ELECTROPALATOGRAPHY TREATMENT FOR SCHOOL-AGED CHILDREN WITH RESIDUAL /ɹ/ ERRORS

by

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Bachelor of Science, 2018
Texas Christian University

Submitted to the Graduate Faculty of the Harris College of Nursing and Health Sciences
Texas Christian University
in partial fulfillment of the requirements for the degree of

Master of Science

May 2020

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A Thesis for the Degree

Master of Science

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ACKNOWLEDGEMENTS

I would like to thank Dr. Christopher Watts, Mrs. Lynn Flahive, and Dr. Ahmed Rivera-Campos for their expertise, assistance, patience, and guidance throughout the process of completing this thesis. Without your support this thesis would not have been possible. I would also like to extend my gratitude to the four participant's and their families for their participation in this study. Lastly, I would like to thank the TCU Harris College of Nursing & Health Sciences and the TCU Graduate Student Senate and Graduate Studies for providing the funds for me to travel to Florida to present my thesis at the American Speech-Language-Hearing Association 2019 Convention.

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Introduction

This paper considers the use of electropalatography (EPG) in treating school-aged children with residual /ɹ/ errors in connected speech. In speech-language pathology, the treatment of /ɹ/ misarticulation is a common challenge. Traditional therapy techniques do not always yield successful outcomes, resulting in the need to search for alternative treatment options (Hitchcock et al., 2017; Preston et al., 2014; Preston et al., 2018). Alternative treatments which utilize visual Biofeedback techniques, for example ultrasound and electropalatography (EPG), give speakers real-time visual feedback of tongue movements and connections (Nordberg et al., 2011). The purpose of the present study was to investigate the efficacy of electropalatography treatment in school-age children with residual /ɹ/ errors.

Rhotic Errors

The phoneme /ɹ/ is a late-emerging sound that is one of the most difficult sounds to treat using traditional articulation therapy techniques (Hitchcock et al., 2017; Preston et al., 2014; Preston et al., 2018). Tongue placement for /ɹ/ production is obscured within the oral cavity, thus /ɹ/ is not a visual sound and it is not easy for children with rhotic errors to correct by looking in a mirror or at a clinician (Hitchcock et al., 2017; Preston et al., 2018). Evidence from ultrasound and other visual technologies have demonstrated that /ɹ/ can be produced with a variety of tongue shapes (Preston et al., 2014). For example, the dorsum (middle) of the tongue can be dipped, sloped, or flat depending on the speaker, and still be phonemically correct (Hitchcock et al., 2017; Preston et al., 2018).

The two predominant categories of tongue shapes for /ɹ/ are described as retroflexed and bunched (Hitchcock et al., 2017; Preston et al., 2018). A retroflexed tongue has a raised tip and a lowered dorsum, whereas a bunched tongue has a lowered tip and a raised dorsum (Hitchcock et al., 2017; Preston et al., 2018). In both the root (back) of the tongue is always retracted (Hitchcock et al., 2017; Preston et al., 2018). In addition, the sides of the tongue need to be lifted to form a midline groove through which sound energy is directed (Hitchcock et al., 2017; Preston et al., 2018). In children with rhotic errors, the tongue shape during /ɹ/ production is often distorted (Hitchcock et al., 2017; Preston et al., 2018). For example, /ɹ/ distortion may be characterized by a low tongue blade, high tongue dorsum, or a lack of tongue root retraction (Preston et al., 2018).

Any speech errors that have not been successfully eliminated by eight years of age are considered residual errors. Many children grow out of speech sound errors, but those with residual errors struggle in successfully communicating their wants and needs to others (Van Riper, 1972). Unsuccessful communication can have a negative impact on the academic, social and emotional aspects of a child's life (Hitchcock et al., 2017). Rhotic errors often become residual errors in children because visualization of mouth structures used to produce the /ɹ/ sound is difficult, presenting a barrier to visual feedback as a treatment modality (Van Riper, 1972). When a child's progress in traditional therapy plateaus for an extended period of time, it is frustrating for both the child and the clinician to continue therapy when it does not yield positive results (Hitchcock et al., 2017).

Traditional Articulation Therapy

Traditional articulation therapy is characterized by varied techniques whose implementation are determined by the specific sound error, the client's needs, and the resources available (Klein, 1995). While the specific characteristics of sound errors can vary from one child to the next, all show one or more of the following patterns: substitution of one sound for another, distortion of a sound, omission of a sound, or addition of a sound in continuous speech (Van Riper, 1972). These patterns indicate the way a child incorrectly uses the various properties or features of speech sounds (Van Riper, 1972). Children with these speech sound errors often do have principles and rules that govern and organize their speech sound production patterns (Van Riper, 1972).

According to Van Riper (1972), there are four main goals that should be a part of all articulation therapy for misarticulations to be successfully corrected. One, the client must learn the characteristics of the targeted phoneme and how his or her errored articulation is different: Two, the client must learn how to produce the targeted phoneme on his or her own: Three, the client must develop a stable use of the targeted phoneme in isolation, syllables, words, phrases, and sentences; and four, the client should be able to use the targeted phoneme in continuous speech or under any conditions (Van Riper, 1972). However, when these four goals are not achieved, the child's speech errors can persist and become residual errors.

Even if the errors are minor, school-aged children and young adults with residual speech errors often encounter negative judgements from their peers (Byun & Hitchcock, 2011). According to a survey of school speech-language pathologists (SLPs), 91% of 98 respondents reported encountering clients whose speech sound errors did not respond to traditional articulation therapy (Ruscello, 1995). When a child's speech errors cannot be corrected through traditional techniques, school SLPs are forced to make an ethically difficult decision: do they continue to provide therapy that does not yield results, or do they dismiss the child even though he or she still has residual speech errors? (Ruscello, 1995).

Visual Biofeedback

Visual biofeedback technology has been introduced to help reduce the frustrations and improve the outcomes for clients with residual and challenging speech errors (Hitchcock et al., 2017). To improve treatment outcomes, it has been argued that a client must obtain an accurate visual and auditory representation of the target phoneme before mastering a speech movement pattern (Byun & Hitchcock, 2011). Shuster (1998) found that children with /ɹ/ misarticulation manifested an impairment in the ability to discriminate correct versus distorted /ɹ/ sounds from their own productions. If a child cannot determine the auditory difference between a misarticulated /ɹ/ and correctly produced /ɹ/, there is a strong likelihood that traditional articulation therapy will be unsuccessful (Byun & Hitchcock, 2011). Visual biofeedback technology allows for visualization of speech features that are difficult to see with typical therapy tools such as a mirror (Hitchcock et al., 2017). Establishing a conceptual link between the visualization of articulation placement for speech sound production and the auditory perception of the resulting sound pattern can promote the remediation of speech sound errors, based on the theories of Van Riper (Van Riper, 1972).

Early research evidence shows that visual biofeedback intervention can be successful in correcting residual /ɹ/ errors in children (Byun & Hitchcock, 2011). The addition of visual feedback of the articulatory structures to the existing acoustic feedback facilitates clients' comprehension of why the phoneme is errored when they produce it (Wood et al., 2009). The visual biofeedback allows children to change their production patterns to match a model that will result in the target sound pattern (Byun & Hitchcock, 2011). As new biofeedback technology becomes increasingly available in the marketplace, researchers are working to determine the most effective technology or combination of technologies for treating challenging speech impairments, including residual errors.

Three of the most common biofeedback technologies are visual-acoustic biofeedback, ultrasound biofeedback, and electropalatographic biofeedback (Hitchcock et al., 2017). Visual-acoustic biofeedback entails the client viewing a computer-generated sound representation of his or her verbal production. Ultrasound biofeedback utilizes an ultrasound probe to produce a real-time image of the client's tongue movements while he or she is speaking. Electropalatographic biofeedback uses an artificial palate with electrodes to display the client’s tongue contact patterns at the palate while producing sounds (Hitchcock et al., 2017). Research evidence supports the use of all three technologies for effective intervention in treating some forms of a speech sound error, but it is yet to be determined which technique is the most effective for treating specific target sounds, such as errors in /ɹ/ production (Hitchcock et al., 2017).

Electropalatography

Electropalatography (EPG) is a computer-based technology that visually shows the tongue’s contact with the hard palate during speech (Wood et al., 2009). EPG is a relatively new technology that has only been used for the treatment of speech disorders in a few specific cases. This technology is a relatively noninvasive modality in which the client wears an electrode-filled artificial palate which is custom fit to the roof of their mouth (Wood et al., 2009). With forty to sixty electrodes, the artificial palate records the timing and location of the tongue when it contacts the hard palate in continuous speech (Nordberg et al., 2011). The electrodes in the artificial palate are activated when the client’s tongue contacts them, and the EPG system records electrode activation at a speed of 10 milliseconds (Wood et al., 2009). A client’s articulation pattern for a phoneme is then compared to a model template of the correct pattern or can be compared to the pattern of a clinician’s production (Hitchcock et al., 2017).

Existing studies have investigated the use of EPG for treatment of speech disorders across different clinical populations. EPG has been found to be effective in the treatment of speech disorders due to cerebral palsy (Nordberg et al., 2011), Down syndrome (Wood et al., 2009), acquired apraxia of speech (Mauszycki et al., 2016), and hearing impairment (Bacsfalvi et al., 2007). The degree of success reported in existing studies supports the need to further investigation of the effectiveness of EPG in children with different types of speech sound errors.

Nordberg's, Carlsson's, and Lohmander's (2016) study on the use of EPG to treat speech disorders in five children with cerebral palsy resulted in a significant improvement in articulatory contact patterns. All five children presented with posteriorly placed articulation of the dental/alveolar target consonants /t/, /d/, /n/, and /s/ (Nordberg et al., 2016). The center of gravity (COG) and alveolar total (AT) were calculated from EPG software data (Nordberg et al., 2016). At the conclusion of the study, COG values were significantly higher in the initial and medial target /t/ and in all final targets except /d/ and /n/ (Nordberg et al., 2016). AT levels were significantly higher for all initial targets, medial targets, and the final /t/ target (Nordberg et al., 2016). Nordberg, Carlsson, and Lohmander (2016) concluded that EPG was a valuable tool for the visualization of articulation patterns in children with cerebral palsy and articulation disorders in that it facilitated positive clinical outcomes.

Wood et al.'s (2009) study on the use of EPG to treat speech disorders in two children with down syndrome resulted in both children making progress in correct sound placement. In this study, treatment was delivered twice a week over a 12-week period. The first child in the study was able to achieve correct lingual palatal placement for /s/ at the word and sentence level with and without EPG feedback. The second child in the study was able to achieve correct lingual palatal placement for both /k/ and /g/ in words and in connected speech. At the conclusion of this study the authors suggested that EPG represented a novel and effective approach for residual speech errors in children with Down syndrome" (Wood et al., 2009).

Mauszychi et al.'s (2016) study on the use of EPG to treat speech sound errors in four individuals with acquired apraxia of speech resulted in improvements in articulatory accuracy for all four participants. Three out of the four participants demonstrated positive acquisition effects and generalization effects for all the target speech sounds treated. All participants demonstrated positive acquisition effects with the majority of the speech sounds treated and two out of the four maintained high percentages of articulatory accuracy for target speech sounds. The authors concluded that EPG represented a promising modality for improving articulation accuracy in speakers with apraxia or speech (Mauszychi et al., 2016)

Bacsfalvi's, Bernhardt's, & Gick's (2007) study on the use of electropalatography to treat vowel errors in adolescents with hearing impairment resulted in notable changes observed in three adolescents. This study included a six-week intervention period using EPG and ultrasound as complementary biofeedback techniques. Eight out of 15 vowel targets showed improvement. to the authors conclude that the ability to visualize changes in the oral cavity during sound production leads to greater awareness of vowel space and how the tongue must move throughout that space for accurate productions (Bacsfalvi et al., 2007).

Smart Palate

Smart Palate (Complete Speech, Orem, UT) is an EPG system that contains three different parts: a customized artificial palate with forty-two sensors, a microprocessor that synchronizes the palate contact data and audio signal, and software that displays the real-time palatal contact patterns (Fabus et al., 2015). One study which investigated the utilization of the Smart Palate system for articulation disorders in three children reported positive outcomes in two children when the EPG was used concurrently with (Fabus et al., 2015). The third child, who had /ɹ/ misarticulations, regressed in correct /ɹ/ production at the conversational speech level but improved in correct /ɹ/ production at the sentence level.

The limited research available on the effectiveness of EPG in correcting specific speech sound errors warrants further investigation. For school-aged children with residual /ɹ/ errors who plateau in therapy, EPG may be an effective next option. The purpose of this study was to investigate efficacy of EPG treatment in school-age children with residual /ɹ/ errors. The specific research question asked: will EPG using the Smart Palate system improve residual /ɹ/ errors in school-aged children who have plateaued in previous treatment which used traditional articulation therapy and ultrasound techniques?

