Native Mandarin Speakers' Production of English Fricatives as a Function of Linguistic Task Type and Word Position: A Spectral Moment Analysis

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Native Mandarin Speakers’ Production of English Fricatives as a Function of
Linguistic Task Type and Word Position: A Spectral Moment Analysis

Lindsey McCall Wing

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of
Master of Science

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ABSTRACT

Native Mandarin Speakers’ Production of English Fricatives as a Function of Linguistic Task Type and Word Position: A Spectral Moment Analysis

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Master of Science

The purpose of this study was to analyze the phonetic production of fricatives across differing word positions and task types. Further knowledge about the fricative production of second language learners of English would potentially improve the ability to teach correct pronunciation and improve the productivity of second language programs. All participants in this study were native speakers of Mandarin Chinese with English as their second language. A total of 12 subjects participated, all of whom had English proficiency ratings ranging from novice to advanced. The speakers were between 21-51 years of age, with each speaker having between 2 to 6 years of experience learning English in their country of origin. Using acoustic and spectral moment analyses, the acoustic nature of four types of fricative productions (/f/, /θ/, /s/, and /ʃ/) were analyzed as a function of linguistic task type and word position. Although a number of measures were found to differ significantly as a function of word position and task type, the majority of statistical analyses were not found to be significant. This lack of significance may be due to the specific methodology used, the speakers’ atypical voicing patterns, and/or decreased length of sound productions. Findings of this study may indicate that second language learners’ production of fricatives vary minimally across differing word positions and task types.

Keywords: obstruent, fricative, spectral moments, task type, second language acquisition
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DESCRIPTION OF STRUCTURE AND CONTENT

This thesis, *Native Mandarin Speakers’ Acquisition of English Fricatives as a Function of Linguistic Task Type and Word Position: A Spectral Moment Analysis*, was part of a larger collaborative project, portions of which may be submitted for publication, with the thesis author being one of multiple contributing coauthors. The body of this thesis was written as a manuscript suitable for submission to a peer-reviewed journal in speech-language pathology. An annotated bibliography is presented following the reference section in Appendix A.
Introduction

It is estimated that over 1 billion people are currently learning English worldwide, with approximately 375 million learning English as their second language. Second language (L2) acquisition has become increasingly relevant in today’s world as more and more individuals desire to learn a language different from their native tongue. In many parts of the world the ability to speak and understand English has transitioned from “a marker of the elite,” to a basic skill needed for entering the workforce. Second language learners of English have reported lifestyle improvements such as educational opportunities and increased earning potential that have come from L2 acquisition. Although English as a second language can lead to advances in quality of life, learning a new phonological system, with speech sounds foreign to an individual’s L1, can be particularly challenging for many individuals. Furthermore, if English language productions are unclear due to speech sound errors, the benefits derived from English as a second language could be mitigated.

L2 Acquisition of Obstruent Speech Sounds

One sound category that L2 English learners often have difficulty acquiring are obstruent sounds, which are speech sounds formed by obstructing airflow within the vocal tract (Colantoni, Steele, & Edcudero, 2015). In American English, the obstruent speech sounds include stops, fricatives, and affricates. Oral stops such as /p/, /b/, /t/, /d/, /k/, and /g/, are produced when a speaker completely obstructs the flow of air within the vocal tract, allowing the air pressure to build behind the closure, followed by a rush of air out of the oral cavity when the obstruction is released (Davenport & Hannahs, 2005). Fricatives, such as /s/, /z/, /θ/, /v/, and /ð/, are produced by forcing air through a narrow channel made by placing two articulators close together, which causes frication in the airflow (Shadle, 1990). Affricates, such as /ʤ/ and /ʧ/, described as a
combination of both a stop and a fricative, are produced in one homorganic movement of the articulators (Davenport & Hannahs, 2005).

Second language learners often struggle to acquire new obstruent sounds that are not found in their native language. To illustrate, consider English, French, and Spanish. All three languages have a contrast between voiceless and voiced stops (e.g., English “two” /tu/, “do” /du/). However, new categories of stop consonant sounds are created by differences in voice onset time (VOT). VOT is a temporal difference in milliseconds between the release of the stop closure and the onset of the glottal vibration of the following vowel or approximant consonant (Colantoni et al., 2015). In English, phonemically voiced stops are produced with a relatively small VOT, while voiceless stops involve a much longer VOT. To contrast, both French and Spanish voiced stops have a negative VOT while voiceless stops have a short VOT, like that observed in English (Lisker & Abramson, 1964). Thus, because of differences like these, English stops are harder for French and Spanish speakers to learn.

Similar to stop consonants, L2 learners may have difficulty acquiring fricative and affricate sounds that are not present in their native language. The Mandarin language, specifically does not contain the fricative phonemes /v/, /ʒ/, /θ/, /ð/ or the affricates /ʤ/ and /ʧ/ (Deng, 2014; Ladefoged & Maddieson, 1996; Zee, 1999). Because these obstruent sounds are not part of the Mandarin language, L2 learners may have difficulty learning the articulation patterns required to produce these sounds in a native-like manner.

Although an obstruent sound may be present in both a speaker’s native and target language, the sound may not occur across all linguistic contexts. In Mandarin, there are only two sounds typically spoken in the final position of syllables, the sonorants /n/ and /ŋ/ (Cardoso, 2011; Cheng, 1987; Nasukawa, 2004). Considering that syllables in English are commonly
closed by a consonant, Mandarin speakers learning English as an L2 may be able to produce a newly acquired speech sound in initial word position but have difficulty when it is in word final position. Mandarin speakers learning English will often omit word final consonant sounds entirely (Fang & Ping-an, 1992). As speakers of a second language strive to acquire obstruent sounds that are not part of their native language, or are not found across all linguistic contexts, L2 acquisition becomes increasingly difficult (Colantoni et al., 2015).

**Measurements of Obstruent Speech Production**

Second language learners’ difficulties in producing English obstruents can be measured using a number of different techniques. One method used to provide a qualitative evaluation of how native-like L2 sounds have been acquired by learners is through perceptual ratings. This has become an increasingly beneficial tool in examining the ways that native speakers of English perceive the productions of L2 learners of English. A study performed by Hayes-Harb, Smith, Bent, and Bradlow (2008) analyzed the productions of voiceless word-final stop consonants in English by both English and native Mandarin speakers. Their findings indicated that native Mandarin listeners were more accurate than native English listeners at identifying Mandarin-accented English words, providing evidence of an interlanguage speech intelligibility benefit for listeners (Bond & Fokes, 1991; Hayes-Harb et al., 2008). A study by Yohikyuki and Brandenburger (1986) also used perceptual ratings to evaluate L2 consonant productions of elementary school students. Predictions of oral reading fluency from listeners’ perceptual ratings were found to be relatively accurate.

The dynamic properties of obstruent consonants with lingua-palatal contact have also been examined through the use of electropalatography. In 1975, Fletcher, McCutcheon and Wolf, developed an electropalatographic system using a pseudoplatate and a series of electrical
sensors that display the speaker’s speech contact patterns on a monitor (Fletcher et al., 1975). Electropalatography has been used by researchers and clinicians to better understand the lingua-palatal contact during obstruent production in both children (Gibbon, Hardcastle, & Dent, 1995) and adults (Dean, 2008). One specific study by Hacking, Smith, Nissen, and Allen (2016) successfully used EPG to evaluate L2 learners’ productions of palatalized and unpalatalized Russian obstruents.

Second language learners’ acquisition of obstruents can also be measured using different types of acoustic analysis. As mentioned previously, one type of acoustic analysis used to describe the production of stop consonants is the measurement of VOT (Peng & Ann, 2004). Lee and Iverson (2012) used VOT to measure the stop production of Korean-English bilingual children, finding that bilingual children employed different patterns of VOT in comparison to both English and Korean monolinguals. Furthermore, the authors reported that bilingual children at around 5 years of age do not yet have fully separate stop systems for each language. In addition to VOT, the acoustic properties of obstruent consonants have been measured using relative duration (Flipsen, Shriberg, Weismer, Karlsson, & McSweeny, 1999; Lisker & Abramsom, 1964), intensity (Kim, 2004; Nissen & Fox, 2009), and second formant vowel transitions (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967).

Spectral moment analysis (SMA) is a more recent technique that quantitatively describes and provides detailed information about the spectral characteristics of obstruent consonant productions (Forrest, Weismer, Milenkovic, & Dougall, 1988; Fox & Nissen, 2005; Nissen & Fox, 2005; Nittrouer, 1995). These spectral moment values can be used to identify unique and discrete patterns of acoustic energy within the speech signals that are perceptually relevant (Nissen & Fox, 2005). Spectral moment analysis uses statistical moments to quantify how the
noise energy within consonant sounds is distributed across a range of frequencies. Spectral moment analysis often uses a Fast Fourier Transform (FFT) spectrum derived from a window of analysis. Each FFT spectrum is considered a randomly distributed probability from which four statistical moments are calculated. These statistical moments, previously examined by researchers such as Forrest et al. (1988), are termed the spectral mean, spectral variance, spectral skewness, and spectral kurtosis.

