The Influence of Task Type on Speech Production by Second Language Learners of German: An Electropalatographic Study

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ABSTRACT

The Influence of Task Type on Speech Production by Second Language Learners of German: An Electropalatographic Study

Elizabeth Cope
Department of Communication Disorders, BYU
Master of Science

Electropalatography (EPG) is a computer-based system that tracks and measures contact patterns between the tongue and palate during speech production. The present study is focused on how the lingua-palatal contact patterns of native English speakers learning German as a second language (L2) differ as a function of task type. The fricatives ich-Laut [ç] and ach-Laut [x] were used as the target sounds, placed in nonsense words, short sentences, and spontaneous speech. The productions of the fricatives in the varying speech tasks were gathered from 12 university students enrolled in their second semester of a university level course of German. Comparisons were made using electrode mappings, percentages of regional contact, duration, and center of gravity measures. Duration measures showed that nonsense words were found to have the greatest duration for both fricatives when compared to the other task types. Percentage of activation measures showed that [ç] presented with similar activation in the medial and posterior regions of the palate across task type, whereas the activation in medial and posterior regions for [x] were found to differ more significantly across task type. Specifically, short sentences and spontaneous speech had similar posterior activation, but differed in medial activation, while nonsense words were different in both regions. Center of gravity measures were also greater in short sentences and spontaneous speech compared to nonsense words for [x]. It is anticipated that the data and information in this thesis will provide insights into the role of linguistic task type and EPG technology as instructional tools for L2 learners.

Keywords: electropalatography, German, second-language acquisition, task type
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DESCRIPTION OF THESIS STRUCTURE

This thesis, *The Influence of Task Type on Speech Production by Second Language Learners of German: An Electropalatographic Study*, is part of a larger study exploring the effectiveness of EPG technology as an instructional tool in second language acquisition. The analyses conducted in this study were based on a set of recordings originally collected by Lester (2017). Portions of this thesis may be submitted for publication, with the thesis author being included in the list of contributing coauthors. An annotated bibliography is provided in Appendix A, a table of the stimuli for this study is included in Appendix B, and the consent form used in this study is provided in Appendix C.
Introduction

Electropalatography (EPG) is a technique that is used to measure contact patterns between the tongue and the hard palate during articulation of speech and swallowing. It is a computer-based system that provides real time visual biofeedback through a pseudopalate that is customized to fit an individual’s hard palate and upper teeth. The pseudopalate contains 124 electrode sensors that are systematically placed from the alveolar ridge to the back molars, which are activated when the tongue touches them. Wires extend from the pseudopalate to a small processing box that is also connected to a computer (Fletcher, 1992). The computer displays a graphic of the hard palate with the electrode sensors shown as small dots. When the electrodes are activated by the tongue, larger dots are displayed on the screen, providing speakers with visual biofeedback of their tongue contact patterns.

EPG technology has been used for the assessment and treatment of a number of different speech disorders (Carter & Edwards, 2004; Dagenais, 1995; Pena-Brooks & Hedge, 2007). The visual biofeedback has been used to assist in the remediation of acquired articulation disorders due to acquired brain injury or cerebrovascular accident, especially in individuals who have not responded successfully to traditional treatment methods (Gibbon & Paterson, 2006). EPG technology has also been found to be beneficial in treating other types of acquired communication disorders, such as apraxia of speech (Bartle-Meyer, Goozée, & Murdoch, 2009; Southwood, Dagenais, Sutphin, & Garcia, 1997) and disordered speech as a result of cleft palate, (Michi, Yamashita, Imai, Suzuki, & Yoshida, 1993), glossectomy (Fletcher, 1988; Suzuki, 1989), and Parkinson’s disease (McAuliffe, Ward, & Murdoch, 2006).

In addition to helping treat acquired communication disorders, EPG can be beneficial for children who are having difficulty developing the speech sounds of their native language. In
American English, the sound contrasts that are commonly remediated using EPG include /s/ and /ʃ/ fricatives, /l/ and /r/ liquids, and stops that are inappropriately fronted and backed. A study conducted by Dagenais (1995) to evaluate the use of EPG for treating children with articulation and phonological disorders found it to be an effective clinical tool to target and treat these commonly misarticulated English sounds. EPG may assist a child to visualize and understand how to physically move their tongue to more accurately produce a misarticulated sound. A study by Gibbon, Hardcastle, and Dent (1995) evaluated the clinical efficacy of EPG in a 3-year project involving a group of 23 children and young adults with a speech sound disorder. At the end of the study, 18 of the 23 participants who completed their EPG treatment regimens showed improvement in their ability to produce the targeted speech sounds of /s, ʃ, tʃ, t/. Three months following the EPG intervention, auditory-based analysis of slowly produced speech revealed that the participants could produce perceptually normal articulations of the sounds targeted in therapy (Dent, Gibbon, & Hardcastle, 1995). These findings provide preliminary evidence that EPG can be successfully used to treat developmental speech sound disorders in school-aged children.

Just as EPG has been shown to be effective in helping individuals acquire sound contrasts in a speaker’s native language, a limited amount of research has indicated that EPG may also be beneficial for acquiring sound contrasts as a speaker learns a second language (L2; Bright, 1999; Gibbon, Hardcastle, & Suzuki, 1991; Schmidt, 1998). For many L2 learners a traditional approach to language instruction which emphasizes auditory feedback may be sufficient to acquire proper articulation and intelligibility in a second language. However, in some cases, L2 learners have difficulty acquiring unfamiliar speech sounds in the L2, or even acquiring L2 sounds in a native-like manner. EPG technology may play an important role in second language
instruction by providing the added benefit of visual feedback to help achieve accurate articulation.

Best (1995) explained one of the reasons that L2 learners may face difficulty in learning to discriminate and produce non-native-like sounds in his Perceptual Assimilation Model (PAM), which is a speech perception model that predicts such difficulties. It is assumed that awareness of sounds comes before production, thus, if language learners are unable to perceive a difference between two phonemes, then it is not likely that their production will be accurate (Bright, 1999; Flege, 1991). According to PAM, L2 learners try to categorize unfamiliar, yet similar, L2 sounds into already existing phonemic categories of their native language. This process of assimilation can become an issue because speakers fail to perceive or produce the phonetic differences between the two sounds based on auditory feedback alone (Bright, 1999; Flege, 1991).

Similar to the PAM, Flege’s (1995) Speech Learning Model (SLM) describes the perceived phonetic similarity between sounds, but through perceptual equivalence rather than assimilation. Non-native sounds are perceptually categorized to the most perceptually similar category, but a difference is still detectable. Thus, an accent is often the result of the speaker producing the non-native sound through their native phonetic category. If a non-native sound is perceptually dissimilar from all other sounds in a speaker’s native language, then it is perceived and acquired as a new sound category and is often produced in a more native-like manner than similar sounds over time.