Methods

Participants

To be eligible for the study, it was required for participants to be native English speakers with residual rhotic (/ɹ/) errors. Participants were diagnosed with rhotic errors through the Secord Contextual Articulation Test (S-CAT) and an informal speech sample collected by the researcher prior to inclusion, and acquisition of baseline data (S-CAT; Secord & Shine, 1997). To be included, participants were required to score below the normal range on the S-CAT. Also, participants had to exhibit 20% or lower correct rhotic productions in a 50-utterance speech sample. Participants were required to score within the normal range on a language assessment and cognitive assessment to be eligible for this study. Finally, participants were recruited who did not make improvements in previous articulation treatment which used traditional and ultrasound approaches.

Recruited participants included three males and one female between the ages of eight and ten. Prior to the start of this study, each participant's parents completed an informational background form (Appendix A). Based on the reported data, all four participants came from dual income households and six out of the eight participant's parents earned a master's degree or higher education level. All participants were from the suburbs of the Dallas – Fort Worth Metroplex and were attending elementary schools in the area. Other than residual rhotic errors, participants were typically developing and did not present with any other speech and/or language deficits nor any cognitive delays. Before baseline data was acquired, the Clinical Evaluation of

Language Fundamental (CELF-5) and the Test of Nonverbal Intelligence (TONI-4) were completed to confirm developmentally appropriate language skills and nonverbal intelligence (CELF-5; Wiig, Semel, & Secord, 2013; TONI-4; Brown, Sherbenou, & Johnson, 2010).

The four participants all received previous traditional articulation therapy services targeting rhotic errors in the TCU Miller Speech and Hearing Clinic at a frequency of twice per week. Also, all participants completed at least one semester of subsequent articulation therapy utilizing visual biofeedback via ultrasound technology at the same clinic. Previous articulation therapy utilizing traditional and ultrasound techniques was administered twice a week for 30 minutes each session, over an eight-week consecutive period.

Settings

All baseline and intervention sessions took place in the TCU Miller Speech and Hearing Clinic on the campus of TCU. During sessions only the participant, researcher, and interobserver / supervisor were present in the room. A one-way observation mirror allowed parents in an external observation hallway to watch and listen to each session. A laptop with the Smart Palate software was located in the middle of a table in the room, and a computer was set up in the corner to record each participant's visual palate map and acoustic rhotic productions throughout each session. Each participant sat at the end of the table, directly facing the laptop. The researcher was directly to the right of the participant, and the interobserver / supervisor was directly to the left of the participant. Each individual in the room had an equal view of the laptop and Smart Palate image.

Materials

Materials included a HP EliteBook 850 lap top with the Smart Palate software and the Smart Palate electrode retainers. All participants had an individual Smart Palate electrode retainer, which connected to the computer via a cord. A 13-inch MacBook Pro Touch ID 2.3GHz Quad-Core Processor 256GB Storage laptop camera was used to record all baseline and intervention sessions. Three printed probe lists and data sheets were used to collect and record data the same way each session.

Response Definitions and Measurement System

All participants started the first baseline session and traditional articulation therapy session on the same day. For the first participant, baseline sessions were held on consecutive weekdays for 30-minutes each. For the second, third, and fourth participants 30-minute baseline sessions were held biweekly with three consecutive weekday sessions conducted before intervention sessions started. All participants attended biweekly 30-minute intervention sessions. Data from probes was acquired at the end of every session.

The percent of /ɹ/ phonemes correctly produced at the word level was measured using three different probe lists. One list contained initial /ɹ/ words, another one contained final /ɹ/ words, and the third one contained initial /ɹ/ cluster words. The three lists had equally challenging words containing the /ɹ/ phoneme in the initial, final, and initial cluster position of words.

All words were chosen from the book, *40,000 Selected Words* (Blockcolsky, Frazer, & Frazer, 1987).

Table 1: Trained and Untrained words chosen:

/ɹ/ Position		Trained or Untrained
Initial	radio, roof, rusty, red, reaping, rake, racoon, rice, rapid, rose	Trained
Initial	room, rowing, rain, ribbon, rhyming, rock, rug, rhino, wrap, resting	Untrained
Initial Cluster	bread, frog, practice, dragon, trash, cry, trick, graphic, bridge, vroom	Trained
Initial Cluster	freedom, three, grass, drum, frame, bragging, truck, crib, straw, breed	Untrained
Final	midair, ajar, mother, feather, vampire, guitar, car, appear, pear, hammer	Trained
Final	encore, bear, zipper, four, kicker, fire, hair, doctor, attire, tiger	Untrained

All word stimuli were chosen randomly using the RANDBETWEEN function in excel. This formula was used three times to select the initial /ɹ/, final /ɹ/, and initial /ɹ/ cluster word lists. After the initial /ɹ/, final /ɹ/, and initial /ɹ/ cluster word lists were randomly selected, the

RANDBETWEEN function was used again to randomly select words for the trained and untrained probe lists and to determine the four probe lists (Appendix E, F, G, and H) used at the end of each treatment session. In addition, the RANDBETWEEN formula was used to pick which randomized probe list (Appendix E, F, G, and H) was given at the end of each treatment session.

Word stimuli were counted as correct when the participant used the /ɹ/ phoneme in the correct position of the word, both the researcher and interobserver perceived a correct production, and the participant scored higher than an 80% on the Smart Palate software tongue contact to palate electrode accuracy measure. For example, if the child produced the word "ride" with the /ɹ/ correctly produced in the initial position and 87% accuracy on the electrode accuracy measure, then "ride" was counted correct on the data sheet. When another phoneme was used in place of the /ɹ/ phoneme, the word was counted wrong. For example, if the word on the list was "run" and the child said "wun" then the word was counted wrong. When a phoneme other than the targeted /ɹ/ phoneme was produced incorrectly, the word was still counted right as long as the /ɹ/ phoneme was produced correctly. For example, if the word was "rabbit" and the child said "rabbi" then rabbit would still be right because the initial /ɹ/ phoneme was correct. However, if the child said "wabbi" for rabbit then rabbit would be counted wrong because the initial /ɹ/ phoneme production was errored.

A simple word chart data sheet was used to record /ɹ/ productions at the word level every baseline session (Appendix B, C, and D). The first column of the chart contained each word of either the untrained or trained probe list. The second column listed the position (initial, final, or initial cluster) of the /ɹ/ phoneme in each probe word. The third column, each word was either given a score of one for the correct production of the /ɹ/ phoneme in the targeted word or a score of zero for an incorrect production of the /ɹ/ phoneme in the targeted word. Scores were based off of the criteria listed in the previous paragraph. The same data sheet was printed and used to record the data collected from each baseline session. Data was collected on both the untrained and trained probe list of words during the last five minutes of every baseline session.

A second simple-chart was used to record the percent of correctly produced /ɹ/ phonemes each intervention session (Appendix E, F, G, and H). The total number of correctly produced /ɹ/ words was recorded for both the untrained and trained probe lists. This number was divided by ten (the total number of opportunities to correctly produce /ɹ/ words) to compute the percent of correctly produced /ɹ/ phonemes in each probe list. In addition, the total number of correctly produced trained and untrained /ɹ/ were combined and divided by 20 (the total number of opportunities to correctly produce trained and untrained /ɹ/ words) to compute the percent of correctly produced /ɹ/ phonemes in each probe list. These percentages were how progress was monitored throughout baselines and intervention.

Observers were trained by the researcher prior to baselines starting. Observers attended 1-hour biweekly sessions for two weeks at the TCU Miller Speech and Hearing Clinic. Training sessions were held in clinic room #141 with the lap top and Smart Palate software, Smart Palate device, probe lists, and data sheets. During the first week, sessions focused on the Smart Palate software and the palate pattern for the /ɹ/ sound. During the second week, sessions focused on the scoring procedure. Observers were taught how a child's response earned one point based on the criteria explained above. After the procedures were explained, the researcher tested the observers by reading through the probe lists and pronouncing some of the words correctly and some of them incorrectly. This procedure was repeated until observers achieved 90% accuracy on scoring the /ɹ/ words produced by the researcher.

Interobserver Agreement Procedures

Interobserver agreement data collection occurred at every baseline and intervention session. The observer was either present in the session, observed the session from the observation hallway, or watched the session recording after it occurred. Reliability was calculated via interobserver point by point agreement. The researcher's data was directly compared to the interobserver's data on a single-probe word basis. For example, if the first word on the probe list was "race" and both the researcher and the interobserver gave the child a one for his or her /ɹ/ production then the researcher and interobserver agreed. However, if the researcher gave the child a one for his or her first /ɹ/ word production but the interobserver gave the child a zero, then the researcher and interobserver disagreed. The total interobserver agreement percent was calculated by taking the total number of agreements divided by the total number of disagreements plus agreements, times one-hundred (Watkins & Pacheco, 2001). Formula:

Total interobserver agreement percentage =

agreements/disagreements + agreements x 100

Experimental Design

The data collected in this study was obtained and recorded through a multiple probe single-subject design (Kratochwill et al., 2013). A multiple probe design was used because /ɹ/ production was a learned behavior and baseline data was collected intermittently, but intervention data was collected consistently. The four probe word lists were established by the researcher prior to the start of this study.

Repeated measurements were taken during the baseline phase to control for maturation and instrumentation. Also, consistent performance on baseline measures were obtained from each participant before intervention started. All treatment sessions followed the same protocol to monitor procedural infidelity. To account for an equal selection of participants, each study participant was recruited from the TCU Miller Speech and Hearing Clinic clientele and had participated in traditional and ultrasound therapy prior to this study. Participant one missed four sessions (2 weeks) due to a family vacation in the middle of the intervention period. This participant was still able to complete all sessions required to complete the study. All four participants completed the study.

Experimental Conditions and Procedures

The researcher started every baseline session with 25 minutes of traditional articulation therapy. Only the /ɹ/ phoneme was addressed, and no biofeedback technology was used. Word stimuli in traditional articulation therapy sessions were not on any of the four probe lists. During the last five minutes, the researcher administered the three probe lists. The researcher and interobserver both took data when probes were administered.

All participants received eight weeks of articulation treatment using EPG lead by the researcher. Treatment sessions focused on their production of the /ɹ/ phoneme. The first treatment session for each participant was dedicated to informing participants about EPG and participant adjustment to the SmartPalate device. The next 15 treatment sessions followed the same protocol. Each session started with five minutes of the oral coordination module. The oral coordination module was an exercise on the SmartPalate software that required the participant to use his or her tongue to touch certain parts of their palate based on where the sensors lit up on the computer screen. This exercise helped participants acclimate to wearing the SmartPalate device and to develop a visual and sensory representation of their tongue to palate connection. The next 20 minutes of the session targeted tongue to palate connection when the client produced /ɹ/. The /ɹ/ phoneme was elicited and practiced in multiple contexts during session. It was either produced in isolation or in the initial, initial cluster, medial, or final position of words. Words from the trained probe list were used as stimuli during intervention sessions. However, words from the untrained probe lists were not used in intervention sessions. During the last five minutes, the randomly chosen probe list was administered by the researcher. Both the researcher and interobserver took data on the participant's performance on each probe list.

Procedural Fidelity Data Collection

All participants received eight weeks or 16 sessions of electropalatography treatment for their rhotic errors. The same intervention session protocol was used for every session across all four participants. Also, the same four probe word lists were used for all of the participants and were always administered at the end of a session. The researcher provided all therapy in the baseline and intervention sessions. The same interobservers monitored and took data on all sessions. All sessions were held in the same therapy room in the TCU Miller Speech and Hearing Clinic.

The number of baseline / traditional articulation therapy sessions each participant received differed because of the staggered start dates for the intervention. Participant one received eight baseline sessions before starting electropalatography treatment. Participant two received three baseline sessions before starting treatment. Participant three received 11 baseline sessions before starting treatment and participant four received five baseline sessions before starting treatment. Also, the specific words used to practice correct production of the /ɹ/ phoneme varied amongst the participants. Word production variation was due to each individual participant's motivation and interests. Participant performance on probes at the end of each baseline and intervention session varied between all four participants.

Probe data was collected intermittently during baselines and consistently during the intervention period. Data was obtained the last five minutes of a session. One probe list was randomly assigned to each session using the randomization formula on Microsoft Excel. The researcher read one word at a time on the probe list and then the participant repeated the word while wearing the electropalatography device. Both the researcher and interobserver took data using the same data collection forms (Appendix B, C, D, and E). The researcher's and interobserver's data were compared after every collection. The interobserver point by point agreement equation was used to determine reliability.

