# Effect of Accent Familiarity on Language Processing via Alpha and Beta Brain Wave Activity

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Language is one of the defining characteristics of human social interactions and, as such, has been a main focus of scientific research over the years. Human speech is widely varied with multiple different languages and further diversified by the presence of accents. The current study was designed to test the effects of familiarity of geographically diverse accents on the amplitudes of relaxed, i.e., alpha (~10 Hz), and alert, i.e., beta (~20 Hz), brain waves. It was expected that accents that were easier to understand, or more familiar, would present with more alpha wave activation, demonstrating a more relaxed state due to easier understanding, while accents that were harder to understand, or less familiar, would present with more beta wave activation, demonstrating a more alert state due to increased focus necessary for speech comprehension. Alpha and beta wave activation was measured by placing electrodes on the scalp to record the differences across several areas on the surface of the brain and presenting clips of varying accents in spoken English to the participants. Beta waves recorded showed no significant difference between any of the groups in the study. However, alpha waves showed multiple different significant results: the amplitudes showed an overall decrease as the location associated with the speaker's accent increased in geographical distance from the testing location, and there was an interaction between location and familiarity to foreign accents. These results suggest that more foreign accents do have an effect on the amplitudes of alpha waves and that there is some connection between experience with foreign accents and these effects.

Abbreviations: EEG – Electroencephalography; FFT – Fast Fourier Transform; ERD – event related desynchronization; ERP – event-related potential

Keywords: Electroencephalography; Alpha Wave Activation; Beta Wave Activation; Accented speech

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## Introduction

Spoken language is essentially a human ability that has long differentiated us from other mammals. There are roughly 6,500+ different spoken languages in the world today and an even greater amount of accent variations of those languages (Anderson, 2004). Spoken language is a key form of human communication, as it is able to convey a wide range of expressions that other animals are largely unable to do (Fitch, 2000). A wide range of studies has focused on spoken language and how it interacts and is ultimately linked to our brains.

Dufour et al., (2013) measured event-related brain potentials, or ERP, to determine differences in processing over time for different vowel discriminations in regional accents. By comparing several different regionally-accented vowel groupings, they found that there was an electrophysiological difference between the vowel pairings compared to one single vowel presentation. When detecting differences between the vowel pairs, processing occurred at different times: 200 ms after the stimulus presentation for the control pair, 300 ms after the first test-pair presentation, and 300 ms after stimulus presentation for one pair when regional speakers were tested. The control pair contained a word form that speakers from both regions would be familiar with, while the test pairs contained a letter sound that did not exist in the language variation of one of the regions they tested (Dufour et al., 2013). Results from this study showed that determining differences between regional pronunciations of vowel pairs occurs later in processing than discriminations for control vowel pairs. This is important, as many foreign languages either lack or have different pronunciations for the same word(s), and this shows that there is an impact on processing speed for unfamiliar pronunciations.

Goslin et al. (2012) investigated the processing of regional and foreign accents via ERPs. They were specifically looking at two possible hypotheses: the Perceptual Distance Hypothesis and the Different Processes Hypothesis. The former hypothesis states that the mechanism responsible for regional accent processing is a more refined, or attuned, version of the same processing that would be used for a completely foreign accent. The latter hypothesis suggests that the processing for regional and foreign accents would be distinct in a cognitive, and perhaps neural, locus. Using three accents, each of varying distance from the regional area of the study, they found that more local, and familiar, accents are more easily processed due to more cohesion with their personal lexicon, and foreign accents require more processing due to the addition of elements from a foreign lexicon, thus supporting the Different Processes Hypothesis (Goslin et al., 2012). Since the Different Processes Hypothesis states that the method for processing regional and foreign accents would be different, it would support our idea behind this study that there might be a range of different processing responses depending on the foreignness of an accent.

