P4, Pz, P7, P8) and participants' familiarity with English accented Spanish. Negative correlations were found for gender (800-1100: $r=-0.43$, $p<0.01$; 1100-1400: $r=-0.48$, $p<0.01$) but not for number effects (800-1100: $r=-0.03$, $p=.85$; 1100-1400: $r=-0.20$, $p=.25$, see Figure 2). Thus, only in the case of gender violations the increase of familiarity with the foreign accent resulted in a progressive reduction of the P600 waveforms difference[5].

---Figure 2---

[5] The N400 effect size (calculated between 400 and 550 ms over bilateral centro-posterior electrodes) did not correlate with accent familiarity ($r=-0.24$, $p=0.16$).

To check for a progressive adjustment of the ERP responses during the course of the experiment, additional ANOVAs were carried out after splitting the data into two blocks corresponding to the first and the second half of the experimental session (as in Hanulíková et al., 2012). A repeated measure ANOVA including the factor Block was carried out for each of the ERP effects previously reported[6]. The analyses showed a main effect for both LAN and N400 (LAN: $F(2,70)=3.18$, $p<0.05$; N400: $F(2,70)=4.88$, $p<0.05$) with no modulation over time (Agreement x Block, LAN: $F(2,70)=1.01$, $p=0.37$; N400: $F(2,70)=0.26$, $p=0.77$). The analyses in the P600 time window (800-1400 ms) showed a three-way interaction (Accent x Agreement x Block: $F(2,70)=4.05$, $p<0.05$). Follow-up analyses showed that the P600 effects for native accent were present in the first block ($F(2,70)=3.27$, $p<0.05$; number vs. correct: $t(35)=1.85$, $p<0.05$; gender vs. correct: $t(35)=2.03$, $p<0.05$) but not in the second ($F(2,70)=0.90$, $p=0.41$). In the foreign accent, no P600 effect was observed in the first block ($F(2,70)=0.14$, $p=0.87$), while in the second block there was a P600 effect only for number errors ($F(2,70)=5.11$, $p<0.01$; number vs. correct: $t(35)=2.80$, $p<0.01$; gender vs. correct: $t(35)=0.13$, $p=0.55$; see Figure 3). Thus, the LAN effect observed in native accent and the N400 effect observed in foreign accent were similar over the course of the experiment. In native accent, there was a reduction of the P600 effects from the first to the second block. In foreign accent, gender violations never showed a P600 effect, while number violations did towards the end of the experiment.

---Figure 3---

Discussion

Non-native speakers often retain a foreign accent and show persistent difficulties in achieving high degrees of L2 proficiency, especially in the syntactic domain (Hahne, 2001; Weber-Fox & Neville, 1996). Some L2 grammatical rules can be particularly difficult to acquire, due to

[6] Subset of electrodes corresponding to the topographic distribution of each ERP effect were included in the analyses (LAN: left fronto-central sites; N400: bilateral centro-posterior sites; P600: bilateral posterior sites).

construction characteristics and cross-linguistic similarities (Fraceschina, 2005; Gass, 1984; White, 2003). As a result, foreign accented speech can contain some grammatical errors that are more frequent than others (Franceschina, 2001; Mariko, 2007). The present study examined how native listeners deal with different types of morphosyntactic violation in foreign accented speech comprehension and tested whether their syntactic analysis is modulated by input error typicality. Spanish natives listened to Spanish sentences that were pronounced by native and non-native speakers. The sentences contained violations that were either common (i.e., gender violations) or not (i.e., number violations) in English accented Spanish. The ERP results showed that native listeners' brain responses changed depending on the speaker's accent and the error type. In native accented speech, both types of morphosyntactic violations elicited a P600 response preceded by greater left negativities as compared to correct sentences. When the same violations were produced by non-native speakers with a foreign accent, the electrophysiological responses changed as a function of error typicality: whereas the uncommon errors (i.e., number violations) elicited a P600 effect, the common errors (i.e., gender violations) elicited an N400 effect. These findings are in line with previous ERP studies showing changes in electrophysiological responses to morphosyntactic violations as a function of speaker identity (Hanulíková et al., 2012; Grey & van Hell, 2017) as well as construction frequency (Coulson et al., 1998; Hahne & Friederici, 1999). The present results update previous research evidence on error frequency effects (Coulson et al., 1998; Hahne & Friederici, 1999) showing that native listeners' brain activity is sensitive not only to the error frequency within the experimental session but also to the error frequency within the lifetime. In addition, these findings extend previous research on foreign accented speech (Grey & van Hell, 2017; Hanulíková et al., 2012) showing that native listeners do not reduce their grammatical repair processes with all grammatical errors in accented speech, but they specifically do it with those errors that are commonly encountered in a given foreign accent. Thus, the results of the current study showed, for the first time, that native listeners' syntactic analysis is sensitive to the typicality of grammatical errors from a specific set of speakers (e.g., non-native L2 speakers).