Procedural fidelity was assessed at every intervention session. Procedure fidelity was monitored with direct observation and informal self-report (Barnett et al., 2013). The interobserver assessed the researcher based on the intervention procedure protocol checklist (Appendix I). The researcher also used the intervention procedure protocol checklist to informally assess her procedural fidelity. The researcher and interobserver calculated procedural fidelity by taking the total number of agreements divided by the total number of disagreements plus agreements, times one-hundred (Watkins & Pacheco, 2001). Formula:

Total procedural fidelity agreement percentage =

agreements/disagreements + agreements x 100

Analyses

Data was collected for three consecutive baseline sessions leading up to the first intervention session. The researcher administered and collected data on the selected probe list during the last five minutes of every intervention session. Data collection was stopped after the participant reached the sixteenth intervention session. When interobserver agreement data was not at an acceptable level, the interobserver and researcher re-visited the scoring protocol and then the researcher tested the observer by reading through the probe lists and pronouncing some of the words correctly and some of them incorrectly. This procedure was repeated until the observer achieved 90% accuracy on scoring the /ɹ/ words produced by the researcher. When procedural fidelity data was not at an acceptable level, the researcher and observer reviewed the intervention procedural protocol and the researcher practiced the protocol with the observer until 90% accuracy was achieved. Experimental conditions were changed when a participant decreased in progress during the intervention period. The SmartPalate software, client behavior, and procedural protocol was re-evaluated to determine if a change needed to be made.

Data was presented in a line graph with percent of correctly produced /ɹ/ words on the y-axis and time on the x-axis. Three-line graphs were created for each participant. The green line graph represented each participant's data for total percent correct. The purple line graph represented each participant's data for percent correct for trained words. The blue line graph represented each participant's data for percent correct for untrained words. Each participant had a different number of baseline data points, but all participants had 16 intervention session data points. A functional relation was determined by calculating the percentage of non-overlapping data between the baseline and intervention sessions. All percentages needed to exceed the 70% non-overlap data threshold in order for a functional relationship to be present.

Cohen's D statistic was used to determine the effect of the electropalatography treatment (Becker, 2000). Cohen's D was calculated for each participant's first three probes and last three probes to determine the effect size that 16 electropalatography treatment sessions had on each participant's /ɹ/ production. In addition, Cohen's D was calculated between each participant's first three probes and post-treatment probe to determine the effect size that 16 electropalatography treatment sessions had on each participant's /ɹ/ production three months after treatment ended. Cohen determined that d=0.2 is considered a small effect size, d=0.5 is considered a medium effect size and d=0.8 is considered a large effect size. Therefore, if two groups' means don't differ by at least 0.2, then the difference between the groups is not practically significant. Formula:

Mean 1 – Mean 2 / S pooled

Results

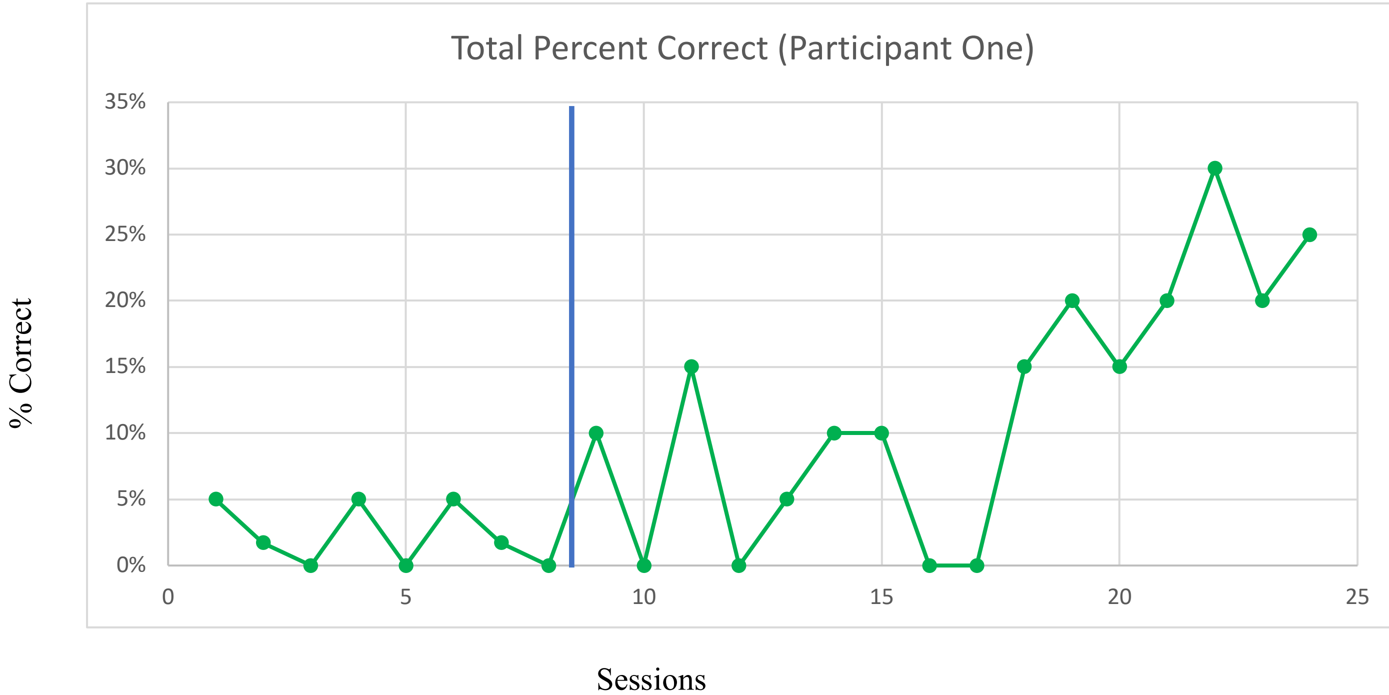
Table 2 displays the number of total (trained and untrained) correct productions for each participant on each probe list administered. The three consecutive baseline probes had a maximum number correct of 60. The 16 intervention probes had a maximum number correct of 20 productions. The mean correct productions for the three consecutive baseline probes was 12.1 correct productions with a standard deviation of .76. The mean correct productions for the 16 intervention probes was 8.36 correct productions with a standard deviation of 1.83.

Table 2: Total Productions Correct (Trained and Untrained)

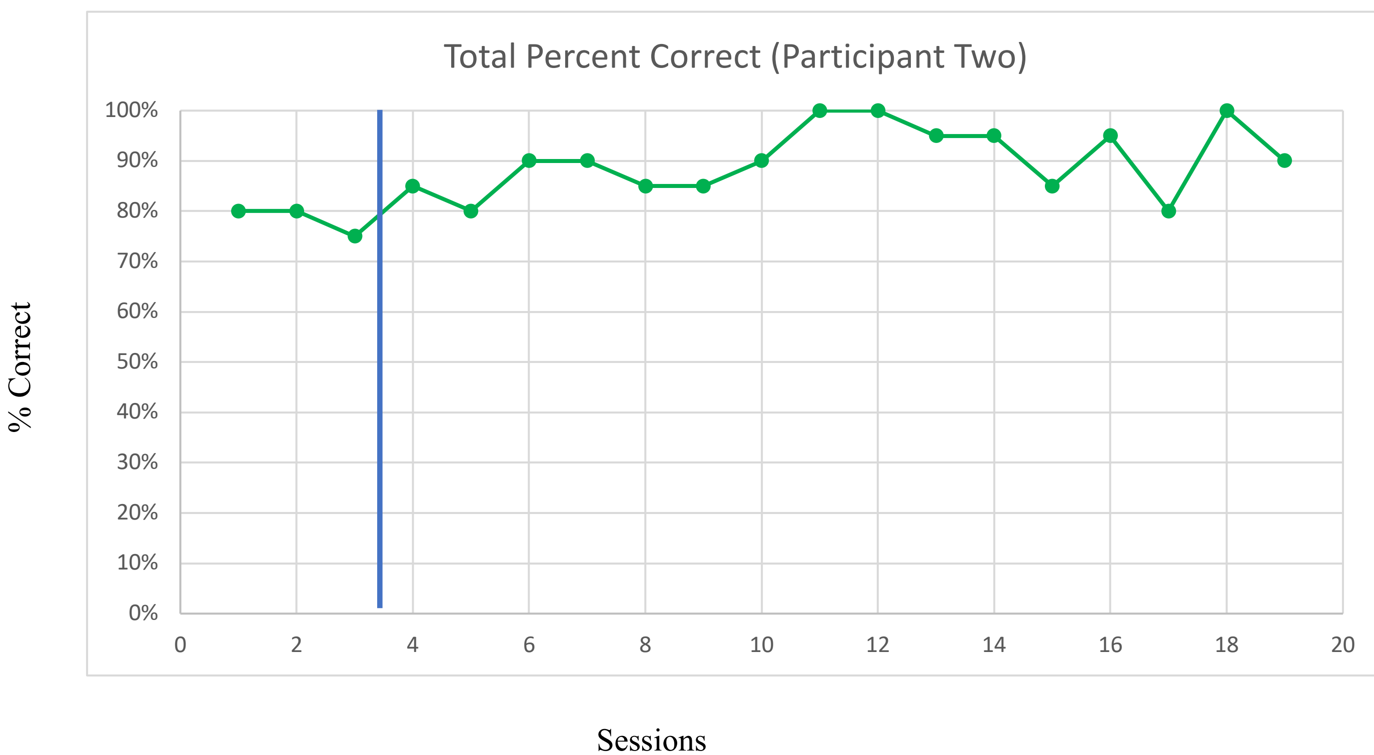
Probe #	Participant One	Participant Two	Participant Three	Participant Four	Probe Average
1	3	48	0	0	12.75
2	1	48	0	0	12.25
3	0	45	0	0	11.25
1	2	17	4	0	5.75
2	0	16	8	0	6
3	3	18	5	0	6.5
4	0	18	5	4	6.75
5	1	17	6	12	9
6	2	17	5	0	6
7	2	18	8	0	7
8	0	20	13	0	8.25
9	0	20	14	1	8.75
10	3	19	14	2	9.5
11	4	19	14	2	9.75
12	3	17	14	0	8.5
13	4	19	14	2	9.75
14	6	16	17	0	9.75
15	4	20	16	6	11.5
16	5	18	16	5	11

Graphs 1 through 4 represent the total percent correct of /ɹ/ productions across untrained and trained probe lists for each participant. Participant one averaged 2% correct /ɹ/ productions with a standard deviation of .03 on the eight baseline probes. On probes nine through 24, participant one averaged 12% correct /ɹ/ productions with a standard deviation of .09. Participant two averaged 78% correct /ɹ/ productions with a standard deviation of -0.03 on the three baseline probes. On probes four through 19, participant two averaged 90% correct /ɹ/ productions with a standard deviation of .07. Participant three averaged 5% correct /ɹ/ productions with a standard deviation of .08 on the 11 baselines probes. On probes 12 through 27, participant three averaged 54% correct /ɹ/ productions with a standard deviation of .24. Participant four averaged 0% correct /ɹ/ productions with a standard deviation of 0 on the five baseline probes. On probes six through 21, participant four averaged 9% correct /ɹ/ productions with a standard deviation of .16. Graph 5 displays the total percent correct /ɹ/ productions across untrained and trained word lists and across all four participants. The average percent correct across all four participants was 20% correct /ɹ/ productions for the three consecutive baseline probes with a standard deviation of .35. The average percent correct across all four participants was 41% correct /ɹ/ productions for the 16 intervention probes with a standard deviation of .37.

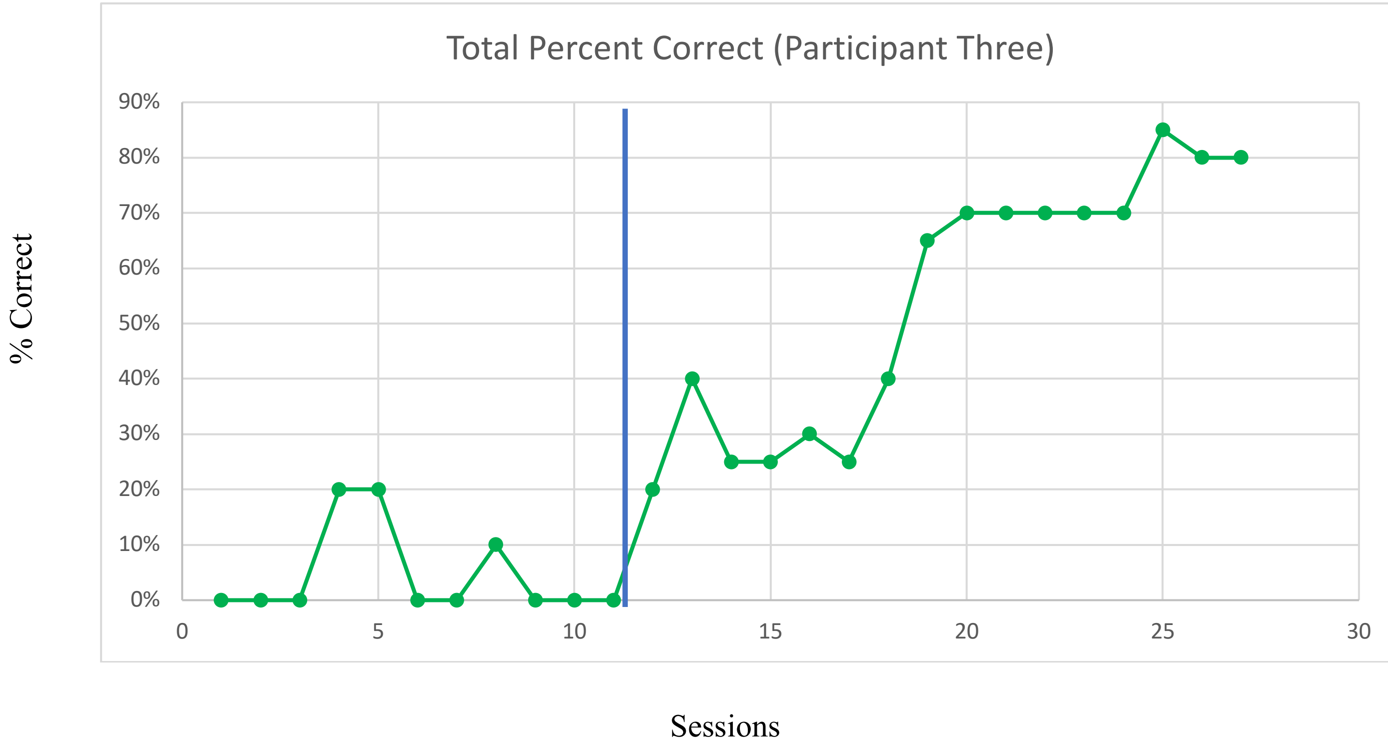
Graph 1: Total Percent Correct Participant One



