USING MODIFIED RESONANT VOICE THERAPY TO ENHANCE SPEECH INTELLIGIBILITY IN A PRE-LINGUALLY DEAFENED INDIVIDUAL: AN EXPERIMENTAL CASE STUDY.

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This is to certify that the thesis entitled:
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Abstract

Altered speech articulation, oral and nasal resonance, voice quality, and breath management may impact the intelligibility and prosodic characteristics of speech in pre-lingually deafened individuals. This case study examines the efficacy of modified resonant voice therapy (MRVT) targeting breath control, vocal quality, and oral resonance on overall enhancement in speech intelligibility. Results showed reduction in severity of roughness, breathiness, noise-to-harmonic ratio and pharyngeal resonance. Participant also demonstrated increased speaking fundamental frequency, maximum frequency, maximum intensity, maximum phonation time, s/z ratio, breath group, intelligibility (i.e. words and sentences) and score on the *Voice Related Quality of Life*. Inconsistent differences were found in nasality measures. The measurements obtained in this study depict the effectiveness of MRVT, noting overall improvement in breath control, voice quality and speech intelligibility. Maintenance of these characteristics was evident one-month post MRVT.

Keywords: aural rehabilitation, modified resonant voice therapy, speech intelligibility

Research studies, over the years, have indicated that there are distinct differences in speech and voice characteristics between individuals who are deaf or hard of hearing (HoH) and individuals with normal hearing (Calvert, 1962; Subtelny, Whitehead & Samar, 1992; Higgins, Carney, & Schulte, 1994; Lenden & Flipsen, 2007; Nguyen, Allegro, Low, Papsin, & Campisi, 2008). These differences may be attributed to greater reliance on vibrotactile feedback to compensate for the reduced or altered auditory feedback (Higgins, Carney, & Schulte, 1994; Lenden & Flipsen, 2007) and manifest as variations in a) speech articulation, b) voice quality, c) oral and nasal resonance, and d) breath management for speech, which may impact the overall intelligibility and prosodic characteristics of spoken expression. The following paragraphs discuss these variations in greater detail.

Speech Articulation

Deaf individuals tend to rely on vibrotactile feedback to complement and compensate for the reduced auditory feedback (Higgins, Carney, & Schulte, 1994). This may appear as "excessive force" on the production of certain sounds, such as plosives /p, t, k/, which in turn can be a source of perceived breathiness in deaf speech (Calvert & Silverman, 1983). Other common inaccuracies of articulation include: voicing, sound substitution, nasality, misarticulation of consonant blends and omissions (Osberger & McGarr, 1982). Osberger and McGarr (1982) explain that voicing requires coordination in the timing of respiration, phonation and articulation. Since deaf speakers exhibit reduced coordination, misarticulations tend to occur in which voiced consonants become voiceless and vice versa. Elimination of initial and/or final consonants (typically omission of high frequency speech sounds) in a production is also very common for deaf speakers (Osberger & McGarr, 1982).

Voice Characteristics

In deaf/HoH speech, differences were noted in loudness, laryngeal quality and resonance quality, which Lenden & Flipsen (2007) included under the broader category of voice. With reduced auditory input, deaf/HoH individuals may have difficulty modulating their loudness effectively and tend to speak softer than the norm (Calvert & Silverman, 1983; Lenden & Flipsen, 2007). Another possible source of reduced loudness may be attributed to the breathy vocal quality (Subtelny, Whitehead and Orlando, 1980), physiologically related to inadequate adduction of the vocal folds resulting in the escape of air during speech production. Behrman (2013) described that "the force of air from the lungs exerted on the vocal folds" is the primary contributor to controlling loudness. Without adequate breath support, the force exerted on the vocal folds will not be sufficient to increase loudness. Calvert (1962) described the laryngeal quality of a deaf individual to be "tense, flat, breathy, harsh and throaty". As mentioned above, there is a speculated need for vibrotactile feedback to compensate for reduced auditory feedback. By imposing greater adduction and muscular tension on the vocal folds, a deaf individual will receive this feedback, but it also results in a strained/pressed voice with harsh-like qualities (Subtenly, Whitehead & Orlando, 1980; Higgins, Carney, & Schulte, 1994; Lenden & Flipsen, 2007).

Another manifestation of vibrotactile feedback is exhibited in the distinctive pharyngeal focus and cul-de-sac resonance associated with quality of the voice of a deaf/HoH individual (Calvert, 1962; Boone, 1966; Subtelny, Whitehead & Samar, 1992). This vocal quality is attributed to a neutralized tongue position and associated with tongue retraction, hyoid bone elevation and larger vertical dimension of the laryngeal pharynx (Subtelny, Li, Whitehead & Subtelny, 1989; Subtelny, Whitehead & Samar, 1992). While this change in articulatory posturing provides more proprioceptive and tactile information, it also impacts the production of sounds, particularly vowels. The constrained tongue position reduces the oral space, vowels are produced in a neutral manner with a lowered second formant, reducing discriminability of production (Subtelny, Whitehead & Samar, 1992; Higgins, Carney, & Schulte, 1994). An additional contributor to the pharyngeal resonance is enhanced nasal resonance influenced by inefficient velopharyngeal (VP) management consequent to reduced auditory input (Nguyen et al., 2008). This variability in VP control may result in hypernasality, as air is released through the nasal cavity across all sounds, impacting both articulation and vocal quality.

Subtelny, Whitehead and Samar (1992) examined the possible causes of pharyngeal resonance in deaf individuals. Recordings of the voice of four women with severe bilateral sensorineural hearing loss, presenting with moderate-to-severe pharyngeal resonance, were analyzed. These women used hearing aids and their speech was identified as semi-intelligible by the researchers. Their voice recordings were compared to ten adult women with normal hearing and completely intelligible speech. A significant lowering of the second formant of vowels was noted to be vowel dependent for the four deaf women. Limited tongue movement was found to be a contributing factor to the significance between the formant structure of deaf and hearing women.

Higgins, Carney and Schulte (1994) assessed the physiological productions of the speech and voice of adults with hearing loss. The speech and voice of eleven adults (seven women and four men) with moderate-to-profound hearing loss was analyzed for phonatory and velopharyngeal/articulatory measures and compared to that of eleven adults (seven women and four men) with normal hearing. The adults with hearing loss were found to have intelligible speech, but abnormal voice quality (strained, breathy, high pitch, and cul-de-sac resonance). Vocal hyper-constriction was observed and thought to be purposed for tactile feedback. Increased loudness was expected to be used for an attempt at auditory feedback. No significant gender differences were noted.

Breath Management for Speech

Adequate breath support is needed to manipulate the vocal folds and appropriately produce certain voice characteristics. Clinically, it has been observed that poor breath support in deaf individuals stems from the reduced airflow management (Forner & Hixon, 1977; Whitehead 1983; Lane, Perkell, Svirsky, & Webster 1991; Lane et al., 1998). Forner and Hixon (1977) studied the speech breathing of 10 prelingually deafened male adolescents. They described their articulation as poor and characterized their voices as breathy and harsh. Moreover, they found that during reading activities, these 10 individuals unnecessarily tended to expend excessive air. In addition, these male deaf speakers used a variety of lung volumes, most of which were below normal at the start of speech. As a result, these speakers tended to pause for replenishment of air more frequently. Similarly, Whitehead (1983) found that 15 prelingually deaf males with unintelligible speech began speaking without enough air and expended too much air, which resulted with abnormal volumes below their functional residual capacity.

Lane, Perkell, Svirsky and Webster (1991) completed a study analyzing the breathing patterns of three post-lingually deafened adults, who were implanted with cochlear implants. These subjects were instructed to read a passage three times with a 20-minute break in between each trial. The volume of air during their speech breathing was measured using an inductive plethysmograph protocol. This group of researchers explained that the hearing loss resulted in a reduction of breath management during speech, describing the usage as varying between excessive and inefficient. They concluded that auditory feedback plays a significant role in the regulation of airflow management. In a later study, Lane et al. (1998) clarified that the improvements of breath management in individuals, who received amplification, was not directly related to hearing and auditory feedback. Instead, it is a result of "changes in respiratory and glottal pressure made to achieve reductions in SPL [speech sound level] (which [is] directly regulated by hearing)" and a reduced effort to provide the lungs with enough air, in turn providing efficient and adequate breath support for speech (Lane et al., 1998).

Prosody

To enhance the sensory feedback, an individual with hearing loss may utilize expiratory airflow in lieu of acoustic information. If this is not augmented by appropriate breath support or proper regulation of expiratory airflow, it may manifest as variations in prosody and speech suprasegmentals (Moseley, 1996; Lenden & Flipsen, 2007). Lenden and Flipsen (2007) listed the characteristics of prosody as: phrasing ("the flow of speech"), rate and stress. They noted that the typical speech production of an individual with a hearing loss is not continuous, but rather words are produced individually with atypical pauses in between them (Boone, 1966; Lenden & Flipsen, 2007). As a result of this discontinuous speech, the rate of speech tends to be slower (Boone, 1966; Lenden & Flipsen, 2007). Deaf individuals also present with atypical inflection patterns, in which it is common for every word to receive equal stress (Subtelny, Whitehead & Orlando, 1980; Lenden & Flipsen, 2007). Along with this unique quality is monotonality. Similar to how each word is produced with equal stress, they are also produced with equal pitch (Boone, 1966; Calvert, 1962; Lenden & Flipsen, 2007). This results in difficulty with intonation, which can affect sentences by blending them together without natural indications that one has begun and another has ended. Due to this monotone quality of speech, there is no differentiation between questions and statements, adding to irregular phrasing (Lenden & Flipsen, 2007).

Lenden and Flipsen (2007) analyzed the prosody and voice characteristics of the conversational speech of pre-lingual deaf children with cochlear implants. Conversational samples for six children (five girls and one boy) were obtained every three months. They were recorded during sessions in which graduate students and the parents played with the children, provided a variety of topics and toys. Though phrasing and pitch were not identified as a significant problem, deviances were noted in rate, loudness and laryngeal quality. However, researchers concluded that out of all the characteristics analyzed, stress and resonance were the most problematic and should be the focus of treatment.