A study done by Del Giudice et al. (2014) looked at the effects of familiarity of voices, as well as the sound of the subject's own name, on the production of brainwaves. They found that familiar voices, and the utterance of subjects' own names, elicited a strong alpha event-related desynchronization (ERD). This alpha level ERD correlates to a decrease in alpha waves and a subsequent rise in beta activity. This is because alpha waves (~10 Hz) have been associated with a relaxed feeling and, conversely, beta waves (~20 Hz) have been associated with a state of arousal/awareness. Del Giudice et al. (2014) attribute this to the participants engaging additional neural resources when listening to a personally relevant stimulus. We believe that a similar reaction may be occurring when a participant listens to a more familiar accent in comparison to a foreign one.

The present study investigates gaps in previous research examining the effects of accent familiarity on the alpha and beta brain waves in humans. While previous research has examined the effects of native, regional, and foreign accents on brain activity, the current study examines the effects of participants' experiences, or familiarity, with various accents on alpha and beta waves. We predict that accents that are more familiar to an individual will cause an increase in alpha brain wave activity. This is because it is much easier to understand someone speaking in a more familiar accent and thus reduces the amount of processing required to understand what is being said. Additionally, we predict that the more unfamiliar an accent is to an individual, the greater will be the increase in beta brain activity that will be observed. This is due to the increased brain processing that is generally needed to understand an individual that has a more foreign accent.

## Material and Methods

### *Participants*

Twelve right-handed, undergraduate students from Roanoke College in Salem, Virginia, who ranged in age from 20-22 years-old, were recruited for the experiment. Only right-handed people were used because previous research has shown that brain organization of the language processing center has the potential to be nonuniform in left-handed individuals and this could have a negative impact on the data by making it unreliable (Knecht et al., 2000). For the purpose of balancing, the researchers recruited approximately six male participants and six female participants. All participants were required to have normal audition and no pre-existing neurological conditions, and willing to give signed consent to participate in this study.

*Equipment*

The EEG signals were recorded using PowerLab 26T. The analog input from the electrodes was amplified and converted to digital form by the PowerLab 26T manufactured by AD Instruments, Inc., Colorado Springs CO before being sent to a computer for additional processing by LabChart 7 software. A signal sent from an external Cedrus StimTracker device to the same computer indicated the time that stimuli were presented, which LabChart 7 software recorded. A Dell XPS 15z laptop computer ran the LabChart 7 software and presented on an external monitor that the experimenter could view but not the participant. SuperLab 4.5 presented the stimuli on the monitor of the laptop.

*Stimuli*

The stimuli for this experiment included four different male speakers, each of whom were from places of varying distance from Salem, Virginia. Four types of accents were presented in recordings based on differing levels of familiarity. The places of origin that were chosen were: Maryland, Kentucky, England, and the Ukraine. These locations were meant to represent Standard or minimally accented American, Southern American, English, and Ukrainian accents respectively. The main criteria for choosing these places was based on distance, and therefore hopefully familiarity with the accents, from Salem, Virginia. The recordings used in this project are used by special permission of the International Dialects of English Archive (IDEA), online at http://www.dialectsarchive.com.

Clips of at least 60 seconds (mean 65.9 s, standard deviation of 6.5 s) were obtained from different places in each of the male speakers' original voice recordings (See Table 1). The speakers all told personal stories about themselves and/or read from a scripted story. All clips lasted until the natural end of a sentence and were not ended early. A total of eight clips, two from each speaker, were selected for use. Participants listened to the clips through Coby digital CV-120 over-the-ear headphones at a speaker volume of 30% on the computer.

