EFFECTIVENESS OF ULTRASOUND BIOFEEDBACK IN THE TREATMENT OF SPEECH SOUND DISORDERS WITHIN A SCHOOL ENVIRONMENT

by

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ABSTRACT

Implementation of ultrasound visual biofeedback (UVB) for remediation of speech sound errors in speech pathology has been successful when applied in controlled clinical settings, but no research has been completed to determine the method's effectiveness in a less controlled environment. The purpose of this research project was to evaluate the effectiveness of UVB in the remediation of Speech Sound Disorders (SSD) in a school setting. A multiple baseline multiple probe single case design was developed to examine the effects of ultrasound treatment. Participants would include up to 10 children diagnosed with SSDs. For each participant, two speech sounds in error will be monitored throughout the course of the study, one receiving treatment with UVB and the other being observed for generalization. Implications of possible results for this study in terms of implementation of UVB treatment into a school setting and future research are discussed, as well as barriers to research due to the COVID-19 pandemic.

LITERATURE REVIEW

Introduction

Speech sound disorders (SSD) can be defined as a delayed acquisition of developmentally appropriate speech sounds, which leads to reduced intelligibility of speech (Anthony et al., 2011). Studies have found a range in the number of children living with speech sound errors, depending on the population being studied and the time period in which data was collected. Prevalence of a speech delay in children under the age of 17 varies greatly from 2.3% to 24.6% when looking at literature between 1967 and 1997 (Law et al., 1999). The difference in reports is likely due to the definitions of SSD used, assessment tools, and methodology of sample collection.

Looking specifically at the presence of speech sound disorders at the age many children begin elementary school, prevalence appears to remain stagnant between 4 and 8 years. At age 4 prevalence of a speech disorder was 3.4% (Eadie et al., 2014). At age 6 prevalence was 3.8% (Shriberg et al., 1999), and at age 8 it was 3.6% (Wren et al., 2016). Among children with a communication disorder, 48.1% of 3 to 10 year olds struggle with speech sound problems. This number decreases to 24.4% for 11 to 17 year olds (Black et al., 2015).

Individuals with speech sound disorders may also have difficulties outside of expressive phonology, which can have an impact on educational success. Eadie et al. (2015) found the comorbidity between SSD and language disorder, or the likelihood of having both conditions at the same time, to be 40.8% within a population of four-year old children. The research also found a 20.8% comorbidity between SSD and poor pre-literacy skills. Children with SSD often have undeveloped phonological skills in awareness, representation, speech perception, speech production, segmentation and identification. These deficits lead an increased risk of having difficulty learning to read (Leitao et al., 2004, Anthony et al., 2011).

Speech sound disorders are especially prevalent within a school setting. According to ASHA's 2020 Schools Survey Report, 88.9% of school speech language pathologist (SLPs) regularly serve children with speech sound disorders. Based on this data, nearly all school-based SLPs report being exposed to, assessing, and treating speech sound disorders while working in this environment.

Overall, speech sound disorders are frequently seen by SLPs in both clinical and school settings, making the treatment for this impairment an important topic. SLPs have relied on traditional articulation therapy, the Cycles approach, and more recently biofeedback technology to treat these disorders. Ultrasound visual biofeedback (UVB) technology is becoming a more supported and accessible option to treat speech sound errors. With changes in technology, price and accessibility, ultrasound scanners are becoming an appealing option for remediation of speech sound errors.