Therapeutic Approaches

Individually or in combination, all the factors above characterize the speech and voice production of an individual with hearing loss and differentiate it from a person with normal hearing. It needs to be emphasized that these differences are not a result of any structural or functional dysfunction, but are consequences of physiological compensation for reduced auditory feedback. Typically, in a post-lingually deafened individual, the speech patterns may retain their original characteristics after appropriate aural management. In contrast, for a pre-lingually deafened adult, the speech and voice characteristics may or may not change depending on the quality and type of amplification (i.e. hearing aid/cochlear implant), timing of management and whether an aural rehabilitation program was undertaken.

To address decreased intelligibility, these clients have previously sought traditional aural rehabilitation (AR), which includes tasks and activities targeting both perception and production to build receptive and expressive skills, respectively (Moseley, 1996). To address perception, the client participates in analytic and synthetic training, such as sound discrimination (analytic) and word/sentence identification (synthetic). For speech production, speech intelligibility is frequently targeted by a focus on articulatory precision. While this addresses one factor that impacts speech intelligibility, the outcome is slow or incomplete as other segmental and suprasegmental features (i.e. loudness, voice quality, oral and nasal resonance, breath management) are not managed directly. Thus, there is a need for a treatment plan that augments pronunciation skills with coordination of breathing, reducing vocal strain, increasing loudness, improving oral and nasal resonance to expand vowel space and improve vocal quality for a more global improvement in speech intelligibility.

One such therapy approach could be resonant voice therapy (RVT), which focuses on optimizing forward focus and resonance (Verdolini & Stemple, 2000). Dr. Katherine Verdolini developed this system in the early 2000s. The goal of this holistic approach is for the client to achieve resonant voice, which is defined as "voice production involving oral vibratory sensations" (Stemple, Glaze, & Klaben, 2010). Its technique increases vibrotactile and sensory focus at the face, lips and nose (Seligmann, 2005; Chen, Hsiao, Hsiao, Chung, & Chiang, 2006; Salvador & Strohauer, 2010). This is an effort to shift the vibrotactile focus from the pharyngeal cavity to a more forward placement, decreasing the original pressed resonance. Additionally, this shift makes the vibrotactile feedback tangible, which permits the individual to self-monitor their performance in and outside of the therapy room, allowing for maintenance.

RVT training begins with a warm-up that includes stretching maneuvers and breathing, as it is the major support for all following stages (Verdolini & Stemple, 2000). Prior to the core program, a basic training gesture is introduced in which non-speech sounds are used to train the client how to use forward focus in conjunction with adequate breath support. The following seven stages continue with non-speech sounds and proceed to syllables, words, phrases, sentences, paragraphs and conversation across the hierarchy. In addition to resonance quality and breathing, each stage addresses other voice characteristics: one (rate, intensity), two (rate, pitch, loudness, inflection), three (inflection), four (all in paragraphs), five (all in conversation), six (all in the presence of background noise), and seven (all including emotional manipulations). A home program is supplemental to the training held in the therapy room. The client is sent home with instructions pertaining to essential parts of each stage and each skill must be mastered through additional home practice (Verdolini & Stemple, 2000). By training the client to use proper breath support and resonance, their atypical voice characteristics will be improved (Stemple, Glaze, & Klaben, 2010).

Chen, Hsiao, Hsiao, Chung and Chiang (2006) examined the outcome of resonant voice therapy on female teachers with voice disorders. Twenty-four female teachers, with at least one voice symptom frequently occurring, received resonant voice therapy for 90 minutes per week for eight weeks. Outcome measures included perceptual, physiological, acoustic, aerodynamic/respiratory, and functional aspects. Results showed significant reduction in severity of roughness, strain, monotonality, pharyngeal resonance, hard attack, glottal fry and score of physical scale in the *Voice Handicap Index*. Participants also demonstrated increased speaking fundamental frequency, maximum frequency and maximum intensity. No significant difference was found in perturbation and breathiness measures. The researchers concluded that resonant voice therapy is effective for school teachers.

In theory, RVT would target the atypical characteristics of deaf speech, but its effects have only been studied on voice-disordered teachers, singers and professional speakers with normal hearing (Chen, Hsiao, Hsiao, Chung, & Chiang, 2006; Salvador & Strohauer, 2010). Given the management components of resonant voice therapy and the characteristics of deaf speech, we speculate that adding modified resonant voice therapy will augment traditional aural rehabilitation and target the characteristics of deaf speech originally unaddressed. However, a research study addressing this resonant voice therapy has not been completed before with the deaf population. A pilot clinical study using a modified form of resonant voice therapy has indicated improvements in fundamental frequency, maximum phonation time, s/z ratio and nasality measures (Mejia, Jaiswal, Palmer, & Allen, 2016). The purpose of this study is to examine the change in voice and resonance characteristics pre- and post- modified resonant voice treatment in a pre-lingually deafened adult with amplification (i.e. hearing aid). And so, we have formulated the following question: Is there a difference between pre- and post- measurements in the voice characteristics of a pre-lingually deafened adult with a hearing aid as a result of five weeks of modified resonant voice therapy? We have gone a step further and decided to look at specific voice characteristics, including:

1. Is there a difference between pre- and post- measurements of breath control?
2. Is there a difference between pre- and post- measurements of voice quality?
3. Is there a difference between pre- and post- measurements in speech intelligibility?
4. Is maintenance of breath control, voice characteristics and speech intelligibility evident one month post- modified resonant voice therapy?

Provided this five-week regimen of modified resonant voice therapy, the null hypothesis is that there will be no change in pre- and post- measurements of 1) breath control, 2) voice quality and 3) speech intelligibility. In addition, it is hypothesized that there will be no evident maintenance of breath control, voice characteristics and speech intelligibility one-month post-treatment.

Methods

This case study will examine and compare changes in pre- and post- measures of respiratory, phonatory and articulatory function, as a result of a five-week regimen of modified resonant voice therapy.

Participant

The participant was selected based on the following criteria (1) having a bilateral moderately severe to profound sensorineural hearing loss, (2) hearing loss was identified at birth to within five years, (3) is currently fitted with hearing aid/cochlear implant, (4) exhibits speech or resonance patterns consistent with early acquired deafness, (5) has fair to good communication skills, and (6) self-reports comfortability using spoken American English (since it was the intended primary language for use in therapy) or a combination of oral and manual (Spoken English with ASL/SEE). Exclusion criteria included the presence of (1) accented English, (2) any current or past history of laryngeal, neurological or craniofacial abnormalities, and/or (3) an active ear infection. Participant received information about the study protocol and informed consent was obtained. Once recruited, the participant completed all assessments and enrolled in a five-week regimen of modified resonant voice therapy.

One 30-year-old female with congenital (pre-lingual) deafness and a communicated clinical goal of enhancing her vocal resonance and speech intelligibility was invited to participate in this study. Participant was recruited via the Gallaudet University Hearing and Speech Clinic (GUHSC). Information from a questionnaire, along with pre-assessment of the participant's listening skills was used to determine eligibility. Participant, a student, has congenital hearing loss and identifies as both hard of hearing and Deaf. She reported a profound hearing loss in the left ear and a moderate-to-severe loss in the right ear, in which she wore a hearing aid. Participant described feeling comfortable using her voice when she stepped off Gallaudet University's campus, as well as with her family and friends, which she averaged to less than one hour per week. Using the *National Technical Institute of the Deaf (NTID) Voice Evaluation Form: Qualitative Measures*, the researcher evaluated the participant's vocal quality. The *NTID Voice Evaluation* examines the following vocal parameters: pitch register and control, prosody, respiratory control, resonance and vocal tension. Each item has a unique five-point scale, generally identifying normal to severe vocal quality. The participant was found to have severe pharyngeal resonance, meeting the inclusionary criteria.

In addition, participant needed to achieve the indicated performance on the following assessments:

- *Ling Six Sound Test* (identify all Ling 6 sounds)
- *Receptive Tracking* (demonstrate skill in repairing communication breakdowns)
- *CID Sentences* (80% accuracy, presented in the auditory- visual mode)
- *Pronunciation Skills Inventory* (demonstrate an understanding and use of the syntactic structure and pronunciation rules of Standard American English)

The researcher determined the participant's auditory function at the time of evaluation using the *Ling Six Sound Test*. The *Ling Six* is a behavioral listening check to provide information regarding her auditory functioning levels across the speech frequencies. The participant demonstrated difficulty identifying the sounds with 25% accuracy (3/12). Provided auditory-visual training of the sounds, she achieved 42% (5/12). This indicated that she was able to perceive sounds across the speech frequencies, but had difficulty recognizing and identifying the sounds which may be contributing to her difficulties with understanding speech. An informal tracking procedure was used to evaluate participant's receptive strategy use. The researcher read a passage, a few words at a time, and asked the participant to repeat them back verbatim. The participant did not hesitate to ask the researcher to repeat the sentence. When asked what else she could ask the speaker to do to assist in her comprehension of the details, she described telling the researcher to stop blocking her mouth and to speak more clearly.

To assess speechreading skills, the *Central Institute for the Deaf (CID) Everyday Sentences* were administered. For this test, the participant was presented with one set of ten unrelated sentences. The client's ability to identify the salient information was evaluated. Scores were then interpreted into a profile rating score, ranging from "1" to "5", with "1" indicating that the client understood the entire message, and "5" indicating that the client did not understand the message. When presented a purely auditory condition, the participant achieved a raw score of 25, yielding a percentage score of 50% accuracy and a profile rating of 3 (indicating that she "understands with difficulty about one-half of the message and can follow the gist of the conversation"). It was observed that the participant was able to gather some information, even when she could not determine specific words within the sentence. This was evident by her writing the words she heard in the appropriate order, as well as using context clues (e.g. "by the end of the month" instead of "before the first of the month"). It was observed that participant relied heavily on lipreading, based on her performance when visual information was removed, as well as self-admission.