The first spectral moment, or spectral mean, defines the frequency of average energy distribution throughout the segment of the consonant being evaluated. Following the methodology found in previous SMA studies (Nissen & Fox, 2005; Nissen & Fox, 2009), for a stop consonant, this may be limited to the 10-20 milliseconds of acoustic noise energy following the release of the stop burst. Whereas for a fricative, the window of analysis typically includes a larger segment of noise energy centered at the beginning, middle, or end of the fricative. The second spectral moment, or spectral variance, describes the frequency variability over which the spectrum is distributed. The third spectral moment, the spectral skewness, describes the asymmetry of the probability distribution of frequencies. A negative spectral skewness signifies that the median value of the spectrum has a higher frequency than the mean (Nissen & Fox, 2005). The fourth spectral moment, or spectral kurtosis, describes how compact the energy distribution is. If the kurtosis is high, the spectral peaks are sharper and more defined. If the kurtosis is low, then the distribution of the spectrum is relatively flat (Marshall, 2012; Tomiak, 1991). These four spectral moments can be used to provide a quantitative description of the noise energy within obstruent consonants. A dynamic view of the consonant production can be obtained by combining multiple cascading windows of analysis.
One of the earliest studies to utilize SMA was conducted by Forrest et al. (1988). In this study, researchers aimed to statistically discriminate between different stop and fricative phonemes. This discrimination was based on the pattern of spectral energy within the associated noise segment. Using a discriminant analysis of the spectral moment data from the initial 20 milliseconds of the stop burst, the authors found that the phonemes /p/, /t/, and /k/ could be accurately classified statistically at a rate of 92%. Their findings indicated that velar stops are statistically distinguishable by the degree of spectral kurtosis more than any other spectral moment measure. In contrast, labial and alveolar stops were differentiated more by the spectral mean and skewness values (Forrest et al., 1998). A later study by Jongman, Wayland, and Wong (2000) reported on results that were consistent with those of Forrest et al. Jongman et al. found that the spectral mean, skewness, and kurtosis could be used to statistically distinguish between both voiced and voiceless fricatives. However, colleagues such as Nissen and Fox (2005) have since reported that the only spectral moment measure that correctly classifies all four places of fricative articulation is spectral variance.

Spectral Moment Analysis has also been used to examine the acquisition of obstruent consonants in young speakers of American English. One study by Nittrouer, Studdert-Kennedy, and McGowan (1989) looked at the acquisition of fricative-vowel syllables in children ages 3, 4, 5, and 7. The authors concluded that young children whose phonological system is still developing have a broader minimal domain of articulatory organization than adults. This may be due to possibility that young children have not yet fully mastered the segmental structures of speech. A second study by Nissen and Fox (2009) examined the acoustic and spectral patterns of stop consonants in the speech of children between the age of 3 and 5 years. Following analysis, the authors reported that normalized amplitude, spectral slope, and all four spectral moments
carried significantly as a function of place of articulation. Another study by Nissen and Fox (2005) analyzed the acoustic and spectral properties of fricative production in young children. The authors concluded that the measures of fricative duration, normalized amplitude, spectral slope, and all four spectral moments varied significantly as a function of place of articulation. Although these studies provide a good understanding of the spectral nature of obstruent production in young native speakers of English, SMA has not previously been used to analyze the production patterns of second language learners. Thus, it is of interest to examine if SMA is effective in describing fricative productions of L2 learners across word position and task type.

**L2 Production across Task Types**

The ability of L2 speakers to verbally communicate may vary depending on the linguistic task type. Studies have found that speakers will often modify the language they use depending on the communication environment. Tavakoli and Foster (2008) found that L2 learners used more elaborate language when expressing a story in a less-formal setting. A study by Gilabert, Baron, and Llanes (2009) reported that as a communication task becomes more complex, L2 learners use more precise language and give more effort to succeed at the task.

Differences in the linguistic task type can also impact the nature of a speaker’s speech patterns. For example, a speaker may modify their speech when reading word lists or sentences in a laboratory environment as compared to the more naturalistic context of recalling experiences or engaging in open-ended conversations. A number of studies have reported on the specific effects that different linguistic task-types have on phonetic production (Kuiken & Vedder, 2011; Lindblom, 1989).

Research performed by Lindblom (1989) reported that speakers adjust their degree of articulatory precision according to the linguistic context. In formal settings, speakers tend to
hyperarticulate, whereas in informal ones, undershooting (or hypoarticulation) is more likely. Lindblom termed this phenomenon as the Hyper- and Hypoarticulation Theory of speech production. Research by Kuiken and Vedder (2011) and Gurzynski-Weiss, Long and Solon (2007) has also reported on the effects that task-type variability has on speech output. Kuiken and Vedder analyzed the performance of L2 learners on an oral speaking task and a written task, both of varying complexities. The authors reported that, in the oral and the written mode, task complexity affected accuracy with respect to lexical errors; students made fewer errors in the complex task compared to the noncomplex task. However, no interaction between task type and proficiency level was found in this specific study. Gurzynski-Weiss et al. also analyzed the effects of increasing task complexity in second language pronunciation. The authors reported on differences in vowel production across simple and complex tasks. Results of this study implied some benefit of task complexity manipulation for L2 productions.

Although more naturalistic linguistic tasks would likely have increased ecological validity, the instructional techniques used in some L2 classrooms is a repetition-based approach, whereby the instructor says a single word and the students repeat the targeted word back. Hence, most studies involving L2 learners of English, have also used this same task type to evaluate learner’s ability to produce speech sounds in a native-like manner. It is common for researchers to elicit speech from L2 participants by having them produce lists of single words or words embedded within a carrier phrase, such as “say _____ again” (Forrest et al., 1988; Jongman et al., 2000; Nittrouer, 1995). Less emphasis has been placed on evaluating speech production elicited from spontaneous or narrative tasks. It is unclear how well L2 learners generalize their production of obstruent sounds across different linguistic contexts.
Thus, using SMA, the purpose of this study was to analyze the fricative production of L2 learners of English across the following task types: a carrier phrase, paragraph form, and spontaneous speech prompts. It is hypothesized that the speakers’ production of fricatives in the final word position will be less accurate due to the fact that final consonants sounds are not found in the Mandarin language. It is also hypothesized that the speakers’ phonetic persistence will decrease during spontaneous speech prompts due to the increased cognitive and linguistic complexity of these tasks. Further knowledge about the fricative production of L2 learners of English would potentially improve the ability to teach correct pronunciation and improve the productivity of L2 programs.

Method

Speech Recordings

This study acoustically analyzed the speech recordings collected from 12 English second language students enrolled at the English Language Center (ELC) located at Brigham Young University. All participants were native speakers of Mandarin Chinese with English as their second language. The speakers were between 21 and 51 years of age, with each speaker having between 2 to 6 years of experience learning English in their country of origin. Participants’ speech proficiency levels ranged from novice to advanced. The proficiency guidelines were based on an extensive battery of tests including reading, writing, listening, speaking, vocabulary, and grammar. Proficiency levels correspond to the American Council for the Teaching of Foreign Languages (ACTFL; Swender, Conrad, & Vicars, 2012). A detailed listing of the speakers’ proficiency levels is outlined in Table 1. The speech recordings were collected in a quiet-room environment using a high-quality condenser USB microphone (Audio-Technica AT2020USB+). Recordings were made with the sampling rate of 44.1 kHz with a quantization of
24 bits. The speakers produced the speech recordings in four different types of linguistic tasks in order to elicit speech in a variety of task types from highly structured reading task to less structured spontaneous speech. These tasks included producing words in a carrier phrase, reading a paragraph, recalling a fairytale, and answering open-ended questions.

