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The impact of speaker accent on discourse processing: a frequency investigation

Trisha Thomas[12], Clara D. Martin[13], Sendy Caffarra[1456]

[1] Basque Center on Cognition, Brain and Language, San Sebastian, Spain
[2] Harvard University, 50 Church st, Cambridge, MA, 02138, USA
[3] Basque Foundation for Science (Ikerbasque)
[4] University School of Medicine, 291 Campus Drive, Li Ka Shing Building, Stanford, CA 94305 5101, USA
[5] Stanford University Graduate School of Education, 485 Lasuen Mall, Stanford, CA 94305, USA
[6] University of Modena and Reggio Emilia, Via Campi 287,41125 Modena, Italy

Author's note

Correspondence concerning this article should be addressed to Trisha Thomas, Harvard University Graduate School of Education, 50 Church st, Cambridge, MA, USA
Email: tbthomas4993@gmail.com; https://orcid.org/0000-0001-8323-1012.

Abstract

Previous studies indicate differences in native and foreign speech processing (Lev-Ari, 2018), with mixed evidence for differences between dialectal and foreign accent processing (Adank et al., 2009; Floccia et al., 2006, 2009; Girard et al., 2008). Two theories have been proposed: The Perceptual Distance Hypothesis suggests that dialectal accent processing is an attenuated version of foreign accent processing (Clarke & Garrett, 2004), while the Different Processes Hypothesis argues that foreign and dialectal accents are processed via distinct mechanisms (Floccia et al., 2009). A recent single-word ERP study suggested flexibility in these mechanisms (Thomas et al., 2022). The present study deepens this investigation by investigating differences in native, dialectal, and foreign accent processing across frequency bands during extended speech. Electroencephalographic data was recorded from 30 participants who listened to dialogues of approximately six minutes spoken in native, dialectal and foreign accents. Power spectral density estimation (1-35 Hz) was performed. Linear mixed models were done in frequency windows of particular relevance to discourse processing. Frequency bands associated with phoneme [gamma], syllable [theta], and prosody [delta] were considered along with those of general cognitive mechanisms [alpha and beta]. Results show power differences in the Gamma frequency range. While in higher frequency ranges foreign accent processing is differentiated from power amplitudes of native and dialectal accent processing, in low frequencies we do not see any accent-related power amplitude modulations. This suggests that there may be a difference in phoneme processing for native accent types and foreign accent, while we speculate that top-down mechanisms during discourse processing may mitigate the effects observed with short units of speech.

Keywords: speech, accent, spoken discourse processing, EEG

A frequency investigation of accent discourse processing

1. Introduction

In today's globally mobile society, the study of speech accents is more relevant than ever. Numerous studies have shown that unfamiliar or accented speech can impair comprehension due to the unique challenges it presents to listeners (Floccia et al., 2006; Munro and Derwing, 1995; Schmid and Yeni-Komshian, 1999; Anderson-Hsieh and Koehler, 1988; Major et al., 2002). As cross-cultural interactions become increasingly common, it is important to investigate the underlying mechanisms involved in processing non-standard speech in its multiple forms. Most studies focus on contrasting foreign accent with native accent using behavioral or evoked responses from electrophysiological (EEG) methods. Here we use a less common EEG technique to study how our brain responds to not only native and foreign accent but also dialectal accent.

While foreign accent is often the focus when discussing non-standard speech, dialectal speech can also be considered non-standard speech from the perspective of a native listener. A dialectal accent would come from a native speaker of the same language as the listener who is from a different county or geographical region. These accent types possess native phoneme variations, distinguishing them from foreign accents that often contain non-native variations resulting from the sounds or syntactic rules of the native language of the speaker. Because of these differences, this study aims to understand how dialectal accent is processed in relation to native and foreign accent.

It is generally agreed upon that foreign accent presents the greatest challenge to the listener as compared to native accent. Foreign accents are often identified more readily than dialectal accents and have a greater impairment on lexical retrieval (Girard et al., 2008; Floccia et al., 2009). However, the impact of dialectal accents remains understudied, and it is not clear what its impact is on brain responses compared to foreign and native accents. The findings of Girard and colleagues (Girard et al., 2008) and Floccia and colleagues (Floccia et al., 2009) seem to be in line with the Different Processes Hypothesis, which suggests that there are qualitative differences in the processing mechanisms recruited for dialectal and foreign speech normalization (Floccia et al., 2009). According to this hypothesis, the qualitative distinction between foreign and dialectal accent processing lies in the phonological familiarity of the accents and the cognitive mechanisms required for speech normalization. Dialectal accents involve native phonemes, allowing listeners to rely on pre-existing phonological categories, making adjustments within their familiar phonetic system. This results in more efficient processing. In contrast, foreign accents introduce non-native phonemes, requiring listeners to engage in more effortful cognitive processes, such as phoneme decoding and acoustic mapping, which are necessary to handle unfamiliar sounds. These processes often involve increased top-down processing, where listeners must rely on context and prior knowledge to compensate for phonetic unfamiliarity. This distinction reflects a fundamental difference in the type of processing mechanisms: dialectal accents involve adapting familiar sounds, while foreign accents necessitate processing unfamiliar, non-native phonemes, engaging different cognitive resources.