Table 1: Stimulus Table

| IDEA Speaker Maryland 1 | |
|---|---|
| Block A | Personal Story<br>1:23 to 2:30 |
| Block B | Scripted Story<br>0:09 to 1:22 |
| **IDEA Speaker Kentucky 8** | |
| Block A | Scripted Story<br>0:13 to 1:14 |
| Block B | Personal Story<br>1:45 to 2:45 |
| **IDEA Speaker England 8** | |
| Block A | Personal Story<br>0:38 to 1:42 |
| Block B | Personal Story<br>1:56 to 3:00 |
| **IDEA Speaker Ukraine 2** | |
| Block A | Scripted Story<br>2:52 to 3:52 |
| Block B | Personal Story<br>3:55 to 5:13 |

*Procedures*

Guidelines provided by Roanoke College's Institutional Review Board were followed during the experiment (IRB number 15PS098). Participants signed the informed consent before five lead shielded electrodes were placed on each participant's scalp. The electrodes were held in place using elastic headbands. The primary signal electrode for Channel 1 was placed on the forehead, at Fp2, to measure frontal lobe processing, comprehension, and understanding. The other electrode in Channel 1 was on the back of the head, at Oz, to serve as a reference base for the other electrodes, as no activity was expected to be observed due to the absence of visual stimuli in the experiment. For Channel 2, two electrodes, one over the language processing center of the brain (around Wernicke's area in the Parietal/Temporal region) at T3, and the other placed on the other side of the scalp in a symmetrical fashion at T4, were positioned in order to pick up on lateralized initial language processing. The positions of the electrodes for Channel 2 were chosen because of previous research on the language processing areas of right-handed persons (Binder et al., 1997). A common ground for both channels was placed at Fp 1.

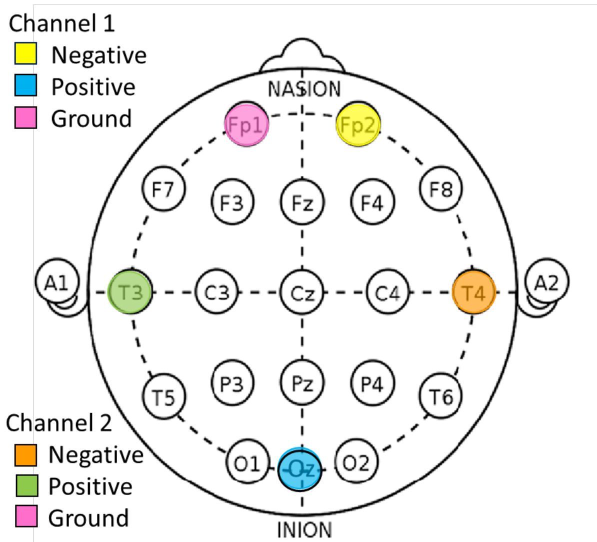


**Figure 1: Electrode Channel Placement**
Consistent placement of five electrodes was used across participants for two channels of input. The Channel 1 signal measured higher-level frontal lobe activity, and the Channel 2 signal measured lower level temporal lobe activity.

Artifacts on the EEG were reduced by keeping the subjects' head stabilized by having them rest it on a pillow. Additionally, eye-blinks were controlled for by having the participant close his or her eyes, wear a blindfold, and focus on the audio clips during their duration. All participant data was collected in the EEG experiment room on the fifth floor of the Life Science building at Roanoke College. These measures help in reducing the artifacts in the EEG recording due to muscle movements, which improves the overall quality of the recordings.

Each audio clip was played for at least 60 seconds so that the participants had ample time to listen to the accents and interpret what was said. SuperLab 4.5 was used to randomize the order in which the audio clips were presented to the participants. Two blocks, each around 6 minutes long, were completed by each participant to gather more data on the brainwave states. Each block consisted of four clips, each one from a different speaker. Breaks in between the clips were all 10 seconds long to allow the participant to relax and orally give answers to the task (described below). Taking into account all of the previous time demands, the total average time of data collection was around 15 minutes long, with an additional 15 minutes for set-up and clean-up.

To keep the participants focused on the stimuli, we asked participants to count the number of times the word "that" was said during the speech clips. Participants were then asked for the word count at the end of each clip during the 10 second rest period. This task was used to prevent the participants from losing focus on the speakers and to encourage them to listen more intently. Actual comprehension of the accent was not directly measured as the emphasis of the study was on how the participants reacted to the accents. However, participants were asked to rate their level of understanding of the accents on a scale of 1 to 7 (1 being very easy to understand; 7 being very hard to understand) in an effort to validate whether the most foreign accents were actually difficult to understand and the most native, or familiar, were actually easy to understand.