Table 1

*Speaker Demographics*

<table>
<thead>
<tr>
<th>ID</th>
<th>Gender</th>
<th>L1</th>
<th>Age</th>
<th>English Proficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Female</td>
<td>Chinese</td>
<td>22</td>
<td>Intermediate Mid</td>
</tr>
<tr>
<td>2</td>
<td>Female</td>
<td>Chinese</td>
<td>24</td>
<td>Intermediate Mid</td>
</tr>
<tr>
<td>3</td>
<td>Female</td>
<td>Chinese</td>
<td>24</td>
<td>Advanced Mid</td>
</tr>
<tr>
<td>4</td>
<td>Female</td>
<td>Chinese</td>
<td>24</td>
<td>Advanced Mid</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>Chinese</td>
<td>51</td>
<td>Intermediate High</td>
</tr>
<tr>
<td>6</td>
<td>Female</td>
<td>Chinese</td>
<td>24</td>
<td>Advanced Low</td>
</tr>
<tr>
<td>7</td>
<td>Male</td>
<td>Chinese</td>
<td>29</td>
<td>Intermediate Mid</td>
</tr>
<tr>
<td>8</td>
<td>Female</td>
<td>Chinese</td>
<td>27</td>
<td>Advanced Mid</td>
</tr>
<tr>
<td>9</td>
<td>Female</td>
<td>Chinese</td>
<td>25</td>
<td>Novice High</td>
</tr>
<tr>
<td>10</td>
<td>Male</td>
<td>Chinese</td>
<td>21</td>
<td>Intermediate Mid</td>
</tr>
<tr>
<td>11</td>
<td>Male</td>
<td>Chinese</td>
<td>22</td>
<td>Advanced Mid</td>
</tr>
<tr>
<td>12</td>
<td>Male</td>
<td>Chinese</td>
<td>27</td>
<td>Intermediate High</td>
</tr>
</tbody>
</table>

**Carrier phrase.** The target fricatives, /f/, /θ/, /s/, and /ʃ/ were embedded in real English words in both initial and final syllable position. All words were in monosyllabic form and in CVC (consonant vowel consonant) format. The target fricative sounds were followed or preceded by a high-front vowel (/i/ or /I/). The eight elicited words were feet, beef, think, teeth,
The same set of eight words elicited in the carrier phrase task were embedded in two unique narrative paragraphs, approximately 160 words in length. Speakers were asked to read each paragraph aloud, presented in random order with a one-minute break in between if desired. For more details on each paragraph, please refer to Appendix B.

Fairytale recall. The speakers were also asked to recite from memory a culturally-familiar fairytale. Given a list of possible prompts (as provided in Appendix B), speakers were given the opportunity to select which fairytale they felt most comfortable recalling. Speakers were asked to recall as many details from the fairytale that they could; examiners aimed to gather approximately 5 minutes of story recall from each participant. Although the number of times a speaker produced a targeted fricative was uncontrolled, the aim of this study was to elicit five productions of each fricative in both initial and final word position.

Open-ended questions. Speakers were asked a series of open-ended questions in a conversational setting. In total, spontaneous productions were gathered for approximately 5 minutes. The number of questions asked varied among participants depending on the length of their responses to each question. Similar to the fairytale recall task, the number of tokens for each sound and word position varied according to the speakers’ responses, however the aim of the study was to elicit five tokens of each fricative in both initial and final word position. A list of the potential questions that were asked of participants is provided in Appendix B. For the purpose of this study, the fairytale recall task and open-ended questions were merged together.
and analyzed as a whole, targeting spontaneous speech prompts. This was done in order to increase the total number of spontaneous speech tokens.

All participants signed an informed consent form prior to participation in the present study. A copy of this form is provided in Appendix C.

**Data Analysis**

The spectral moment analysis of the target fricatives followed the methodology found in Nissen & Fox (2005) and Fox & Nissen (2005). By using a waveform display, the onset and offset of target fricative productions were segmented, assisted by spectrographic inspection using Adobe Audition (Version 5.0.2). Sudden changes in the degree of diffuse noise energy and number of zero-crossings of the waveform was used to identify the onset and offset of each fricative. Time values of segmentation (in ms) were recorded into a text file and subsequently checked, corrected, and re-checked using a Matlab computer program. After this was done, in order to verify accuracy and reliability of waveform segmentation data, 5% of all tokens were independently analyzed by a second person and again correlated with the original segmentation of each respective token. Using Pearson Correlations, the first and second sets of measurements had a correlation of $r^2 = .99, p < 0.0001$, with a mean absolute difference of 6.04 ms.

To limit the influence of electronic noise and high frequency hiss above human perception, all speech samples were filtered to include frequency information between 70 Hz and 15,000 Hz. Each of the four spectral moments (mean, variance, skewness, and kurtosis) were computed based on the power spectra derived from an FFT of the middle 50% of the noise energy for the fricative consonants. In order to compare the findings of this study to previous research using SMA (e.g., Forrest et al., 1988; Jongman et al., 2000; Nissen & Fox, 2005; Nittrouer, 1995), each window interval was then pre-emphasized by first-differencing. Each
Fricative production was spectrally analyzed with 2048-point FFTs, resulting in both real and imaginary components. The individual FFT spectra were converted to a normalized power spectra by dividing the relative amplitude of each frequency point by the sum amplitude of analysis points. Using methods outlined in Forrest et al. (1988) and Nissen (2003) a normalized power spectra was calculated from the FFTs as follows: 

\[ P(k_j) = \frac{P(k_j)}{\sum(P(k_1) + \ldots + (k_{1024}))} \]

\( P = \) relative power \( k = \) real-valued frequency point \( j = \) from 1 to 1024

These normalized power spectra mentioned above were then considered random distribution probabilities, from which the first four statistical moments were computed. The spectral mean statistic was computed as follows:

\[ \text{Spectral mean} = \sum [k_j P_j] \]

\( P = \) relative power \( k = \) real-valued frequency point \( j = \) from 1 to 1024

The spectral variance statistic was calculated by taking the sum of each frequency point’s squared deviation from the mean as follows:

\[ \text{Spectral variance} = \sum [(k_j - m_1)^2 P_j] \]

\( P = \) relative power \( k = \) real-valued frequency point \( j = \) from 1 to 1024 \( m_1 = \) spectral mean

The spectral skewness statistic was computed as follows:

\[ \text{Spectral skewness} = \sum [(k_j - m_1)^3 P_j] \]

\( P = \) relative power \( k = \) real-valued frequency point \( j = \) from 1 to 1024 \( m_1 = \) spectral mean

The spectral skewness statistic was then normalized and expressed as a coefficient as follows:
Spectral skewness_{\text{normalized}} = \left[ \frac{m_3}{(m_2^{3/2})} \right]

m_2 = \text{spectral variance}

m_3 = \text{spectral skewness}

The spectral kurtosis was computed as follows:

Spectral kurtosis = \sum [(k_j - m)\text{P}_j]

P = \text{relative power}

k = \text{real-valued frequency point}

j = \text{from 1 to 1024}

m = \text{spectral mean}

The spectral kurtosis statistic was then normalized and expressed as a coefficient as follows:

Spectral kurtosis_{\text{normalized}} = \left[ \frac{m_4}{(m_2^2)} - 3 \right]

m_2 = \text{spectral variance}

m_4 = \text{spectral kurtosis}

**Statistical Analyses**

The spectral moment values were averaged across repetitions and participant. Repeated-measures analysis of variance (ANOVA) was used to determine significant acoustic variation in the speakers’ fricative productions as a function of task type and word position. Dependent measures included fricative duration, fricative intensity, and the first four spectral moments measures (mean, variance, skewness, kurtosis). Results of significant $F$-tests include a measure of effect size, partial eta squared, or $\eta^2_{\text{partial}}$. Furthermore, pairwise comparisons for significant within-subject factors were done using General Linear Model repeated-measures contrasts; comparison significance was determined using the appropriate $F$-tests.
Results

**Voiceless Labio-dental Fricatives /f/**

The duration of the voiceless labio-dental fricative productions varied significantly as a function of word position, $F(1,8) = 9.53, p = .015, \eta^2_{partial} = .54$. In the initial position, the fricative productions were 155 milliseconds and in final position they decreased to 120 milliseconds. The specific values for the dependent measures as a function of task type and position are listed in Table 2. No additional statistical tests were found to be significant.

**Voiceless Inter-dental Fricatives /θ/**

The statistical analyses for the voiceless lingual-dental fricative productions did not reveal any statistically significant differences between any of the dependent measures. The specific values for the dependent measures as a function of task type and position are listed in Table 3.