Select portions of the *Pronunciation Skills Inventory (PSI)* were administered to assess the participant's knowledge and usage of the rules of English pronunciation. Results indicated that she demonstrated strengths in the following areas: consonant and vowel decoding, knowledge and use of the grammatical constructs of contractions and of the past tense –ed, as well as identification of number of syllables in words. Her areas of need included: sounds/phonemes associated with specific letters and identification of stressed syllables in words. Despite these results, given the participant's motivation and clinical need for intervention, the graduate student researcher decided to provide therapy instructions in American Sign Language (ASL), eliminating the requirements for understanding spoken English instructions. In addition, the researcher provided an hour of auditory training prior to the voice therapy session. Results of this training will not be provided, but will be included in the discussion to account for possible influences on her progress.

Modified Resonant Voice Therapy (MRVT)

A trained speech-language pathology master's student provided the therapy. Participant sat across from the researcher for effective modeling and visual feedback. Therapy followed hierarchical stages of speech tasks with increasing order of difficulty and communication contexts ensuring generalization. The sessions lasted for 90-minutes each, once a week for five successive weeks. Within each therapy session, five minutes at the start was allotted for a check-in and five minutes at the end for reflection and homework assignments. The rest of therapy included about 30 minutes of breathing and stretching maneuvers and 50 minutes of vocal training (Chen, Hsiao, Hsiao, Chung, & Chiang, 2006).

Stretching and Breathing Maneuvers

The start of each session focused on warm-up exercises involving body stretching and breathing maneuvers.

- Stretching Exercises: The researcher described and modeled stretches (Appendix A) for the participant to copy for 3-10 seconds each (Verdolini & Stemple, 2000). The first two weeks of therapy stretches were held for 10 seconds. During the following weeks, the length of each stretch depended on reported practice and tension felt by participant and auditory-perceptual strain noted by researcher.

- Breathing Exercises: In the initial session, the researcher counseled the participant about breath management and demonstrated diaphragmatic breathing. To practice maintaining breath control each week, the participant completed speech breathing exercises by reading phrases and sentences of increasing length, while maintaining adequate breath support. To further train coordination of breath support and promote oral resonance, the participant completed flow phonation, in which she breathed and phonated through straws of different diameters (Titze, 2006). Following this, a typical resonant voice therapy warm-up was conducted, in which the participant repeatedly breathed out all air on /f/ (Verdolini & Stemple, 2000).

Resonant Voice Training

Across the five weeks of training, the participant partook in a modified form (Appendix B) of the seven stages of resonant voice therapy as designed by Dr. Verdolini (Verdolini & Stemple, 2000) with instructions provided in ASL. Resonant voice is correlated with the use of more energy in the higher harmonics, increasing the spectral properties. According to Yeni-Komshian and Bunnell (1998), listeners of the speech of a deaf individual value spectral properties more than the timing of speech. Timing heavily depends on pauses, syllable duration and stress (Osberger & Levitt, 1979). For this reason, activities involving the modification of rate (i.e. fast-slow repetitions) was removed from the protocol. In addition, this resonant voice training will be modified to focus on using adequate breath support, in accordance to the importance of the properties listed in the introduction.

Home Exercises: The participant was assigned homework after every session as practice of each skill learned in the session. The home program involved 15-20 minute sessions, twice per day, including stretches, the basic training gesture and the selected level of hierarchy. The participant fully disclosed infrequent practice, due to her academic and employment requirements. She explicitly reported practicing lip trills, m + vowel repetitions and diaphragmatic breathing during 3/5 weeks of treatment.

Measures and Equipment

The outcome of MRVT was assessed through multiple measures, including acoustic, aerodynamic, spectral, auditory-perceptual and functional measurements. All measures were obtained pre- therapy, post- therapy (final week) and one-month post therapy. Voice samples were obtained in a quiet therapy room. Data from the participant (sustained vowel, reading, conversation) was recorded and analyzed using features of the Multi-Speech module of the Kay Pentax software (Sampling rate: 44,100) and high quality acoustic recording. A handheld microphone (SHURE PG48), was fitted to the participant's mouth with a mouth-to-microphone distance of four to five centimeters (cm). An audio recorder (TASCAM, DR-40 Linear PCM Recorder), positioned using a tripod, recorded the voice signal.

Results

Acoustic and Spectral Measurements

The *Multidimensional Voice Program* (*MDVP*) task assesses perturbation measures. The participant sustained the vowel sound /a/ for at least four seconds using a comfortable pitch and loudness throughout. Using *Real Time Pitch*, the following voice samples were recorded and analyzed:

- A reading of the *Rainbow Passage* in a comfortable pitch and loudness,
- 30-second sample of conversation,
- Softest possible production of "The baby is sleeping,"
- Loudest possible production of "Hey, Taxi!" without strain,
- Highest possible production of "whoop" without strain, and

- Lowest possible production of "boom" without a gravelly voice quality.

These voice samples were used to measure frequency and intensity variability and range, as well as obtain spectral measures. Graph 1 and Table 1 (below) show the fundamental frequency for both conversation and reading during pre-, post-1 and post-2. Pre- therapy, the participant's fundamental frequency (F0) was within normal limits for both reading (221.27 Hz) and conversation (218.28 Hz). During the last week of therapy (post-1), the participant's F0 largely increased (Reading- 234.65; Conversation- 223.45). At post-2, the F0 decreased (Reading- 228.87; Conversation- 219.6), but not below the pre-therapy F0. Both maximum frequency and energy (Tables 2 and 3) followed a similar pattern (rise at post-1 and decrease at post-2, but not below pre), indicating maintenance of the increased range. Additionally, maximum frequency greatly increased from pre (318.4 Hz) to post-1 (697.5 Hz) and post-2 (622.54 Hz), indicating improvement in modulating her pitch in the higher frequencies.

1

	Pre	Post-1	Post-2	Norms
[illegible]	221.27	234.65	228.87	[illegible]
	Pre	Post-1	Post-2	
[illegible]	218.28	223.455	219.6	

<u>Tables 1-3:</u> These tables demonstrate pre-, post-1 and post-2 measures for mean habitual F0, min-max frequency range and min-max energy range.

<u>Frequency Range Norms:</u> Gelfer, 1989

<u>Intensity Range Norms:</u> Sulter, Schutte & Miller, 1995

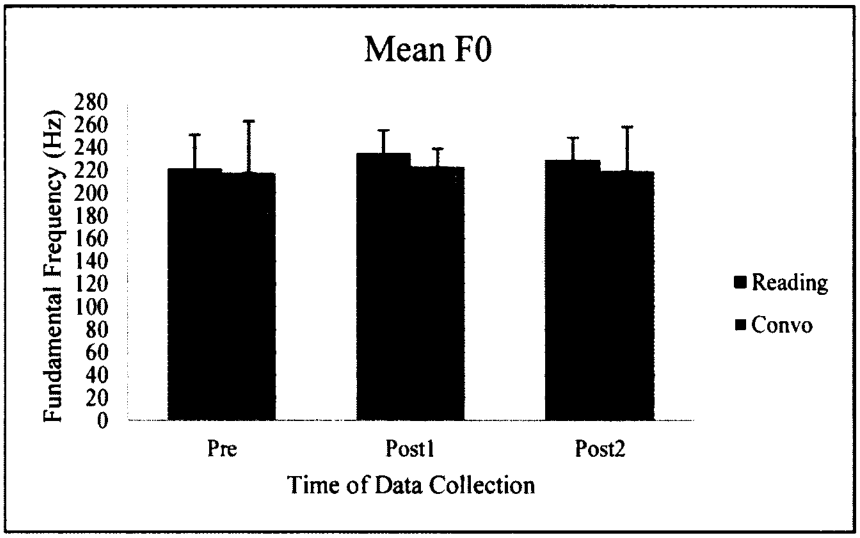
2

	Pre	Post-1	Post-2	Norms
Min F0 (Hz)	130.15	213.08	171.615	**Mean: 127.1**
Max F0 (Hz)	318.4	697.75	622.54	**Mean: 1102.2**

3

	Pre	Post-1	Post-2	
[illegible]	18.92	39.55	40.68	<u>Avg. M/F:</u> 49– 102 dB SPL
[illegible]	71.82	75.89	74.33	

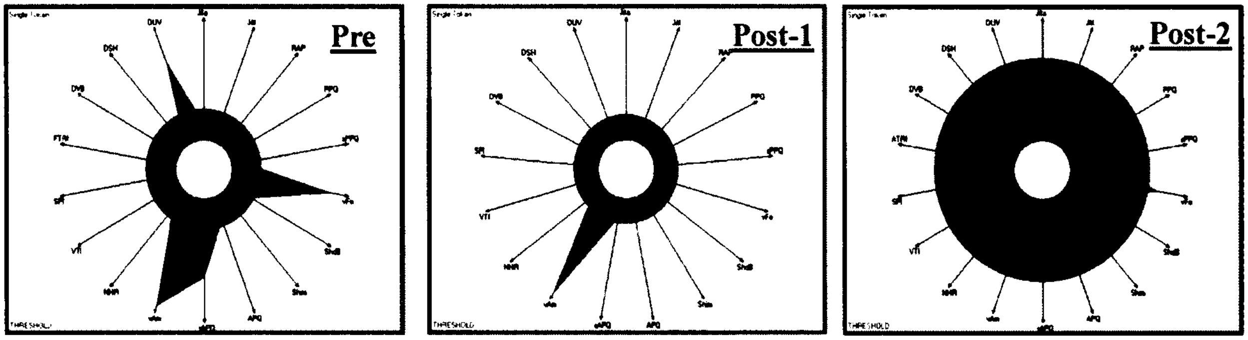
Graph 1: This graph depicts the change in fundamental frequency (Hz) in a 30-second conversation and reading (*Rainbow Passage*) across pre-, post-1 and post-2 data sessions. Standard deviation (SD) bars reflect SD assessed through the Multi-Speech module.