### *Survey*

After listening to all of the speaker clips, the participants were then asked to complete a survey on handedness, past travel experiences, family origins/accents, foreign language experience/knowledge, and other demographic information. This was done so that participants could be grouped during the analysis of the data to determine if familiarity with foreign accents was a factor during processing.

### *Data Analysis*

For the analysis of the data in this experiment, we first ran a repeated measures ANOVA to determine if there was any overall difference in the data between the groups we created using the survey question answers. In order to find our IV measure for familiarity, we tried to create equal-sized groups and ended up using whether the participant had traveled abroad or not, which gave us a group of eight who had traveled abroad and a group of four who had never traveled abroad. We compared the wave amplitudes that were found by the FFT process across each of the speaker accent locations (Maryland, Kentucky, England, and Ukraine) for each of the groups.

While merely traveling abroad would not guarantee a greater knowledge of or experience with foreign-accented speech than diligent study of a foreign language, of greater interest to the researchers is whether or not exposure to foreign-accented speech through some means, such as traveling abroad, would aid in understanding of more geographically distant foreign-accented speech.

## Results

Electrodes were grouped into channels and analyzed separately in order to differentiate areas of early and deeper processing. The electrodes that fed into Channel 2 picked up on early auditory processing in the vicinity of the temporal lobe and were taken together in comparison to electrodes in Channel 1 that measured deeper understanding and comprehension in the vicinity of the frontal lobe. Both channels found statistically significant differences for the levels of alpha brain wave amplitudes, but neither found any significant results related to the beta brain wave amplitudes.

The data for early auditory cortex, i.e., the temporal lobe, shows that there is a significant effect of the location of the accent through a linear trend. This trend shows an overall decrease in alpha wave amplitude as the presented accent became more foreign ($F(1,10)=6.295$, $p=0.031$, Fig. 2). We feel that a linear trend analysis is justified given that the intentional ordinal relationship of the accents allows them to be considered as a set, and is in line with our hypothesis on the effect of location on alpha waves. There was no significant main effect for familiarity ($F(1,10)=0.009$, $p=0.927$), nor for location ($F(3,30)=2.386$, $p=0.089$), nor an interaction effect ($F(3,30)=0.482$, $p=0.697$), Fig. 2).

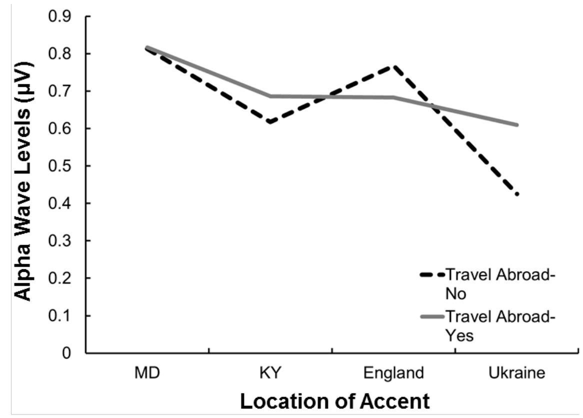


**Figure 2. Temporal Lobe (Channel 2) average.** Levels of Alpha waves of both Traveled Abroad and Not Traveled Abroad groups were compared as a function of the location of the speaker.

The data for higher level processing, i.e., the frontal lobe, shows that though there was not a main effect of familiarity ($F(1,10)=0.663$, $p=0.434$, Fig. 3), an interaction effect was found between subject familiarity and how foreign the presented accent was, meaning the accent presented had a different impact on the subjects based on whether or not they had traveled abroad, with the amplitudes of the non-traveled group shifting down ($F(3,30)=3.648$, $p=0.024$). A linear trend was also seen in the frontal lobe alpha levels as found in the temporal lobe, and shows that as the accents became more foreign, the amount of relaxed brain activity decreased regardless of the channel, or area, measured ($F(1,10)=14.529$, $p=0.003$, Fig. 3).