On the other hand, the Perceptual Distance Hypothesis offers a different perspective, suggesting that accents can be placed on a continuum based on their acoustic distance from native speech. According to this hypothesis, both dialectal and foreign accents are processed similarly, with the main difference being the degree of deviation from the native speech. Dialectal accents, being closer to native speech, are processed more efficiently, whereas foreign accents, being more acoustically distant, are processed with greater difficulty. This suggests that dialectal accents are essentially an attenuated version of foreign accents (Clarke & Garrett, 2004). Some behavioral studies have provided support for this hypothesis, with Adank and colleagues (Adank et al., 2009) reporting decreased processing speed as accents become less familiar or more foreign. An earlier study by Floccia and colleagues (Floccia et al., 2006) also provided evidence for this hypothesis when they found slower word recognition for words uttered in an unfamiliar dialectal accent, and even more slowly in a foreign accent.

In addition to behavioral techniques, EEG methods have been employed to investigate accented speech comprehension due to their ability to provide valuable time-sensitive information. One common technique for investigating the effects of accent on speech processing using electrophysiological methods is the Event-Related Potential (ERP) analysis. Event-related potentials (ERPs) are a type of neurophysiological measurement technique created by signal averaging used to study brain activity in response to specific events or stimuli. ERPs related to speech processing have shown that the time course of speech analysis changes as a function of accent.

Early evoked responses typically associated with phonological analysis have mainly shown differences between foreign and native accent, supporting the Different Processes Hypothesis (see Thomas et al., 2022; Goslin et al., 2012). In late evoked responses the results are more mixed, with some studies supporting the Perceptual Distance Hypothesis (see Jiang et al., 2020) and others the Different Processes Hypothesis (see Hanulíková et al., 2012). While ERP studies have been instrumental in understanding differences between processing mechanisms of native and non-native accented speech, because this technique reduces the complexity of the electrophysiological signal to one time-dependent variable, it does not allow for tracking multiple rhythmic processes occurring in parallel. Therefore, it is also useful to focus on the frequency domain of the EEG signal when studying linguistic processes, especially in the case of sentences and discourses where the rhythmic activity of the brain can be tracked over large time windows.

While time-based approaches, such as ERP analysis, can provide us with beneficial information, time-frequency methods offer two main advantages. They provide information about electrophysiological activity in a naturalistic situation (passive listening to continuous speech) and they are able to detect electrophysiological brain activity undetectable by ERPs, reflecting different parallel oscillatory patterns that are not time-locked to the presentation of a stimulus. Oscillations are thought to reflect the coordinated activity of large groups of neurons and may play a critical role in synchronizing neural processing across different brain regions. These oscillatory patterns are generally categorized according to their frequency bands: delta (< 4 Hz), theta (4-8 Hz), alpha (9-12 Hz), beta (13-25 Hz) and gamma (> 25 Hz). Power spectral density estimation is a time-frequency analysis that calculates the distribution of power in different frequency bands. Previous studies have linked different frequency bands to different aspects of speech processing, such as phonetic analysis, semantic processing, and syntactic integration.

In the field of linguistic research, three frequency bands have been characteristically linked to linguistic properties of speech: the delta, theta and gamma bands (for review, see Giraud & Poeppel, 2012; Grabot et al., 2017; Meyer et al., 2017). However, significant research on sentence processing has also correlated changes in beta band power with linguistic processes, particularly in relation to semantic and syntactic predictions. In comparison, the alpha band has been less frequently investigated in this domain, although some studies suggest its involvement in general cognitive functions that support linguistic tasks.

Within low-frequency ranges (i.e., delta and theta), it has been long suggested that theta oscillations reflect syllable tracking. Peña and Melloni found that theta power was higher when listening to forward utterances as opposed to backward ones (which disrupt the syllabic structures of the utterance), suggesting that theta power is involved in tracking syllable patterns (Peña & Melloni, 2012). Several studies have provided evidence that theta oscillations synchronize with syllable onset (Luo & Poeppel, 2007; Howard & Poeppel, 2012; Peelle et al., 2013; Doelling et al., 2014) and thus aid in the identification of syllable boundaries. Limited additional studies have also suggested that theta oscillations may be additionally involved in lexical-semantic retrieval (Bastiaansen et al., 2008) and syntactic processing (Bastiaansen et al., 2002). Delta bands have been linked to intonation or prosodic processing due to their phase coherence with the pitch contour of speech (Giraud & Poeppel, 2012; Bourguignon et al., 2013; Mai et al., 2016).

