The Effectiveness of Using Electropalatography to Remediate a Developmental Speech Sound Disorder in a School-Aged Child with Hearing Impairment

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The Effectiveness of Using Electropalatography to Remediate a Developmental Speech Sound Disorder in a School-Aged Child with Hearing Impairment

Kristina L. Pickett

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

The Effectiveness of Using Electropalatography to Remediate a Developmental Speech Sound Disorder in a School-Aged Child with Hearing Impairment

Kristina L. Pickett
Department of Communication Disorders
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Advances in instrumentation and computer technology such as electropalatography (EPG) have offered additional types of feedback to more traditional therapy for individuals with speech disorders, specifically those with hearing impairment. The purpose of this study was to document whether therapeutic integration of EPG visual feedback in combination with traditional articulation therapy for a school-aged child with an articulation disorder secondary to hearing impairment was more effective than traditional therapy alone. One participant received five sessions of each therapy approach. Six adult listeners rated the quality of the participant’s production of /r/ in words recorded during the therapy sessions. The EPG plus a traditional approach to therapy was more effective in treating the misarticulation of /r/ than traditional therapy alone. The integration of EPG therapy into traditional methods was an effective way of treating an articulation disorder for an individual with hearing impairment.

Keywords: electropalatography, articulation treatment, hearing impairment
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Finally, my deepest love goes to my husband Ethan. Thank you listening to the nights of complaints and always helping me see the positive in life. You are my greatest support and best friend.
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DESCRIPTION OF STRUCTURE AND CONTENT

The body of this thesis is written as a manuscript suitable for submission to a peer-reviewed journal in speech-language pathology. An annotated bibliography is presented in Appendix C.
Introduction

Traditional approaches to remediating speech sound disorders often rely on tactile (e.g., physical stimulation) and auditory feedback. However, some individuals are resistant to traditional therapy and may benefit from treatment that involves additional types of feedback (Clark, Schwarz, & Blakeley, 1993; Ruscello, 1995). These alternative approaches to therapy may include the use of visual feedback to help an individual correct their speech (Barry, 1989; Bernhardt, Clark, et al., 1993; Dagenais, 1995, Dagenais, Critz-Crosby, Fletcher, & McCutcheon, 1994; Dent, Gibbon, & Hardcastle, 1995; Fletcher, Dagenais, & Critz-Crosby 1991; Ruscello, 1995). Electropalatography (EPG) is one example of a visual feedback system that may be successful in treating some types of speech sound disorders in school-aged children who are resistant to traditional therapy (Bernhardt et al., 2003, Fletcher et. al, 1991; Gibbon & Hardcastle, 1987; McAuliffe & Cornwell, 2008, McLeod & Searl, 2006). In particular, it makes sense to utilize an EPG appliance in treating populations that may not gain the typical benefit from auditory cues during therapy, such as children with hearing impairments (Dagenais, 1992; Fletcher, 1992; Fletcher et al., 1991). Only a few studies investigating the efficacy of using EPG for a population with hearing impairment has made a direct comparison between the two therapy approaches (i.e., traditional articulation therapy versus integrated therapy using EPG) in a controlled manner (Dagenais et al., 1994).

Traditional Approach to Articulation Therapy

Traditional speech sound therapy can be defined as an approach that uses auditory feedback and tactile cueing (Clark et al., 1993; Grigos, Hayden, & Eigen, 2010; Lohman, Fucci, & Marinellie, 2001; Ruscello, 1995). In typical speech development, movements become habituated during the first few years of life (Lohman et al., 2001). This pattern of development
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allows even relatively young speakers to converse rapidly and focus on expressing ideas, rather than the specific mechanical movements needed for each speech sound or word. Typically children will use auditory feedback to self-monitor and fine-tune their speech productions to match the speech sounds they hear in their environment (McFarland & Baum, 1995). Speech therapists can use this *auditory feedback loop* in assisting children adapt their own productions to match the therapist’s correct productions. Speech therapists may also give verbal cues on how the child can manipulate the articulators to where placement occurs during correct sound production.

Speech therapists will also commonly use tactile cueing to assist children with speech sound disorders. When incorrect speech sound production is acquired at an early age, it creates habitual motor patterns that can be very difficult for the individual to change at a later age of development. Tactile cueing aids in breaking habitual speech by providing information to the speaker about where movements begin and how they should be produced, which ultimately improves motor planning and execution for later habituation of correct sound production (Grigos et al., 2010). In traditional articulation therapy, children are given verbal instruction for lingual positioning in the oral cavity for sounds; however, some children may not conceptually understand commands given by verbal instruction alone (Lohman et al., 2001). Using only auditory feedback in the treatment of speech sound disorders may be unsuccessful because clients have an incorrect perceptual model of the sound, thus additional cueing modalities, such as tactile, may be needed to increase both oral and lingual awareness prior to achieving correct speech sound production (Clark et al., 1993; Grigos, et al., 2010). Traditionally, tactile cueing has been provided through methods as simple as touching a child’s articulators with a gloved finger or a drinking straw to indicate the correct placement of the tongue or lips for a particular
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sound. However, tactile cueing during therapy has also involved custom-made devices such as removable acrylic plates (Clark et al., 1993) or specialized cueing tools (e.g., Speech Buddies©; Rogers, Galgano, & Chesin, 2011).

**Visual Feedback**

Using multiple feedback modalities within treatment (e.g., combining tactile, auditory, and visual feedback) may increase the initial learning and retention of correct speech sound production (Ruscello, 1995; Wingo & Hoshiko, 1972). In a three-study review, Ruscello (1995) found that when more than one mode of feedback was used to treat speech sound disorders, the efficacy of therapy increased. In addition to auditory and tactile feedback commonly used in traditional approaches to therapy, visual feedback can also facilitate correct speech production (Barry, 1989; Bernhardt et al., 2003; Clark et al., 1993; Dagenais, 1995, Dagenais et al., 1994; Dent et al., 1995; Fletcher et al., 1991; Ruscello, 1995). Visual feedback can be provided to a client through a number of different therapy techniques, ranging from using a mirror to show lip movement to EPG.