Speech Treatment in the School Setting

Implementation of remediation strategies for speech sound disorders by school SLPs can differ from other clinical settings such as private clinics, university clinics and research clinics. Differences in treatment implementation can be borne from logistics and time constraints that school SLPs need to consider. It is important to consider the pre-requisites for a client to receive speech and/or language intervention in a school setting. In order to qualify for speech services in a school, SLPs must look closely at a child's willingness to communicate in the classroom, ability to present orally, and social interactions with peers outside of class to determine if the child qualifies for their services (ASHA, 2020). A child is dismissed from speech-language pathology services in the school once it is determined their speech-language disability no longer has an adverse effect on educational performance. These components are still very important in a private clinical setting, but they do not need to play as large of a role in treatment qualifications. Furthermore, school SLPs carry a large caseload and must cooperate with classroom teachers to balance individual speech-language therapy goals with overall educational success. During a typical month, school SLPs treat a median of 47 different students (ASHA, 2020). In this setting, clients are often pulled out of the classroom to participate in speech-language pathology treatment. The client and clinician may meet for about a half hour either once or twice a week.

Treatments for Speech Sound Disorders

Traditional articulation therapy. Traditional articulation therapy is commonly used in school and clinical settings, and the method places an emphasis on drill and repetition. This treatment typically provides an auditory model of a correct sound production as well as verbal and visual cues that can be used to encourage the client to adjust tongue shape for the target sound. Often, clinicians cue the client by having them practice producing a phoneme that appears to have a tongue shape similar to the targeted phoneme. For example, shaping a retroflex rhotic approximant /ɹ/ from the lateral /l/ (Preston et al., 2019). This approach is often used in a school setting due to its low costs, clear hierarchical approach, and ease of implementation for developmental sound errors. Overall, this treatment method has been proved successful in treating speech sound errors, but some clients do not improve or generalize. Clinicians often report difficulty in describing complicated articulatory shapes or movements that take place within the oral cavity for the target sound when they cannot be seen (Preston et al., 2019).

Cycles Approach. The cycles approach (also referred to as Hodson's approach) generally involves (1) a pattern-focused selection of targets, (2) targeting that proceeds in cycles between different incorrect speech patterns, and (3) auditory input of correct sound production in words, which is mixed with production activities (Rudolph & Wendt, 2014). Although widely used by school-based (SLPs), there is limited evidence on its efficacy. A systematic review by Hassink and Wendt (2010) presents inconclusive evidence on Cycles for remediation of speech sound errors in the pre-school population. A multiple baseline design work by Rudolph & Wendt (2014) found some suggestive evidence of its efficacy in three young children with severity of errors ranging from moderate-severe to severe. Given the limited evidence supporting this treatment approach for young children and its common use by school-based SLPs, children that undergo this treatment can have limited progress in remediation of speech sound distortions that will continue to be present as the child matures. Although speculative, the wide use of this treatment approach by school-based SLPs might be borne from the treatment's ease of implementation and low costs.

Biofeedback Technologies. Biofeedback approaches provide live information of the articulatory gestures made when attempting production of the target sound. Two visual biofeedback technologies used for remediation of speech sound errors are electropalatography (EPG) and ultrasound imaging (UI).

EPG requires an artificial palate to be placed in the client's mouth, which electronically records the timing and location of tongue-palate contact (Hitchcock et al., 2017). This is used to provide individualized feedback to modify the contact. Due to certain speech sounds requiring a specific tongue-palate contact configuration, EPG allows for monitoring this contact for tongue sections (e.g. lateral sides, tongue dorsum) that are further along the mouth and are harder to see. Contrary to the aforementioned approaches, EPG is invasive, palate fit and sensitivity can vary for the individual, children can outgrow the artificial palate, and treatment requires a custom-fit pseudoplate to be made for the client. This makes the treatment financially costly and less practical to complete in a large-scale clinical setting (Jonathan et al., 2013). In a school setting, implementing EPG can be challenging for SLPs with a large caseload due to the cost of equipment and the need for customized individual plates for each child.