Within high-frequency ranges (i.e., beta and alpha), more previous research has been done on gamma oscillations' role in speech processing. Traditionally, synchronization of the gamma band amplitude has been suggested to reflect phonemic-categorical perception (Lehongre et al., 2011). Ortiz-Mentilla and colleagues found that even as early as 6 months of age, high gamma power is enhanced during the discrimination of native phoneme contrasts, suggesting that it plays an early role in the perception and categorization of phonemic features, allowing for preferential processing of native phoneme contrasts (Ortiz-Mantilla et al., 2013). While low gamma synchronization has been linked to acoustic processing (Gross et al., 2013). The Beta frequency band has also been correlated with linguistic processes. It has been shown to decrease in situations of mismatch between semantic predictions and reality (Lewis & Bastiaansen, 2015; Lewis et al., 2016; see also Weiss & Mueller, 2003 for beta band power role in semantics). The mid-range alpha frequency, however, is mostly attributed to more general cognitive functions and has been classically related to the inhibition of task-irrelevant information (for review, see Klimesch et al., 2007) and suppression of cortical excitability (Jensen and Mazaheri 2010). Despite alpha being associated most prominently with generalized top-down mechanisms, some previous works have provided evidence that it may play a role relevant to sentence comprehension in verbal working memory (Krause et al., 1996; Maltseva et al., 2000; Jensen et al., 2002; Sauseng et al., 2005; Leiberg et al., 2006).

While there are many studies linking various neural oscillations to linguistics processes, very little work has been done to differentiate dialectal and foreign accents in the frequency domain (but see Pérez et al., 2015). While behavioral and ERP studies have provided evidence for both previously proposed hypotheses, this is the first study to our knowledge comparing neural oscillations of foreign, dialectal and native accent perception. Examining discourse through the frequency domain allows us to see how speech accent affects brain rhythmic activities at different frequency ranges thus enabling us to understand the robustness of previously observed evidence in favor of either the Perceptual Distance or Different Processes Hypothesis.

1.1. The Present Study

The present study aims to investigate how the brain processes accented speech across different frequency bands using electrophysiological methods. We critically evaluate the aforementioned previously proposed hypotheses of accented speech processing in order to clarify the processing of foreign, dialectal and native accented speech. Special attention is placed on disentangling how we process dialectal accent from both native and foreign accent during the listening of short stories. Analyses include Power spectral density estimation for each accent condition because of its relevance to EEG analysis of extended speech. Specifically, we focus on Delta, (1-3 Hz) Theta (4-8 Hz) and Low Gamma (25-35 Hz) waves, associated with prosodic, syllabic and phonemic processing, respectively (see Meyer, L., 2017 for a review).

The Different Processes Hypothesis and the Perceptual Distance Hypothesis were not developed for a specific level of language analysis. Hence we will apply and test their predictions across all frequency bands. The Different Processes Hypothesis suggests that dialectal accents, due to their use of native phonemes and familiar phonological rules, will be processed similarly to native accents, with a categorical distinction between native/dialectal and foreign accents in the delta, theta, and low gamma bands. This suggests that the predicted native/non-native dichotomization should be particularly evident in the low gamma band, which reflects phonological analysis, as dialectal accents rely on the same phonemic categories as native speech. In contrast, the Perceptual Distance Hypothesis predicts a gradient in power amplitude across all frequency bands, with dialectal accents falling between native and foreign accents, reflecting their relative acoustic distance from native speech.

2. Materials & Methods

2.1. Participants

Thirty Spanish natives[1] participated in the study. One participant was excluded due to low performance on the target detection task (see method section for further explanation of this task; mean accuracy of this participant: 37.5%). Another participant was excluded for low comprehension question performance (mean accuracy: 53.3%). The final sample of participants

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[1] Due to their geographical location in the Basque Country, all participants were also fluent in Basque as early L2

consisted of 28 females[2] (mean age: 22.7 years, *SD*: 3.56, age range: 19-31 years, Spanish age of acquisition: 0). All participants lived in the Basque country and considered the Basque-Spanish accent as their native accent. All participants were right-handed and had normal or corrected-to-normal hearing and vision. No participant reported a history of neurological disorders. All participants reported low familiarity with both Cuban and Italian accents, with exposure amounting to less than 2 hours per week for all participants. Specifically, only two participants indicated any exposure to Cuban-accented Spanish, and another two reported exposure to Italian-accented Spanish. Participants also reported limited familiarity with other dialectal and foreign accents. Eighty-five percent of participants reported less than 10 hours per week of exposure to dialectal accents, while 90% of participants reported less than 10 hours per week of exposure to foreign accents. All participants signed an informed consent form before taking part in the study that was approved by the Basque Center on Cognition, Brain and Language ethics committee. They received monetary compensation for their participation.