A great deal of progress has been made in EPG technology. Historically, therapists used non-electric palatography to obtain a visual display of a client’s articulation. One example involved the clinician dusting powder onto the hard palate of the client. When the client would articulate a specific speech sound, the tongue-to-palate contact could be seen by determining where on the palate the dusting powder was absent. Another technique involved placing a thin sheet of tinfoil on the client’s hard palate. The tongue would then indent the tin foil during speech to reveal tongue-to-palate contact patterns (Fletcher, 1992). Over time palatography evolved into electropalatography, a computer-based system that dynamically tracks and displays
tongue-to-palate contact patterns using a series of electronic sensors (Fletcher, McCucheon, & Wolf, 1975).

An EPG system, such has been recently developed by SmartPalate International® (SPI), uses a relatively thin (0.5 - 2mm) pseudo-palate that contains 124 gold-plated electrodes arranged in a grid pattern across the surface of the pseudo-palate. The pseudo-palate (similar to an orthodontic retainer) is created from a stone model of the individual’s upper teeth and palate. This pseudo-palate is designed to extend from the back of the upper molars to the front of the oral cavity. The tongue-to-palate contact patterns are measured by electrical sensors, which transmit information through a wire extending out of the front of the mouth to a processing box. The processing box collects and transfers the contact data to a computer at a rate of 200 times per second, where it is then displayed as a visual representation on a computer screen.

Clinical Application of EPG

EPG can assist in the remediation of specific types of speech sound disorders for a number of reasons. First, Dagenais (1995) states that EPG’s greatest strength is that “it provides a dynamic, real-time, visual presentation of articulatory gestures that are not normally seen” which then “allows objective assessment and provides objective, consistent articulatory goals during therapy” (p. 305). The EPG system developed by SPI allows the client to view their articulation patterns and compare their speech production to a model provided by another individual. A second advantage to EPG therapy is that while the cost of the pseudo-palate has been considerable in the past, recently developed EPG systems are now more affordable for a greater number of clients and speech therapists (Dagenais, 1995). Third, as EPG technology has advanced, pseudo-palates have become relatively thin and more comfortable to wear. Fourth, for clients who are resistant to traditional approaches to therapy, EPG is an additional method of
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treatment, especially for clients who need to relearn already established motor patterns (Barry, 1989; Dent et al., 1995; Gibbon et al., 1995). It is important to note that EPG has been found to be most effective for individuals over the age of 7, likely due to the need for greater cognitive ability, awareness, and motivation to take advantage of the visual feedback (Carter & Edwards, 2004).

In particular, EPG therapy may be valuable in treating speech sound disorders secondary to hearing impairment. Individuals with hearing impairment often have difficulty perceiving the auditory characteristics of speech sounds, which is the primary means of cuing during traditional therapy. Speech errors commonly exhibited by individuals with a hearing impairment may include voiced-voiceless errors, omissions/distortions of initial consonants, omission of consonants in clusters, omissions/distortions of final consonants, nasalization, substitution of one consonant for another, and intrusive voicing between neighboring consonants (Massaro & Light, 2004). Dagenais et al. (1994) reviewed whether EPG therapy is more effective than traditional means of therapy in treating speech sound disorders for individuals with a hearing impairment. Two groups of nine children with profound hearing loss were given either EPG therapy or traditional aural-oral therapy. Results indicated equal improvement in articulation intelligibility for both groups over a 3-4 week period; however, individuals who participated in EPG therapy produced better consonant linguapalatal contact patterns and higher scores on listener identification ratings than those in the traditional group, whose contact patterns were also measured using EPG.

In fact, palatography and electropalatography was initially developed to assist deaf children view and acquire speech sounds (Fletcher, 1992). A study by Fletcher et al. (1991) indicated that using EPG-enhanced therapy for adolescent individuals with profound hearing
impairment significantly improved their productions of the consonants /t, d, k, g, s, z/ in a 3-4 week period of time. Dagenais (1992) found that EPG is most effective when sounds are initially being remediated. Further, Bernhardt et al. (2003) reported that severity of the speech disorder was not a predictor of EPG therapy success. Individuals made the greatest gain in consonant productions that were absent or near-absent in their pre-treatment speech production. These findings suggest that for individuals with a hearing impairment, EPG therapy is most useful in early stages of remediation with sounds that are absent or near-absent in production.

There is a need for further understanding about how the visual cues provided by EPG technology can be most effectively used to remediate speech sound disorders in children with a hearing impairment. Therefore, the purpose of this study is to document whether therapeutic integration of visual feedback in combination with traditional articulation therapy for a school-aged child with a speech sound disorder secondary to hearing impairment is more effective than traditional therapy alone. The specific focus of this study is on the remediation of the /r/ speech sound in initial, medial, and final word position. The effectiveness of both types of therapy was evaluated based on ratings of correct sound production from a group of adult listeners.

Method

Participant

A 13-year-old male participant (CS) with a bilateral moderately-severe sensorineural hearing loss participated in this study. CS was a native English speaker with no reported history of cognitive or language impairment and has received amplification since infancy to allow for adequate receptive language development. CS also had no orthodontic work and no reported palatal or dental abnormalities. A hearing evaluation conducted two years previously reported speech reception thresholds at 45 dB HL for the right ear and 55 dB HL for the left ear. The
participant’s speech discrimination abilities were moderate in the right ear (100% at 75 dB, 45 dB with masking), but severely impaired in the left (100% at 90 dB, 55 dB with masking). Tympanometry revealed normal, compliant middle ear function in both ears.

The participant has received speech therapy services from a certified speech-language pathologist in a public school setting since preschool. In the year prior to the initiation of this study, CS received therapy to remediate the /t/, /d/, /n/, /l/, and /r/ speech sounds. Therapy occurred 20 minutes once a week. At the beginning of the study, /r/ production in initial, medial, and final word position was the only phoneme still being addressed in therapy. The participant, guardian, principal, and a school-district representative read and signed an informed consent document. Approval was obtained from the Brigham Young University Institutional Review Board for Human Subjects Research prior to data collection. See Appendix A for the consent form used to obtain assent of the participant and permission of the guardian for participation.

Procedures

**Pseudo-palate construction.** Prior to the collection of therapy data, a dental impression was created by a local orthodontic technician. From the dental impression, a stone model was created which was then shipped to SPI to create a custom-fit pseudo-palate. The pseudo-palate resembles an orthodontic retainer extending from the central incisors to the back molars, thereby covering the hard palate and for some individuals the initial portion of soft palate. The device has 124 gold-plated sensors arranged in a grid pattern across the surface of the pseudo-palate on a flexible printed circuit (see Figure 1). The contact data are then transmitted through several wires to a processing box, which collects and transfers the contact data to a computer. These data can then be displayed as a visual representation of the articulatory contact patterns, providing both
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Figure 1. Pseudo-palate Sensor Pattern

the instructor and learner a real-time visual display of how the tongue is contacting the palate during speech.