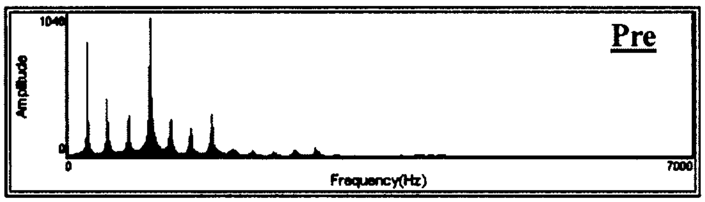
As shown in Table 4 (below), the perturbation measures assessed (i.e. jitter, shimmer, noise-to- harmonic ratio) decreased across pre-, post-1 and post-2, indicating an overall reduction of roughness, breathiness and noise in the voice signal, respectively. This overall reduction (evident in Figure 2) is accounted for in the education and treatment of diaphragmatic breathing and forward focus. As explained in the introduction, by using resonant voice, an individual will naturally use more energy in the higher harmonics. Viewing the Long-Term Average Spectrum (Images 4-6), increase in the higher harmonics is largely evident in post- treatment data sessions, indicating increased use of resonant voice.

Table 4: This table depicts the change in measures of jitter, shimmer and NHR across pre-, post-1 and post-2 data sessions based on Multi-Speech measures.

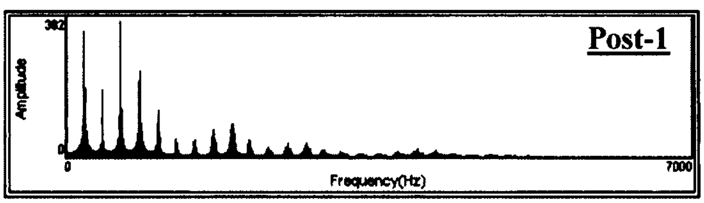
	Pre	Post-1	Post-2
[illegible]	0.855	0.69	0.54
[illegible]	3.81	2.08	1.29
NHR	0.13	0.12	0.11

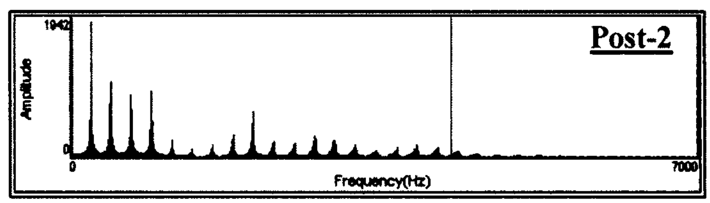


Figures 1-3: Picture graphs of perturbation measures acquired through *MDVP* analysis for pre-, post-1 and post-2. Red indicates abnormal measures, whereas green denotes the norm.



Figures 4-6: Long-Term Average Spectrum graphs of sustained phonation /a/ for pre-, post-1 and post-2.





To assess nasality, stimuli from *Simplified Nasometric Assessment Procedures- Revised* (*SNAP-R*) were used to obtain a nasalence percentage. Traditionally, the participant would put on the headset, making sure that the separation plate, which measures the amount of air emitted from the nasal cavity, is placed against his/her upper lip at a 90-degree angle. However, this participant wore glasses, therefore the headset was removed and the participant held the plate against her lip with frequent checks of positioning by the researcher. This was the only alteration to the *SNAP*-R protocol. While using this headset, the participant held different sounds /a, i, s, m/, produced different patterns of syllables (i.e. papapapapapa and mamamamama) and read three stories differing in the quantity of nasal consonants included.

Evidenced in the graph below (Table 4), nasalence measures fluctuated throughout the therapy period. In total, there are 11 non-nasal measures, 5 nasal measures, 2 sustained vowel measures, two stories and nasal sentences. 5/11 non-nasal measures, 4/5 nasal measures and 1/2 vowel measures decreased consistently across all three data sessions. 4/11 non-nasal measures and nasal sentences increased across the sessions. The remaining measures (2/11 non-nasal measures, 1/5 nasal measures and 1/2 vowel measures) fluctuated. However, only /sha/ increased in nasality at post-2 with the others decreased to below pre- therapy nasality. During reading tasks, nasalence patterns were also inconsistent. Overall, these results indicate that the participant maintained an overall decrease of nasality, but still demonstrated difficulty monitoring nasal resonance, resulting in mild-moderate hypernasality.

pa,pa,pa...	12	14	15	na,na,na...	43	36	35
ta,ta,ta...	8	8	16	mi,mi,mi...	66	59	37
ka,ka,ka,...	7	8	20	ni,ni,ni...	64	48	40
sa,sa,sa...	9	10	11	Prolonged /a/	40	41	38
ʃa, ʃa, ʃa...	14	10	19	Prolonged /i/	84	76	73
pi,pi,pi...	50	43	24	Prolonged /s/	49	0.35	0.35
ti,ti,ti...	49	47	28	Prolonged /m/	90	90	78
ki,ki,ki...	50	45	30	Zoo Passage	35	21	31
si,si,si...	52	56	32	Rainbow Passage	26	32	37
ʃi, ʃi, ʃi...	43	33	32	Nasal Sentences	42	42	56
ma,ma,ma...	47	55	34				

Table 5: This table depicts the change in nasalence measures across pre-, post-1 and post-2 data sessions.

Aerodynamic/Respiratory Measurements

To obtain the participant's maximum phonation time (MPT), which measures glottic efficiency, she held the sound /a/ for as long as she possibly could at a comfortable pitch and loudness without straining herself. To obtain s/z ratio, which indicates if there is a laryngeal pathology (0.8-1.4 normal; <0.8 pressed; >1.4 glottal incompetence), the participant held the sound /s/ for as long as she possibly could without straining herself. Subsequently, the participant was instructed to follow the same procedure for the sound /z/. Three trials of each were obtained to ensure the longest productions and the participant's best performance. To further assess the participant's respiratory control for speech, a breath group measure, in which the number of words per breath is counted, was obtained during counting and reading.

Table 6: This table contains pre-, post-1 and post-2 data for maximum phonation time (MPT) and s/z ratio, both measured in seconds. The best time out of three trials is listed.

Norms: Goy, Fernandes, Pichora-Fuller, & van Lieshout, 2013

Measure	**MPT**	**s/z ratio**	**Breath Group**
PRE	19.4s	0.74	6.93
POST-1	20.0s	0.87	8.18
POST-2	16.8	0.99	8.18
Norm	**15s**	**0.8-1.4**	**5**

MPT lengths fluctuated across the three data points, but all measures were within normal limits (Table 6). A slight increase in MPT was noted from pre- (19.4s) to post-1 (20.0s). Then, a decrease of 3 seconds was recorded (16.8s). During this post-2 task, the researcher observed that the participant was functionally using diaphragmatic breathing, but not forward resonance, which may have impacted her time. s/z ratio consistently increased. Pre- therapy, the participant's s/z ratio was below the normal range (0.74), indicating pressed laryngeal function. Post-1 (0.87) and Post-2 (0.99) increased achieving a near 1/1 ratio at one-month post- therapy, indicating maintenance of normal laryngeal function. While counting, the participant named the numbers 1-20 on one breath in each occasion (i.e. pre-, post-1 and post-2), demonstrating strain towards the end of the sequence. While reading, the participant read the following number of words per breath 6.93 (pre), 8.18 (post-1) and 8.18 (post-2). These measures indicate a maintained increase in airflow management during speech.

Auditory-Perceptual Ratings

Recorded voice samples (spontaneous speech) were assessed for voice quality using the *Consensus Auditory- Perceptual Evaluation of Voice (CAPE-V)* by two professionals with experience in voice treatment. All voice samples were coded and randomly assigned to a judge for rating. Voice samples were rated on overall severity, roughness, breathiness, strain, pitch, loudness and oral/nasal resonance. Each judge provided a score on a 100-point scale (a span from mildly to moderately to severely deviant), identifying consistent or intermittent voice quality. Scores from the two judges are listed below (Table 7).

Judges agreed on breathiness and loudness, scoring them normal (0) or near normal (1.5). In terms of pitch, judge 1 scored the participant normal across pre-, post-1 and post-2. Judge 2 scored the pitch mildly above normal across all three time points. Though the scores varied across judges, both agreed that the post-2 voice recording contained an increased level of strain compared to pre-therapy recording and then, decreased at post-2. Referring to roughness, judge 1 scored a gradual decrease (21 to 9.5 to 6) and judge 2 scored a maintained increase at post-1 and post-2 (6 to 11 to 11). The scores of "overall severity" varied between the judges. Judge 1 scored maintenance from pre- to post-1 and a decrease at post-2 (25 to 25 to 13). Judge 2 scored an increase in overall severity at the post- data collections (32 to 47 to 41).

Both judges added nasality as a quality, though they differed in the severity, indicating an impact on the listener. Judge 1 scored hypernasality as mild, noting a decrease at post-1 (19 to 11). Judge 2 scored hypernasality as moderate-to-severe, increasing to severe at post-1 and post- 2 (50 to 77 to 73). Additionally, judge 1 added oral resonance as a quality, noting its reduction across time (32 to 30 to 24). In sum, judge 1 noted overall reduction across the three data sessions in overall severity, roughness, breathiness, pitch, loudness and oral resonance. Additionally, she noted variability with strain and nasality. Judge 2 observed an increase at post-1 in the following measures: overall severity, roughness, strain, pitch and nasality. She scored a decrease in these measures, but not below the pre- therapy score, except for roughness which remained consistent. She noted consistency with breathiness and loudness across all three time periods.

Table 7: This table contains pre-, post-1 and post-2 data for *CAPE-V* scores from all judges. Each column per time point pertains to the same judge.

Overall Severity	25	32	25	47	13	41
Roughness	21	6	9.5	11	6	11
Breathiness	1.5	0	1.5	0	0	0
Strain	16	6	36	16	9.5	9
Pitch	0	5	0	11	0	8
Loudness	0	0	0	0	0	0
Nasality	19	59	11	77	16	73
Oral Resonance	32		30		24	

Using the recordings of conversation, the graduate student researcher, research assistant and four professionals with experience with aural rehabilitation/voice therapy judged the client's intelligibility using the *Gallaudet Intelligibility Rating Scale* (Table 8; Appendix I) and vocal quality using the *NTID Voice Evaluation* (Table 9). Judges, who did not know the topic of the conversation, rated randomized recordings using the *Gallaudet Intelligibility Rating Scale* (*Intelligibility*), a scale from 1-to-5, which ranges from "understood by the general public" to "cannot be understood". Pre-treatment scores averaged about a 4, indicating that "The client's speech is very difficult for the general public to understand. He/She is probably only understood by family and/or teachers." Both post- treatment scores averaged about a 3, indicating that "The public has some difficulty understanding the client initially, but the client can be understood once the listener adjusts." This indicates an overall slight improvement in the participant's general intelligibility, which is consistent with the scores from the *Fisher-Logemann Test of Articulation* (below).