2.2. Materials

Three dialogues were recorded by six female speakers in their thirties with differing accents. Each dialogue was recorded by two speakers of the same accent (native, foreign, dialectal). Each pair of same-accent speakers recorded the three stories (total of recorded stories: 9). Story type and pair of speakers were fully counterbalanced so that each participant listened to dialogues produced by each pair of speakers without repetition of the same story (total of 3 stories presented). Stories were recorded in a Basque-Spanish native accent, a Cuban-Spanish

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[2] Only females were recruited for this study in order to avoid cross-gender listening effects (Banaji and Hardin, 1996; Cacciari and Padovani, 2007)

accent and an Italian-Spanish accent (i.e., hereafter native, dialectal and foreign accent, respectively). The native speakers were born and lived in Spain (Basque country). The dialectal and foreign speakers were chosen for their strong accents and high level of Spanish (in the case of the Italian speakers).

Each accent brings distinct phonological and prosodic characteristics to the recordings. Basque-accented Spanish typically features stronger syllable-timing and distinct intonational patterns influenced by the Basque language. Basque speakers tend to produce slightly longer vowels and have a less varied intonation compared to standard Spanish. Additionally, Basque-accented Spanish often includes fricative sounds and aspiration of certain phonemes, particularly in the pronunciation of "s" (Hurch, 2013; Frota et al., 2020). Cuban-accented Spanish, representing a dialectal variation, is characterized by consonant weakening (e.g., dropping of final consonants, particularly "s"), vowel reduction, and a fast speech rate. Cuban Spanish also exhibits strong intonational variation, often with a rising intonation at the end of sentences. Additionally, there is a notable aspiration of "s" in casual speech, which differs from both Basque-accented and standard Spanish (Jajo-Yacoub et al., 2023). Italian-accented Spanish reflects the influence of Italian phonology, particularly in the hyperarticulation of vowels and word endings, as Italian is a vowel-timed language. Italian speakers often maintain clear, distinct vowel sounds, which can result in hyperarticulation compared to native Spanish speakers. Additionally, Italian-accented Spanish tends to exhibit intonation patterns similar to Italian, including rising intonation and stress patterns that differ from both Basque and Cuban-accented Spanish (Giavazzi & Krämer, 2009; Gili Fivela et al., 2015).

Overall, the recordings did not significantly differ in duration (ms) across accents [foreign: 519.7, *SD*:128.7; native: 505.7, *SD*: 137.2; dialectal: 519.9, *SD*:131.6; one way

ANOVA: ($F(2,117) = 0.15$, $p = .86$)]. Accent strength ratings were collected from a separate normative study consisting of eleven participants (average age =23, *SD*=10) who completed a short online survey where they listened to clips of each accent and rated the accent strength from 1 (mild accent) to 5 (strong accent). Results showed an effect of accent (one-way ANOVA: $F(2,10)=6.01$, $p = .009$). Follow-up analyses of the clip ratings corrected with the Fisher's Least Significant Difference (LSD) showed that the dialectal accent was not significantly different from the native accent ($t(10)=2.13$, $p = .06$), the foreign accent was significantly different from the native accent ($t(10)=3.16$, $p < .001$) and the dialectal and foreign accents were not rated significantly different from each other in terms of strength ($t(10)=1.15$, $p = .28$). After applying a Bonferroni correction (corrected *p* threshold = 0.017), the comparison between the foreign accent and the native accent remains significant ($p < .001$), while the other comparisons do not reach significance. Ten comprehension questions for each dialogue were also created[3].

2.3. Procedure

Participants carried out a blocked-design experiment consisting of 4 blocks, three speech blocks and one silence block[4]. Participants were seated in a sound-attenuated room in front of a computer screen and were asked to listen to narrative dialogues (or silence) and occasionally perform a target detection task to maintain their attention by pressing the spacebar with both index fingers when they heard certain target words ("amigo/a/os/as"). After each block, they filled out a questionnaire with 10 comprehension questions about the dialogue. Each block consisted of a dialogue (or silence) presented through speakers while a fixation cross was displayed on the screen throughout the entirety of the dialogue. The experimental session lasted

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[3] See appendix for list of questions

[4] This was added as a potential baseline in case the EEG of our preferred baseline (the pre-target silent segment) would have been too noisy

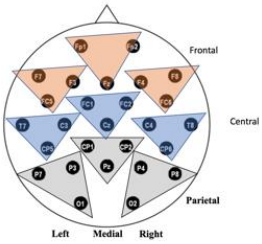
about an hour. During the silence block, participants still occasionally heard the target words and had to press the spacebar. The block order was counterbalanced across participants.