One possible explanation of the present pattern of results is that participants' previous experience with English accented Spanish resulted in error-specific ERP responses during foreign accented speech comprehension. Based on their previous exposure to English accent, the native listeners were aware of the probabilistic differences between gender and number violations in Spanish uttered by English natives (as reported in the language-background questionnaire). This knowledge shaped their expectations about the grammaticality of foreign accented sentences. Since gender violations were highly probable in English accented Spanish, the lack of P600 likely reflects a minimized conflict between what listeners expected and what they perceived (Van de Meeredonk et al., 2009), associated with reduced grammatical repair processes (Friederici, 2002). In contrast, the presence of less likely grammatical errors (i.e., number violations) disconfirmed native listeners' expectations, giving rise to grammatical repair processes (reflected by a P600 effect), as also observed for both types of (uncommon) errors in native accented speech. The correlation analyses further confirmed a relation between participants' prior experience (as measured by familiarity ratings) and ERP responses. The more the native listeners were familiar with the foreign accented speech (and, hence, with its distributional properties), the fewer the attempts to repair gender errors (as reflected by the P600 effect) at the individual level. This might suggest that the amount of experience native listeners have with a foreign accent dynamically changes the way they treat morphosyntactic errors in accented speech, without preventing successful communication (as reflected by high accuracy rates in the online comprehension questions).

An alternative explanation is that the reduction of grammatical repairs is not specifically related to participants' experience with English accented Spanish, but to general knowledge about error distribution in foreign accents (i.e., among all existing languages, grammatical gender is less common than grammatical number; Greenberg, 1963). Note that a subset of participants (n=16) reported to be familiar with French accented Spanish, and there was no significant correlation between the amount of French accented Spanish exposure and ERP effects (P600 effect size to gender errors in foreign accent: 800-1100: r=.29, p=.27; 1100-1400: r=.20, p=.45). This seems to suggest that the present findings cannot be the result of general experience with any type of foreign accent. However, it is still possible that participants' expectations were not based exclusively on their experience with English accented Spanish, but more generally on their experience with accents of gender-free languages.

Both explanations support the idea that the brain can adapt to changes in distributional properties of linguistic input and refine its expectations about the upcoming structures based on previous experience (Fraundorf & Jaeger, 2016; Kleinschmidt, Fine, & Jaeger, 2012; Luka & Barsalou, 2005; Thothathiri & Snedeker, 2008; Viebhan et al., 2017).

Besides the lack of P600 effect, gender violations in foreign accented speech elicited a greater central posterior negativity as compared to correct sentences. Based on its latency and topographic distribution, this effect can be categorized as an N400 effect (Kutas & Federmeier, 2011). As in Grey and van Hell (2017), this effect likely reflects increased difficulties in lexico-semantic integration of the target word. Normative ratings and participants' offline reports showed that although each sentence could be successfully segmented word by word (as reflected by the intelligibility measures), word integration was considered more difficult in foreign than in native accent. In similar adverse listening conditions, previous studies showed that native listeners tend to over-rely on any available contextual cue to comprehend accented speech (Goslin et al., 2012; Lev-Ari, 2015; Romero-Rivas et al., 2016). Although our experimental sentences were semantically low constraint, the pre-target determiner might have worked as a cue for lexical processing of the upcoming target noun. In this case, the gender-disagreeing determiner represented a more disruptive cue than the number-disagreeing determiner, since it provided misleading information about the lexical identity (gender) of the upcoming noun (Jescheniak & Levelt, 1994; Roelofs, 1992). Thus, our results confirm that the presence of misleading lexical cues (e.g., gender-disagreeing determiner) drastically hinders semantic integration of the upcoming noun in adverse listening situations, such as accented speech perception (Grey & van Hell, 2017).