**Voiceless Alveolar Fricatives /s/**

The spectral means of the voiceless alveolar fricative productions were found to differ significantly as a function of both the task type and word position, $F(2,22) = 4.97, p = .017, \eta^2_{partial} = .31$. As shown in Figure 1, the fricative /s/ exhibited a higher spectral mean for the paragraph task when in initial word position. The statistical analysis also indicated a significant interaction effect for spectral variance between task type and word position, $F(2,22) = 3.85, p = .037, \eta^2_{partial} = .26$. As shown in Figure 2, the spectral variance was higher in the initial word position when the productions were elicited through the carrier phase when compared to the other elicitation conditions. The skewness of the voiceless alveolar fricative also varied significantly as a function of word position, $F(1,11) = 5.12, p = .045, \eta^2_{partial} = .32$. The skewness values in the initial position were found to be lower than the values in the final position (-1.76 and -1.61).
Table 2

Spectral Moment Means and Standard Deviations as a Function of Task Type and Word Position
for the Voiceless Labio-Dental Fricatives /f/

<table>
<thead>
<tr>
<th>Measures</th>
<th>Task Type</th>
<th>Initial Position</th>
<th>Final Position</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Mean Duration⁴</td>
<td>Word</td>
<td>182.04</td>
<td>49.08</td>
</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>138.56</td>
<td>24.65</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>143.72</td>
<td>46.42</td>
</tr>
<tr>
<td>Spectral Mean⁵</td>
<td>Word</td>
<td>2727.93</td>
<td>1179.77</td>
</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>2338.83</td>
<td>1174.13</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>2518.64</td>
<td>658.31</td>
</tr>
<tr>
<td>Spectral Variance⁶</td>
<td>Word</td>
<td>6.30</td>
<td>2.14</td>
</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>4.12</td>
<td>1.84</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>5.16</td>
<td>1.73</td>
</tr>
<tr>
<td>Spectral Skewness</td>
<td>Word</td>
<td>-2.76</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>-3.04</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>-2.94</td>
<td>0.58</td>
</tr>
<tr>
<td>Spectral Kurtosis</td>
<td>Word</td>
<td>6.78</td>
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<td></td>
<td>Paragraph</td>
<td>8.81</td>
<td>6.10</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>8.65</td>
<td>6.05</td>
</tr>
<tr>
<td>Mean Intensity²</td>
<td>Word</td>
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<td></td>
<td>Paragraph</td>
<td>-44.32</td>
<td>7.55</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>-43.95</td>
<td>7.00</td>
</tr>
</tbody>
</table>

Note. ⁴Measured in milliseconds (ms). ⁵Measured in hertz (Hz). ⁶Measured in megahertz (MHz). ²Measured as relative sound pressure level calculated by a root mean squared method.
Table 3

*Spectral Moment Means and Standard Deviations as a Function of Task Type and Word Position* for the Voiceless Lingual-Dental Fricatives /θ/

<table>
<thead>
<tr>
<th>Measures</th>
<th>Task Type</th>
<th>Initial Position</th>
<th>Final Position</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Mean Durationa</td>
<td>Word</td>
<td>101.33</td>
<td>64.57</td>
</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>95.61</td>
<td>47.56</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>103.24</td>
<td>44.63</td>
</tr>
<tr>
<td>Spectral Meanb</td>
<td>Word</td>
<td>3393.09</td>
<td>1122.78</td>
</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>3550.67</td>
<td>1419.35</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>4171.94</td>
<td>1507.21</td>
</tr>
<tr>
<td>Spectral Variancec</td>
<td>Word</td>
<td>6.93</td>
<td>2.69</td>
</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>6.29</td>
<td>3.21</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>5.62</td>
<td>3.99</td>
</tr>
<tr>
<td>Spectral Skewness</td>
<td>Word</td>
<td>-2.31</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>-2.32</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>-2.13</td>
<td>0.74</td>
</tr>
<tr>
<td>Spectral Kurtosis</td>
<td>Word</td>
<td>4.66</td>
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<td></td>
<td>Paragraph</td>
<td>3.58</td>
<td>3.34</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>4.39</td>
<td>4.15</td>
</tr>
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<td>Mean Intensityd</td>
<td>Word</td>
<td>-45.73</td>
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<td></td>
<td>Paragraph</td>
<td>-44.06</td>
<td>6.00</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>-43.05</td>
<td>9.51</td>
</tr>
</tbody>
</table>

*Note.* aMeasured in milliseconds (ms). bMeasured in hertz (Hz). cMeasured in megahertz (MHz). dMeasured as relative sound pressure level calculated by a root mean squared method.
Figure 1. Spectral Mean Values as a Function of Task Type and Word Position for Voiceless Alveolar Fricative /s/ Productions.
Figure 2. Spectral Variance Values as a Function of Task Type and Word Position for Voiceless Alveolar Fricative /s/ Productions.
Furthermore, the intensity of the voiceless alveolar fricative varied significantly as a function of word position, $F(1,11) = 33.11, p < .001, \eta^2_{\text{partial}} = .75$, and also as a function of task type, $F(2,22) = 4.59, p = .021, \eta^2_{\text{partial}} = .29$. The intensity was highest during word list tasks and lowest during spontaneous speech tasks (-31.23 and -34.75). Additionally, intensity values were higher in the initial position and lower in the final position (-31.67 and -34.01). The specific values for the dependent measures as a function of task type and position are listed in Table 4. No additional statistical tests were found to be significant.

**Voiceless Palatal Fricatives /ʃ/**

The mean durations of the voiceless palatal-alveolar fricative productions were found to be significantly different as a function of the task type and word position, $F(2,8) = 9.37, p = .008, \eta^2_{\text{partial}} = .70$. As shown in Figure 3, the durations were higher in the initial word position when produced in the carrier phrase and spontaneous speech tasks, but higher in the final word position for paragraph prompts. In addition, the spectral variance was found to vary significantly as a function of task type, $F(2,8) = 8.49, p = .011, \eta^2_{\text{partial}} = .68$, with higher values for the participant’s spontaneous speech (45 MHz), followed by the carrier phrase (34 MHz) and paragraph reading tasks (34 MHz). The spectral skewness of the voiceless palate-alveolar fricative also varied significantly as a function of task type, $F(2,8) = 7.49, p = .015, \eta^2_{\text{partial}} = .65$. The spectral skewness was highest for the paragraph reading (-0.24) and carrier phrase conditions (-0.26), compared with the participant’s spontaneous speech (-0.72). The specific values for the dependent measures as a function of task type and position are listed in Table 5. No additional statistical tests were found to be significant.
Table 4

*Spectral Moment Means and Standard Deviations as a Function of Task Type and Word Position for the Voiceless Alveolar Fricatives /s/*

<table>
<thead>
<tr>
<th>Measures</th>
<th>Task Type</th>
<th>Initial Position</th>
<th>Final Position</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Mean Duration*</td>
<td>Word</td>
<td>204.61</td>
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</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>195.29</td>
<td>23.23</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>510.19</td>
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</tr>
<tr>
<td>Spectral Meanb</td>
<td>Word</td>
<td>5940.43</td>
<td>1624.02</td>
</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>6340.42</td>
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</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>5664.13</td>
<td>1578.91</td>
</tr>
<tr>
<td>Spectral Variancec</td>
<td>Word</td>
<td>2.05</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>2.16</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>2.64</td>
<td>0.97</td>
</tr>
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</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>-1.66</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
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<td>0.92</td>
</tr>
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<td>Word</td>
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<td>2.85</td>
</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>2.25</td>
<td>2.48</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>3.29</td>
<td>5.91</td>
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<tr>
<td>Mean Intensityd</td>
<td>Word</td>
<td>-29.92</td>
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</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>-30.99</td>
<td>6.60</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>-34.10</td>
<td>6.29</td>
</tr>
</tbody>
</table>

*Note.* aMeasured in milliseconds (ms). bMeasured in hertz (Hz). cMeasured in megahertz (MHz). dMeasured as relative sound pressure level calculated by a root mean squared method.
Figure 3. Duration Values as a Function of Task Type and Word Position for Voiceless Palato-Alveolar Fricative /ʃ/ Productions.
Table 5

*Spectral Moment Means and Standard Deviations as a Function of Task Type and Word Position*

*for the Voiceless Palato-Alveolar Fricative /ʃ/

<table>
<thead>
<tr>
<th>Measures</th>
<th>Task Type</th>
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<th>Final Position</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Mean Duration</td>
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</tr>
<tr>
<td></td>
<td>Paragraph</td>
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</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>171.85</td>
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</tr>
<tr>
<td>Spectral Mean</td>
<td>Word</td>
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</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>5812.50</td>
<td>175.74</td>
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<td>Spontaneous</td>
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<td>553.30</td>
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<td>Spectral Variance</td>
<td>Word</td>
<td>3.58</td>
<td>1.24</td>
</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>3.50</td>
<td>1.18</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
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<td>1.50</td>
</tr>
<tr>
<td>Spectral Skewness</td>
<td>Word</td>
<td>-0.38</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>-0.21</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>-0.56</td>
<td>0.36</td>
</tr>
<tr>
<td>Spectral Kurtosis</td>
<td>Word</td>
<td>-0.39</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>-0.12</td>
<td>1.47</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>-0.61</td>
<td>0.31</td>
</tr>
<tr>
<td>Mean Intensity</td>
<td>Word</td>
<td>-36.68</td>
<td>10.10</td>
</tr>
<tr>
<td></td>
<td>Paragraph</td>
<td>-37.34</td>
<td>9.84</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>-37.31</td>
<td>9.79</td>
</tr>
</tbody>
</table>

*Note.*  

\(^a\)Measured in milliseconds (ms).  
\(^b\)Measured in hertz (Hz).  
\(^c\)Measured in megahertz (MHz).  
\(^d\)Measured as relative sound pressure level calculated by a root mean squared method.
Discussion

It was hypothesized that the speakers’ articulatory accuracy would decrease during less structured tasks due to the increased cognitive demands of the spontaneous speech elicitation conditions. However, across the six dependent variables for the four fricative phonemes the findings of this study found only few statistically significant differences as a function of task type. For example, the speakers’ intensity of the fricative /s/ was lower during spontaneous speech tasks. Results of this study also found that for the fricative /ʃ/ the spectral variance was higher during the spontaneous speech tasks and the spectral skewness was found to be lower during the paragraph elicitation condition. Despite these few isolated differences across task type, the majority of the statistical tests were not found to be statistically significant.