Ultrasound Visual Biofeedback. UVB is another form of biofeedback therapy used to treat speech sound disorders. As biofeedback technology has become more affordable and portable in different settings, it has become a potential option for speech treatment. Ultrasound displays an image of a moving line, which represents the client's tongue shape, on a screen that can be viewed by both the clinician and client. (Preston et al., 2013). The image can provide information on tongue root, dorsum, blade, lateral sides and midline groove movement. (Bernhardt et al., 2007, Lee et al., 2015)

UVB potentially assists in treating speech sound disorders because of the immediate feedback it provides to the client while producing a sound, allowing an opportunity for correction of the tongue movement. (Preston et al., 2013, Preston et al., 2014, Preston et al., 2019). Ultrasound differs from other articulation therapies because it provides a view of parts of the mouth and tongue than cannot be seen without technological aid. Also, UVB therapy sessions contain a defined structure that may serve well in a school setting, including development of a general motor plan (GMP), drilled activity, and high-frequency feedback to create an optimal learning experience (Preston et al. 2014). Overall, research has shown that UVB therapy should be considered a viable option for SLPs when treating speech sound disorders, Childhood Apraxia of Speech, and Residual Speech Sound Errors (Sugden et al., 2019, Preston et al., 2013, Preston et al., 2014). Studies conclude that UVB has the potential to help improve persistent speech sound errors in several populations, and should be considered when other treatment approaches have not been successful. The results indicate that SLPs can feel confident that a short-term ultrasound treatment plan, as long as they follow the methods present in the research, can yield improvements in speech sound errors, and therefore be worth the investment in cost and training.

Since nearly 90% of school-based SLPs provide treatment for students with SSDs (ASHA, 2020), it is important to consider if this method serves as a more advanced and beneficial form of treatment for SSDs when compared to popular approaches used in the school setting, such as traditional articulation treatment or Cycles approach. Research has demonstrated the success of using UVB in the remediation of SSDs within a structured clinical environment, while providing solutions to several setbacks present in already established treatments. However, these findings cannot be generalized from a controlled clinical research setting to schools, due to the school SLP's unique caseload and constraints. It is possible that the rigorous structure of UVB treatment will not properly translate to the school setting. Therefore, it is crucial to examine the benefits and drawbacks of UVB technology when treating SSDs specifically in a school environment.

The purpose of this current study is to observe if similar results in the amelioration of speech sound errors in children that received ultrasound biofeedback treatment at a more controlled clinical research environment is also observed at a setting similar to the everyday experience of an SLP (e.g. schools). Through the training of school speech pathologists in UVB treatment, and collecting data from their caseload, it is possible to observe if ultrasound biofeedback produces results in a school setting that resemble the findings from research in clinical practice. The research question for this study is as follows:
Is the ultrasound visual biofeedback method an effective approach for the remediation of speech sound errors at a school setting?

METHODS

Participants

Up to ten children will be recruited for this study. All children will comply with the following inclusion criteria: (1) have a diagnosis of speech sound errors, (2) have more than one speech sound in error, (3) be at least 7;0 years old, (4) have an accuracy of 20% or less on accurate speech sound production of the target sound as measure by a 20-item word list criterion reference test, (5) pass a hearing screen, (6) have no diagnosis of cognitive impairment, and (7) have no experience or history with UVB as a treatment approach for their speech sound errors. All children will be recruited from schools in the Fort Worth Independent School System where the school SLP has been trained in the use of UVB for remediation of speech sound errors. School based SLPs trained in the use of UVB for speech participated in an UVB training workshop at TCU during the month on June in the year 2020. The Clinical Evaluation of Language Fundamentals (CELF-5) standardize test will be administered for purposes of describing participants' language skills.

Selection of target sound for remediation

Based on the child's school speech sound evaluation a 20-item word list containing the target sound in error in various word positions and contexts will be administered. For example, a 20-item word list for /s/. Two speech sounds in error with a 20% or less production accuracy will randomly be selected, one for UVB treatment and one for monitoring generalization effects. For example, a child with production errors of /s/ and /l/. One speech sound will randomly be selected for remediation with UVB while the other will be monitored but will not be a target for remediation using UVB. Participant's production on this task will be audio recorded and rated by two independent raters who will also be blind to the purpose of the study.