The ERP findings in native accented sentences showed biphasic responses to morphosyntactic violations, in line with previous ERP studies on morphosyntactic analysis in Romance languages (Molinaro et al., 2011). Consistent with our predictions, a P600 effect was present for both gender and number errors, suggesting that similar processes of syntactic analysis and repair were carried out for both types of violation. However, gender violations elicited a longer lasting P600 effect as compared to number violations. A similar difference has been already reported in a previous ERP study on Spanish morphosyntactic analysis (Barber & Carreiras, 2005) and it has been associated with the lexical nature of the grammatical gender feature, which would elicit costlier reanalysis processes as compared to the grammatical feature of number. Both grammatical errors also showed left negative effects in the earlier time window. Although these effects were observed in the same time window of the N400 component, they showed a different topographic distribution and no significant correlation with the N400 effect size (as shown by follow-up analyses: gender, *r*=-0.01, *p*=.94; number, *r*=-0.14, *p*=.40). Based on their topographic distribution, these left negativities can be categorized as LAN effects (Friederici, 2002). The LAN effect has been typically observed in response to local morphosyntactic violations in Romance languages and it has been interpreted as reflecting processes of syntactic integration (Gunter et al., 2000), morphosyntactic mismatch detection (Friederici, 1995; Hagoort, Brown, & Osterhout, 1999), or working memory load (Coulson et al., 1998). The cognitive processes reflected by the LAN are characterized by a high degree of automaticity (Gunter et al., 1997, 2000), and they are usually observed when listerners have been widely exposed to the auditory stimuli and have achieved high levels of proficiency in understanding the linguistic input (Caffarra, Molinaro, Davidson, & Carreiras, 2015; Steinhauer, White, & Drury, 2009). The occasional exposure to foreign accent might not have been enough to trigger automatic processes of syntactic analysis. This might explain why these negative effects, thus far, have only been observed in native accented speech but not in foreign accented speech (Grey & van Hell, 2017). The present results suggest that while late controlled processes of syntactic analysis (eliciting P600 effects) can be observed in both native and foreign accent, automatic processes of error detection (associated with LAN effects) are not easily observed in foreign accented speech.

Finally, the results from the block analyses suggested that there was a progressive adjustment of native listeners' late responses in both accents. The progressive reduction of the P600 effect in response to morphosyntactic violations in native accent suggests that the listeners changed the way they treated an error as a function of its frequency of occurrence in the experiment, with reduced reanalysis processes after having been exposed to the same type of violation several times (as in Hahne & Friederici, 1999). In the case of foreign accent processing, no significant P600 effect was observed for gender violations throughout the experiment, as a function of participants' previous experience. In contrast to native accent processing, the P600 effect for number violations in accented speech became evident only in the second half of the experiment. This difference between blocks might be due to initial difficulties in detecting the presence of a number error in foreign accented speech. It should be noted that all number violations presented in our study were omission errors (i.e., there was always a missing morphosyntactic marker "s" or "es" at the end of the target noun). It is possible that detecting a missing phoneme in adverse listening conditions became easier towards the end of the experiment, when the participants were more adapted to non-native speakers' accent and more able to perceive reliable phonetic variations (Clarke & Garrett, 2004). Altogether, the present results suggest that native listeners' late responses to syntactic errors are highly flexible and can change depending on both a longterm naturalistic experience to specific utterances (i.e., foreign accented sentences) and a short-term exposure (i.e., number of errors being presented during an experimental session). These results are consistent with theoretical models assuming that parsing is sensitive to the frequency of exposure to syntactic structures (Mitchell, Cuetos, Corley, & Brysbaert, 1995).