Findings of this study do not fully support the findings reported by Kuiken and Vedder (2011) who concluded that task complexity influences production patterns, in particular with respect to lexical errors. Participants of Kuiken and Vedder’s study were found to make fewer errors in a linguistically complex task compared to a relatively noncomplex task. The results of the current study also minimally support the findings reported by Robinson (1995), termed the Robinson Cognition Hypothesis. Robinson reported that while the complexity of a task increases, L2 learners make fewer errors and their syntactic complexity of their performance increases (Robinson, 1995).

When considering normative data of SMA values for native English adult speakers (Jongman et al., 2000; Nissen & Fox, 2005), L2 speakers participating in this study demonstrated a number of differences. In particular, the standard deviation values for the dependent measures were consistently high across the different experimental conditions. This relatively high amount of variability was found both within and between participants. In addition, the average spectral
mean values for /f/ of approximately 2500 Hz is lower than has been reported in previous studies (Jongman et al., 2000; Nissen, 2003). These differences in spectral mean from previous data collected from native English speakers may be due to the misarticulation of the place of fricative constriction or due to voicing during the production of the voiceless speech sound. Difficulties in the /f/ and /v/ contrast is not uncommon in nonnative L2 learners. The portion of the fricative productions analyzed within this study were extracted from the middle portion of sound to avoid the influence of possible voicing from surrounding sounds. It was observed that for a number of tokens the duration of fricative tokens, regardless of word position or task type, was significantly shorter than typical productions by native English speakers. Thus, it is possible that for the shorter fricative tokens the medially-located 40 ms analysis window may have included some voicing interference from surrounding vowels. However, a post-hoc analysis using a 20 ms window indicated no significant differences in the SMA values when compared to the use of a 40 ms window.

Irrespective of the length of the fricative tokens, the SMA methodology used in this study was not designed to account for voicing in the medial sections of the speech sound. Thus, if the L2 learners substituted a voiced fricative such as /v/, instead of the voiceless fricative /f/, the SMA mean values would have been affected in a substantial manner. This limitation in methodology could be addressed by having the SMA algorithms only include frequency components above 750 Hz, thereby avoiding the relatively high amplitude voicing components that can have a significant effect on the SMA averages. Difficulties with the place of articulation and/or voicing may also have been the reason for the relatively limited contrast difference in spectral mean between /s/ and /ʃ/ as well.
It was also hypothesized that the L2 learners’ production of the English fricatives would vary as a function of word position, due largely to the fact that in Mandarin, there are only two sounds typically spoken in the final position of syllables, the sonorants /n/ and /ŋ/ (Cardoso, 2011; Cheng, 1987; Nasukawa, 2004). Considering that syllables in English are commonly closed by a consonant, Mandarin speakers learning English as an L2 may be able to produce the English fricatives in initial word position but have difficulty when the sound is in word final position. However, the findings of this study found only a few significant differences across word position. For example, the speakers’ duration of the fricative /f/ decreased in the final word position when compared to the initial. Results of this study also found that the spectral skewness values of the fricative /s/ were lower in the initial position than in the final. Additionally, the intensity of the fricative /s/ was higher in the initial position and lower in the final position. Despite these few findings, the majority of the statistical tests were not found to be significant across word position.

The lack of significant differences between fricative sounds produced in initial and final word position may have been due to the L2 learners’ ability to self-select which sounds and words they used during the spontaneous speech tasks. Research by Fang and Ping-an (1992), has indicated that Mandarin speakers learning English often omit final sounds entirely because their native language does not utilize final consonants. A post-hoc review of the spontaneous speech data collected in this study confirmed that the participants were often choosing not to produce words with fricatives in the final position. The number of instances that participants used an initial fricative sound was approximately six times more frequent than words with a fricative in final position. In general, these findings agree with the findings reported by Fang and Ping-an.
Spectral Moment Analysis has been used to evaluate the acquisition of new sounds in a speaker’s native language, including young children (Nissen & Fox, 2009; Nittrouer et al., 1989). However, prior to the present study, SMA has not previously been used to analyze the sound productions of L2 learners. Considering the inherent limitations of SMA, it may be of value to use methods of analysis that may better accommodate the amount of variation in production abilities often found in L2 learners. In essence, the SMA used in the current study may be too narrow in scope to examine the sound productions in a valid manner. A logical next step would be to evaluate the fricative productions across task type and word position using perceptual ratings from native listeners. The use of a perceptual study may be more appropriate because the human auditory system is able to evaluate multiple acoustic and spectral cues of sound productions simultaneously. It would also be of value to include a larger, more homogenous group of L2 learners. Utilizing a greater number of participants may increase the prevalence of significant relationships within the data and would likely be a better representation of native Mandarin L2 learners in general.

In addition, it may be of value in future research to consider the L2 learners’ reading proficiency levels. Considering two of the three tasks used in this study required the speakers to read aloud, the reading proficiency levels of each participant likely should have been considered. These levels could have affected speakers’ performance on tasks such as reading printed sentences and paragraphs. Within spontaneous speech, speakers were able to control the sounds and sentences they put together. Specifically, we observed that native Mandarin speakers were highly selective of the sounds they used and tended to avoid sounds that they had difficulty producing.
Despite these limitations, this study provides additional understanding toward how native Mandarin L2 learners’ acquisition and production of English fricatives may change as a function of linguistic task type and the word position of the sound. This study is unique in that it uses SMA to examine the production of fricative speech sound in L2 learners. There is also ecological value in this study’s evaluation of spontaneous speech, an area of research that is underdeveloped within the field of second language acquisition.
References


Objective: This article outlined the simplification of forms ending in obstruents by native speakers of Mandarin. Principles: The authors outline that one problem that Mandarin learners of English face is the mastery of English codas. Challenges arise because the Mandarin language does not allow the nasal /m/, any liquids, or any obstruents in the coda position. The authors also outlined that Mandarin learners of English often devoice coda obstruents. The authors believe that devoicing of English coda stops by Mandarin speakers provides a clear case of the emergence of the unmarked. Conclusions: The authors argue that the devoicing and bisyllabicity effects result from universal markedness constraints that are present in all grammars but are masked in the learner’s native language grammar by the effects of higher ranking constraints. The article proposes a model of second-language acquisition in which learners, under pressure from interlanguage data, begin to construct an interlanguage grammar in which the rankings of constraints may differ from the native-language ranking. Markedness effects that are not visible in either the native or the target language may become visible in the interlanguage data.


Objective: The purpose of this study was to investigate the acquisition in perception of post-vocalic word-final stops by speakers of Brazilian Portuguese learning English as a foreign language in a classroom environment. Method: Participants for this study included 51 post-adolescent Brazilian Portuguese speakers. Participants were divided into four groups based on their proficiency in English. Proficiency level was determined in consideration of a participant’s exposure to L2 in a classroom environment, their placement in a school’s proficiency system, and answers to a background questionnaire. Participants sat in front of a computer screen, listened to English words, and decided whether they ended in a consonant or vowel. Participants also had an option to select “I don’t know” when they were uncertain. Results: Statistical results of the experiment indicated that codas are likely to be perceived in the following instances: a) in more advanced levels of proficiency, b) in the context of segments that belong to the class of...
coronal and labial, and c) when the coda consonant is preceded by a lax vowel. **Conclusions:**

The authors outlined that the results show a correlation between speech perception and production, and support the view that perception precedes production in the development of second language codas. Furthermore, the results suggest that perceptive competence develops in a manner that is comparatively parallel to the later development of productive competence.