As suggested by these theoretical models of L2 learning, the speech patterns of an L2 learner’s native language can either facilitate or interfere with learning the sounds of a second language. For example, native Japanese speakers often have difficulty discerning between the liquid sound contrasts of /l/ and /r/ in the English language. These difficulties may be due to the
fact that these sounds have no phonemic distinction in Japanese. The /l/ and /r/ sound contrast is not present through perception or production. In one study conducted by Gibbon et al. (1991), native Japanese speakers were asked to detect a difference between /l/ and /r/ using auditory feedback and then EPG. It was found that the native Japanese speakers were able to more accurately detect a difference in /l/ and /r/ sound contrasts through EPG because of the variation in contact patterns that is visually available through biofeedback.

EPG technology has also aided native Thai speakers in learning English as a second language. A study conducted by Schmidt (1998) found that EPG technology can help to reduce errors in second language learning as it allows individuals to utilize visual information that is not available for traditional methods of L2 instruction. The study included three native Thai speakers who were recorded saying single nonsense syllables in English. Each participant was seen bi-weekly over the course of a total of 24 weeks. Findings indicated that all three participants increased their ability to produce the target sounds in a native-like manner. Anecdotally, the participants reported that they had more success using EPG compared to previous methods of traditional instruction that only involved auditory information.

EPG technology has also been found to be effective in helping Spanish speakers acquire a second language. In a study by Bright (1999), three native Spanish speakers learning English used EPG to help them produce English sound contrasts with stops, fricatives, and vowels in a more native-like manner, thereby reducing their accent. Using visual biofeedback from EPG, the participants were able to reduce their accent by decreasing word errors by 43% at the sentence level.

These studies (Bright, 1999; Gibbon, et al. 1991; Schmidt, 1998) have provided some support for EPG being a valuable tool for L2 instruction in Spanish, Thai, and Japanese.
However, the research regarding the use of EPG with additional languages, such as native English speakers learning German, is limited or has yet to be conducted. Native English speakers learning German as an L2 have been found to have difficulty producing some German sounds with native-like accuracy, particularly the voiceless fricative allophones *ich*-Laut and *ach*-Laut ("Laut" being the German equivalent of "sound"). Although both allophones are of the sound spelled <ch> and are produced in the same manner, the place of constriction in the vocal tract differs between the two sounds. The *ich*-Laut or [ç] allophone is produced following front vowels while the *ach*-Laut or [x] allophone is produced following central and back vowels (Macfarland & Pierrehumbert, 1991). The [ç] is articulated near the center of the hard palate and the [x] is articulated more posteriorly near the velum. These sounds are commonly substituted by native English speakers learning German for the English palatal fricative /ʃ/, or even the voiceless velar stop /k/ (Moulton, 1962).

Recent studies (Isaacson, 2015; Lester, 2017) described the lingua-palatal contact patterns between [ç] and [x] allophones produced by native English-speaking students learning German as an L2 and a comparative group of native German speakers. The native German speakers were found to have a distinct difference in contact pattern between [ç] and [x]. Specifically, the [ç] allophone was produced in a more anterior place of articulation, while the [x] was produced more posteriorly. Compared to the native German speakers, the L2 speakers were found to have less distinction between these same allophones. Their speech was characterized by a more anterior constriction for [x], with an increase in the degree of medial contact, thereby reducing the width of the central groove.

The findings from these studies (Isaacson, 2015; Lester, 2017) were drawn from real words produced in a fixed carrier phrase. However, it is unclear how L2 learners of German may
produce these same allophones across a variety of linguistic contexts elicited through differing types of speech tasks. For example, do the contact patterns of the allophones change for speech that is elicited through a reading task compared to speech that is elicited through spontaneous conversation? One theory of L2 speech production supports the idea that formal speech produced in a relatively controlled environment is more native-like as it is more carefully monitored by the speaker (Edwards, 2008). Edwards suggests that when individuals are reading, they are more concentrated and aware of their speech productions, often producing speech at a slower pace, thus allowing the target sound to be fully and accurately articulated. This includes reading tasks such as word lists and short paragraphs. It is also worth noting that the need to focus on grammar in spontaneous speech can take focus and concentration of off pronunciation of sounds, whereas this is not an issue in reading tasks.

In contrast, a study by Moyer (2004) concluded that spontaneous speech was produced in a more native-like manner compared to speech produced while reading. The author attributed the increase in articulatory accuracy to differences in suprasegmental and pragmatic features such as tempo, rhythm, style, and linguistic control. However, it was noted from this study that the outcomes could have been influenced by the phonotactic and segmental characteristics included in each task. Specifically, the reading passages were designed to contain challenging phonotactic and segmental features, whereas the spontaneous speech was uncontrolled and could avoid the same challenging linguistic features. A study that controlled the linguistic content indicated that there was no significant difference in native-like or accented production between the spontaneous and read material (Munro & Derwing, 1994).

Considering that the findings of these studies are mixed (Edwards, 2008; Moyer, 2004; Munro & Derwing, 1994), further research is needed on how task type might affect the speech
production patterns of L2 learners. Thus, the aim of this study is to investigate how native English L2 learners’ production of the German fricative allophones might differ as a function of the linguistic task type (single syllable nonsense words, sentences, and spontaneous speech). EPG will be used to measure the L2 learners’ production of [ç] and [x] in terms of lingua-palatal contact patterns.

**Method**

This study is part of a larger study examining the efficacy of implementing EPG biofeedback for second language learning. The audio and EPG recordings analyzed in this study were collected by Isaacson (2015) and Lester (2017).

**Participants**

This study involved 12 participants drawn from a larger group of students learning German as an L2, all of whom were Brigham Young University students, who ranged in age from 17-25 years. Each participant had completed one introductory semester of German instruction, and were currently enrolled in their second semester of German. Each participant was a native English speaker with typical development in the anatomy of their vocal tract, including dentition and hard palate. Moreover, none of the participants were found to have a history of speech or language disorder. Approval for this study was received prior to data collection from Brigham Young University Institutional Review Board for Human Subjects Research. An informed consent document was read and signed by each participant, and all participants were compensated for their participation in the study.

**EPG Sensor**

Before data collection began, each participant was contacted through email and instructed to have an impression of their upper teeth and palate made at a local dental office. An EPG
sensor was created by SmartPalate International© from each participant’s dental impression. The EPG sensors (2mm thick) were similar to an orthodontic retainer, customized to fit the shape of each individual’s upper teeth and palate. The sensor extended from the front teeth to the back molars (Fletcher, 1992). Each sensor was comprised of 124 gold-plated electrodes that were organized in a grid-like pattern across the surface, as displayed in Figure 1. The electrode data are processed by a microprocessor I/O device that is worn around the neck of the user. The microprocessor transfers contact pattern data through a USB cord to a PC computer. This allows the instructor and the L2 learner to view their contact patterns in real time on a computer screen.