Finally, the present pattern of results can help further characterizing some ERP components. These findings are in line with the idea that the P600 reflects late controlled processes that are modulated by error probability and participants' conscious strategies (as in Coulson et al., 1998; Gunter et al., 1997; Hahne & Friederici, 1999). Secondly, our results in the native accent condition support the idea that the LAN reflects automatic processes (Gunter et al., 1997; 2000) since the LAN effect reported here did not change across experimental blocks. Finally, the lack of correlation between N400 and LAN effects within participants is not compatible with the idea that LAN effects are residual artifacts of N400 effects (Osterhout, McLaughlin, Kim, Greenwald, & Inoue, 2004; Tanner & van Hell, 2014).

Conclusion

Native speakers, in their interaction with non-native speakers, often have to deal with foreign accented sentences containing different types of grammatical errors. Not all these errors are equal in frequency, and some mistakes can be more frequent than others. The present study showed that the way native listeners treat morphosyntactic errors in foreign accented speech changes as a function of error typicality. Grammatical errors that are not typically produced by non-native speakers are likely to be detected and repaired. Grammatical errors that are typically produced by non-native speakers do not trigger late processes of reanalysis and repair. The present study shows that neural processes of morphosyntactic analysis can dynamically adjust to indexical cues as well as distributional regularities. Presumably, these speaker-dependent adjustments in signal processing facilitate successful communication between native and non-native speakers.

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Table 1. English age of acquisition (AoA) and proficiency of the 36 Spanish native participants.

	Mean (SD)
AoA (years)	7.3 (5.0)
Formal education duration (years)	10.5 (3.4)
English lexicon (tot: 100)	70.1 (7.4)
English grammar (tot: 100)	80.1 (10.0)

Note. English lexicon was assessed by using LexTALE (Lemhöfer & Broersma, 2012). The grammar test consisted of a grammatical judgement task on 40 English sentences. Half of the sentences were correct and the other half contained different types of grammatical violations (e.g., wrong tense, missing determiner, person disagreement etc.).

Table2

Table 2. Examples of experimental materials. Target nouns are underlined.

	Sentence example	Translation
Correct	▪ *De repente el color del cielo cambió.*	▪ Suddenly the$_{SM}$ color$_{SM}$ of the sky changed.
	▪ *Ayer el plan de la visita era bastante largo.*	▪ Yesterday the$_{SM}$ schedule$_{SM}$ of the visit was quite long.
	▪ *Para cuidar la mente es importante hacer ejercicio.*	▪ To take care of the$_{SF}$ mind$_{SF}$ it is important to do exercise.
	▪ *No encuentro la llave que estaba guardada en la caja.*	▪ I don't find the$_{SF}$ key$_{SF}$ that was in the box.
Gender	▪ *De repente la color del cielo cambió.*	▪ Suddenly the$_{SF}$ color$_{SM}$ of the sky changed.
	▪ *Ayer la plan de la visita era bastante largo.*	▪ Yesterday the$_{SF}$ schedule$_{SM}$ of the visit was quite long.
	▪ *Para cuidar el mente es importante hacer ejercicio.*	▪ To take care of the$_{SM}$ mind$_{SF}$ it is important to do exercise.
	▪ *No encuentro el llave que estaba guardada en la caja.*	▪ I don't find the$_{SM}$ key$_{SF}$ that was in the box.
Number	▪ *De repente los color del cielo cambió.*	▪ Suddenly the$_{PM}$ color$_{SM}$ of the sky changed.
	▪ *Ayer los plan de la visita era bastante largo.*	▪ Yesterday the$_{PM}$ schedule$_{SM}$ of the visit was quite long.
	▪ *Para cuidar las mente es importante hacer ejercicio.*	▪ To take care of the$_{PF}$ mind$_{SF}$ it is important to do exercise.
	▪ *No encuentro las llave que estaba guardada en la caja.*	▪ I don't find the$_{PF}$ key$_{SF}$ that was in the box.

Note. S: Singular; P: Plural; M: masculine; F: feminine.

Table 3. Lexical properties of the target nouns (extracted from the EsPal database, Duchon, Perea, Sebastián-Gallés, Martí, & Carreiras, 2013). Minimum and maximum values are given in parentheses.