**Objective:** The purpose of this study was to examine the perception of English vowels by native speakers of Italian. **Method:** For Experiment 1, the first group of participants were native speakers of Canadian English while the second group consisted of native speakers of Italian. The perceptual stimuli consisted of consonant-vowel consonant (CVC) English words. **Results:** In two preliminary experiments, Italian university students, living in Canada for three months, were found to have difficulty discriminating sounds as they often identified both members of each contrast pair as instances of a single Italian vowel. In follow-up experiments, early learners obtained higher discrimination scores than the late learners. The early learners who used Italian often, but not the early learners who used Italian seldom, were found to differ from native speakers of English in perceiving English vowels. **Conclusions:** Two important conclusions were drawn regarding second language perceptual learning: a) learning an L2 in childhood does not guarantee a nativelike perception of L2 vowels, nor does the establishment of a sound system for the L1 preclude a functional nativelike perception of L2 vowels and b) although the late learners generally perceived English vowels less accurately than the early learners, some perceived them accurately.


**Objective:** The purpose of this study was to construct a reference database against which misarticulations /s/ can be compared. **Method:** Acoustic data for 26 typically speaking 9 to 15-year-olds were examined to resolve measurement issues in acoustic analyses, including alternative sampling points within the /s/ fricative. An /s/-sample task was administered to all participants as part of a 90-minute protocol conducted by a speech-language pathologist. The /s/-
sample task was embedded in a larger 120-item task. 120 total tokens were produced in the carrier phrase “Say _____ again.” All tokens were recorded within a single session. Speakers were allowed to take a quick break after completing 60 tokens. Each of the production were segmented and analyzed using a 20-ms Hamming window. Results: Means and standard deviations for each of the spectral moments for the onset, midpoint, and offset of the frication of /s/ were reported within the article. The study reported on significant set differences for both frequency mean and frequency skew. The authors did not find statistically significant differences across age ranges. Conclusions: The authors concluded that linear scale data for the first and third spectral moments are considered essential to characterize /s/ independent of phonetic context. The article also suggested that information on the fourth moment does not add significant insights into the characteristics of /s/ in typically speaking children from 9-15 years of age.


Objective: This study described a quantitative systemized approach for classifying word-initial voiceless obstruents. Method: The subjects included five females and five males with ages ranging from 18 to 31. Participants were presented with a list of monosyllabic words beginning with a voiceless obstruent. Each word of the set was paired with the carrier phrase “I can say again” and repeated six times. The data was analyzed using Fast Fourier transforms (FFTs), collected every ten milliseconds, and measured from the onset of the obstruent through the third cycle of the following vowel. The first four moments (mean, variance, skewness, and kurtosis) were then calculated from linear and Bark transformed spectra. Results: The moments were analyzed using three-dimensional graphs for each place of articulation. The study found that voiceless stops could be classified with an average of 92% accuracy. This was derived from the first forty milliseconds of the voiceless stop. Furthermore, 98% of sibilants were classified correctly via the discriminant analysis from the first 20 milliseconds of the consonants. Conclusions: This study concluded that a quantitative procedure can be used to classify features of word-initial obstruents.
Objective: This study aimed to analyze the sex-related differences found between male and female fricative production. Method: One hundred total participants engaged in this study—fifty male and fifty female, all of whom spoke a central Ohio version of Standard American English. The participants were organized into five separate groups with ten male and ten female speakers in each group. Fast Fourier transforms (FFTs) were calculated and fricative spectral moment analysis was prioritized. Spectral moments for each individual fricative were calculated with a 40 millisecond Hamming window at four different locations. Results: The following spectral measures were analyzed: spectral peak, spectral slope, spectral mean, spectral skewness, and spectral kurtosis. According to this collected data, sex-specific differences in fricative articulation were found in the speech of prepubescent children. Additionally, the article explained that the spectral means declined for /ʃ/ as age increased, regardless of speaker sex. However, across all age groups a similar age-related decline for /s/ was only exhibited by male speakers. Conclusions: The study concluded that a portion of sex-linked differences may be associated with learned or behavioral factors; the article supports the idea that articulatory development follows different patterns in girls as opposed to boys, differences which may start to emerge as early as 6-7 years of age.


Objective: This study aimed to investigate the impact of manipulating the complexity of three different types of oral tasks within conversational interactions. Method: Sixty Spanish-speaking volunteers between the ages of 18 and 40 participants in this study. The sixty subjects took part in three types of interactive tasks: a decision-making task, an instruction-giving task, and a narrative task. Within each task type were simple and complex levels of the task, all of which were done with a partner. Task complexity changed within each learner’s experience. Additionally, each subject rated the task on a scale of task difficulty, personal stress, confidence, interest, and motivation. Results: Difficult, stress, and confidence were the variables effected by
task type. The results of this study may suggest that increasing the cognitive complexity of tasks may contribute to enhance interaction. **Conclusions:** As a task becomes more complex, language learners are more precise, reorganize the delivery of their message, and work towards being successful in the task. The authors proposed the conclusion that these findings can help learners in their interlanguage development as increasing the complexity of a task may improve interaction.


**Objective:** This study tests the theoretical predictions regarding effects of increasing task complexity for second language pronunciation. Specifically, the authors analyzed whether more complex tasks lead to more “pronunciation-focused language-related” episodes and positively impact accuracy of phonetic form during task completion. **Method:** Seventeen L2 Spanish learners completed simple and complex map tasks where the pronunciation of Spanish vowels was made task specific. **Results:** No statistical difference in learner-produced “pronunciation-related language related” episodes in the simple and complex tasks. Vowel production, however, moved in a target like direction for one of five segments during the complex task. **Conclusions:** The authors concluded that there are some benefits of task complexity manipulations for L2 pronunciation.


**Summary:** Electropalatography (EPG) is a clinical and research tool used to observe the dynamic movements of the tongue during continuous speech. EPG has been used to research many aspects of articulation and coarticulation in several languages. This technology could also be useful in assessment and treatment of a variety of speech disorders. The authors advised that, because of the limitations of EPG in detecting tongue-to-palate proximity or which part of the tongue is creating a speech sound, a multi-channel approach should be taken to supplement EPG data with aerodynamic data, movement tracking devices, or acoustic data. EPG as a clinical tool has proven itself to be effective, and the use of EPG could provide a unique opportunity for
researchers to learn more about the development and complex nature of articulatory patterns. The authors discussed the clinical applications of EPG within this article and defined its limitations as well.


**Objective:** The purpose of this study was to analyze the intelligibility of native and mandarin-accented English speech for native English and native Mandarin listeners. **Method:** The stimuli for this study was obtained from a database of native and non-native English speech, located from the Northwestern University. Thirty total participants served as “listeners” for this study. All participants also performed a sentence reading task using a carrier phrase. The next phase of this study was a judgement task. **Results:** The authors reported on evidence of an interlanguage speech intelligibility benefit for listeners (ISIB-L). However, there was no evidence of an interlanguage speech intelligibility benefit for talkers (ISIB-T). The speech intelligibility benefit for listeners was only for low phonological proficiency listeners and low phonological proficiency speech. Variations in the demands associated with different tasks may be responsible for variation in findings reported in the literature. **Conclusions:** The authors reported on ISIB-T, whereby non-native listeners may find non-native talkers sharing their native language background more intelligible than they do native talkers. ISIB-L showcases how non-native listeners may outperform native listeners in comprehending non-native-accented speech.


**Objective:** This study aimed to accurately classify place of articulation for fricatives. **Method:** Twenty speakers, ten male and ten female, were recruited from the student population at Cornell University. All eight English fricatives (f, v, θ, ð, s, z, ʃ, ʒ) were recorded in CVC syllables using the carrier phase “say __ again.” The fricatives were in the initial position, followed by a vowel, and all final consonants were a /p/. Each CVC token was repeated three times, resulting in a total of 144 tokens per subject. All recordings were obtained in a soundproof booth with a high-quality microphone. Protocols also listed that the spectral peak location of each fricative was
analyzed using a 40-ms full Hamming window. FFTs were calculated using a 40-ms full Hamming window as well. **Results:** Spectral peak location decreased in frequency as place of articulation moved further back in the oral cavity. Data analyzed regarding gender differences indicated that the spectral peak location for females was significantly higher than for males. The authors found that spectral moments distinguished all four places of fricative articulation. **Conclusions:** The article’s results indicate that spectral and amplitudinal information provide the most critical information to place of articulation in fricatives; acoustic properties can provide information about all four places of articulation, despite variation in speaker, vowel context, and voicing.