2.4. EEG Data Recording and Time-Frequency 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 (see Figure 1). 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 250 Hz. Impedance was kept below 10 KΩ for the external channels and below 5 KΩ for the electrodes on the scalp. A low-pass filter of 30 Hz and a high-pass filter of 0.01 Hz were applied. A low-pass filter of 30 Hz was applied only to improve the ICA performance and detect the independent components responsible for ocular artifacts; the resulting ICA weights were then applied to the original unfiltered recording (see Dimigen, 2020; Hyvärinen et al., 2001; Klug & Gramann, 2020; Winkler et al., 2015). Vertical and horizontal eye movements were corrected by performing an Independent Components Analysis (ICA). The fastICA method was used. Time-frequency analysis of continuous EEG data was done with a Morlet wavelet decomposition using MNE software (Gramfort et al., 2013). This method was used to decompose trial time-frequency values between 1 and 35 Hz for the 27 electrodes placed on the scalp (steps = 13). The average total power values were baseline-corrected with a log ratio. We used the pre-target 500 ms silent period (-500 to 0 ms) as a baseline. For each accent condition and frequency range, the resulting power was averaged across time and channels.

Figure 1

Schematic of electrode montage with topographic organization labeled



3. Results

3.1. Behavioral Results

Participants showed average accuracy during the online target detection task meant to test attention (mean overall accuracy: 71.4%, *SD*:13.2)[5]. Participants showed high accuracy on comprehension question performance (mean overall accuracy: 83.6%, *SD*:8.7). Importantly, accuracy in target detection (*F*(2, 81) = 1.67, *p* = .19) and comprehension questionnaire (*F*(2, 82) = 0.15, *p* = .86) did not significantly differ across the three accent conditions (target detection: *p* = .10 for Native vs. Italian, *p* = .90 for Native vs. Cuban, and *p* = .09 for Cuban vs. Italian; comprehension: *p* = .81 for Native vs. Italian, *p* = .87 for Native vs. Cuban, and *p* = .92 for Cuban vs. Italian; all p-values > .05). The average accuracy in target detection across the accent conditions was as follows: Native (*M* = 65.38, *SD* = 20.51), Cuban (*M* = 71.79, *SD* = 16.85), and Italian (*M* = 64.74, *SD* = 21.25). The comprehension questionnaire scores were: Native (*M* = 0.80, *SD* = 15.28), Cuban (*M* = 0.87, *SD* = 15.17), and Italian (*M* = 0.92, *SD* = 15.22).

3.2. Time-Frequency Results

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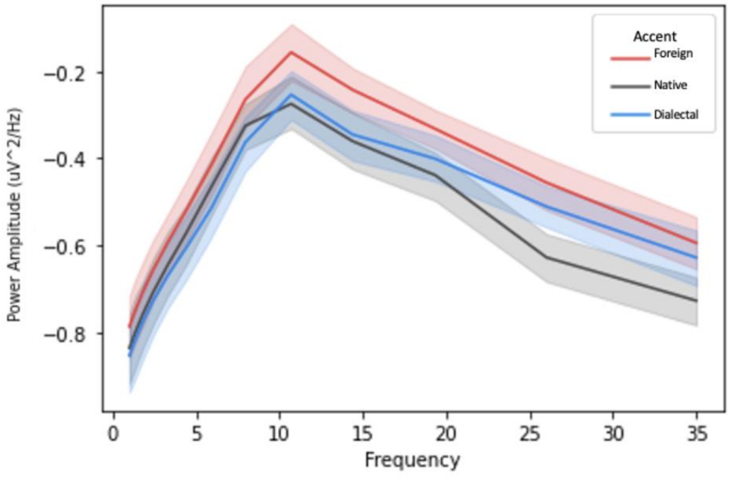
[5] Mean overall accuracy includes the silent block, without silent block mean overall accuracy is 67.31 (*SD*:15.02).
Accuracy was not very high, but note that participants had to pay attention to the information provided in the dialogue together with tracking the words amigo(s)/amiga(s) which accounts for an accuracy not approaching ceiling. Targets appeared 24 times in each text.

Average power amplitude modulation in the EEG of participants was analyzed with a mixed linear model with participants as random intercept and accent as a fixed factor (native, dialectal and foreign). An accent effect was observed only within the gamma frequency range, see Figure 2.

Figure 2

Power amplitude modulation in the EEG across accents

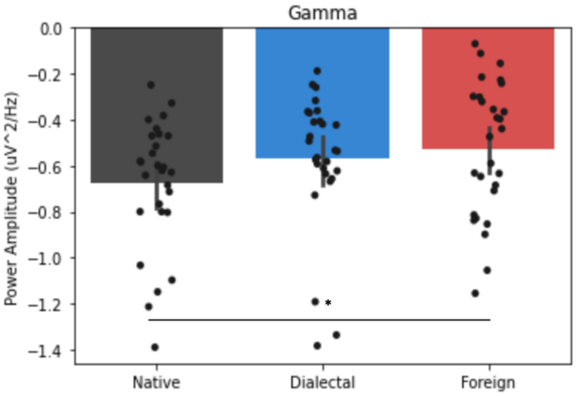


Gamma (25 to 35 hz) phoneme

In gamma frequencies, we found a significant difference between native and foreign accents (native vs. foreign: *β* = 0.15, *SE* = 0.08, *t* = 1.97, *p* = .048). However, no difference was found between dialectal accent and either native or foreign accent (native vs. dialectal: *β*=0.11, *SE* = 0.08, *t*=1.40, *p* = .16; foreign vs. dialectal: *β* = -0.04 *SE* = 0.08, *t* = 0.58, *p* = .56; see Figure 3).