Tables 8-9: This table contains pre-, post-1 and post-2 data for *NTID Voice Evaluation* and *Intelligibility* scores across six judges.

8

PRE	3	4	4	4	3	4	**4.33**
POST-1	3	4	4.5	4	3	3	**3.58**
POST-2	3	3	4	4	3	5	**3.67**

Table 9: NTID																					
Pitch Register and Control							**Avg.**							**Avg.**							**Avg.**
Pitch Register	4	4	5	5	5	5	**4.67**	4	5	5	5	5	5	**4.83**	4	5	5	5	5	5	**4.83**
Pitch Control	4	3.5	5	5	5	5	**4.58**	4	5	5	5	3	5	**4.5**	3	5	4	5	5	4	**4.33**
Prosody							**Avg.**							**Avg.**							**Avg.**
Rate	5	3	5	5	4	4	**4.33**	4	4	4	4	5	5	**4.33**	4	4	4	4	5	3	**4**
Stress and Inflection	4	3	4	4	5	4	**4**	3	5	4	4	4	4	**4**	4	5	4	4	5	3	**4.17**
Blending and Coarticulation	4	2	3	3	4	4	**3.33**	4	3	4	2	3	4	**3.33**	4	4	3	3	4	3	**3.5**
Respiratory Control							**Avg.**							**Avg.**							**Avg.**
Loudness	4	3	4	3	5	5	**4**		5	5	5	5	5	**5**		5	4	1	5	5	**4**
Loudness Control	3	3	3	4	5	3	**3.5**	3	5	3	5	3	5	**4**	3	5	4	2	5	3	**3.67**
Control of Air Expenditure	4	3	4	4	5	4	**4**	4	5	4	4	4	5	**4.33**	4	4	3	2	5	4	**3.67**
Breathiness	4	4	4	4	5	5	**4.33**	4	5	4	3	4	5	**4.17**	4	4	4	3	5	5	**4.17**
Resonance							**Avg.**							**Avg.**							**Avg.**
Nasal Resonance	4	3	4	3	4	4	**3.67**	4	3	4	2.5	3	4	**3.42**	4	4.5	3	3	4	3	**3.58**
Oral Resonance	3	2.5	4	4	4	4	**3.58**	3	4	4	3	3	5	**3.67**	3	4	3	5	4	4	**3.83**
Vocal Tension							**Avg.**							**Avg.**							**Avg.**
Tension/harshness	4	3	4	5	4	4	**4**	4	4	5	5	3	4	**4.17**	4	4	4	5	4	3	**4**

The *NTID Voice Evaluation* scores (above) were variable among judges, therefore averages were obtained. As mentioned, each item has a unique five-point scale, generally identifying normal to severe vocal quality. Consistent with the *CAPE-V* scores, pitch, breathiness and loudness were perceived to be normal or near normal. Qualities rated as a mild problem include: rate, stress and inflection, control of air expenditure and vocal tension. Scores for vocal tension are comparable to those for strain on the *CAPE-V*. Those scored as a moderate problem include: blending and coarticulation, nasal resonance and oral resonance. The difficulties with coarticulation are consistent with the errors from the *Fisher-Logemann* (below). For this participant, nasality has been a consistent problem throughout this study, including nasalence measures and the *CAPE-V*. Similarly, oral resonance received a mild-to-moderate score on the *CAPE-V*.

To measure the participant's speech intelligibility based on articulation, the *Fisher-Logemann Test of Articulation* (*FLTA*) was administered. The participant read a list of words and sentences. These recorded productions were analyzed by the graduate student researcher, identifying correct and incorrect articulation. As described in the introduction, we expect deaf individuals to have difficulty with the articulation of vowels (reduced articulatory space), plosives (increased air expense, inconsistent breath management) and nasals (increased nasality). We expected these sounds to change with treatment, specifically treatment on breathing and oral resonance/forward focus. However, when doing item analysis, as noted in Table 10, the participant did not demonstrate many errors in these sound types. Although articulation was not directly treated, as evident by her scores (Table 10), the participant's intelligibility with words progressively increased across time: 74% (pre), 81% (post-1) and 85% (post-2). A similar pattern is observed with sentences: 73% (pre), 81% (post-1) and 89% (post-2). This improvement in intelligibility is attributed to increased use of forward focus and adequate breath management, allowing for sounds and words to become clearer in connected speech. However, this assessment was scored in real time by the researcher. Therefore, familiarity of the listener to the participant's voice needs to be considered.

Table 10: This table contains percent accuracy for pre-, post-1 and post-2 data of the *FLTA*. The "Words" subtest score is averaged by the number of correct words over total words scored (107). The "Sentences" subtest score is averaged by the number of correct words over total words scored (100).

	Pre	**Post-1**	**Post-2**
Words	74%	81%	85%
Errors	f, v, th, s, z, sh, ʤ, ʧ, ʒ, sp, sl, sn, sk, fr, tr, dr, cr, gr, pl, gl, -l	f, v, th, ʤ, z, g, ng, st, sl, sk, sw, sm, fr, ʒ, te, cr, pl, fl, cl, gl	w, f, v, th, k, g, st, sl, sn, sk, fr, ch, ʤ
Sentences	73%	81%	89%
Errors	g, th, f, v, s, z, ʒ, ʤ, r, ch, w, h, ng, aw, oo, ai	g, k, th, v, z, sh, ʒ, ʤ, ch, ng, ei, oi	t, d, g, k, z, sh, ʤ, oi

Functional Measurements

The functional impact of the participant's voice on everyday life was measured using the *Voice-Related Quality of Life (V-RQOL)*. The *V-RQOL* contains 10 questions that identifies the voice severity from the perception of the individual. The participant rated each statement on a five-point scale, where "1 = none, not a problem," "2 = a small amount," "3 = a moderate (medium) amount," "4 = a lot," and "5 = problem is as 'bad as it can be'." All scores are added to form the raw score, which is changed to a converted score. The converted score is used to identify the severity of the functional impact of the voice disorder. The lower the score indicates the greater the severity. Table 11 (below) lists the participant's scores, demonstrating an overall reduction of functional impact, which suggests self-perceived improvement. Pre-therapy, the participant's score (50) was on the lower end of moderate, indicating a significant impact on her life. During the last week of therapy (post-1), the participant scored on the upper end of moderate (72.5), describing it no longer impacted her life as much, but she still faced challenges with using her voice. One month post- therapy (post-2), the participant's score (80) indicated a mild impact, demonstrating continued functional improvement in her everyday life. Given her scores, MRVT is proven to have a positive improvement on the effect of voice on participant's life.

Table 11: This table contains pre-, post-1 and post-2 data for VR-QOL, as well as their severity correlate

	Converted Score	**Severity**
Pre	50	Moderate
Post-1	72.5	Moderate
Post-2	80	Mild

Reliability

To ensure reliability across measures, all equipment was calibrated before each data collection session. Additionally, the conditions in the room were near exact each session. All measures were recorded using the described methods above for pre-, post-1 and post-2 sessions.

Unfortunately, for many of the measures only one sample was collected (i.e. one reading of the rainbow passage) per session. This does not allow us to account for variability in the day and time during which the samples were collected.

Intrajudge Reliability

To ensure intrajudge reliability, the graduate student researcher re-obtained three measures from each data collection session (i.e. pre-, post-1 and post-2) to verify their accuracy. All measures were determined to be valid (100% identical to the original measures obtained).

Table 12: This table contains pre-, post-1 and post-2 data for *MDVP* and conversation sample, scored by both the researcher at the data collection time and three months later during reliability testing.

	Pre	Post-1	Post-2	Pre	Post-1	Post-2
MDVP						
Jitter	0.724	0.69	0.54	0.724	0.69	0.54
Shimmer	3.117	2.08	1.294	3.117	2.08	1.294
NHR	0.121	0.122	0.119	0.121	0.122	0.119
Conversation Sample						
Mean F0	218.28	223.45	219.6	218.28	223.45	219.6

Interjudge Reliability

Interjudge reliability in this study was accounted for the *CAPE-V, NTID Voice Evaluation* and the *Gallaudet Intelligibility Rating Scale.* Scores are listed in Tables 7-9 above. While analyzing the scoring of the *Intelligibility Scale*, only two of six judges agreed on scores across pre, post-1 and post-2. Scores of the *NTID Voice Evaluation* were also variable with no two judges rating identically. Judges commented that the recorded samples were too short, which may have resulted in abrupt scoring. For these reasons, as mentioned above, averages of the scores were obtained for analysis.

To ensure interjudge reliability throughout the study, scores for acoustic measures were reobtained by the research assistant. Measures are listed below (Table 13):

Table 13: This table contains pre-, post-1 and post-2 data for *MDVP* and conversation sample, scored by both the researcher and research assistant three months later during reliability testing.

	Pre	Post-1	Post-2	Pre	Post-1	Post-2
MDVP						
Jitter	0.724	0.69	0.54	0.644	0.999	0.54
Shimmer	3.117	2.08	1.294	1.894	2.128	1.294
NHR	0.121	0.122	0.119	0.11	0.114	0.119
Conversation Sample						
Mean F0	218.28	223.45	219.6	210.18	220.64	221.08

Both the researcher and research assistant achieved identical scores for perturbation measures (*MDVP*) during the post-2 session. Perturbation measures were within 0.01 to 2.7 units of each other. Conversational frequencies were within 2-8 Hz of each other. Some variability can be accounted for by differences in selection of tokens for analysis.