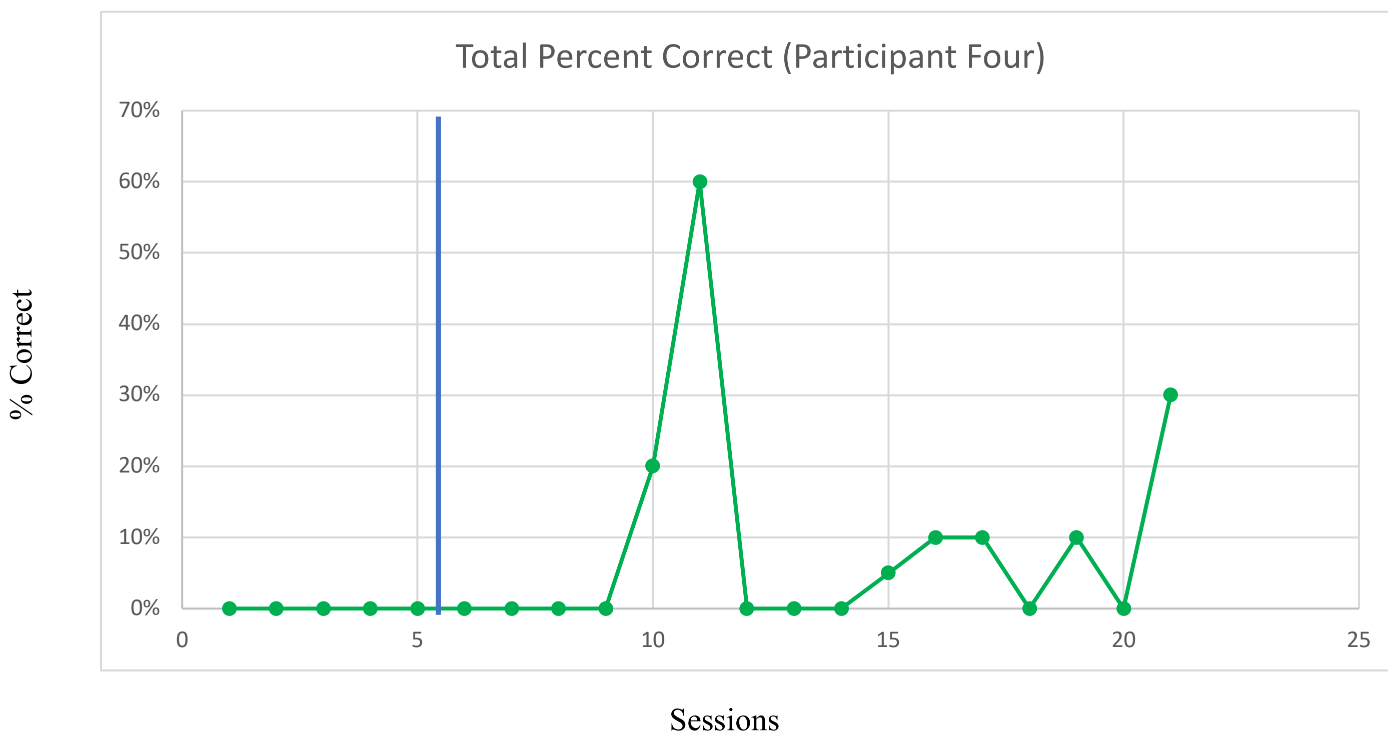
Graph 2: Total Percent Correct Participant Two



Graph 3: Total Percent Correct Participant Three

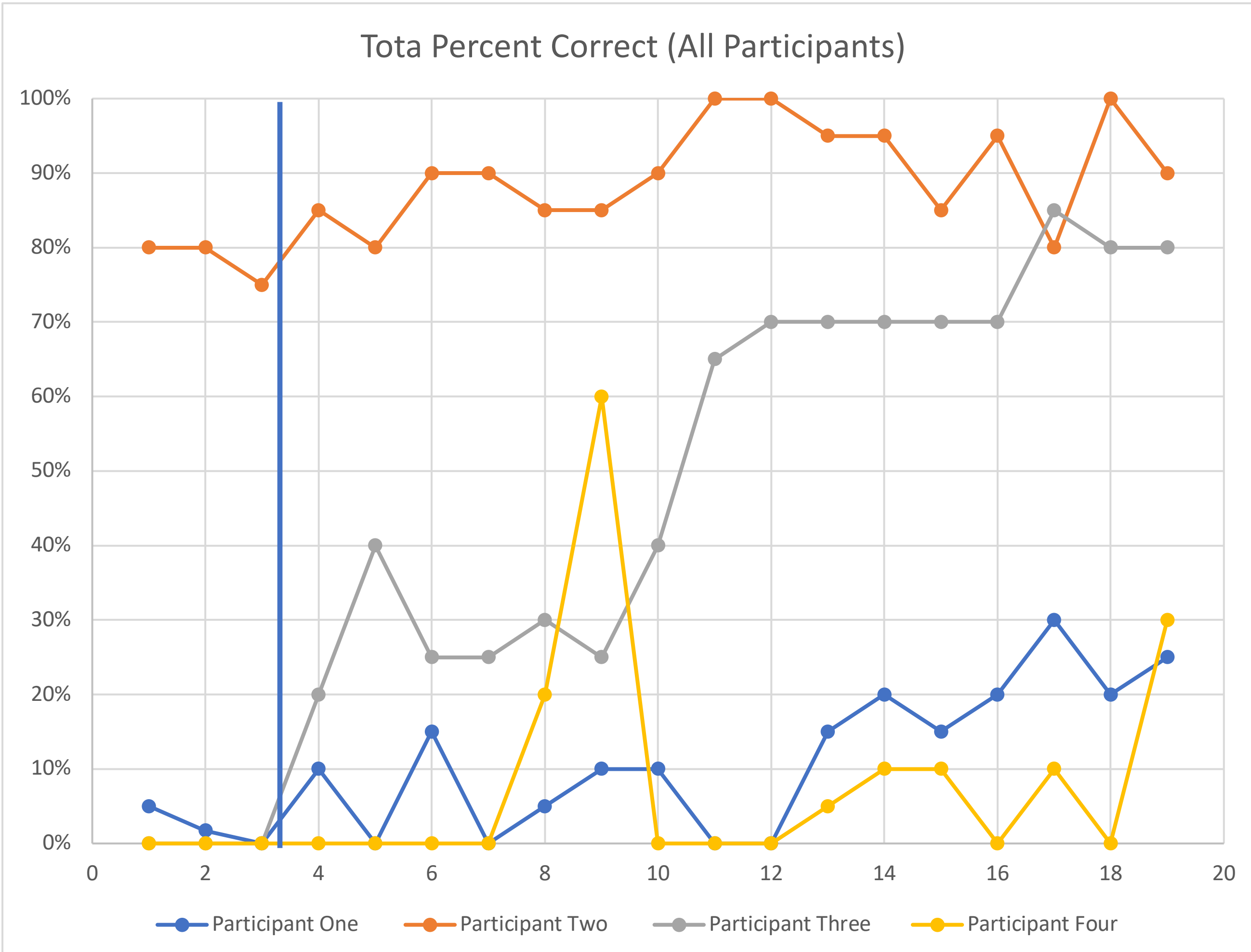


Graph 4: Total Percent Correct Participant Four



Graph 5: Total Percent Correct All Participants

% Correct



Sessions

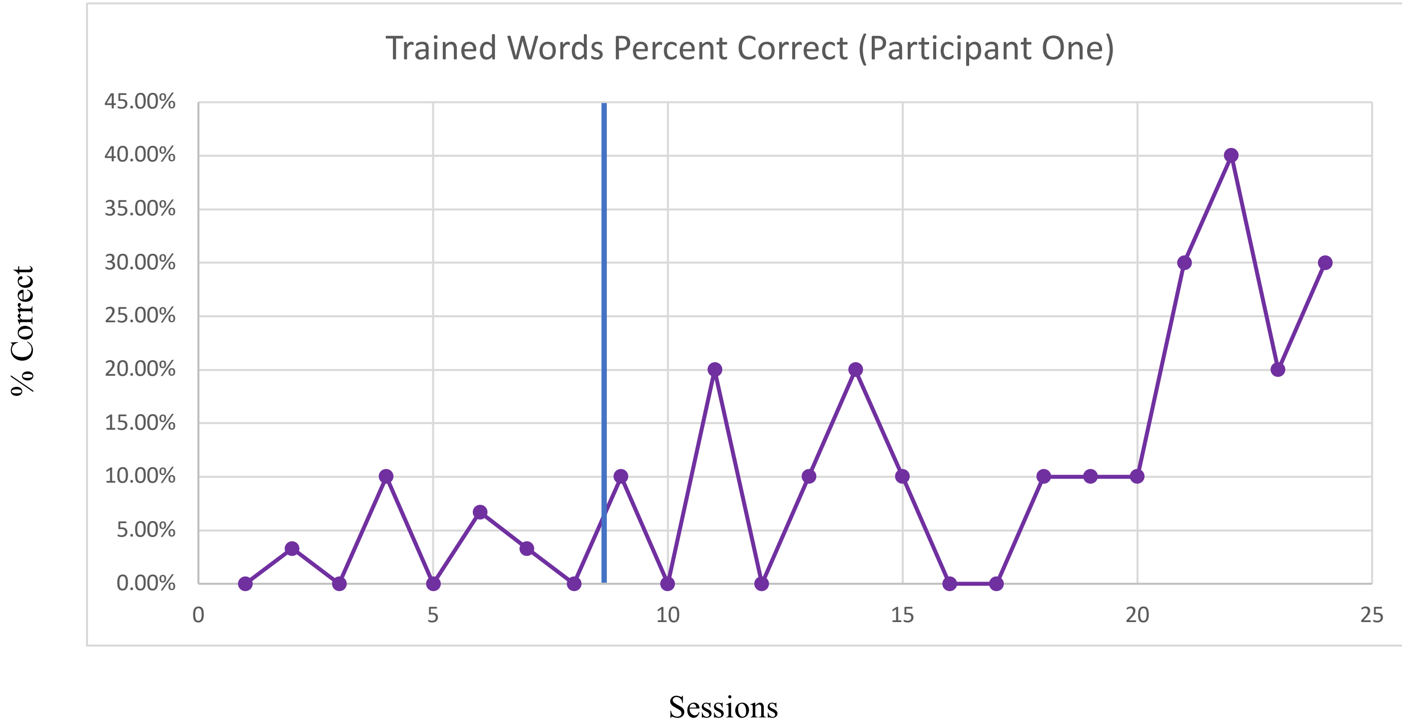
Table 3 displays the number of correct productions of trained words for each participant on each probe list administered. The three consecutive baseline probes had a maximum number correct of 60. The 16 intervention probes had a maximum number correct of 20 productions. The mean correct productions for the three consecutive baseline probes was 6.34 correct productions with a standard deviation of 10.43. The mean correct productions for the 16 intervention probes was 4.47 correct productions with a standard deviation of 1.15.