	Mean	SD
Log frequency (0-4.9)	1.46	0.68
Nº letters	6.53	1.89
Nº phonemes	6.41	1.91
Nº syllables	2.46	0.75
Familiarity (1-7)	5.79	0.74
Imageability (1-7)	5.05	1.27
Concreteness (1-7)	4.92	1.10
Uniqueness point	7.39	1.92

Note. The phonological uniqueness point corresponds to the position of the first phoneme that enables to distinguish the word from other words.

Figure1

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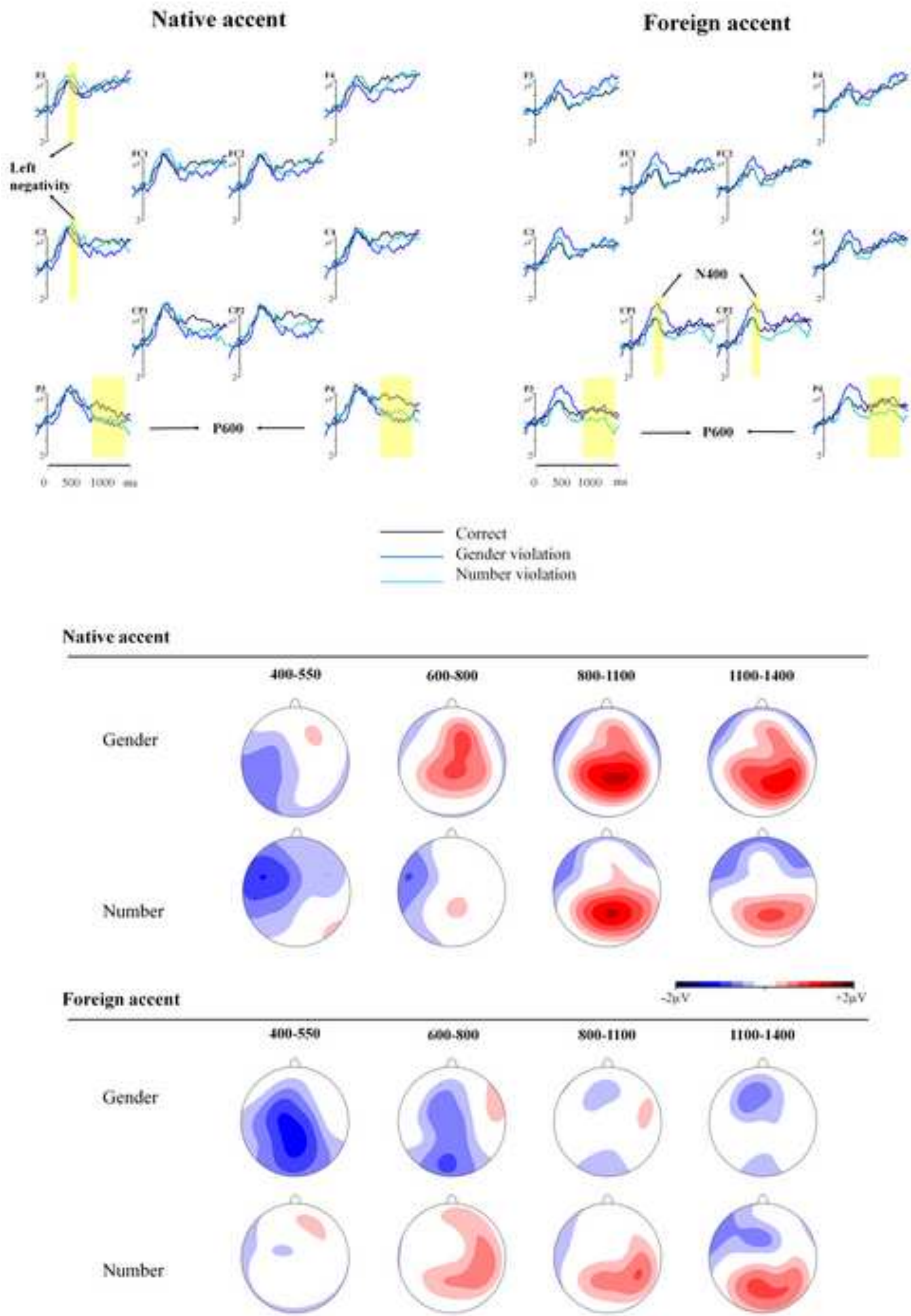