**Treatment methods.** The participant received a total of 10 individual 40-minute sessions once a week at his school, as well as additional baseline and follow-up data collections prior to and following treatment. Following an A/B treatment design, the participant received 5 treatment sessions with a traditional approach to therapy using auditory and tactile cueing, followed by 5 sessions with EPG plus traditional therapy that used auditory, tactile, and visual feedback. Initial baseline data (which will be referred to as initial baseline) was collected before traditional therapy began in a separate session. Traditional therapy follow-up data or EPG therapy baseline data (which will be referred to as EPG baseline) were collected at the beginning of the first EPG plus traditional therapy session. EPG therapy follow-up data collection occurred in a separate session a week after treatment ended. Figure 2 shows the order of data collection and treatment sessions.
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Figure 2. Data Collection and Treatment Order

EPG plus articulation therapy integrated the use of visual feedback from the PalateView software. To promote adaptation to the pseudopalate, CS was given a practice pseudo-palate without embedded sensors made of the same material as the EPG device and was instructed to wear the practice pseudo-palate for approximately 20 minutes a day for the three days prior to the first EPG therapy session. During the EPG plus traditional articulation therapy sessions, the placement of /r/ was highlighted on the screen, and CS was instructed to match his tongue placement to the sensory patterns shown on the PalateView software. Auditory and tactile cues were also provided to CS when the pseudopalate was in place to assist in refining the /r/ sound production. The pseudo-palate was removed for 10 minutes to allow CS to practice /r/ productions without the palate in place. All treatment sessions were provided by a second-year graduate student and supervised by a school-based, certified Speech-Language Pathologist (SLP-CCC).

Stimuli and data collection. The participant read a series of real words three times for initial baseline and follow-up data collection. The stimulus words contained the /r/ phoneme in initial, medial, or final word position (refer to Table 1 for a detailed listing of the words). Experimental data were also collected weekly before each therapy session prior to placing the
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Table 1

*List of /r/ Words Used in Data Collection*

<table>
<thead>
<tr>
<th>Initial Position</th>
<th>Medial Position</th>
<th>Final Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read</td>
<td>Carrot</td>
<td>Hear</td>
</tr>
<tr>
<td>Rat</td>
<td>Forest</td>
<td>Bear</td>
</tr>
<tr>
<td>Rude</td>
<td>Syrup</td>
<td>Car</td>
</tr>
<tr>
<td>Rob</td>
<td>Zero</td>
<td>Boar</td>
</tr>
</tbody>
</table>

pseudo-palate in the mouth by recording this same series of words read through once. The order in which the words were read was randomized prior to each recording and not used during the treatment sessions.

**Recording and editing.** Linguapalatal contact data from the targeted speech productions were transferred from the EPG sensors to a computer every 10 ms. through a USB connector to an I/O processing unit worn by the user. Audio from the participant’s speech productions were recorded through an external head-set microphone (Shure 10C) and sampled at a rate of 44.1 kHz with a quantization of 16 bits. The audio signal was also recorded by an internal microphone (within the EPG device) which was time-locked to the EPG contact patterns being simultaneously recorded. All of the target words were segmented, high-pass filtered above 60 Hz, ramped at the beginning and end of each segmentation, and normalized for intensity using Adobe Audition CS6.

**Data analysis**

A group of 7 adult listeners with experience in articulation disorders recruited from Brigham Young University were asked to rate the quality of the participant’s productions for all data recordings obtained at the beginning of each session. The listeners were native speakers of
American English and reported no history of speech or language disorders. At the time of their participation all of the listeners exhibited pure-tone air-conduction thresholds of less than or equal to 20 dB HL at octave frequencies from 250 to 8000 Hz. The listeners were asked to listen to each stimulus item and rate the quality of the sound production based on the perceived pronunciation and ability to be understood. The order of presentation for the stimulus items was fully randomized.

The signal was routed from a computer hard drive to the listeners via loudspeakers. The listener was seated in a single-walled sound booth meeting ANSI S3.1 standards (American National Standards Institute, 1999). Each participant listened to a series of sample tokens to become familiar with the program before rating the experimental stimuli. The listeners self-selected the intensity level of the presented stimuli, with a starting level of 60 dB HL. The volume range available to the listeners was limited to a safe hearing level. The perceptual ratings took place during one 30 min session. The randomization, stimulus presentation, and subsequent recording of the listeners’ perceptual judgments were controlled by custom software.

Listeners evaluated the stimulus words by using a computerized sliding scale to rate each word from 0 to 100 (0 being highly misarticulated /r/ in words, 100 being relatively well or normally articulated /r/ in words). A brief training of the program and examples of one highly misarticulated and one well-articulated word were presented to the listener prior to the actual test. During the test, the listeners played the word token and submitted responses at their own pace. A written script of perceptual rating instruction can be found in Appendix B.

The stimuli were randomly presented to the listeners twice. Measures of listener reliability were obtained by comparing a listener’s rating between the two presentations of the same stimulus. Comparisons of the two sets of data resulted in a Pearson correlation of 0.81,
with a mean absolute difference of 15.0% across the listeners (RNG = 11.7% - 17.2%). One listener’s ratings were eliminated from further analysis because the intra-rater reliability difference was above 20%.

**Results**

The aim of this study was to determine whether the integration of EPG visual feedback with traditional articulation therapy is more effective than a traditional therapy approach alone in treating a hearing impaired child with a speech sound disorder. The efficacy of each treatment approach was evaluated based on listener ratings from a group of adults who judged the quality (perceived pronunciation and ability to be understood) of a series of /r/ productions recorded at the beginning of each session. Table 2 contains a descriptive listing of the listener rating means and standard deviations across treatment approach and /r/ word position. As illustrated in Figure 3, across the 12 sessions mean listener ratings remained consistent to the initial baseline session through the final session of traditional therapy, with an increase in ratings during the EPG sessions through the follow-up recording.