**Summary:** The chapter discusses the question to what extent the effect of task complexity on linguistic performance in L2 writing and speaking is influenced by the mode in which the tasks have to be performed (oral versus written). The participants in the oral mode were 44 learners of Italian as a second language, with Dutch as their mother tongue. Their performance was compared with that of another group of 91 Italian L2 learners with Dutch L1 who had performed the same tasks in the written mode. Scores on a cloze test were used as a measure of the general level of L2 proficiency of the learners. Our results demonstrate that both in the oral and the written mode task complexity mainly seems to affect accuracy. The authors did not observe an interaction of task type and proficiency level, either in the written or in the oral mode.


**Objective:** This article aimed to characterize the adaptions in the clear production of American English fricatives in a carefully controlled range of communication situations. **Method:** Twenty talkers, ten male and ten female were recruited, all of whom reported normal hearing and no history of speech or language disorders. Eight English fricatives and one vowel were combined to form vowel-fricative-vowel (VCV) syllables. The production of each VCV token was recorded in isolation in conversational and clear speaking styles. Recording were hand annotated
into VCV segments using the PRAAT speech analysis software. *Results:* Across speakers and fricatives, duration increased, and spectral measures including peak frequency, mean, and skewness showed energy concentration in higher frequency regions in clear speech. The study reported that the place of articulation contrasts seemed to be enhanced in clear speech. Nonsibilants decreased in kurtosis in clear speech, whereas sibilants did not. Participants varied significantly in the magnitude and direction of acoustic modifications in clear speech. One variable that did not contribute to clear-to-conversational acoustic differences was speaker gender. This indicates that female to male speakers did not reliably differ in the extent or direction of any acoustic modifications in clear speech. *Conclusion:* This study concluded that there are systematic acoustic-phonetic modifications in the production of clear fricatives. Additionally, the acoustic distances between minimally contrasting sounds were enlarged in clear speech. This indicated that talkers attempt to maintain contrast between category distributions across the inventory of English fricatives. Individual talkers varied widely in the magnitude, and sometimes the direction of these changes; these differences were not related to talker gender.


*Objective:* The purpose of this study was to examine the possible correlations between the linguipalatal contact patterns used to produce the fricatives /s/ and /ʃ/ and the resulting spectral characteristics. *Method:* Participants for this study consisted of eight speakers of American English with no history of previous speech or language disorder. Four different types of speech samples were gathered from the participants including: individual phoneme productions, real and nonsense words, sentences constructed to target specific consonant sounds, and reading passages which were several paragraphs in length. Results were obtained using a EPG system and analyzed using spectral moment analysis. *Results:* The spectral measures for the fricative tokens in the present study were found to be similar to data reported in previous research. The majority of the correlations examined in this study were found to be statistically significant. Yet, none of the correlations accounted for a large proportion of the variance in the data. Generally, the strongest correlations were found between the spectral mean and the symmetry of the contact pattern in the anterior region of the EPG palate. *Conclusions:* Although the width and symmetry
of linguapalatal contact contributes to the spectral signature /s/ and /ʃ/, they are likely only part of a much more complex process.


**Objective:** This study aimed to analyze intraspeaker differences in native and L2 production. The purpose of this study was to present measurable changes in speech production of individuals who speak two languages. **Method:** Ten native Spanish speakers and ten native Korean speakers participated. Participants were placed in a sound-proof booth during the procedure. Tongue movement was measured using a small magnet attached to the upper surface of the tongue. Each participant was asked to read a magazine article, spontaneously answer a simple question, and share a short narrative. All activities were performed in the subject’s native language and English. Tongue movement was tracked and analyzed in relation to peak stroke speed, average stroke speed, stroke distance, and duration. The strength of each participant’s accent was measured on a perspective scale to consider in relation to their language production differences. **Results:** Mean and standard deviation values for these kinematic measures were reported in relation to language spoken and the task type. It was reported that speakers’ stroke peak was significantly slower when talking in their L2. When speaking in English, participants decreased in their peak and average stroke speeds by about 10%. **Conclusions:** Significant intraspeaker differences in peak and average tongue stroke speeds were found when comparing L1 and L2 productions. For both Korean and Spanish, and across all three presented tasks, participants were found to have slower stroke speeds when speaking English. Higher accent ratings were found to correlate with lower stroke speeds and speech-to-pause ratio; L1-L2 kinematic differences were associated with perceptually salient speech features.


**Objective:** This study focused on the acoustic makeup of fricatives produced by adults and young children. **Method:** Child participants were typically developing between 3 to 6 years of age. Additionally, ten adults were recruited to participate in order to form a control group. All subjects were monolingual speakers of American English. Productions of monosyllabic words,
beginning with voiceless obstruents, were elicited. A total of sixty tokens were produced by each participant, elicited from picture identification. **Results:** Acoustic measures of durations, normalized amplitude, spectral slope, and spectral moments were used to analyze productions. It was found that the acoustic parameters of spectral slope and variance were important in the classification of voiceless fricatives. Spectral variance was the only measure to separate all four places of articulation. Furthermore, sibilant contrast between /s/ and /sh/ was less distinguished in children than adults. **Conclusions:** The dependent measures of fricative duration, normalized amplitude, spectral slope, and all four spectral moments varied significantly as a function of place of articulation. This study indicated that the majority of spectral parameters do not differ significantly between nonsibilant fricatives.


**Objective:** This study aimed to examine the acoustic and spectral patterns of stop articulation in the speech of pre-pubescent children. **Method:** Participants included three groups of children between the age of 3 and 5 years of age and one comparison group of adults. Additionally, each group was composed of an equal number of male and female subjects. Target phonemes were elicited from a series of words which contained the initial consonant /p/, /t/, or /k/. Participants produced each word three times while embedded in the carrier phase “this is a ____ again.” These target productions were recorded to a computer in a quiet environment with a low impedance dynamic microphone. **Results:** Spectral slope was one of the spectral measures that was analyzed in this study. Significant differences were found in spectral slopes across place of stop articulation. Within this study, a main effect was obtained for both the sex of the speaker and the age group. Spectral mean, spectral variance, spectral skewness and spectral kurtosis were also analyzed. This may contribute to a greater understanding of speech development in prepubescent children and provide additional insight into possible sex-specific patterns of stop articulation. **Conclusions:** Findings indicated that the dependent measures of normalized amplitude, spectral slope, and all four spectral moments carried significantly as a function of place of articulation.

**Objective:** The purpose of this study was to test the hypothesis that children’s articulatory gestures are not as precisely specified as are those of adults. Nittouer also examined the concept that some patterns of gesture achieve adult-like precision sooner than others. **Method:** This study’s participants included ten adults and thirty children. Twelve consonant-vowel syllables consisting of the consonants /s/, /ʃ/, /t/ and /k/ were used. Syllables were produced in a simple carrier phrase. **Results:** Significant differences in spectral mean were found for childrens’ velar stops, showing that children are more sensitive to vowel production than adults. Adults differentiated fricative consonants sounds more precisely than children did. **Conclusions:** Significant adult versus child stop consonant differentiation was not found, from which the authors concluded that some articulatory gestures reach maturity before others.


**Objective:** This study aimed to test the hypothesis that phoneme-sized phonetic segments emerge as functional units of perceptuomotor control from the child’s gradual reorganization of the gestures forming its early words or syllables. **Method:** Nittouer et al. investigated the acoustic structure of syllables produced by young children and adults. The study analyzed fricative-vowel syllables spoken by 40 subjects. These recordings were analyzed acoustically to determine how well different syllables with fricatives in the initial position were contrasted. **Results:** The authors reported on two independent developmental trends. First, the extent to which speakers differentiated between /ʃ/ and /s/ increased with age. Secondly, the extent to which they coarticulated each fricative with its following vowel decreased. **Conclusions:** The results support the hypothesis that children initially organize their speech gestures over a domain at least the size of the syllable.

**Objective:** This study examines the effects of task type and L2 proficiency on the relationships between L1 and L2 simultaneously across reading and writing tasks of different levels of complexity. **Method:** The analysis was based on a total of 305 Korean high school students learning EFL. Students were presented with five tasks, including comprehension tests and writing prompts. **Results:** The authors concluded that L2 proficiency had a much greater effect on L2 reading and writing than L1. Additionally, the strength of the relationship between more demanding L1 and L2 reading tasks showed a significant difference between the low and high L2 proficiency groups. **Conclusions:** The authors concluded that both L1 reading comprehension and L2 proficiency were significant predictors of L2 reading performance. The results provide empirical support for the idea that L1 and L2 reading skills are intertwined.


