The use of biofeedback in speech therapy for individuals with Down syndrome:

a comparison of ultrasound and electropalatography
Abstract

Many individuals with Down syndrome (DS) have trouble with articulation of speech, which often causes difficulties with their intelligibility. The speech errors of individuals with DS are often difficult to treat with conventional speech therapy interventions, demonstrating the need to establish successful interventions for treating this population. Ultrasound and electropalatography (EPG) are two methods of biofeedback, that provide visual feedback information about the articulation of speech as it is occurring. Individuals with DS hold a relative strength in the area of visual learning, making biofeedback treatment methods a great option.

This paper reviews and compares ultrasound technology and EPG and examines studies investigating the success of these methods on the speech production and intelligibility of individuals with DS. It argues that while both types of technology offer promising results for the treatment of this population, ultrasound should be the preferred technology because of its versatility, non-invasive nature, and relative cost effectiveness.

Key words: Down syndrome, biofeedback, ultrasound, electropalatography, pronunciation
Introduction

Language development is an area of difficulty for children with down syndrome (DS). Speech production in particular can be a challenge, and many individuals face problems with intelligibility. This is related to oral-motor difficulties (Buckley & Le Prèvost, 2002) in the strength, timing, and coordination of muscle movements used in speech (NDSS, n.d.), differences in vocal anatomy, as well as difficulties in other domains. The speech sounds that cause the most difficulty for individuals with DS are: /l/, /ɾ/, /ʃ/, /ʧ/, and /ʤ/, with /ɾ/ being particularly challenging because of the complex tongue movements required to produce it combined with the low muscle tone seen in DS, large tongue, and small oral cavity. Many of the speech errors seen in DS are similar to the phonological processes that children go through during first language acquisition, but in individuals with DS these errors can persist past childhood and into adulthood (Fawcett, Bacsfalvi, & Bernhardt, 2008).

Biofeedback is a technique that uses technology to monitor and provide information about processes and functions occurring in the body (Davis & Drichta, 1980). Applied to speech, biofeedback provides real time information about speech production as it is occurring. Ultrasound imaging and electropalatography are two methods of biofeedback that have been used in pronunciation training in clinical contexts. Ultrasound imaging has been shown to be a helpful tool in the field of language teaching, as well as in clinical settings with individuals with various speech disorders (Preston et al., 2017), because of the interactive and visual nature of the technology. People can directly see the shape and movement of their tongue and use this feedback to improve their articulation (Preston et al.). Electropalatography as well has been found to be useful in therapy, including the assessment and treatment of speech disorders (Wood, Wishart, Hardcastle, Cleland, & Timins, 2009).
Speech errors in individuals with DS are often viewed as difficult to improve in therapy, as they can be resistant to the standard interventions used by SLPs (Wood, Wishart, Hardcastle, & Cleland, 2019), which demonstrates the need to explore new and different intervention options. Individuals with DS are visual learners, which makes members of this population great candidates for biofeedback.

This paper reviews the existing literature on ultrasound and electropalatography and reports on studies that have used the technologies with individuals with DS, comparing the strengths and weaknesses of the two technologies in pronunciation training with this specific population. The technologies are looked at in terms of effectiveness, versatility, invasiveness, cost, as well as other categories relevant to therapy settings. It is hypothesized that while electropalatography provides feedback at a higher level of detail, ultrasound strikes a balance of giving useful feedback while being relatively un-invasive and should be the preferred technology to be used in speech therapy with individuals with DS. The findings of this paper will inform clinicians about the most effective method to help individuals with DS with their speech production in order to improve their intelligibility in their everyday lives.

**Ultrasound**

When using ultrasound, a transducer is placed just below the chin and above the larynx (Bernhardt, Gick, Bacsfalvi, & Adler-Bock, 2005). The transducer sends out ultra-high frequency sound waves, which are reflected back towards the transducer when they hit the air in the oral cavity right above the surface of the tongue (Bird & Gick, 2018). This information is converted into images on a screen that show the shape and location of the tongue at a given point in time. Two viewpoints of the tongue are possible with ultrasound. A sagittal view shows the tongue from root to tip, providing information about tongue backness and height (Bernhardt et
A coronal view shows the height and sides of the tongue, as well as grooving and raising in the midline of the tongue, and vowel tenseness (Fawcett, et al., 2008). Ultrasound is a useful tool for visualizing the speech articulators in pronunciation teaching and learning and has been used in clinical settings with various populations since the early 2000s (Bird & Gick). It provides the best information on tongue shape and place of articulation, as well as some information on manner of articulation. Therapy techniques using ultrasound have been developed for velar and alveolar stops, approximants /l/ and /ɹ/, sibilants /s/, /ʃ/, affricate /ʧ/, and vowels (Bernhardt et al.), which greatly overlaps with the areas of difficulty for individuals with DS.