A repeated-measures analysis of variance (ANOVA) was used to determine if the listener ratings varied as a function of the treatment approach, word position of the /r/, and the linguistic context. The third ANOVA variable of linguistic context was only used as a control variable for productions of /r/ from a variety of differing vowel contexts; thus it will not be discussed in detail. This analysis examined ratings from the initial baseline, post traditional/pre EPG baseline, and a follow-up evaluation recorded one week after the conclusion of therapy. ANOVA results included a measure of effect size, partial eta squared, or \( \eta^2 \). The value of \( \eta^2 \) can range from 0.0 to 1.0, and can be considered a measure of the proportion of variance explained by a dependent variable when controlling for other factors. Greenhouse-Geisser adjustments
Table 2

*Listener Rating Means and Standard Deviations across Session and Word Position*

<table>
<thead>
<tr>
<th>Session</th>
<th>Initial Mean</th>
<th>Initial SD</th>
<th>Medial Mean</th>
<th>Medial SD</th>
<th>Final Mean</th>
<th>Final SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Baseline</td>
<td>18.50</td>
<td>20.75</td>
<td>48.26</td>
<td>31.73</td>
<td>89.25</td>
<td>13.15</td>
</tr>
<tr>
<td>T1</td>
<td>29.34</td>
<td>24.48</td>
<td>42.03</td>
<td>18.80</td>
<td>88.71</td>
<td>13.86</td>
</tr>
<tr>
<td>T2</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>T3</td>
<td>25.95</td>
<td>19.58</td>
<td>40.23</td>
<td>23.86</td>
<td>74.33</td>
<td>24.55</td>
</tr>
<tr>
<td>T4</td>
<td>22.79</td>
<td>19.94</td>
<td>49.31</td>
<td>20.31</td>
<td>78.19</td>
<td>17.06</td>
</tr>
<tr>
<td>T5</td>
<td>14.70</td>
<td>15.76</td>
<td>43.00</td>
<td>20.48</td>
<td>84.56</td>
<td>15.62</td>
</tr>
<tr>
<td>EPG baseline, E1</td>
<td>16.40</td>
<td>13.59</td>
<td>48.60</td>
<td>25.70</td>
<td>87.46</td>
<td>13.72</td>
</tr>
<tr>
<td>E2</td>
<td>37.34</td>
<td>26.05</td>
<td>44.13</td>
<td>23.23</td>
<td>86.76</td>
<td>14.48</td>
</tr>
<tr>
<td>E3</td>
<td>35.54</td>
<td>23.49</td>
<td>43.55</td>
<td>22.81</td>
<td>88.81</td>
<td>12.12</td>
</tr>
<tr>
<td>E4</td>
<td>41.30</td>
<td>23.25</td>
<td>53.42</td>
<td>25.98</td>
<td>88.93</td>
<td>10.36</td>
</tr>
<tr>
<td>E5</td>
<td>54.78</td>
<td>28.52</td>
<td>55.19</td>
<td>28.71</td>
<td>82.67</td>
<td>14.67</td>
</tr>
<tr>
<td>Follow-up</td>
<td>56.54</td>
<td>33.80</td>
<td>69.70</td>
<td>21.31</td>
<td>85.74</td>
<td>15.51</td>
</tr>
</tbody>
</table>

*Note. *Recordings from this session could not be analyzed.*
Figure 3. Mean Listener Ratings Across the Three /r/ Positions. T = traditional therapy treatment session followed by the session number; E = EPG plus traditional therapy treatment session followed by the session number. *Participant had a treatment session during session T2, however the recording quality was poor and was therefore eliminated from the analysis.
were utilized to adjust \( F \)-tests with regard to degrees of freedom when significant deviations from sphericity were found. Furthermore, pairwise comparisons for significant within-subject factors were calculated using General Linear Model repeated-measures contrasts; comparison significance was determined using the appropriate \( F \)-tests.

The ANOVA indicated a significant main effect in the listener ratings as a function of the treatment approach, \( F(2, 10) = 49.21, p < .0001, \eta^2 = .91 \). Pairwise comparisons did not show a significant change between the initial baseline and the post-traditional measure, but a statistically significant increase in ratings was found for the follow-up recordings following the integrated EPG approach (\( p < .001 \)). As illustrated in Figure 4, the mean ratings for the initial baseline, EPG baseline, and follow-up productions were 52.0, 50.8, and 70.7 respectively.

There was also a significant effect of word position, \( F(4, 20) = 184.16, p < .0001, \eta^2 = .97 \), and a significant interaction between the treatment approach and word position, \( F(4, 20) = 29.40, p < .0001, \eta^2 = .86 \). As shown in Figure 5, the increase in listeners’ ratings occurred with /r/ productions in initial and medial word position, whereas listener ratings actually decreased slightly in word-final position.

**Discussion**

For the school-aged child with a speech sound disorder secondary to hearing impairment evaluated in this study, integration of visual feedback in combination with traditional therapy was more effective than traditional therapy alone. The listener ratings indicated that throughout the treatment sessions that used a traditional approach, CS made no progress in the production of /r/ in words. However, the listeners judged that he was able to more clearly produce the /r/ sound after the therapist integrated visual cues from an EPG device, especially for productions recorded
Figure 4. Mean Listener Ratings for the Treatment Assessments.
Figure 5. Mean Listener Ratings for Treatment Assessment by Word Position.
during the last two sessions and the follow-up evaluation. It is possible that with EPG included in therapy, /r/ productions improved because of the additional visual feedback to help compensate for correct tongue placement when auditory cues were not perceived or verbal instruction was inadequate.

Previous research concerning the efficacy of EPG in treating speech sound disorders in children with a hearing impairment is inconclusive. Findings of the present study differed from those of two previous studies (Bernhardt, 1992; Dagenais et al., 1994). Dagenais et al. (1994) reported that participants made equal improvement in articulation intelligibility when given either EPG therapy or traditional therapy for the same amount of treatment time. Dagenais (1992) and Bernhardt et al. (2003) found that EPG therapy was most useful in early stages of remediation of articulation for hearing impaired individuals, particularly for individuals who did not produce consonants prior to treatment. The participant in the present study was able to produce /r/ in some word positions, yet still made significant gains. Dagenais also found that traditional therapy showed greater gains in terms of general speech intelligibility for children with hearing loss when compared to EPG therapy over a two year period. One reason why this difference might have occurred is because at the time of this study, EPG technology was thick and inflexible, which may have negatively affected therapeutic outcomes.