Figure 3

Average Gamma power between accents, CI = 95



In Delta, Theta, Alpha and Beta frequencies, we did not observe any power difference between the three accents (see Table 1, Figure 4).

Figure 4

Average power between accents, CI=95

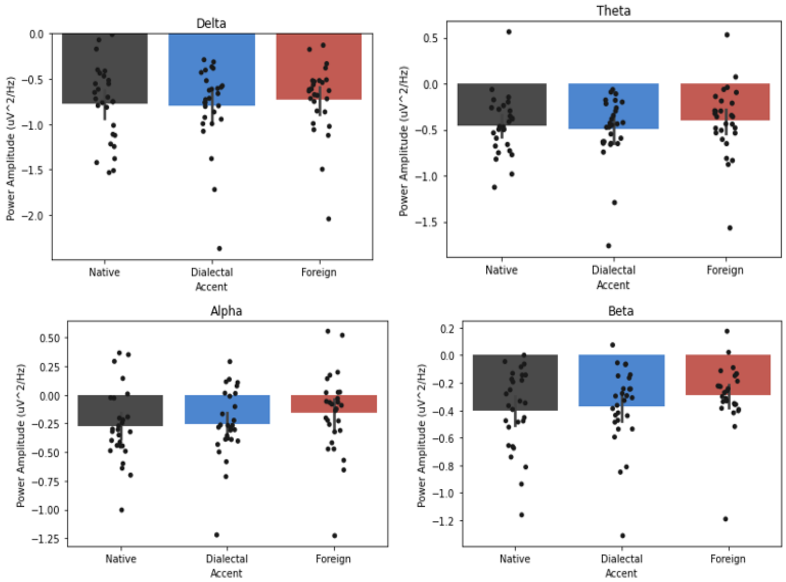


Table 1

Summary of Mixed Linear Model Results for Non-Significant Effects

Frequency band	Accent contrasts	*β*	*SE*	*t*	*p*
Delta (1 to 3 hz) prosody	native vs. dialectal native vs. foreign foreign vs. dialectal	-0.02 0.05 -0.07	0.09 0.09 0.09	0.19 0.53 0.72	.84 .60 .47
Theta (4 to 8 hz) syllable	native vs. dialectal native vs. foreign foreign vs. dialectal	-0.04 0.05 -0.09	0.08 0.08 0.08	0.66 0.49 1.15	.62 .51 .25
Alpha (9 to 12 hz)	native vs. dialectal native vs. foreign foreign vs. dialectal	0.02 0.12 -0.10	0.08 0.08 0.08	0.26 1.48 1.21	.79 .14 .22
Beta (13 to 24 Hz)	native vs. dialectal native vs. foreign	0.03 0.11	0.07 0.07	0.39 1.66	.69 .10

	foreign vs. dialectal	-0.08	0.07	1.27	.21

Note. Summary of mixed linear model results for each frequency range which show a lack of significant differences between accents

4. Discussion

This study aimed to advance previous investigations of online accented speech processing through the lens of oscillatory activity power amplitude fluctuations during listening to different speech accents. We further aimed to better understand the similarities and/or differences between mechanisms of dialectal and foreign-accented speech processing by examining the results in the context of two hypotheses of accented speech processing: the Different Processes Hypothesis and the Perceptual Distance Hypothesis.

Previous studies have mostly been conducted at the level of the single word and have emphasized processing differences between native and foreign speech processing (Lane, 1963; Lev-Ari & Keysar, 2012; Lev-Ari, 2017; Munro & Derwing, 1995; van Wijngaarden, 2001). But whether native listeners process native category variations, i.e. dialectal accent, according to acoustic distance from native speech (Perceptual Distance Hypothesis) or with ‘nativeness’ as a processing category (Different Processes Hypothesis) is less clear.

This study examined these hypotheses by investigating how the brain processes accented speech across different frequency bands using electrophysiological methods. We focused on Delta, (1-3 Hz) Theta (4-8 Hz) and Low Gamma (25-35 Hz) waves, because of their previous association with prosodic, syllabic and phonemic processing, respectively. The low Gamma band was of particular interest because of its relation to phonemic processing. We also considered Alpha and Beta because of their relation to attentional processing and top-down mechanisms.

Unlike studies employing event-related potentials (ERP) that focus on time-domain analyses, our research examined how different speech accents (native, dialectal, and foreign) modulate power in various EEG frequency bands (delta, theta, alpha, beta, and gamma). Interestingly, while many ERP studies (including our own, see Thomas, Martin, & Caffarra, 2022) have demonstrated significant differences in listeners' processing of native and foreign accents, our study revealed no significant differences in power amplitude across most frequency bands (delta, theta, alpha, and beta), except for a significant distinction in the lower gamma band.