To further assess interjudge reliability, Pearson's correlation (Evans, 1996), a statistical measure of the strength of a linear relationship, was obtained for measures with enough data points (Table 14). The strength of the correlation is identified using the absolute value of *r* (.00-.19 is very weak; .20-.39 is weak; .40-.59 is moderate; .60-.79 is strong; .80-1.0 is very strong). This data confirmed previous suspicions of large variability for *NTID Voice Evaluation* scores, which was not a surprise considering the judges' comments about the length of the recordings. However, although the *CAPE-V* scores seemed vastly different, the correlation value (0.48) indicated judges' scores were moderately close to each other. Lastly, the reobtained *MDVP* measures resulted in a very strong correlation between those of the researcher and the research assistant, despite slight variations. In sum, NTID scores should be evaluated with caution, but *CAPE-V* and *MDVP* scores are considered accurate and can be interpreted as listed.

Assessment Measure	*R*	Strength of Correlation
CAPE-V (Table 7)	0.48	Moderate
NTID Voice Evaluation (Table 9)	0.15	Very Weak
Reobtained *MDVP* data (Table 13)	0.99	Very Strong

Table 14: This table contains Pearson's correlation values for *CAPE-V, NTID Voice Evaluation*, and reobtained *MDVP* values.

Conclusion

The measurements obtained in this study (i.e. acoustic, aerodynamic/respiratory, auditory-perceptual and functional) refute the original null hypothesis, noting an overall improvement in breath control, voice quality and speech intelligibility. Maintenance of the aforementioned characteristics was evident one-month post MRVT. Participant's fundamental frequency was within the norm across all three data collection times. Frequency and energy ranges largely increased, demonstrating an improved ability to modulate pitch and loudness. Perturbation measures indicate an overall reduction of roughness, breathiness and noise in the voice signal. Long-Term Average Spectrum analysis shows an increase in the higher harmonics, indicating increased use of resonant voice. Nasalence results demonstrate that the participant maintained a large decrease in nasality, but still struggled to monitor nasal resonance. Aerodynamic/respiratory measures indicate a maintained increase in airflow management during speech.

Intelligibility measures show improvement in the participant's general intelligibility and articulation. The latter is attributed to increased use of forward focus and adequate breath management, allowing for sounds and words to become clearer in connected speech. The functional measurements used in this study indicate a grand impact on the participant's life. The participant shared that she felt more efficient communicating with her voice and that she was able to notice periods of pharyngeal resonance and correct it. She also described focusing on her diaphragmatic breathing and receiving compliments from her family and friends on the improvement of her voice. Overall, the results of this study indicate the effectiveness of modified resonant voice therapy used with a Deaf/hard of hearing female.

Discussion

Throughout this study, this researcher consistently thought of considerations for future studies. The first alteration to the original protocol arose when selecting a participant based on our stringent criteria. Our requirements and assessments were intended for an individual with good listening skills, considering that naturally voice therapy instructions are a spoken language. However, this researcher was fluent in American Sign Language (ASL) and valuing the participant's motivation and clinical need allowed for flexible eligibility criteria. This dilemma brought up an important issue in today's growing field of speech-language pathology, in which therapists are required to provide quality therapy in the language most comfortable to the client/patient. Though the participant for this study was comfortable using her voice, she did not have the receptive skills necessary to receive therapy instructions in spoken English, requiring modification. This is a vital consideration for future studies to include researchers and clinicians knowledgeable of ASL and Deaf culture.

Bearing in mind her difficulties with listening and ethical concerns, the graduate student researcher also provided aural rehabilitation (AR) treatment, instead of selectively training voice and allowing regression in these areas of need. The AR sessions were held the morning of MRVT training for 60 minutes with a 15-30-minute break before continuing with 90-minutes of voice therapy. Unfortunately, due to time constraints of the researcher and participant, this was the only schedule that could be arranged. Though it was invaluable for the participant, three hours of therapy allows for concern of fatigue. This gives way to discussion of the length of the session. Ideally, a voice therapy protocol that includes so many aspects (i.e. stretching, breathing and voice training) would also be intense and multiple times per week. This may or may not be feasible based on the availability of the clinician and the client. Additionally, particularly for the deaf/HoH population, a conjunction of AR and voice must be considered. Work on listening practice was beneficial to the participant as it improved her access to auditory feedback. The effect of the listening training on her ability to use auditory feedback during the voice training and whether it aided in the improvement of her voice was not directly assessed. However, it may have played a role and should be addressed in future studies. Additionally, further studies should consider two one-hour sessions a week with one focusing on AR (e.g. cochlear implant, hearing aid or both) and the other on voice.

Additionally, the allowance of previous speech therapy and knowledge of Standard American English pronunciation should be considered. As indicated in the introduction, individuals of this population may receive speech therapy, focusing on aural rehabilitation and articulation/pronunciation. This may not necessarily influence the results of this voice therapy. However, the treatment of articulation and pronunciation errors may contribute to overall improvements in intelligibility. This may compromise the intelligibility measures used in this study because this type of participant does not necessarily represent the "norm" of the deaf/HOH population (i.e. expected articulation errors). Until further research is completed including participants truly representing the deaf/HOH population, these contributing factors affect the generalizability of this study.

Despite a well-structured protocol, success in treatment is determined by carryover to daily activities, which is brought on by consistent practice. However, environments and life situations can dictate when a client/patient practices and for how long. The participant in this study was a graduate student and held a position of employment. These two areas of her life took up the majority of her time, which resulted in inconsistent practice of the skills she learned in therapy. Additionally, the participant disclosed her diagnosis of an anxiety disorder. This may have impacted her performance during assessments, knowing that their results would determine her improvement or lack thereof. Culturally, this may have impacted her as well, as she only used her voice with other hearing people and may have felt self-conscious, especially during the initial phase of treatment.

To account for these extraneous factors, certain measures should be completed every session. Simple probe measures, such as fundamental frequency and maximum phonation time, will allow the researcher to establish a true trend or pattern. This removes the possibility that measures during post-data sessions were resultant of the participant's ability or inability in that specific moment, as opposed to his/her general ability. Though results of this study are promising, as this was the first study of its kind, more research needs to be completed, including considerations for cultural implications, aural rehabilitation needs and availability for practice of skills learned. Lastly, future studies should consider additional follow-up sessions to ensure a longer period of maintenance.

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Appendix A: Stretches Defined

1. Shoulders
   - Touch elbows in back
   - Stretch arms in front
2. Neck
   - Drop head down slowly in fractions
   - Rotate head up until right on top of the neck, feel neck muscles
   - Lift head away from the neck
   - Tilt ear to shoulder and stretch out opposite arm
3. Jaw
   - Massage the masseters, pull down and forward
   - Push thumbs into masseters with slightly open mouth, pull down and forward
4. Floor of Mouth
   - Press thumb into floor of mouth
   - First make no sound, then produce a vowel with no tongue stiffness
5. Lip Trill
   - No voice
   - Continuous voice
   - Alternating off/on
6. Tongue
   - Tongue trill
     - No voice
     - Continuous voice
     - Alternating off/on
   - Protrude tongue out and down, hands behind back
7. Pharynx
   - Yawn
   - Yawn-sigh with a voice

Appendix B: MRVT Protocol

1. *MRVT Hierarchy Stage 1* (Voiced)

   Step 1. *Ma-ma-ma-ma*..(normal pitch).

   Step 2. Repeat with varying intensity (soft-loud-soft).

   Step 3. Brief instruction (Appendix C) on intonation and its use in speech, followed by practice exercises (Appendix D).

   Ma-ma-ma-ma… as speech with the intonation of spoken phrases.

   Step 4. Chant the following voiced phrases on the note; totally exaggerate articulation and forward resonance.

   a. Mary made me mad.

   b. My mother made money.

   c. My merry mom made money.

   d. My mom may marry Marv.

   e. My merry mom may marry Marv.

   f. Marv made my mother merry.

   Step 5. Brief instruction (Appendix E) on stress and its use in speech, followed by practice exercises (Appendix F). Over-inflect these same phrases as speech.

2. *MRVT Hierarchy Stage 2* (Voiced-Voiceless Contrasts)

   Step 1. *Ma-ma-pa-pa…* normal pitch.

   Step 2. *Ma-ma-pa-pa…* combine soft-loud-soft.

   Step 3. *Ma-ma-pa-pa…* as speech.

   Step 4. Chant the following voiced/voiceless phrases on the note.

   a. Mom may put Paul on the moon.

   b. Mom told Tom copy my manner?

   c. My manner made Pete and Paul mad.

   d. Mom moved Polly's movie to 10.

   e. My movie made Tim and Tom sad.

Step 5. Over-inflect these same phrases as speech. Review Exercises: Intonation and stress (Appendix G).

3. *MRVT Hierarchy Stage 3* (Any Phrase)

Step 1. Chant 5- to 7-syllable phrases on the note.

a. All the girls were laughing.
b. Get there before they close.
c. Did you hear what she said?
d. Come in and close the door.
e. Are you going tonight?
f. Put everything away.
g. Come whenever you can.
h. We heard that yesterday.
i. The player broke his leg.
j. The children went swimming.

Step 2. Over-inflect/exaggerate the same phrases with an extreme forward focus.

Step 3. Repeat the same phrases in a more natural forward speech/voice production, adding focus to the flow of speech (discussing pauses).

4. *MRVT Hierarchy Stage 4* (Paragraph Reading)

Step 1. Read a paragraph written by the participant about any topic (e.g. personal life, hobby, education, etc.) with phrase markers; separate each phrase only by the natural inhalation of air.

Step 2. Repeat with exaggerated focus/intonation/stress.

Step 3. Repeat with a more normal speech/voice production.

Step 4. Repeat the above with paragraphs without phrase markers.

5. *MRVT Hierarchy Stage 5* (Controlled Conversation)

* Practice forward speech placement, intonation and stress in conversation.

6. *MRVT Hierarchy Stage 6* (Environmental Manipulations)

   * Simulate actual speaking environments consistent with the patient's needs (e.g. white noise, restaurant noise, competing speakers, etc.).

7. *MRVT Hierarchy Stage 7* (Emotional Manipulations)

   Challenge the use of resonant voice by animating the discussion with topics that elicit laughter, loud talking, anger, indignation, and other emotions. This stage is introduced using a created dialogue explicitly stating the expected emotions (Appendix H). Then, the transition is made to more natural conversation.