However, several previous studies have reported similar results to the current study. Bernhardt et al. (2003) concluded that while participants with a sensorineural hearing impairment made most gains in early stages of traditional treatment, significant gains were made throughout EPG therapy as well. Dagenais (1992) reported that EPG therapy was most effective for the first year of a two-year study when compared to traditional therapy. Fletcher, Dagenais,
and Critz-Crosby (1991) further reported that adolescents with profound hearing impairment improved significantly in their productions of the consonants /t, d, k, g, s, z/ with EPG therapy.

The results of the present study indicated that progress in producing the /r/ phoneme differed across word position. During traditional articulation therapy, CS did not progress in /r/ productions in any word position. However during the EPG plus traditional therapy approach, CS made significant progress in producing the /r/ phoneme when the target sound was in the word-initial and medial positions, whereas listener ratings actually decreased slightly in word-final position. A possible explanation for this result is that CS produced /r/ in final word position at a relatively high level prior to the beginning of this study, with initial baseline ratings at 80 – 90%. CS received speech therapy before the study began, and possibly learned /r/ in the final position during this therapy. It is possible that listener ratings in the 80-90% range may be reaching a ceiling, given the other characteristics of his speech such as hypernasality and other phonetic distortions. These characteristics may have negatively affected listener’s perception of the /r/ productions. It may also be that judges don’t always give a rating of 100, even to children not receiving therapy for /r/.

The results of the present study may or may not generalize to other child populations with speech sound disorders. Carter and Edwards (2004) suggest qualifying conditions for a child to be given EPG therapy, including chronologic age (at least 7 years old), absence of visual and cognitive abnormalities, sensitivity of the child to the palate, state of dentition, presence of structural abnormalities (e.g., repaired cleft palate), and motor control of the articulators. A child would need to be able to visualize and comprehend the screen in order for the instruction to be meaningful. Thus it is unclear whether a child of a younger age, with less cognitive ability to comprehend the task, would make the same progress as the participant of this study.
Considering the experimental design of the current study, the increased progress in EPG treatment may also be due to order effects. This was a single-subject A/B design, and it may be that the EPG treatment was more effective simply because it was administered second. The client’s gains may have been due to a greater familiarity with the therapist and the specific style of instruction and not due to the therapy approach. It is also possible that the initial five weeks of traditional therapy built a foundation upon which gains could be realized during the second five weeks of therapy, irrespective of the type or approach to therapy.

The differences in progress between the traditional and EPG enhanced approaches to therapy in this study may not occur when working with children who do not have a hearing impairment. Typically hearing individuals are more likely to perceive subtle auditory cues in traditional treatment, thus EPG therapy may not be as advantageous, especially for younger children who have not shown a resistance to traditional methods. Although a number of previous studies have found EPG therapy to be effective when other means of therapy have been unsuccessful (e.g., Barry, 1989; Dent et al., 1995; Gibbon & Hardcastle, 1987; Gibbon et al., 1995), there has not been a comprehensive focus on large-scale, controlled outcome research comparing traditional and EPG related approaches to speech sound remediation.

In addition, it is unclear if the findings of this study will generalize to other types of speech sound disorders. Given that the /r/ phoneme has posterior palatal contact, EPG therapy allows the patient to visualize tongue-to-palate contact in an area that is otherwise difficult to see with a mirror. In theory EPG related approaches would be much more successful in the remediation of speech sound disorders that have a relatively high degree of tongue-to-palate contact (e.g., /t, d, s, ʃ, k, ɡ, ɬ/), whereas similar therapy gains may not occur when remediating sounds produced with a more open vocal tract constriction, such as glides and vowels.
There are a number of limitations with this study. As previously mentioned, it would be beneficial if future research could perform a similar study using multiple participants in an AB/BA design, controlling for factors such as chronological age, type of speech sound disorder, hearing status, and order of treatment. Another limitation with the current study was the nature of the data recordings. Although obtaining recordings in a school setting may be more naturalistic, there may have been differences in recording quality that could have impacted the accuracy of the listener ratings. Data analysis of the current study was limited to a perceptual analysis, thus it may be valuable to also examine the data in terms of tongue-to-palate contact patterns and acoustic parameters.

Despite these limitations, it is hoped that the results of this study will provide additional insights into the effectiveness of using EPG plus articulation therapy compared to traditional articulation therapy for individuals with hearing impairment, particularly for the production of /t/. In addition, it is anticipated that method insights found from this study will facilitate more accurate studies in this area in the future.
References


Appendix A: Participant Consent Form

Parental Permission for a Child to be a Research Participant

Introduction
The aim of this study is to examine the effectiveness of using a palatal sensor and tactile aids to remediate a developmental speech disorder. Your child is being invited to participate in this study because he/she is a native speaker of English with a history of a speech disorder. This study is being conducted under the supervision of Shawn Nissen, Ph.D., an associate professor in the Department of Communication Disorders at Brigham Young University.

Procedures
In this study your child will receive speech therapy using visual feedback from a palatal sensor (similar to an orthodontic retainer), as well as more tradition methods of treatment, such as verbal or tactile feedback. An example of tactile feedback might be touching the palate or tongue with a tactile aid (similar to a plastic straw). Your child will be asked to have a dental impression created by a licensed dental professional. A list of possible dental professionals will be provided, but you are welcome to have an impression created by another dentist or technician of your choice. This study will involve a hearing screening, the sensor fitting, weekly speech therapy sessions (30-40 minutes). The therapy sessions will be conducted by graduate students enrolled in the Communication Disorders Master’s program under the supervision of the licensed speech language pathologist working at your child’s school. Samples of your child’s speech will be collected at the beginning and end of each therapy session, which will then be rated by listeners for intelligibility and pronunciation.

Risks/Discomforts
There are minimal risks associated with participation in this study. The palatal sensors and tactile aids used in this study have been used for a number of years in the speech pathology community without any reports of adverse events. The tactile aids have smooth and rounded surfaces, but there may be some minor discomfort to the child when touching the areas of the palate behind the upper teeth. The palatal sensor is similar to an orthodontic retainer and may cause some minor discomfort to the gums or teeth during use. The participant may encounter some minor discomfort when the dental impression (which is used to create the sensor) is being created. The finished sensor is too large to be accidentally swallowed; in addition it is attached to the data collection unit. Your child’s speech may sound different with the sensor in place and it may take a period of time for them to become accustomed to speaking with the sensor in their mouth.