Table 3: Total Productions Correct (Trained Probe List)

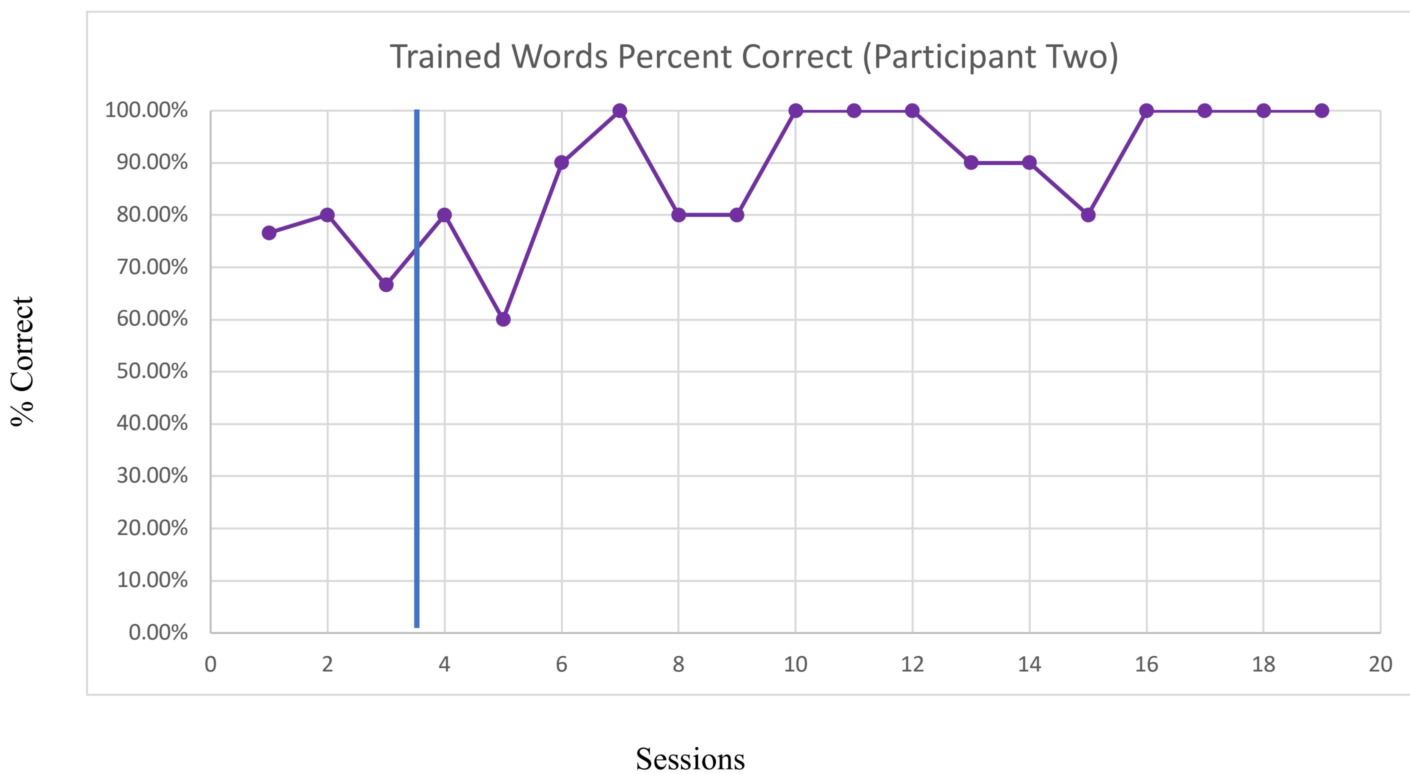
Probe #	RM	CA	KW	HH	Probe Average
1	2	23	0	0	6.25
2	1	24	0	0	6.25
3	0	26	0	0	6.5
1	1	8	2	0	2.75
2	0	6	5	0	2.75
3	2	9	3	0	3.5
4	0	10	2	0	3
5	1	8	4	2	4.25
6	2	8	3	5	4.5
7	1	10	3	0	4.25
8	0	10	9	0	4.75
9	0	10	7	0	4.25
10	1	9	7	1	4.5
11	1	9	7	2	4.75
12	1	8	7	2	4.5
13	3	10	8	0	5.25
14	4	10	8	2	6
15	2	10	10	0	5.5
16	3	10	10	5	7

Graphs 6 through 9 represent the total percent correct of /ɹ/ productions across trained probe lists for each participant. Participant one averaged 2.91% correct /ɹ/ productions with a standard deviation of .04 on the eight baseline probes. On probes nine through 24, participant one averaged 14% correct /ɹ/ productions with a standard deviation of .12. Participant two averaged 74.40% correct /ɹ/ productions with a standard deviation of 0.07 on the three baseline probes. On probes four through 19, participant two averaged 91% correct /ɹ/ productions with a standard deviation of .19. Participant three averaged 5% correct /ɹ/ productions with a standard deviation of .09 on the 11 baseline probes. On probes 12 through 27, participant three averaged 59% correct /ɹ/ productions with a standard deviation of .28. Participant four averaged 0% correct /ɹ/ productions with a standard deviation of 0 on the five baseline probes. On probes six through 21, participant four averaged 12% correct /ɹ/ productions with a standard deviation of .17. Graph 10 displays the total percent correct /ɹ/ productions across trained word lists and across all four participants. The average percent correct across all four participants was 19.39% correct /ɹ/ productions for the three consecutive baseline probes with a standard deviation of .33. The average percent correct across all four participants was 44% correct /ɹ/ productions for the 16 intervention probes with a standard deviation of .38.

Graph 6: Trained Words Percent Correct Participant One

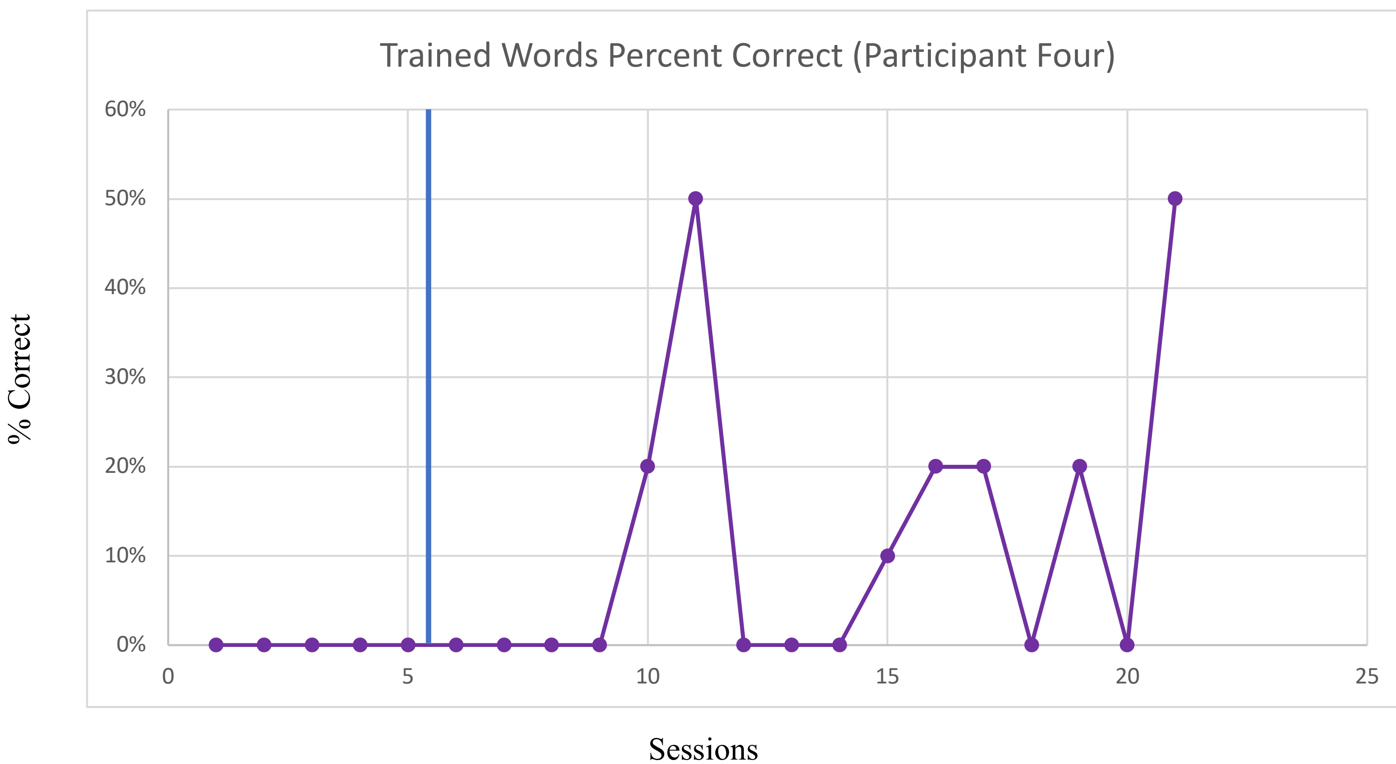


Graph 7: Trained Words Percent Correct Participant Two



Graph 8: Trained Words Percent Correct Participant Three

Graph 9: Trained Words Percent Correct Participant Four



Graph 10: Total Percent Correct All Participants (Trained)

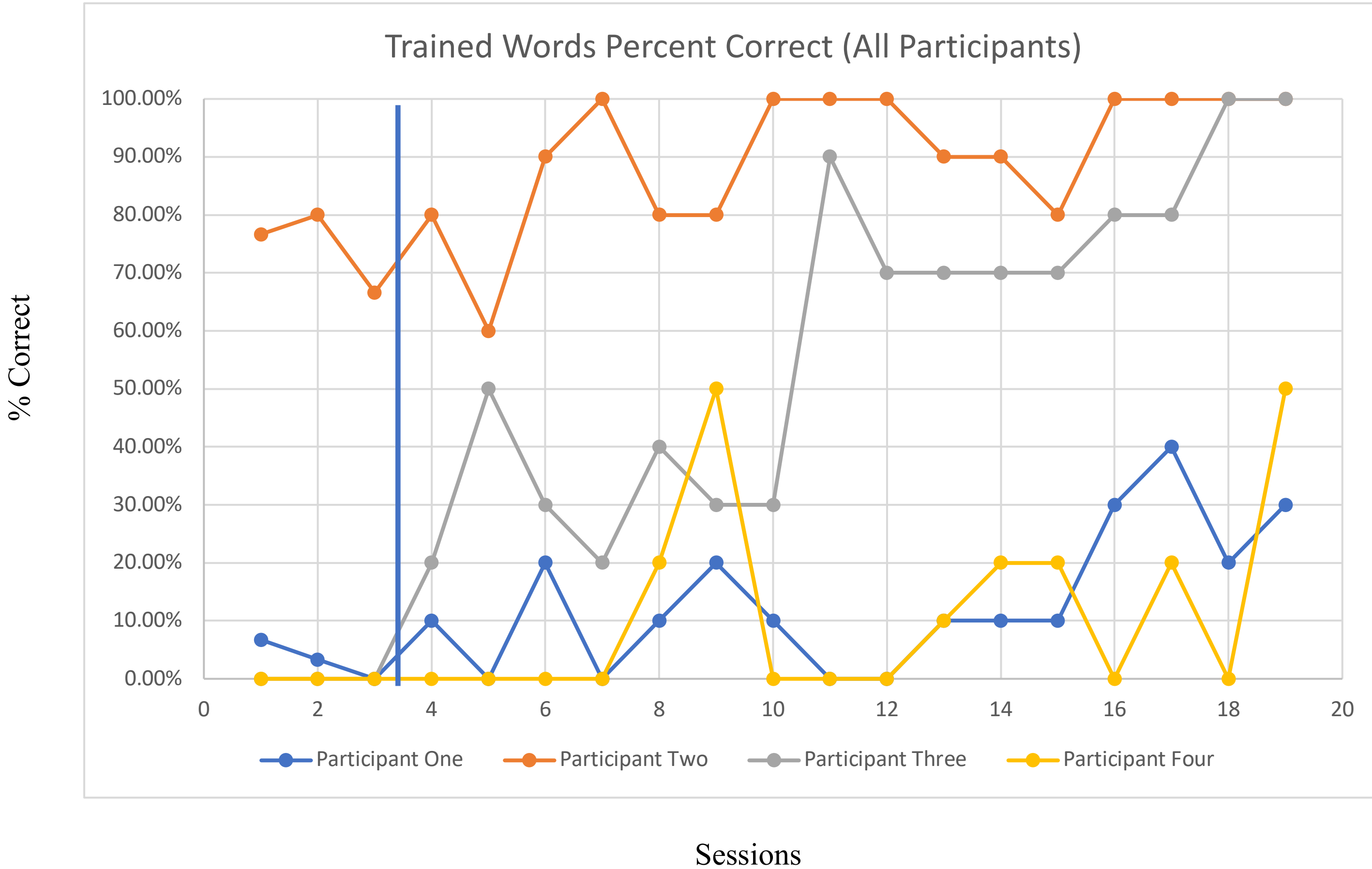


Table 4 displays the number of correct productions of untrained words for each participant on each probe list administered. The three consecutive baseline probes had a maximum number correct of 60. The 16 intervention probes had a maximum number correct of 20 productions. The mean correct productions for the three consecutive baseline probes was 5.75 correct productions with a standard deviation of 9.86. The mean correct productions for the 16 intervention probes was 4.06 correct productions with a standard deviation of .88.