**Stimuli**

The participants were asked to produce the German [ç] and [x] speech sounds with the EPG sensor in place. The target speech sounds were elicited in three different task types: a) nonsense words, b) short phrases or sentences, and c) spontaneous conversation. For the

![Figure 1. EPG sensor and user interface (completespeech.com).](image-url)
nonsense words, the target allophones [ç] and [x] were embedded in the final position of a VC syllable as shown in Appendix B. Five tokens of each nonsense word were produced by each participant. A series of short phrases and sentences contained real words with the target allophones embedded in the final word position. There were four words containing [ç] following a front vowel (/i/) and five words containing [x] following a back vowel (/ɑ/), as seen in Appendix B. In total, 414 tokens were analyzed in the spontaneous task condition. The number of spontaneous tokens varied across individual speakers depending on the content of the message being expressed. The spontaneous speech samples were elicited through a series of open-ended questions.

**Procedures**

Prior to data collection, the fit, comfort, and function of the EPG sensor for each participant was examined. Each participant inserted the sensor and was instructed to report whether the sensor had clicked into place without causing them any pain, and if the fit was comfortable, meaning it was not too loose or too tight. Two of the participants had loose sensors, so their sensors were secured with dental adhesive. The EPG processor was activated and the electrodes were deemed functional. Each participant was given 15 minutes to engage in a conversation in English to adapt to the presence of the sensor in their mouth. The participants were also familiarized with the stimuli by reading each item once prior to the collection of data.

Participants produced the target stimuli during one 60-minute session while seated within a sound-attenuating booth. The nonsense words and short sentences were randomized and each of these lists was read aloud from physical printouts. The participants were given breaks between tasks and upon request. All lingua-palatal contact data were transferred to a PC in real time during data collection, and then saved as a .csv file. Each participant’s speech was also recorded.
through an internal microphone placed in the EPG processor (low-quality waveform) and an external high-quality microphone (high-quality waveform). These recordings were saved on the PC hard drive as .wav files. At the end of the session, each participant was instructed to remove their EPG sensor and produce the target stimuli without it. These data were saved as audio only .wav files and were not used in the current study.

**Data Analysis**

The original audio files were segmented and saved as smaller files according to task type. The onset and offset time points of the target stimuli within each task for each speaker were found and recorded in a text file to the nearest millisecond. The onset of each target fricative was determined by the time point that exhibited a distinct increase in diffuse noise energy while the offset of each target fricative was determined by the time point that exhibited a distinct decrease in diffuse noise energy. If the onset or offset of a target sound could not clearly be identified, or if the production was incorrect, then the data for that production would not be used in further analysis. The onset and offset time points were used to measure the duration of each fricative token.

The recorded time points were also inserted into a custom-designed MATLAB program that calculated the average occurrence of electrode activation for each of the 124 electrodes across a series of sequential 40 milliseconds analysis windows. Thus, depending on the duration of each fricative sample, the number of windows varied for each speech token. From the series of analysis windows for each fricative token, the 40 ms window with the greatest occurrence of overall lingua-palatal contact was used to create the static electrode mappings, percentage of regional activation, and center of gravity (COG) measurements.
Patterns of palatal contact made by the L2 learners of German across task type are reported using descriptive and inferential statistics. Electrode mappings, percentage of regional activation, duration, and COG measurements are provided for both the [ç] and [x] fricatives as a function of task type. Electrode mappings illustrate the average level of lingua-palatal contact made during the production of individual sounds in each task type. A color scheme with four varied shades of blue was used to represent how consistently a given electrode was activated across the 12 participants. The percentage of electrode activation is reported for the anterior, medial, and posterior regions of the palate, as shown in Figure 2.

*Figure 2. Areas of regional activation.*
The COG conveys where the majority of the electrode contact is being made. Following the description provided by Lester (2017), the COG measure was computed by taking the sum of the percentage of activation of each row multiplied by a relative power scale, divided by the total degree of activation across the EPG sensor. The power scale was dispersed from 1 to 14 across the posterior 14 rows of the EPG sensor (excluding the initial row of sensors that measure lip contact). Therefore, the power weight of the 2nd row was 14, the 3rd row was 13, the 4th row was 12, etc. The middle four sensors of rows 8, 13, 14, and 15, as well as the central region were excluded from the COG calculation. This was because of limited contact of the electrodes in these areas due to the shape of the dental arch and the nature of the fricative productions. Thus, the computation of the COG measure is as follows:

\[
\text{COG} = \frac{\sum [A_r(P)]}{\sum (A_t)}
\]

- \(A_r\) = percentage of electrode activation for each row
- \(A_t\) = percentage of total electrode activation
- \(P\) = relative power scale from 1 to 14

**Measurement Reliability**

To examine the reliability of the segmentation of the speech sounds in this study, a second rater segmented 10% of the participant productions. The first and second sets of measurements had a Pearson correlation of \(r = .99, p < 0.001\), with a mean difference of 37.1 ms.

**Results**

*ich-Laut, [ç]*

The mean durations of the productions of [ç] were found to be significantly different as a function of task type, \(F(2,22) = 4.24, p = .028, \eta^2_{\text{partial}} = .278\). As shown in Figure 3, the durations were higher in nonsense words (\(M = 224\) ms), compared to the spontaneous (\(M = 193\) ms) and sentence (\(M = 169\) ms) task conditions.
In terms of electrode activation, the mean percentage of lingua-palatal contact in the medial region was found to vary significantly as a function of task type, $F(2,22) = 4.59$, $p = .022$, $\eta^2_{\text{partial}} = .294$. Pairwise comparisons indicated higher values for the fricative productions of [ç] in the medial region of the palate when embedded in nonsense words compared to spontaneous speech. As displayed in Figure 4, the mean electrode percentage of activation was found to be 89% for nonsense words, followed by 86% for sentences, and 81% for spontaneous speech.

No additional dependent variables were found to differ statistically as a function of task type for the [ç] allophone. Visual displays of the lingua-palatal contact patterns for [ç] across task type are represented in Figures 5, 6, and 7. The specific values for duration, electrode activation, and COG measures are listed in Table 1.

ach-Laut, [x]

The mean durations of the productions for [x] were found to be significantly different as a function of task type, $F(2,14) = 14.89$, $p = .0001$, $\eta^2_{\text{partial}} = .680$. As shown previously in Figure

![Figure 3. Duration of [ç] and [x] across task type.](image)
Figure 4. Percentage of regional activation across task type for [ç].

Figure 5. Electrode mapping for [ç] in nonsense words.
Figure 6. Electrode mapping for [ç] in short sentences.