We found a significant difference between the power amplitude of native and foreign accent in the low gamma frequency range with no clear evidence on whether dialectal accent is differentiated from native accent. Because of this, we ran an exploratory follow-up Bayesian analysis to understand the nature of the null effect between dialectal and native accent. This analysis provided weak support for the null hypothesis (BF: 0.89) and thus evidence that dialectal accent phoneme processing is similar to native accent phoneme processing. This finding shows that unique processing mechanisms are required for the phonological processing of foreign accent throughout discourse processing as compared to native accent types.

This provides evidence for the Different Processes Hypothesis by supporting differential processing for non-native accent but not for dialectal accent as compared to native accent. This is perhaps due to the ‘nativeness’ of the deviations in dialectal pronunciation, meaning that ‘coherent deviations’ (see Wells, 1982; Goslin et al., 2012) of the speech in a dialectal accent are easily adapted to by listeners while foreign deviations make acoustic extraction more difficult. However, it is important to consider the potential influence of accent strength on the observed differences in gamma-band power between native and foreign accents. Foreign accents were rated as significantly stronger than both native and dialectal accents, while native and dialectal accents were rated similarly in terms of strength. This raises the possibility that the observed differences in gamma power could reflect differences in accent strength rather than accent type (foreign vs. dialectal).

Conversely, it is also important to recognize that systematic differences exist between foreign and dialectal accents, beyond just accent strength. Specifically, foreign accents often involve non-native phonemes, which can engage different cognitive and neural mechanisms compared to dialectal accents, which typically consist of phonetic variations within the listener's native phonological system (see Lane, 1963; Munro & Derwing, 1995). Non-native phonemes in foreign accents may pose unique challenges for listeners, particularly at the phoneme-processing level, where gamma-band oscillations are thought to play a critical role. This suggests that the differences we observed in gamma power are likely driven not only by accent strength but also by the phonological characteristics of foreign vs. dialectal speech.

While accent strength may contribute to these effects, it is likely that the nature of the phonemes themselves (native vs. non-native) plays a significant role in the observed neural responses. Unfortunately, due to the limited number of trials and speakers in each condition, we were unable to analyze individual differences in accent strength across speakers within each accent category. Future research should aim to systematically vary both accent type and strength to disentangle these factors and better understand their influence on phonemic processing in the gamma frequency range.

These findings seem to align with previous ERP studies of accent processing, including a previous study on single-word processing (see (Thomas et al., 2022) but see (Goslin et al., 2012). In Thomas et al.’s study, we found a difference between foreign and both native accent variations (native and dialectal) at early ERP components associated with the extraction of acoustic features. Similarly, at ERP components associated with lexico-semantic integration, we no longer observed accent differences. This pattern is somewhat echoed in the present results, where foreign-accented speech primarily affected the phonological processing stage, as captured by lower gamma power amplitude. However, no significant effects were observed in higher-order cognitive processes, such as attention (as indexed by alpha-band activity), or in broader frequency windows typical of delta and theta bands.

The divergence between ERP and oscillatory power analyses likely stems from the different types of neural activity they capture and the experimental paradigms they require. While ERPs reflect only evoked activity, oscillatory analyses capture both evoked and induced activity, providing an alternative and broader view of brain dynamics. Additionally, ERPs often require less naturalistic, highly controlled paradigms (e.g., rapid serial visual presentation) to ensure temporal consistency across trials, whereas oscillatory analyses can be performed in more ecologically valid contexts, such as listening to natural speech. Furthermore, oscillations tend to have a higher signal-to-noise ratio, making them particularly suited for detecting neural processes related to phonological processing, as observed in gamma-band activity processing (Bastiaansen & Jensen, 2012).

The results of the present study similarly suggest that non-native accent affects early stages of phoneme processing both at single-word and discourse levels. They further suggest that these effects are uniquely seen for non-native accents rather than unfamiliar native variations. These results contribute to the literature supporting the Different Processes hypothesis and further support the idea of a binary native/non-native processing mechanism in the more naturalistic setting of extended discourse. Furthermore, accent seems to have the largest effect on phonological analysis while successfully resolved in the semantic processing phase.