Benefits
There are no direct or guaranteed benefits for participants of this study.

Confidentiality
All information provided will remain confidential and will only be reported with no identifying information. All data, including digital recordings of your child’s responses will be kept on a password protected computer in a locked laboratory and only those directly involved with the research will have access to them.

Compensation
Your child will not be compensated for participation in this study.

Participation
Participation in this research study is voluntary. Your child has the right to refuse to participate or withdraw at any time without penalty.

Questions about the Research
If you have questions about this study, 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 permission for my child to participate in this research.

Signed: ___________________________ Date: ________________

(signature of participant’s parent or legal guardian)

Child’s Name: ___________________________
Efficacy of Electropalatography

Child Assent to be a Research Participant

We want to tell you about a research study we are doing. This study is meant to find out more about how best to help kids with their speech. You are being asked to join the study because you speak English and you have worked with a speech teacher before.

If you decide that you want to be in this study, this is what will happen.
- You will come to speech therapy during the week and talk with a speech teacher. Each time it will take approximately 30 minutes.
- We will check your hearing by having you listen to some beeps in headphones.
- We might make a piece of plastic like this (show palate sensor) to put over your top teeth, it’s like a retainer. This piece of plastic then plugs into a computer like a video controller. This is made by having a mold made of your teeth by having you bite into a tray filled with a material that molds around your teeth. The mold takes about 10 minutes to make. This material is a little sticky, but it can be removed by brushing your teeth after it is made.
- You will work with your speech teacher on how to make different kinds of sounds. During that time you will play different games, like "Go Fish", Candyland, or other games.
- Right before and after you play these games, your speech teacher will record your voice with a microphone. We will not play this recording to anyone you know and we will not put your name on it. Then a small group of adults will listen to the recordings to determine if your speech is improving.

Do I have other choices?

You can choose not to be in this study. It’s up to you. If you say yes now, but you change your mind later, that’s okay too. All you have to do is tell us.

Will anyone know I am in the study?

We won’t tell anyone you took part in this study. When we are done with the study, we will write a report about what we found out. We won’t use your name in the report.

Before you agree to be in this study, be sure to ask the person helping with the study to tell you more about anything that you don’t understand.

If you want to be in this study, please sign or print your name.

☐ Yes, I will be in this study.    ☐ No, I don’t want to do this.

Child’s name __________________________ Signature of the child __________________________ Date __________________________

Person obtaining Assent __________________________ Signature __________________________ Date __________________________
Appendix B: Perceptual Rating Instruction Script

General Introduction

We are going to have you listen to a series of words and rate them according to how well the speaker articulated /r/ in each word. Sometime the /r/ will be at the beginning, middle, or end of the word. On this slider (show slider), you see a score of 1 through 100, 1 being used to represent a highly misarticulated /r/, and 100 being a relatively well articulated or normally articulated /r/. During the test, you will play the sound by clicking here (show play sound button), then rate how well articulated the word is anywhere along the scale. Don’t be afraid to use the range of the scale (go really high or really low). When you have selected your rating of the sound, click submit. This will then allow you to click on the play button to listen to another word.

Training Introduction

We are going to start off with a training to help you become familiarized with the program. It will play two words to show you an example of a score of 1 and 100. When you hear the word rude, you will mark 1 on the scale. When you hear the word read, you will mark it as 100 on the scale. These examples were selected to show you poorly and more normally articulated examples. Practice running through the program, and when you are familiar with the program and the sounds let me know.

Actual Test

Now we will run the actual test. Please mark as accurately as possible. Remember, you can mark anywhere along the scale to record articulation for each word. We will go through the test twice, taking about 10 minutes each.
Appendix C: Annotated Bibliography


Objective: The purpose of the study was to evaluate the effectiveness of EPG as a treatment for children and adults who had a variety of speech disorders across etiologies. This publication provides an overview of previous research in this area, including characteristics of clients that may benefit from EPG treatment, and an evaluation of treatment factors that may affect the success of an EPG treatment. Method: Data from two studies were examined to evaluate the effectiveness of EPG therapy for individuals with articulation problems from multiple etiologies. All participants were above the age of 7, but ranged in age (including both children and adults) and etiology. Therapeutic methods were discussed and diagnostic and treatment information of five participants from the two studies described. Results: Results varied, showing improvement for some participants and no improvement for others. Conclusions: Success in EPG therapy is contingent on a number of factors, including cognitive ability, client motivation, and etiology. Relevance to the current work: The success of EPG therapy is discussed.


Objective: The objective of this study was to answer four questions: 1. Would participants of this study make the same gains in articulation using EPG therapy as reported in similar studies for individuals with hearing loss? 2. Is hearing loss severity a predictor of progress in articulation production? 3. How does this type of therapy affect non-target phonemes in comparison to target phonemes? 4. Is EPG therapy a more effective feedback tool in comparison to ultrasound therapy (both visual feedback systems)? Method: Four high-school aged students with moderate-to-severe hearing loss
were chosen for the study. A screening sample was collected 5 weeks before the study. The intervention was divided into two blocks; the first for nine weeks and the second for five weeks (30 minute weekly sessions). Groups were randomly assigned to EPG therapy first, ultrasound training second and vice versa. Data were measured via perceptual listener ratings. Results: Participants made the same reported gains as participants reported in similar studies. Severity of disorder did not appear to be a predictor of gain. Treatment targets improved more than non-treatment targets. Students made greatest gains for consonants that were absent or near-absent in their pre-treatment speech production. There was no significant difference in EPG and ultrasound therapy results. Conclusion: Students with a sensorineural hearing impairment made significant gains in their speech production using either EPG and ultrasound therapy. Relevance to the current work: Sensorineural hearing impaired students have been shown to make gains in speech production using EPG therapy.


Objective: This study tested the effectiveness of using EPG in articulation therapy and tested the predictability of success. The study explained the child specific, disorder specific, and therapy related factors that contribute to successful EPG therapy. Methods: Ten participants with articulation disorders (either primary articulation disorders or disorders secondary to dyspraxia and learning difficulties) were selected and predictions of articulation success were made. Therapy occurred once a week for 10 weeks and followed therapy procedures defined by Hardcastle et al. (1991, p. 67). Three separate assessment procedures were used to analyze pre and post data. Results: There was a significant improvement in all areas measured. Conclusions: There was little correspondence between the original predictions and the outcomes. Relevance to the current work: Articulation therapy success is discussed.