UVB Training workshop

SLPs will be provided 12 hours of ultrasound training. They will receive training through 4 3-hour sessions. Each session will focus on a particular tongue section and will build off of knowledge from previous sessions. Training will be based on the PALs model (participatory adult learning strategy). This model focuses on active learner involvement, practice, and reflection of knowledge to promote professional development. (Dunst & Trivette, 2009).

Baselines

A multiple baseline multiple probe single case design methodology will be used for data gathering and analysis. Baseline for treated speech sound will be staggered across children. For example, one child will have 6 baselines while the next child will have 9 baselines. Baseline will be gathered by perceptually assessing accurate and inaccurate production of the target sounds in various contexts as measured by a 10 item word list read by the participant that includes the target sound in error in a variety of vocalic contexts and word positioning. The 10 item word list will consist of randomly selected words from a pre-constructed work bank (see Appendix A, B, C, and D). To prevent memorization and practice effects, four different 10 item word lists will be created for each sound. Baselines probes will be audio recorded.

Treatment

A Micro/SonoSpeech ultrasound scanner with a 4MHz transducer will be used for delivering UVB treatment. Twelve treatment sessions will be provided for remediation of the targeted speech sound in error. Each session will last for 30 minutes with two sessions per week. During the first 3 minutes of the session, the SLP will review terminology with the child (e.g. parts of the tongue, correct positioning of tongue sections, and review of previous session) followed by 24 minutes of drill practice using UVB using words containing the selected sound in error. During practice, the clinician will use facilitative contexts to promote repositioning of tongue sections for accurate production of targeted speech sound. For example, if repositioning of the lateral sides are needed for accurate production of /s/, then the SLP can use a different speech sound to promote repositioning of the lateral sides (e.g. /n/) for /s/. The last 3 minutes of the session will be used to measure changes in the dependent variable as measured by probes for treated and untreated sounds.

During the practice portion using UVB, the SLP will be using facilitative strategies to help the child in repositioning tongue sections when an error production is made. These strategies were taught to the SLPs as part of their UVB training. For example, using specific vowel contexts for promoting tongue root retraction and raising of lateral sides of tongue. Treatment sessions will be video and audio recorded.

Outcome measures

Probes for treated sound. Participant will read a ten-item word-list created similarly to the word list used during baseline (see Appendix A, B, C, and D). Four different word lists will be created to prevent memorization and practice effects. These probes will be administered at the end of every treatment session and will not contain words used during the baseline phase or treatment phase. Probes will be audio recorded.

Probes for untreated sound. Participant will read a ten-item word-list created similarly to the word list used during baseline (see Appendix A, B, C, and D). Four different word lists will be created to prevent memorization and practice effects. These probes will be administered at the end of every treatment session and will not contain words used during the baseline phase or treatment phase. Probes will be audio recorded.

Data Analysis

Two raters blind to the purpose of this study will be used to perceptually score productions of the selected speech sounds by listening to probe's audio recordings as well as the 20-item word lists used for selection of target sounds. An accurate production will receive a score of 1 while incorrect a score of 0. Raters will do their scoring independently before meeting and comparing results. If raters disagree by more than 20% on their scores for probes they will try to reach an agreement. If an agreement cannot be achieved, a third rater will be used to make the final decision.

Data from each baseline and probes will be plotted on a graph for each participant and for the two speech sounds that were measured (treated and untreated). Data will be visually analyzed for changes in trend and levels. Functional relationship between dependent and independent variable will be assess by using TAU-U.

IMPLICATIONS OF POSSIBLE RESULTS

If a functional relationship between the dependent and independent variables is observed, we will be able to conclude that similar to controlled clinical settings, UVB is beneficial for remediation of speech sound errors in the school setting. This is of great benefit for clinicians who are interested in the application of this tool at schools.