As part of a post-hoc analysis of the data, we looked at how the answers to the difficulty of understanding question compared to the rest of the data. We found that the average ratings of each of the locations corresponded to the linear trend we saw in both channels. Maryland ($M$ = 1.63, $SD$ = .86) and Kentucky ($M$ = 1.63, $SD$ = .91) were ranked as the easiest to understand. England ($M$ = 2.25, $SD$ = 1.12) was rated as slightly harder, and Ukraine ($M$ = 5.46, $SD$ = 1.12) was rated the most difficult to

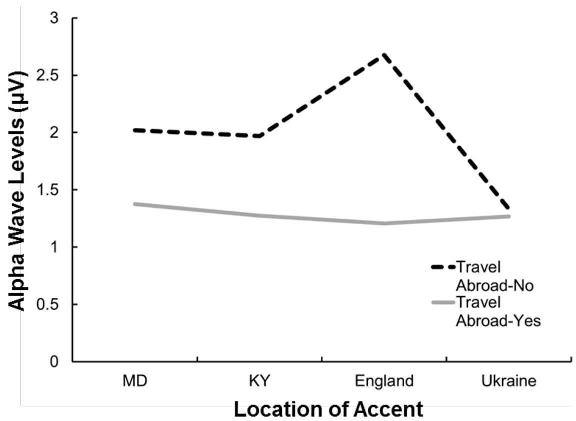


**Figure 3. Frontal Lobe (Channel 1) average.** Levels of Alpha waves of both Traveled Abroad and Not Traveled Abroad groups were compared as a function of the location of the speaker.

understand. A one-way repeated measures ANOVA was conducted to determine the effect of the accent on participants' ratings of the ease of understanding. There was a significant effect of accent on ratings of understanding, Wilks' Lambda = .078, $F(3, 9) = 35.32$, $p < .001$. Least Significant Difference post hoc comparisons revealed a significant difference between the mean understanding rating for the Ukraine accent condition compared to the Maryland accent condition ($p < .001$), the Kentucky accent condition ($p < .001$), and the England accent condition ($p < .001$). Therefore, the Ukrainian accent was the only accent that yielded a more difficult understanding rating. A significant mean difference between the Maryland accent and England accent approaching significance ($p = .032$) was also revealed, indicating participants rated the England accent as more difficult to understand than the Maryland accent. Post hoc analyses also revealed a mean difference approaching significance between the England accent condition and the Kentucky accent condition ($p = .063$). Thus, a linear effect can be observed in the accent understanding ratings, with the Ukraine accent consistently rated as the most difficult to understand, the England accent as slightly more difficult, and the Maryland and Kentucky accents as the least difficult to understand. These findings coincide with our hypothesis that the more foreign the accent, the more difficult it would be to understand, would result in a decrease in relaxed alpha brain waves.

# Discussion/Conclusion

Although the study was looking for changes in both alpha and beta wave amplitudes, the data for alpha waves was the only activity that showed significant changes. In both Channel 1 and Channel 2 there was a significant linear trend for the location of the speaker, which showed that a more foreign speaker correlated to a lower alpha wave for the listener. This is consistent with our hypothesis. This hypothesis was largely made because of studies that have also indicated this possible effect, such as Van Engen and Peelle (2014). Their study looked at the effect of accented speech and listeners' expectations on the overall comprehension of the speech. They found that if the expectations did not match up, then additional cognitive processes were required to comprehend speech.

Additionally, we hypothesized that subjects who were more familiar with foreign languages would have a higher average amplitude of alpha waves, indicating that it required less effort to process the information being spoken. However, our data show the inverse of this. This could be explained by the concept that subjects who were more familiar with foreign languages were able to listen actively and to understand the more foreign speakers, whereas the subjects who were not so familiar with foreign languages may have been more likely to simply tune out the speaker.