Appendix C: Intonation Lesson

In English we have four kinds of intonation patterns: (1) falling, (2) rising, (3) non-final, and (4) wavering intonation.

1. **Falling Intonation**
   a. When we lower our voice at the end of a sentence. This usually happens in statements and in wh- questions.
      i. ***Statements***
         1. Nice to meet you.
         2. I'm going to the movies.
         3. Have a great day.
      ii. ***Questions***
         1. What's your name?
         2. Where does he live?
         3. Why did you do that?
         4. How can I open this?
2. **Rising Intonation**
   a. When we raise the pitch of our voice at the end of a sentence.
      i. **yes/no questions**
         1. Are you American?
         2. Does she know about this?
         3. Can you lend me a pencil?
         4. Is the movie good?
         5. Are we leaving soon?
      ii. **Special Expressions:**
         1. Excuse me?
         2. Really?
3. **Non-final intonation**
   a. The pitch rises and falls within the sentence. This type of intonation is used with unfinished thoughts, introductory phrases, and series of words, as well as when we express choices.
      i. ***Unfinished thoughts***
         1. She bought the magazine, but she didn't read it.
         2. When I finished high school, I got a job.
         3. If I study hard, I'll pass the test.
         4. I'm going outside, for some fresh air.

      ii. ***Introductory Phrases***
         1. As a matter of fact, I do know where she lives.
         2. As far as I'm concerned, she was not suitable for that position.

3. Actually, the movie was pretty good.
4. In my opinion, this car is way too expensive.
5. If you don't mind, I'm going to bed.
6. By the way, have you read that book I lent you?

iii. ***Series of Words***

1. I like playing football, tennis, basketball and volleyball.

iv. ***Expressing Choices***

1. Do you want to stay home or go to the movies?
2. Are you going to travel in March or April?
3. Would you like a coke or some juice?

4. Wavering Intonation

a. Used when we express specific emotions or attitudes (anger, sarcasm, hesitation, fear, amazement) within a word.

i. **Example 1**

1. You did? (curious)
2. You did? (very surprised)
3. You did? (disappointed)
4. You did? (angry)
5. You did. (in agreement)

ii. **Example 2**

1. Thanks a lot. (normal)
2. Thanks a lot. (very happy)
3. Thanks a lot. (sarcastic)

iii. **Example 3**

1. Okay. (normal)
2. Okay. (hesitant or unwilling)
3. Okay! (very excited)
4. Okay! (frustrated and angry)

iv. **Example 4**

1. No! (angry)
2. No? (surprised)
3. No… (hesitant)
4. No. (sarcastic)

Appendix D: Intonation Exercises

1. Would you like water or juice?
2. Nice to meet you.
3. I'm going to the movies.
4. What's your name?
5. Does she know about this?
6. Is the movie good?
7. Are we leaving soon?
8. Actually, the movie was pretty good.
9. Excuse me?
10. I'm going outside, for some fresh air.
11. I like money, movies, mom and mashed potatoes

Appendix E: Sentence Stress Lesson

Stress

Stress is the relative emphasis that may be given to certain syllables in a word, or to certain words in a phrase or sentence.

➔ Why is it important?
- If you put the stress in the wrong part of the word, you can be misunderstood.
- Depending on the part of the sentence you stress, you can change the meaning of what you intend to say.

❖ **Word stress in sentences**
- Part of pronunciation
  - Example: STEAMboat vs. steamBOAT
- Use it to differentiate between words that are similar
  - Example: REcord vs. reCORD
- Combination of the two
  - Example: PHOtograph, phoTOgrapher, photoGRAPHIC

➔ **Rule #1:**
- We stress vowel sounds, not consonant sounds.
- Make the stressed part:
  - Louder
  - Longer
  - At a higher pitch

❖ **Phrase/Sentence Stress**
- Stress words in sentences that are **important to the meaning** of the sentence. They carry the **content** of the sentence.

→**Content Words**
- main verbs
- nouns
- adjectives
- adverbs
- negatives
- wh-words
- interjections

Examples:
- I HAVE to GO to SCHOOL.
- I WANT my BROTHER to WIN.
- It's NOT the BEST IDEA.

→**Function Words**: Your speech is not just about stressing, but also requires **de-stressing, weakening.** In English we de-stress the non-essential, non-content words in a sentence, called the **function words**.
- articles (a, an, the)
- conjunctions (and, but, if)
- prepositions (in, on, next to, behind)
- pronouns (I, me, you, he, she, it, they)
- auxiliary verbs [be (am, are, is, was, were, being, been), can, could, dare, do (does, did), have (has, had, having), may, might, must, need, ought, shall, should, will, would]

Appendix F: Sentence Stress Exercises

1. I will run all the way home.
2. She can play the flute.
3. Springtime is my favorite season.
4. Have you ever had iced coffee?
5. Why are you so excited?

1. I will run all the way home.
    a. You'll walk all the way home?
    b. You'll run all the way to school?
    c. You'll walk half-way home?
    d. John will run all the way home?
    e. John will walk all the way home?
2. She can play the flute.
    a. She can play the piano?
    b. She can't play the flute?
    c. She can hold the flute?
    d. Rachel can play the flute?
    e. Rachel can play the piano?
3. Springtime is my favorite season.
    a. Summertime is your favorite season?
    b. Springtime is your favorite sport?
    c. You don't like springtime?
4. Have you ever had iced coffee?
    a. Yeah, I've had iced tea.
    b. Yeah, I've had hot coffee.
5. Why are you so excited?
    a. Why am I mad?
    b. Bob's excited because it's his birthday.

Appendix G: Intonation Dialogue without Emotion

A: Sir! Sir! I can't find my car!

B: Where is it?

A: I don't know! I left it with you!

B: Well, what do you want me to do about it?

A: I want you to find my car!

B: All right. Calm down. Let me help this customer, then I'll help you.

A: Actually, you need to help me now!

B: People are always wanting me to find their lost cars, take out the trash and make my bed. Do it yourself! You hear that mom?!

A: Excuse me? Where is your boss or another coworker?

B: As a matter of fact, they're not here.

A: You don't know anything!

B: Are you going to call the police?

A: As a matter of fact, I am!

B: Oh, good! There is this crazy guy yelling about his car, that's right over there.

Appendix H: Structured Dialogue with Emotions

A (Shock): Waiter! Waiter! There's a *fly* in my soup!

B (Confused): A *fly* in your *soup*?

A (Scared): Yes! A *Fly*!

B (Annoyed): What's it *doing* there?

A (Surprised): I have *no* idea!

B (Sarcastic): Well, what do you want *me* to do about it?

A (Upset): I want *you* to come and *get it out*.

B (Hesitant): All right. Calm down. In a *few* minutes, I'll come get it.

A (Frustrated): *Actually*, I want you to *get it out now*!

B (Annoyed): *People* are always wanting me to remove *flies, roaches and worms* from their food. Do it *yourself!*

A (Angry): *Really*? Are *you* going to do it or should *I* call your boss?

B (Calm): As a matter of fact, I don't care.

A (Sarcastic): *Thanks* for your help!

B (Curious): Are you going to leave me a tip?

A (Shocked): *Excuse* me? **Storms off**

B (Normal): Have a great day.

Appendix I

GALLAUDET INTELLIGIBILITY RATING SCALE

CLIENT NAME:______________________________

CLINICIAN: ______________________________

1. The client is easily understood by the general public. He/She has no obvious voice and/or articulation errors.

2. The client is easily understood by the general public, but he/she has obvious voice and/or articulation errors.

3. "Good deaf speech." The general public has some difficulty understanding the client initially, but the client can be understood once the listener adjusts to his/her "deaf speech".

4. The client's speech is very difficult for the general public to understand. He/She is probably only understood by family and/or teachers.

5. The client's speech cannot be understood.

Conditions:

- ☐ Known Context
- ☐ Unknown Context
- ☐ Familiar Listener
- ☐ Unfamiliar Listener

Comments:

____
____
____
____

Intelligibility Rating: __________

Appendix J: Speech and Voice Characteristics Matched with Citations

Deaf/ Hard of Hearing Speech/Voice Characteristics	**Citation**
Pharyngeal focus (cul-de-sac)	Subtelny, Whitehead & Samar, 1992; Calvert, 1962; Boone, 1971; Finkeltstein et. al., 1993
Pharyngeal focus caused by a retracted tongue, which reduces the size and modifies the shape of the pharynx	Subtelny, Whitehead & Samar, 1992; Boone 1966, 1967
Neutralized tongue position in deaf women	Subtelny, Whitehead & Samar, 1992; Li, 1980; Subtelny, Li, Whitehead, & Subtelny, 1989
Because of this tongue position, second formant lowered	Subtelny, Whitehead & Samar, 1992; Boone, 1977; Higgins & Carney, 1994;
Prosody and voice	Lenden & Flipsen, 2007; Boone, 1966, 1971; Allen & Arndorfer, 2000; Calvert, 1962; Calvert & Silverman, 1983……………..; Higgins & Carney, 1994
Flow of speech: produce words separately instead of continuous	Lenden & Flipsen, 2007; Boone 1966
Lesser coarticulation	Lenden & Flipsen, 2007; Okalidou & Harris, 1999; Subtelny et al., 1980
Slower rate of speech	Lenden & Flipsen, 2007; Hood & Dixon, 1969; Parkhurst & Levitt, 1978; Boone, 1966
Inappropriate stress patterns	Lenden & Flipsen, 2007; Hargrove, 1997; Subtelny et al., 1980
Don't vary pitch (monotone)	Lenden & Flipsen, 2007; Nickerson, 1975
Loudness – don't speak loud enough	Lenden & Flipsen, 2007; Smith, 1975; Calvert & Silverman, 1983
Monotonality	Lenden & Flipsen, 2007; Nickerson, 1975; Monsen, 1978; Parkhurst & Levitt, 1978; Smith, 1975; Subtelny et al., 1980
Abnormal pitch and restricted pitch range	Lenden & Flipsen, 2007; Boone, 1966; Stathopolous et al., 1986
Degree of hearing loss may play a role in atypical pitch	Lenden & Flipsen, 2007; McGarr & Osberger, 1978
Laryngeal quality: tense, flat, breathy, harsh, throaty	Lenden & Flipsen, 2007; Calvert, 1962
Greater reliance on tactile feedback → constriction and tension → harshness Excessive force on plosives → breathy	Lenden & Flipsen, 2007; Calvert, 1962; Calvert & Silverman, 1983;
Poor adduction → breathy Extra strain from over adduction → tense/strained vocal quality	Lenden & Flipsen, 2007; Subtelny et al. (1980) Higgins & Carney, 1994
Abnormal nasalance (hyper)	Lenden & Flipsen, 2007; Fletcher et al., 1999; Colton & Cooker, 1968; Fletcher & Daly, 1976; Gilbert, 1975; Ysunza & Vazquez, 1993
→ Inefficient control of VP valve as a consequence of absent auditory feedback	Nguyen, Allegro, Low, Papsin, & Campisi, 2008; Ysunza & Vazquez, 1993;
To compensate for auditory feedback they use increased reliance on tactile feedback for speech motor control	Higgins & Carney, 1994
Increased fundamental frequency	Higgins & Carney, 1994; Leder, Spitzer, & Kirchner, 1987; Monsen, 1983; Perkell et al., 1992; Titze, 1989