With these positive results, schools and speech pathologists could adopt the application of UVB and acquire ultrasound scanners to treat speech sound disorders and feel confident the technology is worth the cost (since UBT avoids several of the setbacks present in other treatment methods). Currently, knowledge on how to use UVB among SLPs is very uncommon. Hypothetical results such as this can promote the introduction of UVB knowledge and skills at graduate communications sciences and disorders programs so that more SLPs are prepared to use this strategy.

If a functional relationship between our dependent and independent variables is not found, it could be concluded that the implementation of UVB in a school setting is not as effective in remediation of speech sound errors as when used in a more controlled setting. Additionally, this also raises more questions that should be addressed on future research such as looking into what aspect of UVB at a school setting makes it not as effective as when used in a controlled setting, including treatment structure, length of treatment session, etc. With research aimed at answering these questions, it can be possible to generalize the effectiveness of UVB in more controlled settings to less structured settings such as schools.

BARRIERS TO RESEARCH

Barriers to data collection

The COVID-19 pandemic presented many challenges towards education and research. Due to these setbacks, the collection of data for this research project proved to be unattainable and therefore the analysis of results was also unable to be completed. Despite the constraints COVID-19 provided, this project attempts to answer the research question and pave the way for future research once data collection can be safely completed.

The research question for this project highlights the importance of the educational setting where treatment would be taking place, and the collection of data for this project requires in-person interaction between the clinician and child (for treatment) and members of the research team. During the pandemic, many students were not attending school in-person, and consequently clients were not receiving in-person speech therapy. UVB requires the client to be in person in order to use the machinery, and since many students were opting into tele-therapy during this time, it would have been unrealistic to complete these therapy sessions.

Overall, due to COVID-19 complications and the resulting lack of treatment sessions or data loss due to restrictions to in-person interactions, it would have been too difficult to collect enough data to be able to determine if there was a functional relationship between the dependent and independent variables. Even when planning and having an entire semester of time prepared to collect data, the timeline and ambiguity of when things would return to normal added to the uncertainty of being able to collect the appropriate amount of data.

Barriers to original research project

Some unforeseen barriers to the original research idea allowed me to develop skills to effectively respond to changing situations. Learning how to quickly adapt to unforeseen events and modify research plans will be useful in my future clinical and research experiences. While completing my research, I encountered unpredictable barriers that allowed me to generate new solutions, which resulted in a research project that explores a topic I am passionate about and that pushed me out of my comfort zone to develop my academic skills as a speech-language pathologist.

The decision to limit my research to a proposal was made after my thesis had already been altered several times, some even before the pandemic. At first, the research focused on an entirely different purpose, using ultrasound to look at the rhotic /r/ in the bilingual Spanish speaking population. The travel plans required for this research fell through, and in hindsight it is clear that the pandemic would have prevented this travel anyway. Despite not being able to follow through with this exact topic, during these early stages of my thesis I gained experience reading literature to develop my knowledge of ultrasound technology and treatment, considered the potential this therapy method has for a client population I will likely encounter in the future, and learned how to rebuild after plans were changed.

My thesis then turned to focus on ultrasound in an educational setting, similar to the current project. However, when the pandemic began, my supervising professor and I created and considered a new plan to adapt to the unusual circumstances. For this new design, an online application would be developed that would provide a remote way to teach clinicians how to use ultrasound biofeedback technology during therapy, focusing on the clinicians as the subjects rather than the clients. This project provided a realistic solution to new research and clinical guidelines during the pandemic, and is still an interesting idea worth pursuing in the future. However, after reflecting on this change in direction, I concluded that I would find a research question that focuses on the client directly, rather than clinicians and app technology, to be more engaging. I examined which aspects of my past research I found the most intellectually fulfilling, and decided to commit to a research question that would study the potential of ultrasound biofeedback technology for the treatment of speech sound disorders in schools.

Throughout this process, I am confident that the research question and path I chose, to create a research proposal in a topic that fulfills my interests and is very relevant in the field of speech pathology, to be the best path to develop my research skills as an undergraduate and prepare me to conduct research as a graduate student in the future.