Looking from a more functional perspective, the results found also follow what would be expected. The evidence of a significant difference in Channel 1, which was measuring activity in the frontal lobe, suggests a different level of processing between the two groups (Fig. 3). However, this difference is absent in Channel 2, which was measuring the auditory/language processing center, suggesting that there was no difference between the groups (Fig. 2). This makes sense functionally, as this area of the brain is more in charge of interpreting if words were said, and the frontal cortex is more involved in the higher level processing of these words. So, people who had traveling experience abroad were able to process the words perceived more so than the inexperienced participants.

These findings seem to support the findings of another study examining the adaptation of English speakers understanding foreign-accented English (Clarke and Garrett, 2004). Findings from this study showed that, on average, English listeners took 100+ milliseconds longer to identify key words in a sentence spoken by an individual with a Spanish accent than when compared to a sentence spoken by a native English speaker. This provides support for the current study, because it suggests that foreign accents may require more brain activity for comprehension. Additionally, the researchers found that comprehension of accented speech can be improved via exposure to the specific accent. However, evidence may suggest simple exposure to an accent may not increase comprehension.

The current study's findings also support the findings of Romero-Rivas et al., (2015) looking at the understanding of foreign accents by native speakers. Their study looked at the ability of native Spanish speakers to comprehend both native and non-native speech, and measured participants' brain responses using ERP. They found that, due to the demand on lexical processing, a system where listeners process information through phonetic and acoustic variations, listeners are better able to process semantic violations in native versus foreign speakers (Romero-Rivas et al., 2015). This may coincide with our unexpected results, as the individuals within the groups may have had large differences in lexical information through their experiences abroad, giving them the ability to process the speakers' speech, causing the decrease in alpha waves.

Lexical processing is becoming a widely studied area in neuroscience research, as it is believed to play a key role in the comprehension of languages (Imai et al., 2005). As infants, we become well adapted to the sounds and intricacies of our first language, and from there we tend to prefer and expect these sounds during languages (Imai et al., 2005). This is where the processing mentioned above comes into play, as we compare our lexicon to the sounds we are hearing in accented speech. It would be hard to say if there is any significant difference between the lexicons of our participants, but it would be interesting to see if this is influencing the data, as there was a significant effect between the traveled and non-traveled groups (as there should be some lexical differences between the groups due to more exposure to other languages).

Dunton et al. (2009) looked further into the subject of accent familiarity and its variable effects on processing. Their particular study focused on the effects of accent familiarity on participants who had aphasia. They did this to determine if the accent of a doctor, or other clinician, could have a negative effect on the perceived ability assessment of individuals with acquired brain damage. Dunton et al. (2009) found that unfamiliar accents had a negative impact on the comprehension of sentences spoken when compared to a more familiar accent. The findings from the current study could be applied to the findings of previous research to help explain previous findings about language processing. Bisson et al. (2013) found that during informal learning of foreign languages as a result of incidental exposure, participants picked up the vocabulary meaning of words much more quickly than those who learned the language in a formal, explicit learning session. Applying the results of our study to these findings supports the idea that even incidental learning of foreign language, as a result of exposure to foreign accents from being abroad, facilitates better understanding of foreign speech altogether. Because evidence from our study suggests that those who had been abroad understood foreign accents better, Bisson et al.'s (2013) findings are also supported, in that it makes sense that those exposed to foreign speech while abroad would have better understanding of foreign-accented speech and would be more relaxed and exert less conscious processing effort when listening to the foreign-accented speech.

Future studies in this area could include subjects with a wider background in foreign languages or speakers with a closer connection to the subjects. Also, including a more gradual range of foreign-accented speech might yield meaningful results. Most of the subjects in our study focused on Spanish in their foreign language studies and Hispanic countries during their travels abroad, therefore a Spanish accent may have been a useful option to include in this study in order to account for a better range of foreign accents.

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