Fawcett, Bacsfalvi, and Bernhardt’s (2008) study investigated the use of ultrasound as visual feedback in speech therapy for /ɹ/ in young adults with DS. Participants were three English speaking young adults between the ages of 21 and 24. Participants /ɹ/ productions were assessed twice prior to therapy, and twice after therapy had finished. The researchers used a portable ultrasound machine in 10 out of the 16 therapy sessions during the study, and each participant had a total of 4–5 hours practising with the machine.

Treatment began by introducing the participants to the ultrasound equipment and method through demonstration, written materials, and drawings. Participants also learned about the tongue and its movements through malleable clay models. They then practised various speech sounds and tongue movements with the ultrasound machine in order to get comfortable using the technology. Before using the ultrasound for /ɹ/, they practised discriminating this speech sound from various /ɹ/ substitutions, to be sure that they could identify when they produced this speech sound correctly. The tongue movements required to produce /ɹ/ were then broken down into individual movements and practised using ultrasound, and when a participant
could combine each movement they practised producing the full /u/ vocalization in isolation. The last step was the production of /u/ within words in varying positions.

All three participants made significant improvements in their /u/ production over the course of the study. Prior to therapy, participants had minimal or no /u/ production within words. After receiving ultrasound therapy, two participants had 100% accuracy for /u/ in the word initial position and the third had 50% accuracy, with all three showing signs of generalizing this learning to outside the therapy context. The researchers also collected listener judgements of the participants’ /u/ productions pre and post therapy, and they improved from /r/ being perceived in 0–5% of tokens before therapy, to it being perceived in 45–100% of tokens after therapy. The results of this study suggest that ultrasound is a promising way of improving /u/ in adults with DS. The researchers note that participants lost their skills rapidly when two sessions in a row did not include practice with ultrasound, and they then could not produce the sound until they practiced with visual feedback again. This shows that the technology was assisting them, and participants required continued visual feedback at this stage of learning. To explain this loss of skill, the researchers state that individuals with DS are slower to acquire new motor skills and suggest that they likely need more practise with the machine than typically developing individuals. The researchers reported that participants continued to improve their /u/ production after the study was finished and showed signs of generalizing this sound (Fawcett et al).

**Electropalatography (EPG)**

EPG is a technique that uses a custom made artificial palate that displays the tongue’s contact with the hard palate during speech (Wood et al., 2009). The palate fits against a person’s hard palate and has 62 electrodes that recognize when the tongue touches certain positions of the palate during speech and display this information on a computer screen. EPG has been used in
assessments interventions for speech disorders with a range of different populations. It is particularly useful for speech errors that involve lingual consonants, especially when the difficulties are motor based as in DS (Wood et al., 2019). A target articulation is shown on one side of the screen which an individual attempts to copy and learn from, and their own articulation is shown on the other side (Wood et al., 2009).

Wood et al.’s (2019) study aimed to evaluate the effectiveness of EPG therapy in improving the speech production of school aged children with DS. They compared the use of EPG to EPG informed therapy, as well as usual methods of speech therapy for children with DS. The researchers hypothesized that EPG-based therapy would see the greatest improvement because of the visual learning strength of people with DS. Participants were 27 children with DS aged 8–18 who completed 24 one-hour therapy sessions over a period of 12 weeks. Therapy targeted lingual speech errors that were considered the most disruptive to each participant’s intelligibility. EPG therapy began with a target phoneme in a consonant-vowel or vowel-consonant construction, and then moved to phrase and sentence levels as the participant improved. When the participant had mastered the articulation and generalized it in different contexts, visual feedback was gradually reduced. EPG informed therapy consisted of techniques focusing on expressive and comprehensive language, informed by an initial EPG assessment, which provided a greater amount of information regarding the participants’ articulation errors than typical assessments. Speech intelligibility and speech production were assessed in all groups at four points over nine months.

Results between groups were not statistically significant, but they suggest that participants who received the direct EPG therapy were more likely to maintain and improve on
their learning compared with participants who received EPG informed conventional therapy or no therapy.