*Objective:* This article discussed a new treatment approach of using an appliance at the maxillary arch to help facilitate correct /r/ production. *Method:* Thirty-six participants were chosen for the study based on defined inclusion criteria and were fitted for the appliance. Participants were divided into four treatment groups. *Results:* The participants who used the R-appliance showed statistically significant improvements in /r/ production compared to control groups. *Conclusions:* R-appliances are successful in the remediation of /r/. *Relevance to the current work:* Tactile feedback is discussed.


*Objective:* The purpose of the study was to compare physiologically-based systems (EPG and glossometry) against traditional approaches in the treatment of hearing impaired individuals by reporting on results found in two separate studies. *Method:* A glossometry system was used for therapy of vowel production by means of LED light emission from a pseudoplate placed in the mouth. Palatometry (EPG) was used for the treatment of consonants. In the first study, two groups of nine participants were included in either EPG or traditional aural/oral speech therapy. The follow-up 2-year study included four 10-year-old participants using EPG and traditional treatment. *Results:* Those who participated in EPG therapy showed greater improvement for tongue-palatal contact sibilants. Traditional therapy showed greater gains in terms of general speech intelligibility. EPG was reported as being most effective in the first year of the 2-year study. In the second year, traditional therapy had more of an impact on intelligibility. *Conclusions:* These studies suggest that EPG and other physiologically-based therapy systems are most useful in early stages of learning for hearing impaired individuals, specifically in helping speakers acquire new articulatory patterns. *Relevance to the*
current work: Hearing impaired individuals benefit from EPG therapy, especially for elicitation and sound acquisition.


Objective: A summary of recent findings for EPG diagnosis and treatment of articulation disorders is described. Method: This article first compares and contrasts a traditional articulation approach (mainly through auditory-based or perceptual methods) to EPG (visually oriented method). A case study of EPG therapy for a child who lateralized /s/, /ʃ/, /tʃ/, and /ʤ/ was emphasized. Conclusions: Traditional articulation therapy may not be as effective as EPG if the child has differences in their articulatory postures that may lead to isolated sound errors. These postures may not be identified in traditional articulation therapy. It was also shown that it was efficient and effective to teach children inventories of sounds instead of eliminating processes for phonological disorders.


Objective: This comparison study measured the effectiveness of EPG articulation therapy compared to traditional aural-oral methods for speakers with a profound hearing impairment. Method: Nine children with profound hearing impairments were divided into two groups, an EPG therapy group and traditional aural-oral group. Treatment focused on the consonants /t,d,k,g,s,z,ʃ/, and occurred over 26 50-minute sessions in 3- to 4-week intervals. Data were collected immediately before and after, then 6 months post-treatment using EPG-determined lingualpalatal contacts and listener identifications. Results: EPG-trained participants produced better consonants as determined by the lingual-palatal
contact patterns and perceptual ratings. Participants who received EPG and traditional therapy performed within the same limits on the CID SPINE, a test measuring speech intelligibility. Conclusions: Visually oriented feedback (EPG) provides a viable alternative to traditional type of training. Relevance to the current work: EPG therapy has been shown to be an effective alternative means to traditional therapy approaches.


Objective: The purpose of this study was to review EPG as a biofeedback mechanism in therapy. Method: A successful past EPG study (Gibbon, Hardcastle, Dent, & Nixon, 1995) was summarized and discussed. Results: Successes in the study occurred when clients were taught new lingual patterns, taught to eliminate negative articulation behaviors, and were taught to modify their existing lingual patterns. Conclusions: Some clients were unsuccessful with the therapy for a variety of reasons that include: not being able to complete the study, being too “immature” in age, and unmotivated in their personality. Relevance to the current work: The effectiveness of EPG therapy and qualifying conditions for participants to use EPG was reviewed.


This book describes the development, research, and treatment of articulation disorders. Specific sections in the book explore technological advancements for viewing and treating articulation disorders, including X-ray imaging, ultrasound and magnetic resonance imaging, glossometry, and palatography. Relevance to the current work: Palatography and electropalatography histories are explored.

**Objective:** This study measured whether the palatometry system is a viable alternative to traditional speech training for profoundly impaired individuals. **Method:** Five profoundly hearing-impaired girls (ages 10-16) were selected for the study. Target sounds included /t,d,k,g,s,z,ʃ/. Palatometric analysis and perceptual analysis were performed to measure the progress and outcomes of the study. Therapy was given two times daily for 3-4 weeks. **Results:** Findings varied subject to subject, but all participants acquired better linguapalatal contact patterns (including place and manner) for the target sounds and scored higher on intelligibility reports. Participants gained sounds never included before in their sound inventory, specifically velar and alveolar stops. **Conclusions:** The authors indicate that visual articulatory modeling and feedback of linguapalatal contact patterns is an effective means of teaching consonants and improving speech intelligibility for profoundly hearing-impaired individuals. **Relevance to the current work:** EPG therapy in relation to hearing impaired individuals is discussed.


**Objective:** The purpose of this study was to discuss an initial continuous, computer based palatometry system. Temporal lingual contact patterns of sounds are analyzed using a computer based palatometry system **Method:** A light emitting diode (LED) display was used to measure contact distribution. Syllables /ta/ and /na/ were measured. **Results:** Contact distribution was highly variable, however, individual utterances can be adequately measured and an average of overall utterance variability can be accurately obtained. **Conclusions:** This type of system is an adequate system for measuring dynamic lingual palatal contact. **Relevance to current work:** Initial palatometry is discussed.

**Objective:** The objective of this study was to measure /s/ articulation improvement using EPG therapy. Three categories were used to categorize the main features of /s/: amount of anterior contact, amount of palatal contact, extent of lateral contact. **Method:** A 12-year-old boy with a lateral /s/ was chosen for this study. He received therapy for four one-hour sessions. **Results:** A normal /s/ pattern was achieved after the four sessions, and was maintained at the six-month follow up assessment. **Conclusions:** EPG is an effective way of treating lateralized /s/. Relevance to the current work: The treatment of specific speech sounds in a case study format was considered.