Figure 7. Electrode mapping for [ç] in spontaneous speech.
Table 1

*Dependent Measures for ich-Laut*

<table>
<thead>
<tr>
<th>Measures</th>
<th>Task Type</th>
<th>Mean</th>
<th>SD</th>
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<tbody>
<tr>
<td>Duration</td>
<td>Nonsense</td>
<td>.224</td>
<td>.041</td>
</tr>
<tr>
<td></td>
<td>Sentences</td>
<td>.168</td>
<td>.025</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>.192</td>
<td>.057</td>
</tr>
<tr>
<td>Center of Gravity</td>
<td>Nonsense</td>
<td>4.64</td>
<td>.410</td>
</tr>
<tr>
<td></td>
<td>Sentences</td>
<td>4.74</td>
<td>.328</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>4.55</td>
<td>.425</td>
</tr>
<tr>
<td>Anterior Electrode Activationa</td>
<td>Nonsense</td>
<td>8.33</td>
<td>6.33</td>
</tr>
<tr>
<td></td>
<td>Sentences</td>
<td>11.14</td>
<td>6.20</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>8.80</td>
<td>6.04</td>
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<tr>
<td>Medial Electrode Activationa</td>
<td>Nonsense</td>
<td>89.32</td>
<td>14.74</td>
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<td></td>
<td>Sentences</td>
<td>86.76</td>
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<td></td>
<td>Spontaneous</td>
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<td>16.49</td>
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<tr>
<td>Posterior Electrode Activationa</td>
<td>Nonsense</td>
<td>78.33</td>
<td>8.04</td>
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<td></td>
<td>Sentences</td>
<td>76.66</td>
<td>7.78</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>76.07</td>
<td>6.70</td>
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</tbody>
</table>

Note: aThese values are percentages of electrode activation in each region (anterior, medial, posterior) across task type. The number of electrodes in each region varies.
3, the durations were higher in nonsense words ($M = 225$ ms) compared to the spontaneous ($M = 169$ ms) and sentence ($M = 137$ ms) task conditions.

For productions of [x], the percentage of electrode activation in the medial region of the palate was also found to vary significantly as a function of task type, $F(2,14) = 7.72, p = .005, \eta^2_{partial} = .525$. As shown in Figure 7, pairwise comparisons indicated that speakers produced the [x] fricative with significantly greater contact in the medial portion of the palate when reading sentences ($M = 46\%$) and for spontaneous speech ($M = 42\%$) compared to producing nonsense words ($M = 17\%$).

Additionally, the percentage of activation in the posterior region was also found to vary significantly as a function of task type when producing the [x] allophone, $F(2,14) = 21.16, p = .0001, \eta^2_{partial} = .751$. As shown in Figure 8, pairwise comparisons indicated that speakers produced [x] with significantly greater contact in the posterior portion of the palate for spontaneous speech ($M = 60\%$) and when reading sentences ($M = 58\%$) compared to producing nonsense words ($M = 40\%$).

The COG measure also varied significantly as a function of task type, $F(2,14) = 7.92, p = .005, \eta^2_{partial} = .531$. Pairwise comparisons indicated the productions of [x] were similar in terms of COG when reading sentences ($M = 3.82$) and during spontaneous speech ($M = 3.85$), with a significantly lower COG when the speakers produced nonsense words ($M = 3.07$). The COG values as a function of task type are shown in Figure 9.

No additional dependent variables were found to differ statistically as a function of task type for the [x] allophone. Visual displays of the lingua-palatal contact patterns for [ç] across task type are represented in Figures 10, 11, and 12. The specific values for duration, electrode activation, and COG measures are listed in Table 2.
Figure 8. Percentage of regional activation for [x] across task type.

Figure 9. Center of gravity measures for [ç] and [x] across task type.
### Table 2

*Dependent Measures for ach-Laut*

<table>
<thead>
<tr>
<th>Measures</th>
<th>Task Type</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>Nonsense</td>
<td>.225</td>
<td>.042</td>
</tr>
<tr>
<td></td>
<td>Sentences</td>
<td>.168</td>
<td>.032</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>.137</td>
<td>.051</td>
</tr>
<tr>
<td>Center of Gravity</td>
<td>Nonsense</td>
<td>3.07</td>
<td>.568</td>
</tr>
<tr>
<td></td>
<td>Sentences</td>
<td>3.82</td>
<td>.509</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>3.85</td>
<td>.967</td>
</tr>
<tr>
<td>Anterior Electrode Activationa</td>
<td>Nonsense</td>
<td>1.20</td>
<td>3.07</td>
</tr>
<tr>
<td></td>
<td>Sentences</td>
<td>4.51</td>
<td>3.68</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>7.82</td>
<td>10.46</td>
</tr>
<tr>
<td>Medial Electrode Activationa</td>
<td>Nonsense</td>
<td>17.10</td>
<td>19.48</td>
</tr>
<tr>
<td></td>
<td>Sentences</td>
<td>46.82</td>
<td>21.01</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>42.01</td>
<td>32.51</td>
</tr>
<tr>
<td>Posterior Electrode Activationa</td>
<td>Nonsense</td>
<td>40.73</td>
<td>16.63</td>
</tr>
<tr>
<td></td>
<td>Sentences</td>
<td>58.92</td>
<td>12.65</td>
</tr>
<tr>
<td></td>
<td>Spontaneous</td>
<td>60.47</td>
<td>22.71</td>
</tr>
</tbody>
</table>

Note: *a*These values are percentages of electrode activation in each region (anterior, medial, posterior) across task type. The number of electrodes in each region varies.
Figure 10. Electrode mapping for [x] in nonsense words.

Figure 11. Electrode mapping for [x] in short sentences.
Figure 12. Electrode mapping for [x] in spontaneous speech.

**Discussion**

The purpose of this study was to investigate how the lingua-palatal contact patterns for the [ç] and [x] allophonic sound contrast produced by native English speakers learning German as an L2 differ as a function of task type. The EPG data collected and analyzed revealed that the L2 learners’ speech patterns differ across task type. Inferential statistics indicated that the [ç] fricative allophone varied in overall mean duration and in the degree of lingua-palatal contact in the medial region of the palate, in particular when producing nonsense words. This is likely because the articulation of nonsense words produced in isolation is less likely to be influenced by coarticulation with surrounding sounds. Words in isolation are also often produced at a slower rate as they are the only focus of concentration, allowing for more accurate and precise placement of the articulators, which may result in longer durations. Similarly, with nonsense
words, unfamiliarity and hesitation with the words could have influenced the rate at which they were being produced. This could have created more pauses and longer production of the fricatives.

Despite the statistical differences in duration and contact at the medial region, visual inspection of the electrode mappings for [ç] indicate only minimal variation in articulation across task type. The lack of variation may be due to the [ç] allophone’s place of articulation being similar to sounds already present in English, such as the palatal fricatives /ʃ/ and /ʒ/. Thus, the L2 learners did not have to acquire unfamiliar articulatory movement to a place of articulation that is not already used for other sounds of their native language. Instead, as suggested by the SLM model (Flege, 1995), these L2 learners likely categorized this non-native sound in the most perceptually and motorically similar phonemic category.

Inferential statistics indicated more variation in articulation across task type for [x] compared to [ç]. Differences were found in duration, percentage of activation in the medial and posterior regions, and COG. Contrary to the findings of [ç], the task type of nonsense words had the lowest percentage of activation and the lowest COG for [x], but similarly had the longest duration. The isolated concentration, hesitancy, and lack of coarticulation in nonsense words likely explains the longer duration in this task type for [x] as well. However, unlike [ç], [x] is an unfamiliar sound in the English language. There are no other native English fricatives that are produced as posteriorly as [x], so the articulatory placement of this fricative is unfamiliar to these L2 learners. Therefore, it likely took even more concentration, effort, and awareness to produce.