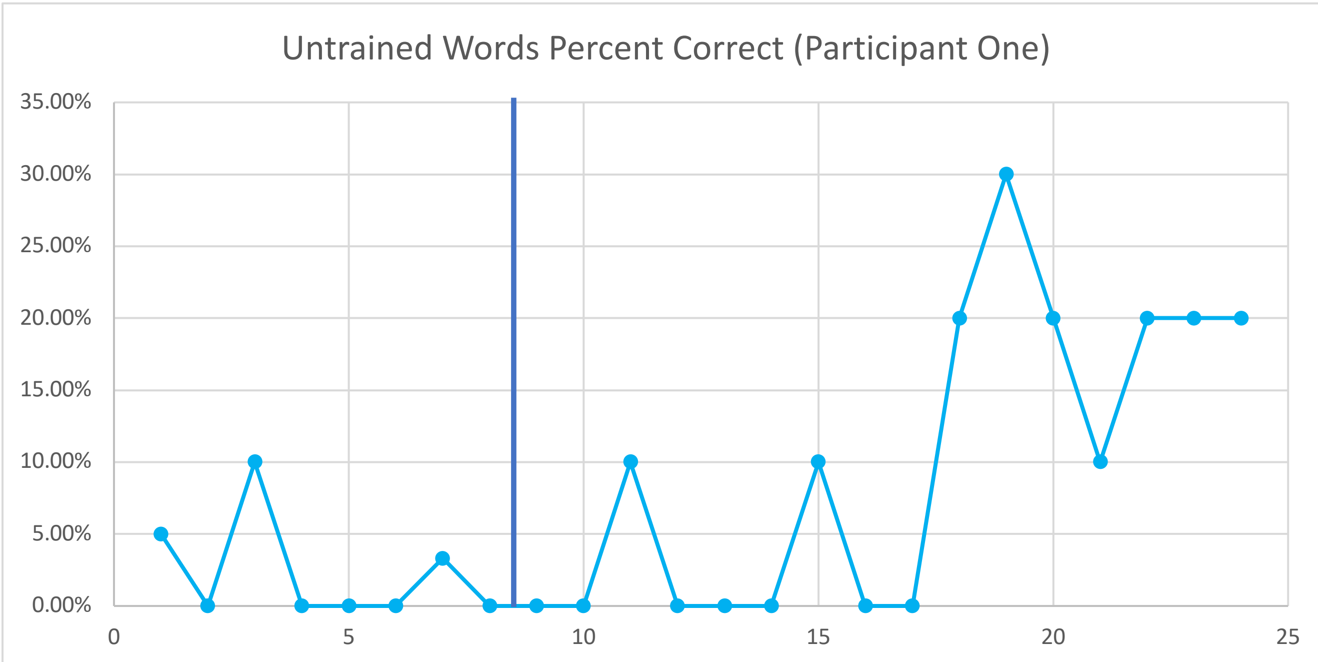
Table 4: Total Productions Correct (Untrained Probe List)

Probe #	RM	CA	KW	HH	Probe Average
1	1	25	0	0	6.5
2	0	24	0	0	6
3	0	19	0	0	4.75
4	1	9	2	0	3
5	0	10	3	0	3.25
6	1	9	2	0	3
7	0	8	3	0	2.75
8	0	9	2	2	3.25
9	0	9	2	7	6
10	1	8	5	0	4.67
11	0	10	4	0	3.5
12	0	10	7	0	4.25
13	2	10	7	0	4.75
14	3	10	7	0	5
15	2	9	7	0	4.5
16	1	9	6	0	4
17	2	6	9	0	4.25
18	2	10	6	0	4.5
19	2	8	6	1	4.25

Graphs 11 through 14 represent the percent correct of /ɹ/ productions across untrained probe lists for each participant. Participant one averaged 2.29% correct /ɹ/ productions with a standard deviation of .04 on the eight baseline probes. On probes nine through 24, participant one averaged 11% correct /ɹ/ productions with a standard deviation of .10. Participant two averaged 75.53% correct /ɹ/ productions with a standard deviation of 0.11 on the three baseline probes. On probes four through 19, participant two averaged 90% correct /ɹ/ productions with a standard deviation of .11. Participant three averaged 7% correct /ɹ/ productions with a standard deviation of .10 on the 11 baseline sessions. On probes 12 through 27, participant three averaged 49% correct /ɹ/ productions with a standard deviation of .23. Participant four averaged 0% correct /ɹ/ productions with a standard deviation of 0 on the five baseline probes. On probes six through 21, participant four averaged 6% correct /ɹ/ productions with a standard deviation of .18. Graph 15 displays the total percent correct /ɹ/ productions across untrained and trained word lists and across all four participants. The average percent correct across all four participants was 19.16% correct /ɹ/ productions for the three consecutive baseline probes with a standard deviation of .34. The average percent correct across all four participants was 39% correct /ɹ/ productions for the 16 intervention probes with a standard deviation of .37.

Graph 11: Untrained Words Percent Correct Participant One

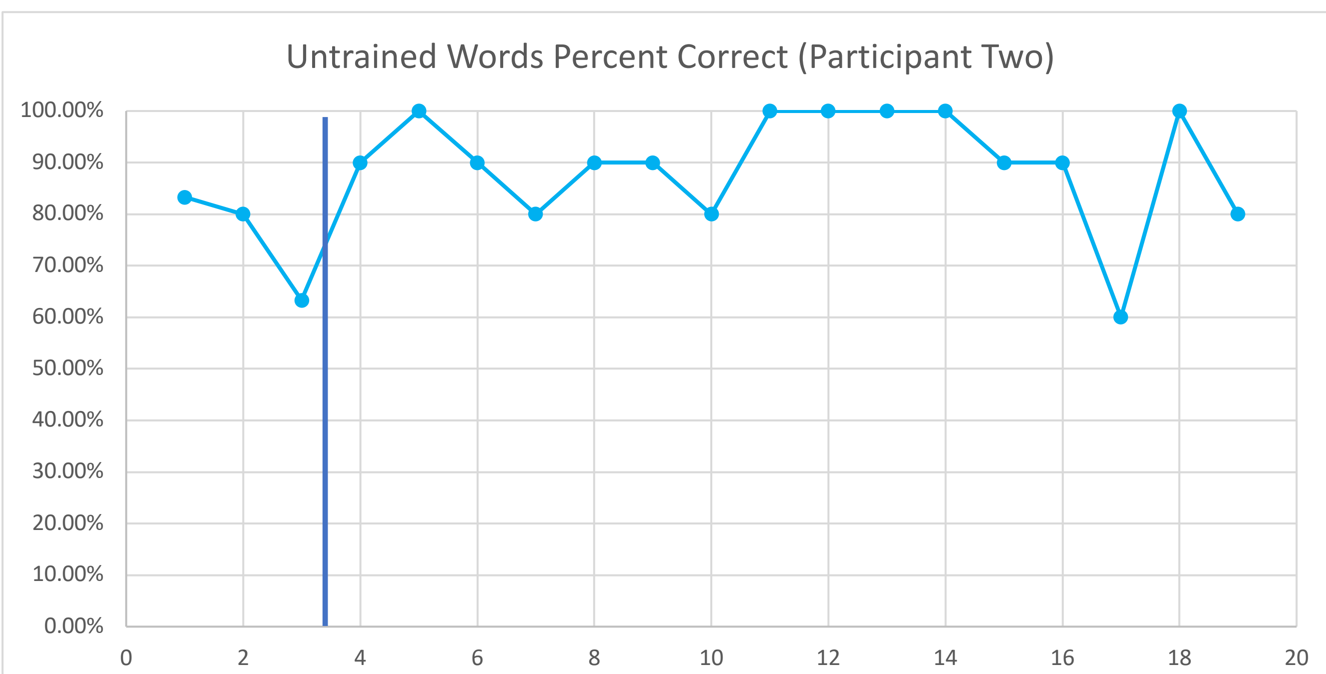
% Correct



Sessions

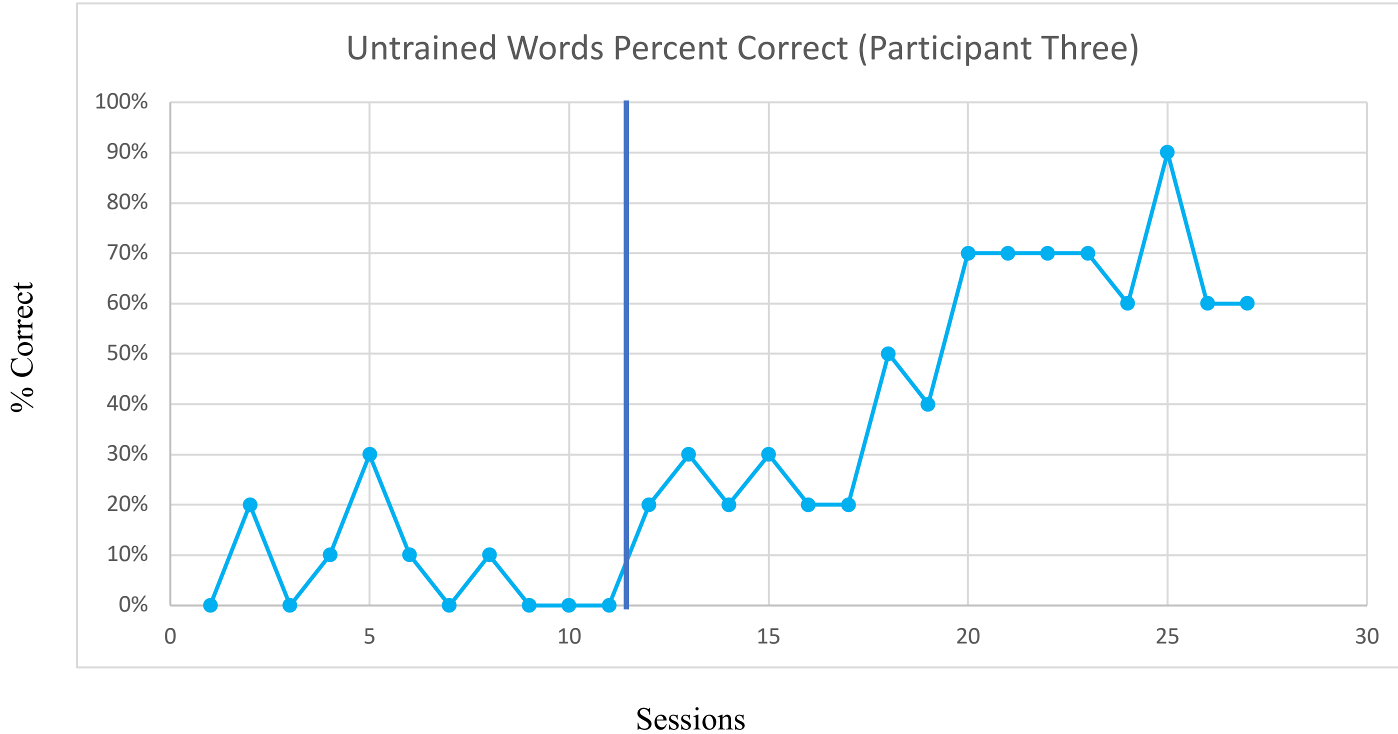
Graph 12: Untrained Words Percent Correct Participant Two