**Objective:** This case study analyzed the effect of using PROMT (Prompts for Restructuring Oral Muscular Phonetic Targets), a tactile cueing intervention approach, specifically by measuring the articulation movement and sound accuracy. **Method:** Two children were chosen for the study, one as a control with typical speech and one with a speech disorder. A motion capture system was used to measure articulation movements. **Results:** Results showed an increase in articulation accuracy and decrease in the movement duration, displacement, and velocity of the articulators after the use of PROMPT. **Conclusions:** This tactile cueing intervention was effective in treating articulation disorders. Relevance to the current work: The use and effectiveness of tactile cueing in therapy was considered.

Objective: Authors of the study hypothesized that verbal instruction may not be enough for teaching young children speech placement because they do not have a developed lingual-tactile awareness. A review of literature shows that a person’s awareness of tongue production in speech is in direct proportion to the age of the individual, and that oral-tactile sensation is developmental in nature. Method: In order to test this hypothesis, 90 participants were organized by age into three age groups of 30 participants and were asked to answer questions about tongue placement in speech. Results: Results showed that adults performed better in the tasks than younger children. Conclusions: This supported the authors’ hypothesis that tactile awareness may be maturational. Relevance to the current work: Tactile awareness is a consideration for tactile therapy.


Objective: The objective of this study was to measure speech perception and production for individuals with hearing loss when given language tutoring from a computer-animated talking head. This talking head shows facial animations with possible transparent skin to allow view of articulators, muscles, voicing, and resonance. Method: Seven participants ages 8-13 with hearing loss were tutored for 6 hours across 21 weeks on 8 categories of segments (organized into voicing, consonant cluster distinctions, fricative vs. affricate distinction categories). This training occurred at the segment and word level. Results: For 7 of the children, perception and production improved and generalized to new words not included in tutoring. Speech production partially deteriorated after 6 weeks when tutoring was not provided. Conclusions: The training method (speech tutoring) rather than some other experience was responsible for the improvement that was found. Relevance to the current work: The use of visual cuing for speech treatment in individuals with hearing impairment is considered and used in the current study.

**Objective:** This case study was designed to measure the improvement of lateral /s/ production using a hybrid EPG and traditional articulation therapy approach. **Method:** Results were measured without the pseudo-palate in place both acoustically by viewing the consonant spectrum, and perceptually by obtaining untrained listeners ratings. Data were collected pre-treatment, post treatment (four weeks long), and after the six week home program. **Results:** Results showed improvement in both perceptual rating and acoustic information, but the EPG readings showed less improvement. **Conclusions:** Visual feedback using EPG was useful initially in achieving accurate tongue-palate contact. **Relevance to the current work:** EPG efficacy is considered.


**Objective:** This study measured the speech adaptation effect when a speaker was given a bite-block for a defined amount of time. **Method:** Speech acoustic data were collected before and after 15 speakers were given a bite-block for 15 minutes. **Results:** While compensation was not immediate or complete, the speaker adapted vowels and consonants to that of more typical speech. **Conclusions:** The authors concluded that speech compensatory strategies may develop over time when given this type of tasks, with vowels adapting more quickly and accurately than consonants. **Relevance to current work:** Speech adaptation is reliant on the speaker’s auditory feedback loop, which is an important component in traditional articulation therapy.
Objective: The purpose of the study was to measure the adaptation time for EPG. Method: Seven adults with typical speech were selected to participate in this study. The participants used EPG over two collection periods and read a passage, produced syllables, and counted in order to measure adaption time for EPG. Three areas were evaluated for adaptation: consonant acoustics, listener perceptions, and speaker ratings. Results: Analysis showed a reduction of spectral mean for the sounds /tʃ, ʃ, s, z, ʤ, and ʒ/ after 60-120 minutes of wearing the palate. Listener ratings showed little to no change in the naturalness of speech when the speaker was wearing the EPG compared to when they were not. Self-ratings showed a significant difference in how they spoke when the EPG was worn in comparison to how they spoke without the EPG. Conclusions: Spectral feature of consonants were initially affected when the EPG was worn, but these numbers improved as adaptation to the device occurred. The optimal adaptation time for relatively normal speech using an EPG was two hours. Relevance to the current work: How much time the participant needs to adapt to the pseudo-palate is considered.


Objective: This efficacy study compared therapy success of a traditional articulation approach with “Speech Buddies”, an intra-oral tactile cueing system in the treatment of /s/ distortions. Method: Twenty participants between the ages of 5-8 who had less than 10 hours of speech therapy were selected for the study and were divided into two treatment groups. One group was given tactile biofeedback therapy along with traditional articulation therapy; the other group did not receive tactile biofeedback therapy. Results: Results indicated that those who received tactile biofeedback performed better than those who did not receive the treatment. Conclusions: It was concluded that
tactile biofeedback is an effective primary treatment option for children with speech disorders. \textit{Relevance to the current work:} Tactile feedback systems available on the market are considered.


\textit{Objective/Method:} The objective of this study was to review literature regarding speech appliances, their success rate, and neurophysiological evidence support their success rate. Five main treatment techniques (imitation, contextual identification, shaping, phonetic placement, moto-kinesthetic training) are described using previous literature. \textit{Results/conclusions:} It was hypothesized that a speech appliance offers sensory cueing, which enables the client to learn the articulatory position and movement of a speech sound. \textit{Relevance to the current work:} The effectiveness of using tactile feedback systems is considered.


\textit{Objective:} The purpose of this study was to compare tactile, imitative, and descriptive input to teach six unfamiliar sounds in isolation. \textit{Method:} Thirty-six subjects (18 male, 18 female) were taught the six sounds using one of the input therapy procedures for each sound. The new target sounds taught included a voiceless fricative, voiced fricative, voiceless roll, voiced roll, voiceless plosive, and voiced plosive. \textit{Results:} The most short-range learning was best achieved using imitative information procedures. It was also shown that teaching sounds as a similar sound group (e.g., voiced and voiceless fricatives) was more effective than teaching the sounds individually, and voiced sounds were more easily taught than voiceless sounds. Tactile procedures were least effective in teaching new sounds, though no treatment procedure was better than the other when teaching sounds in the posterior section of the oral cavity. \textit{Conclusions:} While this study
taught non-English sounds to English speakers, it is concluded that articulation learning procedures would give similar results in teaching sounds for articulation disorders.

*Relevance to the current work:* Effective means of treating articulation disorders are discussed for traditional articulation procedures.