The differences in percentage of activation across task type for the [x] allophone may be related to coarticulation. Electrodes in the anterior region were not active for [x] because it is a posterior sound. The medial and posterior regions, however, did show variation across task type.
The specific phonemic contexts in these task types likely contribute to these variations. The short sentences had structured contexts, whereas spontaneous speech was not constrained and the context depended completely on the participant’s choice of words. It is also apparent in the electrode mappings that medial and posterior lingual contact with the palate is greater in short sentences and spontaneous speech when compared with nonsense words for [x]. This is likely a result of a similar factor – phonemic context and the principle of coarticulation influenced the placement of [x] as the tongue advanced anteriorly to produce other phonemes immediately succeeding [x]. Concentration on grammar, rather than on production for spontaneous speech, could have influenced these findings.

Another factor to consider with these findings is the foreign nature of the place of articulation of [x]. It is evident in the electrode mappings that [x] is produced more accurately in single syllable nonsense words, but its accuracy decreases in structured sentences, and then even more in spontaneous speech. As the L2 learners moved through each task type with the complexity of linguistic context increasing, their articulatory placement moved anteriorly, consistent with the places of articulation with which they are most familiar. This was not apparent in the electrode mappings for [ç] because its place of articulation is not so unfamiliar. COG measures were also influenced by these same factors of coarticulation and foreign place of articulation, thus short sentences and spontaneous speech showed higher measures than nonsense words as a result. These higher measures, however, exhibit less accuracy of contact patterns when compared with native German contact patterns.

As described in previous studies by Isaacson (2015) and Lester (2017), native German speakers produce [x] so posteriorly in the oral cavity that there is little lingua-palatal contact, even in the posterior region. The electrode mappings of the L2 learners producing [x] revealed
that posterior and even medial lingua-palatal contact were present across all task types, thus
displaying the difference between native German speakers’ productions and L2 learners’
productions. Nonsense words had the least lingua-palatal contact medially and posteriorly
compared to other task types, therefore nonsense words in this case were produced in a more
native-like manner, even though the contact patterns still differed greatly compared to native
German productions. The contact patterns for spontaneous speech showed a little activation in
the anterior region and more activation in the posterior region, thus making spontaneous speech
the least native-like in production of [x]. L2 contact patterns for [ç] compared to native German
contact patterns also displayed greater medial and posterior activation across all task types. It
should be noted, however, that the native German contact patterns used for comparison were
taken from nonsense words and real words only.

Edwards (2008) suggested from his study that formal reading tasks allow for more
native-like production of sounds by L2 learners due to increased concentration and awareness of
speech sounds when reading. In the current study, nonsense words were found to have the
longest duration times for both [ç] and [x] out of all the task types. The longer duration could
signify more accurate placement and production of these fricatives in nonsense words as they are
not being produced as stops or influenced by phonemic context. The electrode mappings of this
task type for both target allophones demonstrate this as well. Thus, findings from this study in
terms of duration correlate with Edwards conclusions about formal speech production being
more native-like than informal or spontaneous speech.

Conversely, for percentage of activation and COG, productions of [x] had similar results
for short sentence and spontaneous speech task types, even though the short sentences were in a
structured reading task. These findings are more in line with Munro and Derwing (1994) who
concluded that there was no significant difference in production between structured and spontaneous task types. Unlike nonsense words, short sentences and spontaneous speech have longer linguistic and phonemic contexts in common, which may explain why their productions do not differ as much.

Moyer (2004) concluded that spontaneous speech was produced in a more native-like manner compared to structured reading tasks, but suggested that this was due to the flexibility available in spontaneous speech, meaning that the speaker is able to control what words or speech sounds are used. If a sound is difficult to make, the speaker can choose to avoid that sound, unlike structured reading where the speech sounds are prescribed. The frequency in which a word occurs in a particular language may also influence the production patterns of that sound. Similarly, it is interesting to note that in the current study, it was evident in spontaneous speech that the participants often produced fewer \([x]\) allophones than \([ç]\) allophones. This was true with all back vowels preceding the fricative \([x]\), not just /\(\text{a}\)/. Some participants did not even produce \([x]\) in their spontaneous speech at all. The allophone \([x]\) is not similar to any English fricative, whereas the allophone \([ç]\) is. Thus, Moyer’s suggestion should be taken into consideration. It is important to note, however, that the findings regarding task type by Moyer were drawn from studies with differing methodology than the current study.

Considering that the current study only examined 12 participants’ fricative sounds, it may be beneficial to increase the number of participants, as well as quantify production patterns from a larger variety of sound classes (i.e., obstruents, stops, affricates) and phonemic contexts to account for variability in sound classes. A longitudinal study may also be beneficial to determine increased native-like production patterns with time and experience across differing task types.
It is also important to consider the sensitivity of the electrode mappings used for this study. The mappings did not account for minor differences in activation, thus detailed differences were not fully represented. It may be beneficial to use more activation-sensitive electrode mappings for further research in this area, such as the one presented in Figure 13. This map uses a greater variety of color to highlight variations in electrode activation and accounts for small changes in the percentages.

This study solely focused on how the lingua-palatal contact patterns of the [ç] and [x] contrast differ as a function of task type. Some comparisons were made to native German lingua-palatal contact patterns to help determine the level of native-like accuracy and the amount of variation across task type (Isaacson, 2015; Lester, 2017). However, as previously mentioned, these comparisons were made to native German contact patterns that did not span across task

Figure 13. Example of color sensitive electrode mapping.
type. Thus, it may be valuable to gather native German lingua-palatal contact patterns across task type as well for direct comparisons in further research. This could add to the findings of how contact patterns change across task type in terms of native-like production.

Despite the need for more comparable and sensitive data across time, the current study provides a reliable foundation upon which further research can build. The potential for using EPG as an instructional tool for second language acquisition and the role that task type plays in this is evident from these findings. It can be concluded that mastering a wide range of linguistic contexts is vital to speaking a second language fluently, thus different task types are necessary when learning a second language. This may be similar to how a child acquires a language, in that a child is constantly fine-tuning their place of articulation for accurate productions, progressing from single words to sentences and conversational speech. A more complex linguistic context requires greater skill in articulatory placement and production of sounds. Therefore, L2 instruction should incorporate a variety of task types to challenge L2 learners and aid them in becoming proficient in their second language. Using EPG as an instructional tool can help with accuracy of production in all linguistic contexts.
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APPENDIX A

Annotated Bibliography


*Objective:* This article explores the use of EPG technology to indicate how and where the tongue is used in speech contact patterns. This study focuses on how EPG can help to distinguish and improve these patterns for individuals with apraxia of speech. *Method:* Five stroke patients with apraxia of speech participated in this study. Each participant provided a spontaneous speech sample, and read “The Grandfather Passage” while their speech contact patterns were being monitored. *Results:* The researchers found the use of EPG may be beneficial in providing clients the visual feedback necessary to understand and learn proper contact patterns during speech. *Conclusion:* Recognizing and understanding various speech patterns through the use of EPG can help those with apraxia of speech to more accurately produce target speech sounds which in turn will improve their intelligibility. *Relevance to current study:* EPG technology can be used to improve lingua-palatal contact patterns in speech.