Figure2

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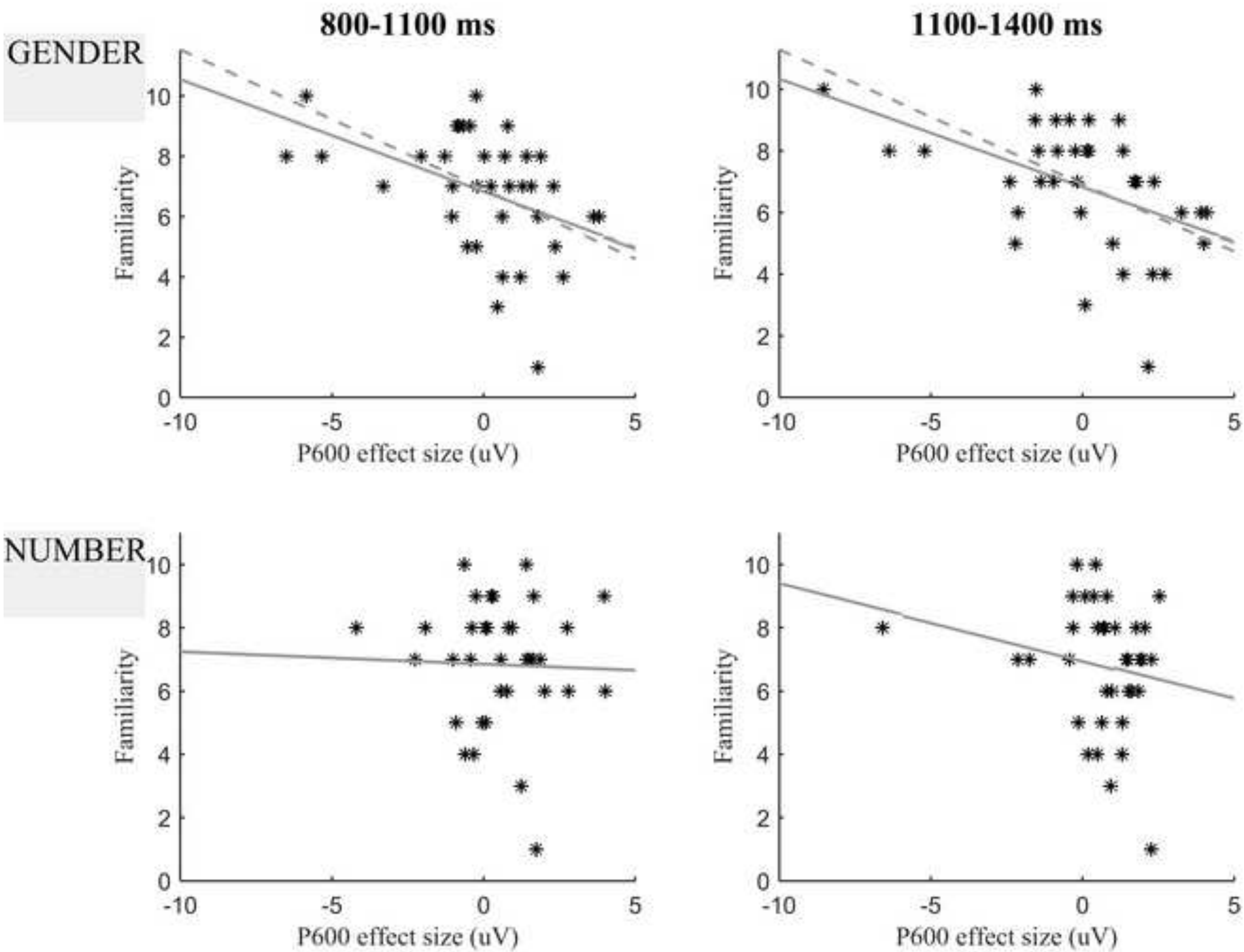

Figure3

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