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Appendix A: Word Bank for Baseline and Treatment Probes with /r/

/r/ initial (25)

- Rock
- Rug
- Raccoon
- Roof
- Raisins
- Rose
- Rain
- Rake
- Ribbon
- Rattlesnake
- Red
- Room
- Radish
- Rhino
- Ruler
- Wrap
- Roost
- Rice
- Radio
- Rectangle
- Race
- Read
- Rat
- Ring
- rhyme

Postvocalic /r/ (25)

- Bear
- Vampire
- Four
- Fire
- Hair
- Doctor
- Hammer
- Chair
- Star
- Spider
- Mother
- Pear
- Zipper
- Feather
- Car
- Guitar
- Tiger
- Helicopter
- Dinosaur
- Beaver
- Deer
- Pair
- Tire
- Door
- year

/r/ clusters (25)

- Truck
- Frog
- Trash
- Drum
- Straw
- Green
- Grapes
- Crayon
- Tractor
- Press
- Prize
- Price
- Practice
- Project
- Pretty
- Train
- Treasure
- Trumpet
- Grass
- Grandma
- Fruit
- Freeze
- Crab
- Crystal
- Frisbee

Appendix B: Word Bank for Baseline and Treatment Probes with /l/

initial /l/ (25)

- Lace
- lid
- Leash
- Lamb
- Lava
- Lizard
- Llama
- Lobster
- Lick
- Leaf
- Left
- Lime
- Laser
- Lion
- Lake
- Lemon
- Lap
- Leap
- Leak
- Lock
- Line
- Late
- Log
- Limo
- Lamp

Final /l/ (25)

- Wool
- Shovel
- Mail
- Fall
- Owl
- School
- Bell
- Nail
- Tool
- Pool
- Seal
- Wall
- Shell
- Small
- Ball
- Peel
- Hole
- Mall
- Doll
- Heel
- Hotel
- Baseball
- Smell
- Stall
- Sail

/l/ clusters (25)

- Black
- Blue
- blush
- Flag
- Flame
- flash
- Gloves
- Glue
- Clue
- cliff
- Clown
- Clock
- Plum
- Slug
- Sled
- Fly
- Flower
- Glass
- Clean
- Planets
- Playing
- Plum
- slow
- Sleeping
- clover

Appendix C: Word Bank for Baseline and Treatment Probes with /s/

initial /s/ (25)

- Seed
- Sofa
- Sun
- Seal
- Soup
- Soap
- Same
- Syrup
- Son
- Salt
- Santa
- Sword
- Sweater
- Sandwich
- Cereal
- City
- Saw
- Socks
- Salad
- Sand
- Soda
- Sick
- Sink
- Sailor
- Sing

final /s/ (25)

- Cactus
- Mice
- Slice
- Fox
- Moose
- Mouse
- Octopus
- Dress
- House
- Purse
- Bus
- Kiss
- Bananas
- Class
- Tennis
- Necklace
- Dice
- Princess
- Grass
- Dress
- Juice
- Vase
- Office
- Voice
- Yes

/s/ clusters (25)

- Snack
- smile
- Slime
- Sky
- Slug
- Scale
- Scared
- Star
- Skates
- Sneeze
- Sleep
- Smell
- Skunk
- Snow
- Storm
- Sled
- Sponge
- Spoon
- Stamp
- Spaceship
- Spider
- Spell
- Spy
- Scarf
- Slide

Appendix D: Word Bank for Baseline and Treatment Probes with /z/

final /z/ (25)

- Bees
- Boys
- Breeze
- Buzz
- Freeze
- Noise
- Daze
- Glaze
- Nose
- Pause
- Quiz
- Sneeze
- Wise
- Disguise
- Sideways
- Sunrise
- Squeeze
- Size
- Surprise
- Wheeze
- Tease
- Please
- Disease
- Jazz
- Lose