*Objective:* This study was conducted to determine the effectiveness of using EPG technology for accent reduction in native Spanish speakers learning English as a second language. *Method:* Three native Spanish speaking females learning English participated in this study. Connected speech samples were examined from each participant before and after EPG therapy by native
English speakers who rated overall intelligibility of the samples. Particular sound classes were emphasized in the samples that were rated. A formal accent test was also performed. Results: The perceptual existence of an accent was reduced to 16% from 59%. Conclusion: The visual feedback that EPG technology provides is beneficial in reducing accents of second language learners. Relevance to current study: The use of EPG in therapy has proved to be beneficial for second language learners.


Objective: The purpose of this study was to determine the effectiveness of using EPG in treating children with persistent speech difficulties with no known etiology. This study also used the results to determine what factors can be used in predicting the types of clients that this treatment would be beneficial for. Method: Baseline measures for each of the ten participants (eight males and two females) were taken using word lists. Each child participated in 10 weeks of EPG articulation therapy, with speech samples gathered with and without the palate inserted before and after the duration of therapy. Improvement for each child was determined by EPG results as well as perceptual judgments. Predictive outcomes for each child were based on age, diagnosis type, oral-motor structure, therapy schedule, and therapy targets. Results: Acoustic and perceptual improvements in the production of consonants were found from the data of all participants. The predictive factors were also found to be reliable in determining prognosis. Awareness and motivation also played a role in the predictive factors. Conclusion: EPG seems to be valuable as a treatment approach for a variety of speech disorders. There are also a number of
predictive factors that have been found in this study, but more assessment on predictive factors is warranted. *Relevance to current study:* EPG is a beneficial treatment tool for speech development in children with speech sound disorders, thus it may also prove to be a beneficial tool for second language learners having difficulty with native sound contrasts.


*Objective:* This study was performed to examine the effectiveness of EPG in diagnosing and remediating articulation and phonological disorders in children. *Method:* Treatment instrumentation options were presented, as well as EPG speech training procedures, and reviews of treatments for articulation and phonological disorders using EPG. *Results:* Some children exhibited systematic differences in articulatory posture, thus re-evaluation of the effectiveness of EPG is needed for these children. Teaching sound inventories as treatment for phonological processes was found to be effective with EPG. Using EPG to teach children articulator positions may allow for generalization of sound combinations and rules. *Conclusion:* EPG has been found to be a useful instrument in remediating speech disorders and finding possible causes to speech problems. *Relevance to current study:* EPG’s visual feedback of lingua-palatal contact patterns permits identification of atypical patterns and sound productions.

This chapter explored variation in L2 phonology. One theory described is that an individual’s capability in speech style can be placed on a continuum from less formal and vernacular to more formal and target-like. More native-like phonology falls on the more formal end of the continuum. This same theory also speculates that speech style is related to the amount of attention or monitoring paid to speech by the speaker, and that different styles of speech are elicited through different task types. Therefore, this theory concludes that tasks such as reading passages or word lists are more carefully monitored, thus the speech outcome in these tasks is more formal and native-like, whereas tasks such as spontaneous speech are not monitored as carefully and result in less formal and less native-like speech. However, various other studies have indicated conflicting findings and have attributed native-like speech styles to other factors, such as the phonological variable under study, linguistic environment, social class, and educational background. Hence, the degree to which task type is related to native-like speech production remains unclear and more research on the subject is warranted. Relevance to current study: Task type could be a contributing factor to the variability in native-like productions of German in native English speakers learning German as a second language.


This chapter focuses on the influence that L1 can have on L2 for adults. The author discusses the acquisition of language for children and describes how children develop their own phonetic categories as they explore the various sounds of a language. The author goes on to explain that
adults learning another language have a disadvantage as they already have phonetic categories in place, thus it is difficult for them to learn to produce unfamiliar sounds that are not part of their native tongue. Instead of recognizing it as a non-native sound, adults often try to categorize such sounds into their existing phonetic categories, which results in distortion or misarticulation of the sound. Therefore, second language learning becomes a top-down process for adults and can be more difficult than for a child. It is mentioned that linguistic knowledge that adults have can be beneficial in learning a second language to some degree, as a better understanding of language itself is present. Adults also retain the phonetic learning ability that helped them to learn their L1 as a child, however, certain factors such as phonetic categories deter their use of this ability to its full extent. In relation to the current study, it is important to understand that unfamiliar sounds are difficult for individuals to produce when learning a second language. The German sound contrast ich-Laut and ach-Laut fit this description for native English speakers, thus it is more difficult for them to produce these sounds with native-like accuracy.


*Objective:* The purpose of this study was to examine speech patterns in individuals with partial removal of their tongue. This study specifically focused on compensatory patterns of articulation and change in dimension. *Method:* Three individuals with varying degrees of partial glossectomy produced pre-determined target sounds with EPG. Acoustic recordings were also gathered for each. *Results:* The contact patterns and acoustic recordings of articulation displayed shifts to parts of the vocal tract while metrical properties, such as width, remained the same. Intelligibility decreased, but was still adequate for communication when compensatory articulation patterns
were used. Conclusion: Compensatory strategies for articulatory patterns have proved to be sufficient in maintaining communicative abilities and intelligibility. EPG can be used to teach these compensatory strategies effectively. Relevance to current study: EPG technology is effective in providing visual feedback for articulation patterns and developing compensatory strategies for various sound productions. Thus, individuals learning German as a second language would benefit from EPG feedback.


The author of this text explored a physiologically-based approach to teaching and learning proper articulation. He specifically focuses on the benefits of using palatometry and outlines EPG technology. The author describes the three dimensions of articulation that are displayed through EPG technology and explains their significance in teaching speech as a motor skill. Fletcher also discusses various benefits of using bio-feedback as an alternate approach to teaching and learning articulation patterns and explicitly defends and explains the design of EPG technology. In relation to the current study, EPG technology provides bio-feedback on articulation patterns that would be beneficial in teaching proper articulation to those who are learning a second language.