Previous studies show that listeners employ top-down resources to process speech in challenging situations, engaging contextual cues, predictive processing, and prior knowledge about the topic to enhance comprehension (Dave et al., 2021; Foucart et al., 2015; cf. Schiller et al., 2020). However, in the alpha frequency band, associated with top-down mechanisms and attentional control/inhibition, we did not observe any significant effects. This is surprising in light of the previous findings, as we may expect to see some engagement of inhibitory processing in attentionally demanding situations, especially given the lingering effects of both dialectal and foreign accent-delivered speech on memory. Thus, whether accent is truly resolved at the phonological level or simply mitigated by the engagement of top-down strategies remains to be further explored and should be additionally scrutinized in future studies. Additionally, future research would benefit from combining ERP and time-frequency band analyses to explore the neural dynamics involved in processing native, foreign, and dialect-accented speech. ERPs provide insights into evoked neural responses to phonetic deviations, while oscillatory analyses capture both evoked and induced activity. Oscillatory analyses, in particular, provide a window into the dynamics of the coupling and uncoupling of functional networks involved in cognitive processing (see Bastiaansen & Jensen, 2012). By integrating these approaches, we can gain a deeper understanding of how different cognitive processes, such as phonological processing and attention, interact during speech comprehension, particularly in naturalistic contexts.

4.1. Conclusion

We found that while in higher frequency ranges, power amplitudes of foreign accent processing are differentiated from power amplitudes of native accent processing, we do not see any accent-related power amplitude modulations in low frequencies. This suggests that while the native/non-native accent distinction modulates the way we process speech at the phonological level, it does not necessarily have an effect at higher levels of processing (i.e., lexicon and semantics).

Conflict of interest

The authors declare no competing financial interests.

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Data availability statement

Code and data to reproduce the reported findings are available at [INSERT URL UPON PUBLICATION]

Author contributions

All authors contributed to the conceptualization of the study. SC and CDM performed the data collection. TT performed the data analysis and carried out the initial manuscript preparation. TT, CDM, and SC collaborated on the final version of the manuscript.

Ethics approval statement

The study was approved by the Basque Center on Cognition, Brain and Language Ethics Committee.

ORCID

TT: https://orcid.org/0000-0001-8323-1012

SC: https://orcid.org/0000-0003-3667-5061

CDM: https://orcid.org/0000-0003-2701-5045

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Appendix

List of comprehension questions

Dialogue 1

(Spanish)
1.¿Durante qué momento del día transcurre el diálogo?
2. ¿Qué está intentando abrir Emma?
3. ¿Qué oficios tienen los personajes?
4. ¿A quién quiere parecerse Emma?
5. ¿Qué tipo de temperatura hace en el exterior?
6. ¿Quién había avisado a Sara de que desconfiase de cierta persona?
7. ¿Cuál es la palabra que empieza por R y que le da miedo a Sara?
8. Mientras hablan ¿está la lámpara encendida?
9. ¿Qué bordan las señoritas de la casa?
10. ¿Qué desayunan los personajes?

(English)
1. During what time of day does the dialogue take place?
2. What is Emma trying to open?
3. What jobs do the characters have?
4. Who does Emma want to seem like?
5. What temperature is it outside?
6. Who had warned Sara that she should distrust a certain person?
7. What is the word that begins with R and that scares Sara?
8. While they are talking, is the lamp on?
9. What do the ladies of the house embroider?
10. What do the characters eat for breakfast?

Dialogue 2

(Spanish)
1.¿A dónde quiere ir Anna?
2.¿En qué tipo de transporte dice Anna que irá?
3.¿Dónde pueden trabajar las mujeres de la ciudad que están solteras?
4.¿Qué les dan a las mujeres que trabajan en la ciudad?
5.¿En qué siglo se desarolla la conversación?
6.¿De quién está enamorada Anna?
7.¿Anna tiene padres?
8.¿Qué cosa se compraría Anna con el dinero ahorrado?
9.¿Quiénes leerán la carta a Elena?
10.¿Qué le pasaría a Elena si le pasara algo malo a Anna?

(English)
1.Where does Anna want to go?
2.What type of transportation does Anna say she will go on?

3.Where can single women in the city work?
4.What do they give to women who work in the city?
5.In what century does the conversation take place?
6.Who is Anna in love with?
7.Does Anna have parents?
8.What would Anna buy with the money saved?
9.Who will read the letter to Elena?
10.What would happen to Elena if something bad happened to Anna?

Dialogue 3

(Spanish)
1.¿A qué temía Carla?
2.¿Qué estaba haciendo la mujer de la casa de enfrente?
3.¿Qué le ofrece Carla a María para beber?
4.¿Cómo se llama el chico que estaba antes en la casa?
5.¿El hermano de María se fue a Israel hace 10 años?
6.¿Cómo se llama el hermano de María?
7.¿Qué les calentaría el cuerpo y les proporcionaría alegría?
8.¿Dónde trabaja Carla?
9.¿Cómo se siente María después de charlar con Carla?
10.¿Qué personajes se inventan Carla y María tomando el té?

(English)
1.What was Carla afraid of?
2.What was the woman from the house across the street doing?
3.What does Carla offer María to drink?
4.What is the name of the boy who was in the house before?
5.Did Mary's brother go to Israel 10 years ago?
6.What is the name of María's brother?
7.What would warm your body and bring you joy?
8.Where does Carla work?
9.How does María feel after chatting with Carla?
10.What characters do Carla and María invent while having tea?