A (2009) study by Cleland, Timmins, Wood, Hardcastle, & Wishart looked into the effectiveness of EPG on individuals with DS aged 10–18 who had severe cognitive deficits. The paper reported the improvements of six participants in the EPG group of a larger study comparing EPG, traditional therapy, and no therapy. Five participants received therapy targeting sibilants, and one received therapy targeting velars. All participants showed qualitative and quantitative improvements post treatment in the percentage of consonants produced correctly, with five out of six showing positive changes in EPG patterns, and the remaining participant showing an improved airstream during consonant production. There was a significant increase in perceptually correct productions as a group, and this study suggests that EPG is a useful tool for individuals with severe cognitive deficits and severely impaired language.

**Comparison and evaluation**

Ultrasound and EPG have various strengths and weaknesses. Ultrasound’s strengths include that the whole tongue is visible (Bird & Gick, 2018) and can be observed dynamically or statically from various views (Bernhard et al., 2005). It provides immediate, real-time feedback, without requiring individual hardware, which means therapy can begin immediately, is relatively inexpensive, relatively non-invasive (Bernhardt et al.), and data is relatively easy to collect (Bird & Gick). Ultrasound can be portable so that therapy can occur in locations convenient to the client (Bernhardt et al.). Despite these strengths, ultrasound also has a number of limitations. It can only image the tongue (Bird & Gick) and does not provide any tongue-palate contact information, or acoustic information. The sagittal and coronal views cannot be examined
simultaneously (Bernhardt et al.). Not all speakers image equally well (Bird & Gick), it can be
time consuming (Bernhardt et al.), and its data more ambiguous to interpret.

EPG’s strengths are that it provides an objective, precise, and detailed analysis of
articulation patterns, and it can help identify errors that cannot be detected by perceptual
analysis. It allows speakers to visualize their tongue contact with the hard palate in real-time and
has few cognitive and language demands (Wood et al., 2019). Disadvantages of EPG include that
it can only be used for lingual speech sounds that contact the hard palate, which leaves out many
consonant and all vowel sounds. In order to use EPG, an individual must have a custom palate
made, which is expensive and invasive. Children can also grow out of their palates (Wood et al.,
2009), and then need to have a new one made if therapy is still required. EPG does not specify
which part of the tongue is making contact with the palate, or what the other articulators are
doing during speech production (Cleland et al., 2009).

Both ultrasound and electropalatography have shown to have the potential to be
successful in helping individuals with DS improve their speech production in therapy settings.
This suggests that it is the general principle of having a visual of the tongue and receiving visual
feedback that is helpful in improving articulation, not specifically the type of technology, which
is what Bernhard, Gick, Bacsfalvi, & Ashdowns found in their (2003) study comparing the two
technologies for use with hard of hearing adolescents. Ultrasound and EPG provide different
types of information about different kinds of articulations, and so are both valuable tools in SLP
with individuals with DS. Overall, ultrasound is a more versatile tool than EPG. Although
ultrasound doesn’t offer specific information about tongue-palate contact, it can still be used to
give useful feedback about the movement of the tongue for articulations that contact the palate.
This is opposed to EPG, which only gives information for articulations in which the tongue
contacts the palate, meaning that it cannot be used for many articulations. Ultrasound is more cost-effective, as there are no individual customizations required, more flexible, as treatment can begin immediately and be stopped with little money wasted if the client does not like the technology or it is not working, and it is significantly less invasive than EPG, as there is nothing being placed inside the mouth. It is also more interactive, as the probe can be passed back and forth between the SLP and client, as they work together to improve on a target speech sound, capitalizing on the social strength in DS.

**Conclusion**

Ultrasound and EPG are both visual biofeedback tools that the literature shows have been successful in helping children and young adults with DS improve their speech production. Ultrasound should be the preferred technology because of its versatility, non-invasive nature, and relative cost-effectiveness. Further research should be done directly comparing the effectiveness of ultrasound and EPG, with the same stimuli, teaching methods, and participant groups, in order to confirm the preliminary findings of this paper. More research has been done on EPG with this particular population, but because of the strengths of ultrasound, future research should be done on the effectiveness of ultrasound on individuals with DS. Research should be done with larger sample sizes and control groups, as well as on individuals with DS of a variety of different age groups in order to determine when in development this tool is most successful. Longitudinal studies should also be done to investigate how the learning from ultrasound fares over time: does production of the target sounds improve, stay the same, or decline over time? The findings of this paper demonstrate the promising progress of research and speech therapy for children and young adults with DS.
References