Objective: The aim of this study was to evaluate the use of EPG technology in second language learning. It specifically focused on the distinction between /l/ and /r/ for native Japanese speakers learning English. Method: The participants for this study were native Japanese speakers learning English as a second language. Their ability to recognize and discern the difference between /l/ and /r/ was evaluated using acoustic instruction alone, as well as biofeedback instruction from EPG. Results: The participants had difficulty discerning the differences between /l/ and /r/ when using acoustic instruction alone. However, their ability to understand the differences between the two sounds greatly increased with biofeedback instruction from EPG. Conclusion: EPG may be helpful in learning a second language as it makes it easier to distinguish the difference between sound classes that appear to be similar or unfamiliar to a second language learner. Relevance to current study: EPG technology proves to be beneficial in helping English second language learners discern the difference between /l/ and /r/ sound contrasts, thus EPG technology may prove beneficial for individuals learning German as a second language, specifically for discerning between the fricatives ich-laut and ach-laut.


Objective: The purpose of this study was to examine speech therapists’ perspectives on the effectiveness of EPG technology in treating children with articulation disorders. Method: An EPG questionnaire was given to 10 therapists who had treated a total of 60 children using EPG technology between the years of 1993 and 2003. The information on the questionnaire included demographics, therapy details (number of sessions, length of sessions, target sounds, etc.), type
of speech disorder, and relative outcomes of each child. Results: Completed questionnaires portrayed /t/, /s/, and /d/ as the most frequently targeted sounds in EPG therapy. There appeared to be improvement in articulation and self-awareness for most participants following the use of EPG, however, generalization of improved articulation was not largely portrayed. Conclusion: EPG technology appears to be beneficial in treating children with various articulation difficulties. Other treatment practices may need to be implemented to promote proper generalization of EPG outcomes. Relevance to current study: Some professionals believe that EPG technology has proved to be beneficial in treating hard cases of articulation disorders where other treatment methods have not proved successful. Therefore, EPG may be beneficial for second language instruction in cases where other instructional and learning methods have not been successful.


Objective: The purpose of this study was to evaluate and determine the defining characteristics of each of the German sound contrasts ich-Laut and ach-Laut. Method: The use of the sound contrast was examined throughout various aspects of the German language to identify the rules of its usage. Results: Ich-laut or [ç] is a voiceless palatal fricative wand ach-laut or [x] is a voiceless velar fricative. These allophones work as complements to each other, each occurring in differing but specific phonetic contexts. The [ç] fricative appears following front vowels while the [x] fricative appears following back vowels. Conclusion: The rules behind this sound contrast make it difficult for non-native German speakers to acquire it proficiently. Relevance to current study: Non-native German speakers often inaccurately produce the German sound contrast ich-
Laut and ach-Laut. This sound contrast consists of a notably high degree of lingua-palatal contact that EPG technology can visually portray through biofeedback. Thus, EPG can be used to help reduce the inaccuracy of articulation of this German sound contrast.


**Objective:** The aim of this study was to evaluate the speech patterns of individuals with Parkinson’s disease using EPG technology. The study specifically focused on lingua-palatal contact patterns and consonant imprecision. **Method:** The participants of this study included a group of individuals with Parkinson’s disease and a control group. Each participant read a carrier phrase aloud (‘I saw a --- today’), specifically targeting initial /l/, /s/, and /t/, while wearing a pseudopalate. Phonetic transcriptions, descriptions of errors, and an explanation of tongue-palate contact patterns and spatial palatal indices were provided for each production. **Results:** The perceptual measures combined with the EPG contact patterns displayed a difference in the rate of undershooting articulatory contacts between the two groups. It appeared that the individuals with Parkinson’s disease more frequently undershot consonant productions, however, the EPG also revealed that many of these individuals still attained the appropriate contact but with reduced force and impaired timing. **Conclusion:** The results from this study indicate that EPG would be useful in instructing lingua-palatal contact pressure levels and timing for individuals with Parkinson’s disease. Therefore, EPG is not only beneficial for teaching contact patterns, but also for teaching timing gestures and contact force. **Relevance to current study:** If EPG is useful in quantifying lingua-palatal contact patterns for individuals with Parkinson’s disease, then it may
also be useful for quantifying lingua-palatal contact patterns for individuals learning German as a second language.


**Objective:** The purpose of this study was to examine the effectiveness of using visual feedback when treating a distorted /s/ resulting from cleft palate. **Method:** Six individuals of similar ages with similar misarticulation patterns and velopharyngeal function were divided into two separate groups that either participated in EPG therapy or traditional therapy. **Results:** The individuals who participated in EPG therapy showed greater increase in intelligibility than the individuals who participated in traditional therapy. **Conclusion:** Visual feedback is helpful in making individuals more aware of tongue placement and frication during sound production. **Relevance to current study:** Biofeedback is beneficial in facilitating proper production of /s/, therefore it may also be beneficial in facilitating proper production of German sounds that are difficult for native English speakers learning German to produce.


The author of this book evaluates and describes varying sound contrasts between the German and English language. Several sound contrasts that are especially difficult for native English speakers learning German are discussed with ich-Laut and ach-Laut being of particular interest. The author explains that the difficulty behind this common sound contrast is likely attributable to it
being a non-native sound that has to be produced while simultaneously evaluating the context. These sounds function as ideal targets as they display varied articulatory contact patterns between native and non-native German speakers.


**Objective:** The purpose of this study was to quantify native-like speech production across various task types with varying degrees of formality and informality. **Method:** The participants for this study included 25 non-native German speakers who immigrated to Berlin and 9 native German speakers. All participants were between the ages of 25 and 35 years. Each participant completed a questionnaire regarding their L2 experience (age of exposure, length of residence, attitude, etc.). Each participant then completed four basic linguistic tasks which included 1) reading aloud 38 words with frequently-cited difficult German sounds in a list form, 2) reading aloud at paragraph at natural tempo, 3) spontaneous speech with topics of personal nature, and 4) reciting a list of 10 short sayings or proverbs in German. Each task was rated by three native German speaking university student volunteers on whether the speaker was native or non-native, and his/her perceived confidence level on a scale from 1-3. **Results:** For the non-native speakers, 36% were judged to be native while 64% were identified as non-native. Of the native speakers, all were identified correctly as native. The third task of spontaneous speech averaged closer to native speech than any other task, while the isolated word list and paragraph reading were furthest from native speech. **Conclusion:** Formality of a task may not be the indicating factor of
precision in speech. Native-like speech is more likely attributed to suprasegmental and pragmatic features such as tempo, rhythm, style, and linguistic control. Fluency may also be a contributing factor. It is important to note, however, that the controlled tasks included challenging phonotactic and segmental characteristics, whereas spontaneous speech is uncontrolled and can avoid these challenging characteristics. **Relevance to current study:** Accuracy of native-like productions in second language learners of German may vary according to task type.


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**Objective:** The aim of this study was to discover the variation in strength of an accent present in native Mandarin speakers learning English between reading and speaking extemporaneously.