% Correct

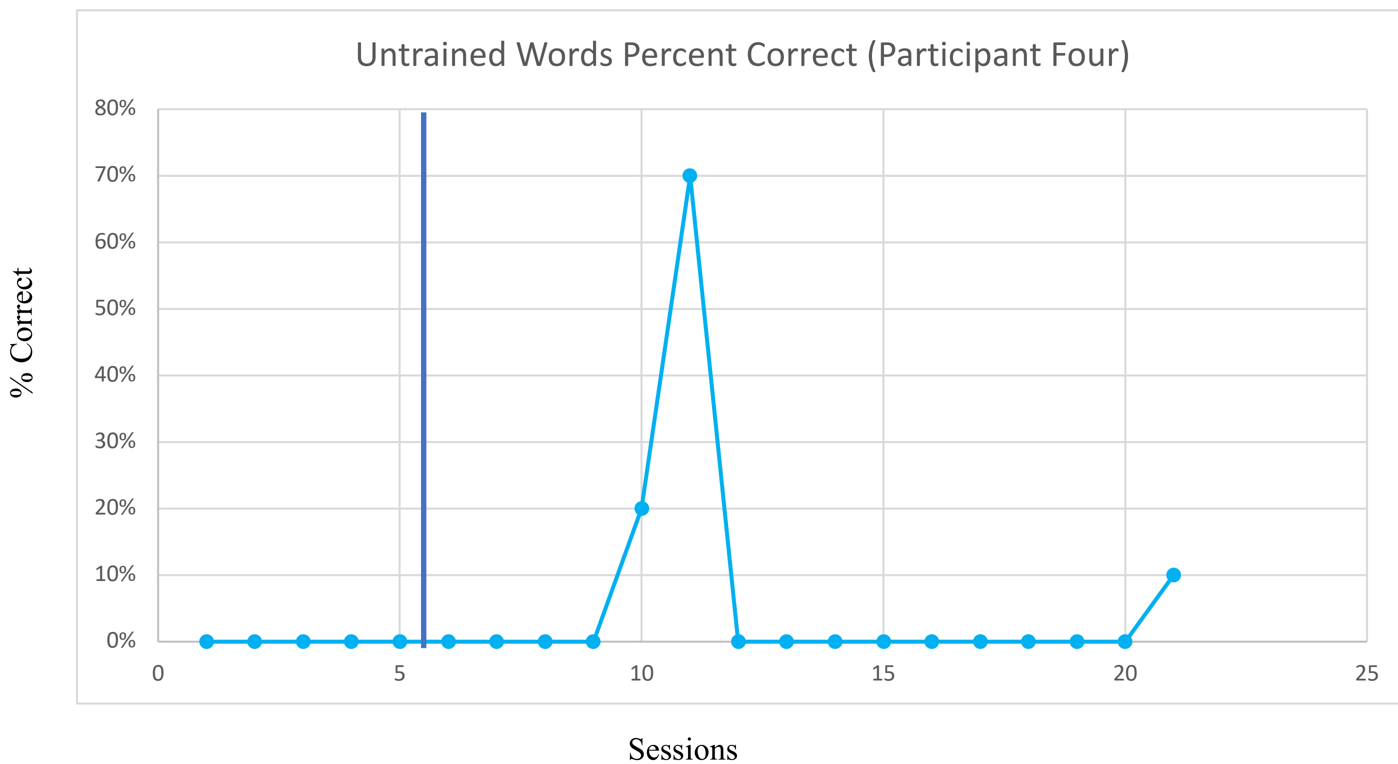


Sessions

Graph 13: Untrained Words Percent Correct Participant Three

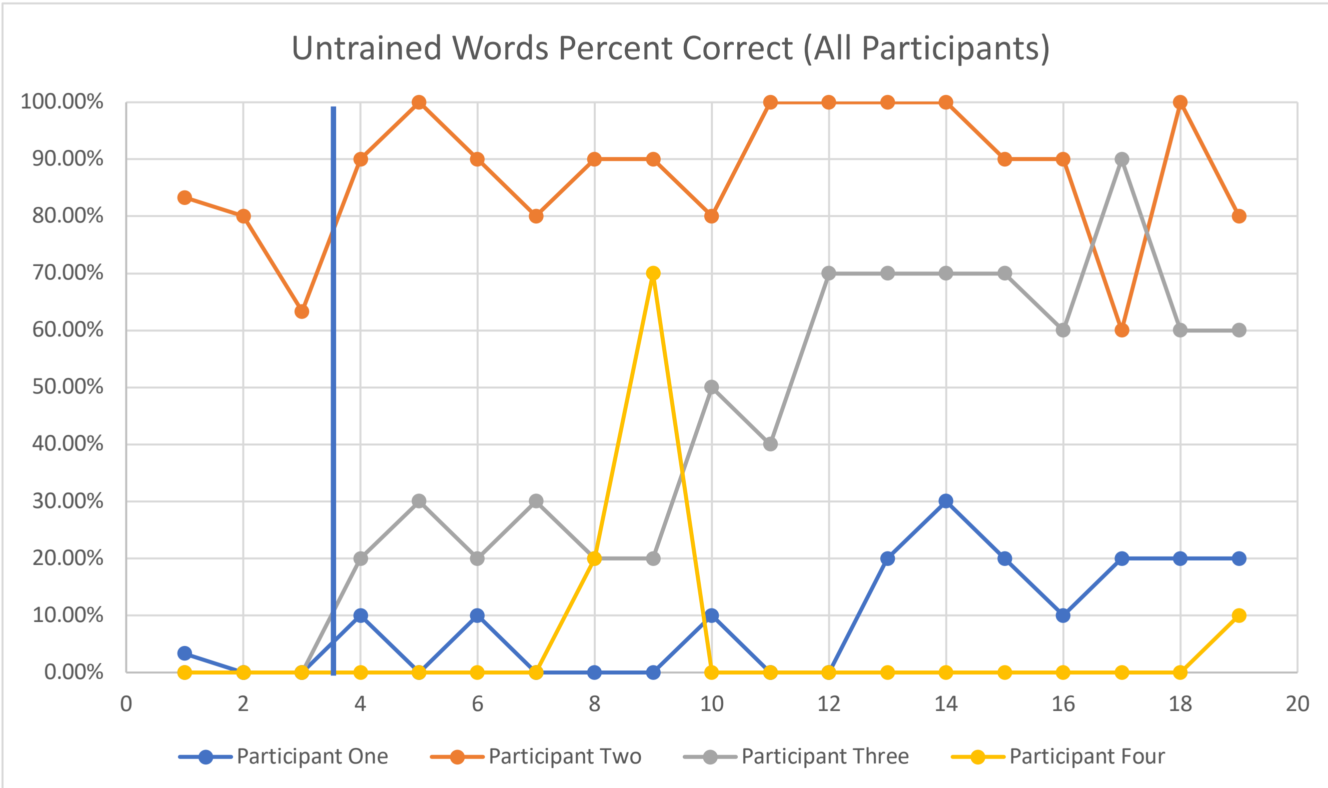


Graph 14: Untrained Words Percent Correct Participant Four



Graph 15: Total Percent Correct All Participants (Untrained)

% Correct



Sessions

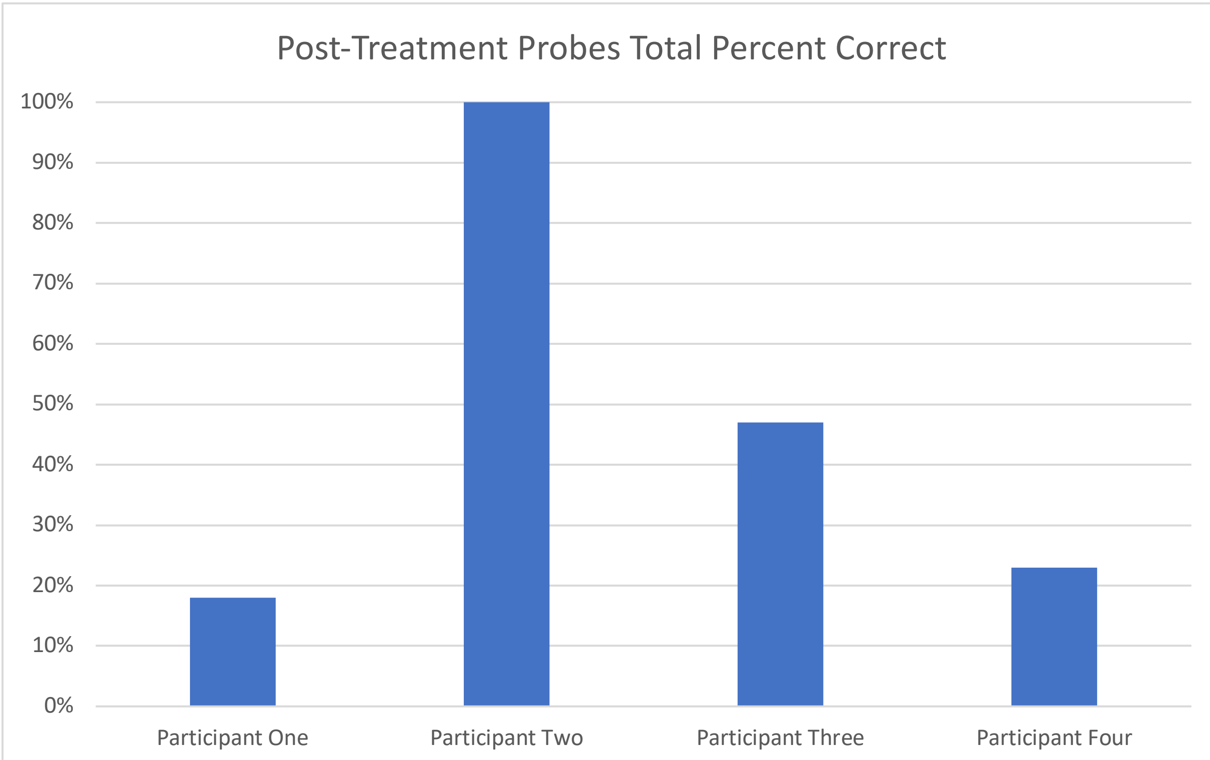
Initial probes were re-administered three-months post the end of treatment. The probe lists were administered without the electropalatography device, due to sizing issues with participants. Table 5 represents the results of the re-administered probes:

Table 5: Percent Correct All Participants (Post-treatment Probes)

Participant	Initial /ɹ/	Final /ɹ/	Initial /ɹ/ Cluster	Mean Correct (s.d.)
One	25%	5%	20%	17% (.10)
Two	100%	100%	100%	100% (0)
Three	40%	55%	25%	40% (.15)
Four	50%	0%	35%	28% (.26)

Graph 16 displays the total percent correct /ɹ/ productions in post-treatment probes across all four participants. The average percent correct across all four participants was 46.25% correct /ɹ/ productions for post-treatment probes with a standard deviation of .13.

Graph 16: Total Percent Correct All Participants (Post-treatment Probes)



Cohen’s D was calculated to compare the probes from the three consecutive baseline sessions to the probes from the last three treatment sessions to determine the effect of electropalatography on /ɹ/ productions. Cohen’s D was 2.97 for participant one, indicating a large effect size. Cohen’s D was 6.67 for participant two, which indicated a large effect size. Participant three had a Cohen’s D of 38.7 indicating a large effect size. Participant four received a Cohen’s D of 4.4 also indicating a large effect size.

Cohen’s D was also calculated to compare the probes from the three consecutive baseline sessions to the one follow-up probe (administered three-months post-treatment) to assess the effect size of electropalatography on /ɹ/ productions after a period of time without treatment. Cohen’s D was 2.03 for participant one indicating a positive impact of electropalatography treatment on participant one’s /ɹ/ productions, even three-months post-treatment. Participant two had a Cohen's D value of 10.37 which indicates improvement positive impact in participant two's /ɹ/ productions. Cohen's D was 3.8 for participant three meaning electropalatography treatment had a positive impact on participant three's /ɹ/ productions. Participant four received a Cohen's D value of 2.5 indicating that participant four made progress in his /ɹ/ productions that was maintained three-months post-treatment.

Discussion

The purpose of this study was to look at efficacy of electropalatography treatment in school-age children with residual /ɹ/ errors. The research question asked if electropalatography will correct residual /ɹ/ errors in school-aged children after the use of traditional articulation therapy techniques were unsuccessful?

Participant one was the third participant to start electropalatography treatment after eight baseline sessions. She had not had any prior orthodontic work, but she was able to adjust to the new palate device after one session of using it. She consistently thought she was elevating the root of her tongue when producing the /ɹ/ sound while traditional articulation therapy was being administered during initial probe sessions. However, once the palate was inserted in her mouth, she was unable to hit the dots that represent the posterior part of the palate, indicating her tongue was not elevated when she produced the /ɹ/ sound. Participant one was also missing contact with her tongue to the middle part of the posterior part of her palate. After multiple treatment sessions, she started to use a retroflexed tongue and move from an /l/ sound to an /ɹ/ sound to get a better /ɹ/ production. These techniques were used throughout the duration of the treatment sessions to maximize progress.

Throughout treatment participant one's tongue strength was questioned. Was she not able to hold her tongue up long enough to make the /ɹ/ sound? Did she have decreased tongue strength? Observations from the researcher indicated that she lacked awareness of where her tongue was in the vicinity of her mouth. It was not observed that participant one had a lack of tongue strength. Also, the percent of tongue strength needed to produce speech is a small percentage of a person's maximum tongue strength, indicating that a lack of tongue strength did not play a role in her difficulty producing the /ɹ/ sound. At the conclusion of this study, it was recommended that participant one should continue biofeedback therapy to improve /ɹ/ productions. She is currently receiving both ultrasound and electropalatography biofeedback therapy treatment to maximize /ɹ/ production improvements.

Participant two was the first participant to start electropalatography after three baseline sessions. He had a retainer that he wears at night, so he was used to having a device in his mouth. He was able to adjust to the palatography device within the first treatment session. Participant two had made progress with his /ɹ/ productions at the word level while in ultrasound therapy. At the conclusion of ultrasound therapy, clinicians indicated that participant two's /ɹ/ productions were improving, but he had not reached 100% /ɹ/ production accuracy in conversational speech.

Observations by the researcher included decreased /ɹ/ production accuracy in conversational speech, due to participant two's rate of speech in conversation. He significantly increased his rate of speaking in conversation, which increased articulation errors across multiple sounds. Also, participant two had irregular vowel and consonant productions in words, such as the /d/ phoneme in radio, which were not /ɹ/ production errors. Rate was monitored throughout the remaining treatment sessions to maximize /ɹ/ production improvements. Also, inconsistently produced words were noted and worked on as they arose in therapy sessions. Participant two was different when compared to the other three participants because of the high percentages of correct /ɹ/ productions during baseline sessions. However, he lacked the ability to self-monitor his /ɹ/ productions, which significantly impacted his accurate /ɹ/ productions in conversation. EPG treatment helped participant two to develop the self-monitoring skills necessary to maintain an appropriate speaking rate and accurately produce the /ɹ/ sound in all speaking contexts. Participant two was dismissed as he was able to self-monitor speech rate and /ɹ/ productions in conversational speech.