**Objective:** This study aimed to describe and analyze consonant voicing and devoicing in the English of Cantonese speakers from Hong Kong. **Method:** This study analyzed data collected from the subjects’ reading provided word lists. The data outlined in this study was collected from two Cantonese speakers. At the time of the study, the two participants were nearly half way done with their Bachelor’s degree in Contemporary English Language. The authors recognize that two subjects may not be a representation of the wide spectrum of Cantonese L2 learners of English. However, the selected subjects are considered to be representative of average university students or educated speakers in Hong Kong. To collect data, word lists were presented. Participants were asked to read the words aloud and each of their productions was recorded. **Results:** The authors looked at stem-final voiced obstruents and found that the rates of voicing and devoicing varied between participants. The authors concluded that stem-final obstruents are more likely to devoice in prevoiceless and word-final positions than prevocalic and pre-sonorant positions. **Conclusions:** Findings suggested that transfer plays a significant role in shaping the L2 English ranking.

**Objective:** This study aimed to analyze if listeners’ perceptual sensitivity to the palatal alternation depends upon the task and exposure to Spanish input. **Method:** Twenty-nine native Spanish speakers participated in the experiment. Thirty L1 English/L2 Spanish listeners were also recruited. A native female Mexican Spanish speaker recorded the stimuli; she read each word three times and the clearest tokens were segmented out and used for experimental stimuli. The target stimuli consisted of six CV/CV (CV-ma) words and six V/CV bisyllabic words. For experiment one, participants were asked to rate stimuli that contrasted only in the palatal variants. **Results:** the native Spanish speakers rated the stimuli as more similar than the L2 learners. Additionally, the native Spanish listeners rated the palatal variants as more “different” in onset position than in medial position. In Experiment 2, the participants heard pairs of non-words and had to judge whether they were the same or different, under strict time pressure. Experiment 3 asked the participants to segment artificial speech utterances. The results from this task suggest that L2 Spanish learners do not benefit from the presence of the palatal alternation when segmenting an input stream. Experiment 4 used an elicitation task. Results from this experiment led the authors to believe that L2 listeners are indeed sensitive to the presence of the stop/affricate allophone in onset position. **Conclusions:** This study presented four experiments that examined how native Spanish and L2 Spanish listeners perceive and use the Spanish palatal obstruent variants across a series of speech tasks. The results suggested that the functional role of native-language speech categories influences the perception of second language sounds and task effects play a role in the degree to which these effects play out.


**Objective:** This study aimed to assess the way that narrative task design influences the oral performance of second language learners. **Method:** Participants were categorized into two groups – 40 learners of English based in London and 60 learners of English based in Iran. All participants were asked to give English narratives of two presented cartoons. Some of the cartoons allowed loose narrative structure and others did not. Some also allowed for background
events and others did not. **Results:** Participants that described the cartoons with both background and foreground information exhibited a higher level of language, giving greater detail and descriptions. When given a tight structure versus a loose structure story, the participants’ language performance was significantly higher on tight structure tasks. **Conclusions:** L2 performance is affected in predictable ways by design features of narrative tasks. The complexity of narrative tasks affects L2 learners’ oral language performance. Tighter structure directly correlates with language performance.


**Objective:** Research was conducted to determine whether perceptual analysis and reading error analysis help in predicting children’s reading proficiency and whether gender affects children’s reading proficiency. **Method:** Eighteen male and Eighteen female fifth and sixth-grade elementary school students were recorded reading two passages twice. Both expert and naïve listeners rated their reading proficiency. The author analyzed reading errors that the participants made in six categories: substitutions, omissions, insertions, reversal, repetitions, and grammatical conversations. **Results:** Predictions of oral reading proficiency were fairly accurate. Ratings decreased as more errors were made. The most common reading errors made were substitutions (34.7% of all errors), repetitions (24.8%), and insertions (17.2%). The girls performed better than the boys on the oral reading proficiency portion. **Conclusions:** Predicting reading proficiency through perceptual ratings is effective, especially when reading pace and reading errors are considered. The reading errors that most commonly occur between the ages of 10-12 are substitution and repetition errors. Oral reading proficiency is higher on average in girls than in boys between the ages of 10-12.
APPENDIX B: TASK TYPE PROMPTS

Paragraph Readings

1. Last spring Tom and Kate went to the beach with their dog. After removing his leash, they watched him climb a steep mound of dirt and leap in the air. Tom split a piece of beef and threw it for the dog to catch in his teeth. They found a good seat in the sand and began to read a letter from a dear friend. After taking a peek at one page, Tom’s head began to tilt back and he began to sleep. Kate started to think, I wonder if Tom covered his skin to screen out the sun. She decided to speak, “Please wake up”. It was too late. Tom had deep burns on his cheek, the skin had started to peel. They decided to clean the sand from their feet and walk to the thrift shop at the top of the street. The shop not only sold cream to treat his burns, but also had kilts and shirts made of fleece. Tom began to preach, “Those poor sheep, I hope they don’t freeze.”

2. One spring evening, mother made a fruitcake to sell at the thrift shop on our street. She split a peach in half and began to peel away the skin. She smiled with her teeth as she began to read the instructions. Next, she told me to please clean the fruit to remove any dirt. With the bowl at a tilt she added cream to the treat. My dear father rose to his feet and kissed her on the cheek. She then gave him a leftover piece of beef to eat. He said, “I need to feed those sheep before I go to sleep.” He quickly rose from his seat, took a leap across the room, and rushed through the screen door. Mother said “I think we should put him on a leash”. With the cake in the oven, she began to speak and preach about her memories swimming in the deep ocean far from the beach and climbing a steep mountain peak to watch men freeze while dancing in shirts and kilts made of fleece.
APPENDIX B: TASK TYPE PROMPTS

List of Fairytales

1. 掩耳盗铃 Plugging One's Ears While Stealing a Bell
2. 塞翁失马 Blessing in disguise
3. 狐假虎威 The fox assuming the majesty of the tiger
4. 狼来了 The wolves are coming
5. 牛郎织女 Chinese Romeo and Juliet
APPENDIX B: TASK TYPE PROMPTS

Open-ended Questions

1. Describe for me what happened on the day that you arrived in the United States.
   o Tell me more about what happened when…

2. Share with me why learning English is so important to you.
   o Tell me more about how English will create opportunities for you.

3. Tell me about a favorite memory when you were young.

4. Tell me about your hometown.

5. Tell me about a recent vacation.

6. Tell me how living in the United States is different than your home country.

7. Tell me a story about a time you had fun with your family or friends?

8. Tell me what you enjoy doing in your free time. Why?

9. Tell me about your education before coming to the ELC.

10. Tell me about your favorite subject in school and why.
APPENDIX C: CONSENT FORM

研究参与者同意书

介绍

本研究是由James Hartshorn博士和Shawn Nissen博士主持，其目的为测试川川视觉反馈方法对学习英文的有效性。而研究的对像是为母语是中文、韩文和日文的学生。研究中的一部分学生将使用一页纸上的传感器来追踪舌头的活动；然后，舌头的活动会在电脑屏幕上展示出来。由于是儿童参与者，而儿童的母语是中文、韩文或日文，故特此邀请来参加此研究。

步骤

凡在扬百翰大学英语语言中心就读，且母语是中文、韩文或日文的学生都受邀参加一项课外的英语发音课程。其课程费用由英语语言中心承担。根据对其讲读的分析，参与者被分为两组：一组学生将得到使用传感器的练习，另一组的学生没有得到传感器的帮助。这些学生必须回答有关发音的习语，以获取自己的发音能力的反馈。参与者需佩戴传感器进行发音练习，而传感器的数据用于分析发音的发音能力。课程结束后，参与者将进行发音能力的测试。

风险与不适

参与本研究的风险极低。所有使用过的口腔传感器或者未使用口腔传感器的参与者均在实验中没有任何明显的不适。由于本研究采用的是较为简单的实验手段，因此在实验过程中，参与者可能会有轻微不适。实验过程中，参与者可能会有轻微不适，但这些不适不会对参与者造成严重影响。

保密性

本研究获得的实验数据将被妥善处理，且这些数据不会泄露给任何可辨识参与者的个人信息。所有数据均在实验学组内使用，只供直接研究者使用。

补偿

除了得到免费的实验材料和免费的实验课程之外，参与数据收集的参与者将收到25美元作为补偿。所有数据收集都将得到参与者同意。

参与

参与者完全自由。如果参与者选择退出，将不影响他们的记录或课程成绩。

关于研究的问题

如果您对本研究有任何问题，可以通过电话(801) 422-4034联系James Hartshorn博士，或者通过电话(801) 422-5050联系Shawn Nissen博士。如果您对作为研究参与者的权利有任何问题，您可以联系BYU IRB Administrator，地址A-285 ASB，Brigham Young University, Provo, UT, 84602，或者通过电话(801) 422-1461。我已阅读并完全理解此同意书。我的问题都已经获得妥善解答，我同意参加此研究。

签名

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