**Method:** The participants for this study included ten native speakers of Mandarin ranging in age from 28-44 years and ten native speakers of Canadian English ranging in age from 23-42 years. The native English speakers acted as the control. The native Mandarin speakers were graduate students at the University of Alberta with high English proficiency. Each participant was given a cartoon with which they created and told a story from. Each story was transcribed and the participants came back for a second session during the same week and read the story. Each session was recorded. 44 native English speakers then listened to each recording and rated the strength of the speaker’s accent. **Results:** There was no significant difference in strength of accent between the spontaneous narrative and the read narrative. It was found, however, that eight of the ten native Mandarin speakers were rated as having a stronger accent on the task (narrative or reading) that was listened to second. **Conclusion:** From this study, there did not
seem to be any difference in strength of accent between read speech and extemporaneous speech. Therefore, it is suggested that previous studies that found a difference between read and extemporaneous speech had those outcomes because of the variation in material (such as different segmental combinations, difficult sound contrasts, etc.). 

Relevance to current study: Second language learners may not vary in perceived strength of accent between task types such as reading and spontaneous speech, but their contact patterns may vary in accordance to native-like productions. EPG would be an accurate way to measure the possible variation in contact patterns.


The purpose of this text is to provide professionals with information about assessment and treatment of articulation and phonological disorders in children. Sound classes, articulation patterns, and treatments to increase intelligibility are all discussed. Of greatest interest is the author’s discourse on the obstruent sound classification, which includes stops, fricatives, and affricates. These sounds are made with complete closure or constriction of the oral cavity, causing a friction noise or completely stopping the airstream. A knowledge and understanding of these sound classes and their production patterns is critical in determining target sounds with appropriate lingua-palatal contact through EPG.

Objective: This study aimed at exploring the use of EPG to assist in the acquisition of English as a second language for native speakers of Thai. Method: Three adult, native Thai speakers with normal bilateral hearing were the participants for this study. They were each supplied a pseudopalate which they used for two weeks prior to the study to reduce any negative effects. Each participant was recorded saying consonant vowel (CV), VCV, and VC nonsense syllables in English with EPG. The syllables included the English sounds: /t, d, k, g, ʧ, l, n, s, z, and f/. Each participant was seen bi-weekly over the course of 24 total weeks. Results: All participants accurately produced targeted sounds. Each also reported the benefit of using visual feedback throughout therapy. Conclusion: EPG technology is helpful in teaching difficult sound contrasts. It is important to note, however, that generalization is not always manifest. Relevance to current study: EPG technology was helpful in teaching difficult sound contrasts in English to native Thai speakers, thus EPG technology could be helpful in teaching difficult sound contrasts in German to native English speakers.


Objective: The purpose of this study was to observe the anticipatory coarticulation patterns of speech in individuals with apraxia. Method: Two adult individuals participated in this study - one with apraxia of speech and one normal control. Each individual was presented a carrier phrase (‘say --- again’) with words that contained vowels /i/, /a/ and /u/. These carrier phrases were produced repeatedly with varying rates of slow, habitual, and fast. Results: It was found that the vowel contact patterns of the individual with apraxia of speech varied and were often inaccurate
in all rates compared to the control individual. *Conclusion:* EPG technology is a sufficient way to identify inaccurate coarticulatory contact patterns in individuals with Apraxia. It may also aid in teaching proper articulation. *Relevance to current study:* If EPG is useful in finding inaccurate contact patterns for individuals with apraxia, it may also be useful in finding inaccurate contact patterns for individuals learning German as a second language, and could help these individuals to achieve proper, native-like articulation.


*Objective:* This study explored the articulatory contact patterns of individuals with glossectomy and cleft palate using EPG. *Method:* 25 individuals with cleft palate and 3 individuals with a glossectomy, all native Japanese speakers, participated in this study. Each participant produced VCV syllables in Japanese. *Results:* The recordings showed that individuals with glossectomies portrayed mixed intelligibility even though palao-lingual contact was limited. Individuals with cleft palate displayed three different cases of misarticulation which include lateral misarticulation, nasopharyngeal articulations, and palatized articulations. *Conclusion:* EPG can be used not only for diagnosis and treatment, but can also be used to evaluate articulatory contact patterns in a wide range of physical conditions. *Relevance to current study:* Since EPG can identify differences in physical conditions, it would be helpful to assess physical conditions in second language learners before using EPG as an instructive tool to make language learning individually efficient.
APPENDIX B

Stimuli

*German Words Used to Elicit Target Sounds in Nonsense Words*

[ç]
- ich

[x]
- ach

*German Words Used to Elicit Target Sounds in Sentences*

[ç]
- deutlich
- hoffentlich
- pünktlich
- wirklich
- möglich

[x]
- nach
- dach
- fach
- ach
APPENDIX C

Consent Form

Consent to be a Research Subject (speakers)

Introduction
The purpose of this research is to provide examine the effectiveness of using visual feedback to assist native English speakers learn German as a second language. This experiment is being conducted under the supervision of Shawn Nissen, Ph.D., an associate professor in the Department of Communication Disorders at Brigham Young University. You are invited to participate because you are an adult learner of German who is currently enrolled in a course in German language instruction and report no known history of a speech, language or hearing problems.

Procedures
Initially, participation in this study will involve approximately one hour of your time. You will be asked to visit a local licensed dental professional to have an impression taken of your upper teeth, which will be created at no cost to yourself. This impression will be used to create a sensor similar to an orthodontic retainer that fits over your upper teeth. You will be asked to make recordings of your speech while producing German speech sounds and reading German words. These recordings will take place in a sound booth located in a research lab on the Brigham Young University campus.

These recordings will then be examined and if it is determined that your German pronunciation might improve by using visual feedback from a thin sensor placed over your hard palate, you will be asked to participate in the follow-up portion of the study. You will then be asked to use the sensor while practicing your pronunciation of common German words. You will practice for one hour and 20 minutes each week for four consecutive weeks in a computer lab on the BYU campus. You will be trained on the use and care of the sensor prior to the initial session of pronunciation practice. At the beginning, end, and four weeks following your pronunciation practice ends you be asked to make recordings of your speech in a sound booth while reading a series of everyday German words. The dental visit, pronunciation practice, and recording sessions will involve approximately 9 hours of your time over the course of approximately 3 months.

Risks/Discomforts
There are no known risks associated with participation in this study.

Benefits
There are no direct benefits provided in this study.

Confidentiality
All data collected will remain confidential and only be reported as group data with no personally identifying information. Records and files will be kept on password protected computers in a locked laboratory and only those directly involved with the research will have access to them.

Compensation
You will be paid $15 for each hour of your participation in this study.

Participation
Participation in this research study is voluntary. You have the right to withdraw at any time without jeopardy.

Questions about the Research
If you have questions regarding this study, you may contact Shawn Nissen, Ph.D., at (801) 422-5056 or shawn_nissen@byu.edu.

Questions about your Rights as Research Participants
If you have questions regarding your rights as a research participant, you may contact the BYU IRB Administrator, A-285 ASB, Brigham Young University, Provo, UT, 84602 or at (801) 422-1461.

I have read and fully understand the consent form. Any questions have been answered to my satisfaction. I give my consent to participate in this research.

Signature: ___________________________ Date: ___________________________

Printed Name: ___________________________