Participant three was the fourth participant to start electropalatography treatment after eleven baseline sessions. He had never had any orthodontic work in his mouth prior to this treatment. Participant three was very hesitant to place and keep the palate in his mouth throughout treatment sessions. The researcher sent home the extra clear palate with participant three's mother during spring break to help participant three adapt to having the device in his mouth. After spring break, participant three continued to complain about the device not being comfortable, but he was still willing to wear it for treatment sessions.

Participant three made significant progress in /ɹ/ productions in isolation and at the word level. Throughout treatment sessions, his tongue would slightly droop on the right side while making the /ɹ/ sound causing an errored production. The right side of participant three's tongue was closely monitored for the duration of treatment sessions to maximize progress in /ɹ/ productions. Participant three is currently receiving traditional articulation therapy to generalize /ɹ/ productions in conversational speech to progress towards dismissal from therapy.

Participant four was the second participant to start electropalatography treatment after five baseline sessions. He had not had any orthodontics prior to starting electropalatography treatment. Participant four was hesitant about the device in the first session but was willing to wear it every session and enjoyed wearing the device by the end of the study. Like participant one, participant four had some difficulty determining where his tongue was in his mouth. However, after three treatment sessions, he was able to accurately move his tongue to make the /ɹ/ production.

In the earlier treatment sessions, participant four had extra tongue contact in the middle of his upper palate. The clinician cued participant four to retract his tongue posteriorly and push the sides of his tongue towards his teeth to maximize /ɹ/ production accuracy. Also, like participant one, participant four started to use a retroflexed tongue and moved from an /l/ sound to an /ɹ/ sound to get a better /ɹ/ production. These techniques were used throughout the duration of the treatment sessions to maximize progress. Participant four had allergies throughout the treatment duration of the study, which increased drooling and open mouth breathing during treatment sessions. The researcher observed that his allergies did not significantly impact participant four's abilities to produce accurate /ɹ/ sounds. Participant four is currently continuing electropalatography treatment to improve /ɹ/ productions in the final position and initial cluster position of words and at the conversational level.

Probe lists consisted of words with the /ɹ/ sound in the initial, final, and initial cluster position of words. Across all participants, /ɹ/ in the initial position of words was the position that was improved first. This finding contradicts Hodson's approach showing that /ɹ/ production in the final position is the first position to improve (Hodson, 2010). Further research is needed to determine if different articulation treatment methods lead to improvements of /ɹ/ production in different positions of words. Also, all four participants received ultrasound therapy prior to the start of electropalatography therapy. Both treatments have significant costs involved and are versions of biofeedback treatment that can be used for articulation treatment. Further research is required to determine if the order of biofeedback treatments impacts results. In addition, for three out of the four participants it was noted that improvement in production of the target sound was achieved in word stimuli where the rhotic approximant was next to vowels that require a retracted tongue root positioning. However, word stimuli where the rhotic approximant was next to a vowel with a more forward tongue root positioning resulted in less production accuracy for the /ɹ/. Further research is needed to determine if words with back vowels and retracted roots impact improvements for /ɹ/ production across a variety of articulation treatments.

Limitations

Although this study did successfully answer the research question asked, it still had limitations. All four children had previous traditional articulation therapy and ultrasound therapy, which were not successful, but could have positively impacted each participant's progress in this study. Another limitation was the adversity some participants had to putting the electropalatography device into his or her mouth. Only one participant had worn an orthodontic device prior to this study. The other three participants took one to three sessions to adjust to having the electropalatography device in his or her mouth. A third limitation is the cost of the dental impression needed to make the palate device. School-aged children are constantly losing teeth and their mouths are growing. If a child continues to need electropalatography therapy over the course of a year they may need to have multiple dental impressions as their mouth changes and grows, which could cost up to $100 for each impression. Two of the four clients needed a new Smart Palate within 8 months of starting electropalatography. For this study TCU provided smart palate devices which cost $179 per child per device. However, each new smart palate device can cost up to $250 per child per device depending on the level of membership with SmartPalate.

Another limitation is the use of the Cohen's D statistic to determine the effect EPG treatment had on each participant's /ɹ/ production. Cohen's D determines practical significance, but not statistical significance (Beeson & Robey, 2006). So, the large effect sizes in this study show that each participant's /ɹ/ production did significantly increase in accuracy, however, it cannot be determined if this was solely due to EPG treatment. A fourth limitation is the accuracy of the Smart Palate software tongue contact to palate electrode accuracy measure technology.

There were instances throughout treatment sessions when a participant's /ɹ/ production would sound accurate, however, the Smart Palate software accuracy measure was below the 80% threshold. On the contrary, there were times throughout treatment sessions when a participant's /ɹ/ production did not sound correct, but the Smart Palate software accuracy measure was 80% or above.

Conclusion

This study looked at the efficacy of electropalatography treatment in school-age children with residual /ɹ/ errors. Data indicated that electropalatography treatment had a significant positive impact on all four participant's /ɹ/ productions immediately at the end of treatment and three-months post-treatment. Further research with more participants is needed to determine the impact of electropalatography treatment on residual /ɹ/ errors in school-aged children from a variety of backgrounds.

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Appendix A: Parent Background Information Form

Your name:

Your child's name:

Mother's Education (check all that apply):

- ☐ High School Graduate
- ☐ Some College
- ☐ Associate's and/or Bachelor's Degree
- ☐ Bachelor's Degree
- ☐ Master's Degree
- ☐ Doctoral or Professional Degree

Father's Education (check all that apply):

- ☐ High School Graduate
- ☐ Some College
- ☐ Associate's and/or Bachelor's Degree
- ☐ Bachelor's Degree
- ☐ Master's Degree
- ☐ Doctoral or Professional Degree

Household Annual Income (please check one):

- ☐ Dual income household
- ☐ Single income household
- ☐ Prefer not to specify

Income Brackets (please check one):

- ☐ Up to $19,050
- ☐ $19,051 to $77
- ☐ $77,401 to $165,000
- ☐ $165,001 to $315,000
- ☐ $315,001 to $400,000
- ☐ $400,001 to $600,000
- ☐ Over $600,000
- ☐ Prefer not to specify

Appendix B: Initial /ɹ/ word data collection form

Word	/ɹ/ Location	Production	Score
	Initial		
	Initial		
	Initial		
	Initial		
	Initial		
	Initial		
	Initial		
	Initial		
	Initial		
	Initial		

Date	Total correct words	Total opportunities	% correct
		10	

Appendix C: Final /ɹ/ word data collection form

Word	/ɹ/ Location	Production	Score
	Final		
	Final		
	Final		
	Final		
	Final		
	Final		
	Final		
	Final		
	Final		
	Final		

Date	Total correct words	Total opportunities	% correct
		10	

Appendix D: Initial /ɹ/ cluster word data collection form

Word	**/ɹ/ Location**	**Production**	**Score**
	Initial Cluster		
	Initial Cluster		
	Initial Cluster		
	Initial Cluster		
	Initial Cluster		
	Initial Cluster		
	Initial Cluster		
	Initial Cluster		
	Initial Cluster		
	Initial Cluster		

Date	Total correct words	Total opportunities	% correct
		10	

Appendix E: Intervention Probe List A

Word	**/ɹ/ Location**	**Production**	**Score**
Roof	Initial		
Bear	Final		
Trick	Initial Cluster		
Drum	Initial Cluster		
Car	Final		
Fire	Final		
Rain	Initial		
Crib	Initial Cluster		
Rock	Initial		
Rhino	Initial		
Doctor	Final		
Reaping	Initial		
Graphic	Initial Cluster		
Three	Initial Cluster		
Feather	Final		
Resting	Initial		
Racoon	Initial		
Ajar	Final		
Vroom	Initial Cluster		
Practice	Initial Cluster		

Date	Total correct words	Total opportunities	% correct
		20	
	Total correct trained words		
		10	
	Total correct untrained words		
		10	

Appendix F: Intervention Probe List B

Word	/ɹ/ Location	Production	Score
Ribbon	Initial		
Zipper	Final		
Frog	Initial Cluster		
Frame	Initial Cluster		
Mother	Final		
Four	Final		
Rug	Initial		
Bridge	Initial Cluster		
Rose	Initial		
Red	Initial		
Attire	Final		
Radio	Initial		
Bragging	Initial Cluster		
Cry	Initial Cluster		
Pear	Final		
Wrap	Initial		
Rake	Initial		
Guitar	Final		
Truck	Initial Cluster		
Trash	Initial Cluster		

Date	Total correct words	Total opportunities	% correct
		20	
	Total correct trained words		
		10	
	Total correct untrained words		
		10	

Appendix G: Intervention Probe List C

Word	**/ɹ/ Location**	**Production**	**Score**
Rhyming	Initial		
Appear	Final		
Straw	Initial Cluster		
Bread	Initial Cluster		
Hair	Final		
Vampire	Final		
Rice	Initial		
Breed	Initial Cluster		
Room	Initial		
Rapid	Initial		
Kicker	Final		
Rusty	Initial		
Dragon	Initial Cluster		
Grass	Initial Cluster		
Encore	Final		
Rowing	Initial		
Wrap	Initial		
Midair	Final		
Graphic	Initial Cluster		
Freedom	Initial Cluster		

Date	Total correct words	Total opportunities	% correct
		20	
	Total correct trained words		
		10	
	Total correct untrained words		
		10	

Appendix H: Intervention Probe List D

Word	**/ɹ/ Location**	**Production**	**Score**
Room	Initial		
Tiger	Final		
Drum	Initial Cluster		
Vroom	Initial Cluster		
Hammer	Final		
Four	Final		
Ribbon	Initial		
Bragging	Initial Cluster		
Rose	Initial		
Rice	Initial		
Car	Final		
Rock	Initial		
Trash	Initial Cluster		
Trick	Initial Cluster		
Hair	Final		
Red	Initial		
Roof	Initial		
Midair	Final		
Bread	Initial Cluster		
Straw	Initial Cluster		

Date	Total correct words	Total opportunities	% correct
		20	
	Total correct trained words		
		10	
	Total correct untrained words		
		10	

Appendix I: Intervention Procedures Protocol

- Welcome participant and lead to therapy room.
- Set up SmartPalate Technology and connect participant's SmartPalate Device to the computer.
- Have the participant complete the oral coordination module for five minutes.
- Work on ten initial /ɹ/ words from the trained probe list.
- Work on ten final /ɹ/ words that are not on the untrained final /ɹ/ probe list.
- Work on ten initial cluster /ɹ/ words that are not on the untrained initial /ɹ/ cluster probe list.
- Work on ten /ɹ/ words chosen by the participant that are not on any of the three probe lists.
- Administer the two randomly selected probe lists during the last five minutes of the session.
- The researcher and interobserver takes data when the researcher administers the probes.
- Dismiss the participant for the day.

ABSTRACT

ELECTROPALATOGRAPHY TREATMENT FOR SCHOOL-AGED CHILDREN WITH RESIDUAL /ɹ/ ERRORS

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Purpose: The purpose of this study is was to investigate the efficacy of electropalatography treatment in school-age children with residual /ɹ/ errors. The specific research question asked is will electropalatography correct residual /ɹ/ errors in school-aged children after the use of traditional articulation therapy techniques and ultrasound biofeedback techniques were unsuccessful?

Methods: The data collected in this study was obtained and recorded through a multiple probe single-subject design. To be eligible for the study, it was required for participants to be native English speakers with residual rhotic (/ɹ/) errors. Other than residual rhotic errors, participants were typically developing and did not present with any other speech and/or language deficits nor any cognitive delays. To account for an equal selection of participants, each study participant was recruited from the TCU Miller Speech and Hearing Clinic clientele and had participated in traditional and ultrasound therapy prior to this study. Repeated measurements were taken during the baseline phase to control for maturation and instrumentation. Also, consistent performance

on baseline measures were obtained from each participant before intervention started. All treatment sessions followed the same protocol to monitor procedural infidelity.

Results: Probe lists consisted of words with the /ɹ/ sound in the initial, final, and initial cluster position of words. Across all participants, /ɹ/ in the initial position of words was the position that was improved first. Participant one is currently receiving both ultrasound and electropalatography biofeedback therapy treatment to maximize /ɹ/ production improvements. Participant two was dismissed as he was able to self-monitor speech rate and /ɹ/ productions in conversational speech. Participant three is currently receiving traditional articulation therapy to generalize /ɹ/ productions in conversational speech to progress towards dismissal from therapy. Participant four is currently continuing electropalatography treatment to improve /ɹ/ productions in the final position and initial cluster position of words and at the conversational level.

Conclusions: This study looked at the efficacy of electropalatography treatment in school-age children with residual /ɹ/ errors. Data indicated that electropalatography treatment had a significant positive impact on all four participant's /ɹ/ productions immediately at the end of treatment and three-months post-treatment. Further research with more participants is needed to determine the impact of electropalatography treatment on residual /ɹ/ errors in school-aged children from a variety of backgrounds.