Appendix J: Literature Review

Study	Purpose	Participants	Methods	Results	Comments/ Conclusion
Lenden, J. M., & Flipsen Jr., P. (2007). Prosody and voice characteristics of children with cochlear implants. *Journal of Communication Disorders, 40*(1), 66-81. doi:10.1016/j.jcomdis.2006.04.004 →Level III	"To analyze the prosody and voice characteristics of conversational speech obtained from prelingual severe to profound deaf children who have multichannel CIs" Questions: 1.Is there evidence in the conversational speech of children fitted with cochlear implants of difficulty with any of the suprasegmentals measured on the PVSP? 2.Are there any developmental trends on any of the suprasegmentals measures on the PVSP relative to CA, HA, or PIA?	• Prelingually deaf • Multichannel CI by age 3 • CI for at least 18 mos. • Only use spoken language • Receptive PPVT within 2 SD • 6 kids (5 girls, 1 boy) • Ages 3;9-6;2 • No other da • All had and continued with individual TX during study	• Conversational speech samples were obtained every three months • Length: 12-21 months • Samples: 5-8 o Total= 40 • Samples were obtained during a larger session. First one included the PPVT. Ranged from 60-90 mins. • Two grad students plus parent/clinician in room • Variety of topics and toys provided • Storytelling avoided • 90 different words targeted • At least 15 minutes of conversation • PVSP Coding • Reliability Test	• Out of all the characteristics analyzed, stress and resonance seemed to be the most problematic • Laryngeal quality significantly correlated with CA, PIA, and HA • Participant 2 is an outlier • Stress significantly correlated with HA and PIA • Resonance significantly correlated with PIA • Looking at the other characteristics, some results were stable and others were improving	• Phrasing and pitch not a significant problem • Resonance and stress an issue • Overall, prosody and voice characteristics are much less of an issue than before • Laryngeal quality improves over time • Stress and resonance correlated with auditory experience, and so should be the focus of TX • PVSP coding may be helpful in the clinic
Chen, S. H., Hsiao, T., Hsiao, L., Chung, Y. & Chiang, S. (2006). Outcome of Resonant Voice Therapy for Female Teachers with Voice Disorders: Perceptual, Physiological, Acoustic, Aerodynamic, and Functional Measurements. *Journal of Voice, 21*(4), 415-425.	"To investigate resonant voice therapy outcome from perceptual, physiological, acoustic, aerodynamic, and functional aspects for female teachers with voice disorders" Wanted to do this because it hadn't been used/tested with teachers. Question: 1.Is resonant voice therapy an effective treatment for female school teachers in reducing voice	• 24 female teachers o have at least one voice symptom o voice symptoms frequently appear • ages 26-56 • Groups of 4	• All received LMRVT • 90 mins/session per week for 8w • SLPs- 4hr training • Auditory Perceptual: o Voice: breathiness, roughness, strain, monotone, resonance, hard attack, glottal fry • Videostroboscopy o rigid o VF pathology, vibration, closure	• Outcomes measured from perceptual, videostroboscopy, acoustic measurements, aerodynamic and functional • REDUCED: severity of roughness, strain, monotone, resonance, hard attack, and glottal fry vocal fold pathology, mucosal wave, amplitude, VF closure, phonation threshold pressure,	• RVT is effective for school teachers → Not randomized; no control → only applies to hyperfunctional voice-disordered patients → used questionnaire to get data from patients, not enough info → not enough phonation measures → no follow-up to ensure maintenance

doi:10.1016/j.jvoice.2006.02.001 -->Level III	problems, enhancing vocal resonance and increasing vocal efficiency, which can therefore increase communication quality? <u>Hypothesis:</u> "Resonant voice therapy is hypothesized to reduce voice problems, enhance vocal resonance and increase vocal efficiency, which can therefore increase communication quality"		o rated: laryngeal pathology, mucosal wave, amplitude, VF closure, phase asymmetry • Acoustic o Real time pitch: F0, intensity, max freq, max intensity o MDVP: perturbation • Aerodynamic o laryngeal valving efficiency and phonation effort • Functional o VHI o Taiwan version	score of physical scale in VHI • INCREASED: speaking F0, max freq, max intensity • NO SIG CHANGE: perturbation and breathiness	
Salvador, K. & Strohauer, K. (2010). From the Voice Studio to the Speech Clinic: Perspectives on Resonance and Resonant Voice Therapy. *Journal of Singing, 67*(1), 19-25. → Level VI	Use literature to demonstrate RVT as an effective preventative training for voice disorders in professional voice users and to describe some areas where voice teachers and SLPs should collaborate <u>Question:</u> Is resonant voice therapy effective in preventing voice disorders in professional voice users?		• Description of RVT • Lit Review describing the prevalence of voice disorders in professional voice users		• Professional voice users are at risk for voice disorders • RVT should be provided by voice teachers (and not SLPs) as a preventative measure • But a lot of voice teachers don't know this is an option, so there needs to be more education and collaboration between voice teachers and SLPs
Seligmann, E. (2005). *Lessac-Madsen Resonant Voice Therapy (LMRVT): A brief Description and Review.* Denver, CO: Summer Vocology Institute.	To give an overview of LMRVT, evaluate its techniques and discuss its effectiveness.				LMRVT addressed vocal hygiene, voice modification and post-therapy self-care. Limited studies have been done to show its effectiveness.

Casper, J. K., & Murry, T. (2000). Voice therapy methods in dysphonia. Otolaryngologic Clinics of North America, 33(5), 983-1002.	To give a quick description of RVT.				RVT is easy voice with vibrotactile feedback. Treatment lasts for 8-12 sessions. Success of RVT depends on the client's ability to generalize the use of resonant voice.

Verdolini, K., Druker D. G., Palmer, P. M. & Samawi, H. (1998). Laryngeal Adduction in Resonant Voice. *Journal of Voice, 12*(3), 315-327.
 	
→ Level III
	"To further pursue the 'resonant voice' phenomenon as a possible example of a voice type involving barely ab/adducted VFs"
	
	<u>Questions:</u>
	1. Will subjects with nodules and subjects with healthy larynges produce "resonant voice" with a similar laryngeal configuration?
	2. Can the electroglotographic closed quotient (EGG CQ) be used to noninvasively distinguish resonant from other voice types?
		• 12 adult singers/actors
		• 6 with healthy larynges and 6 with nodules (3 males and 3 females in each group)
		• 20-39yrs
		• Subjects with nodules had completed previous voice therapy
		• 6-15 years of voice training
			• judges who were blind to the conditions rated adduction while watching a short videoscopic clip
			• laryngeal adduction was also measured using EGG CQ
			• they were seated throughout the trials in a quiet room
			• F0 was calculated first (Count 1-5 hold 3)
			• then training (VFEs)
			• give examples for voice types
			• Experimental tokens: told to repeat anything they heard as an invalid voice type. experimenter and judge were allowed to ask for repetitions
			• videoscopic images collected using a rigid endoscope
			  ○ judged
			• statistical analysis
				• subjects with healthy larynges and those with nodules showed similar results for laryngeal adduction
				• CQs for subjects with nodules were lower than CQs for healthy subjects
				• greatest CQs for pressed voice → CQs for resonant and oral voice → CQs for breathy voice
					• Question 1: Yes and it's important because the laryngeal posture seems to be sufficient for EV-Max. No data on clinical effectiveness on RVT with hyper/hypoadducted patients
					  ○ Two questions arise: what is the potential therapeutic utility of training resonant voice? Why not simply train normal voice? What is the difference between resonant and normal voice?
					  ○ → depends on how the person's normal voice is produced. Similar VF posture in this study may be because of training
					• Question 2: Use of CQ's is limited and not practical for clinical situations
					• These results need to be assessed for generalizability to non-singers/non-actors

Yiu, E. M. L., Chen, F. C., Lo, G., & Pang, G. (2012). Vibratory and perceptual measurement of resonant voice. Journal of Voice, 26(5), 675-e13.	<u>Purpose/Questions:</u> 1. Is there a correlation between the magnitude of auditory-perceptual judgement of resonant voice and the physical vibration in the facial bone in healthy normal subjects?	• 36 healthy normal subjects: 18 male, 18 female • 20-33yrs • native Cantonese speakers with no previous singing	• Subjects produced 3 types of phonations: resonant, habitual non-resonant, strained in the same order • 3 piezoelectric accelometers used to measure the vibrations in the nasal bridge	• significant correlations were found between the physical bone vibration and the auditory-perceptual rating of resonant voice at the nasal bridge BUT correlation of the normalized nasal bridge	• measures from the piezoelectric accelerometer verify training RV by feeling the vibration at the nasal bridge • Using nasal hums/words are also effective for the feelings

→ Level III	2.Will the use of resonant voice increase the magnitude of facial bone vibration in comparison to habitual voice? <u>Hypothesis:</u> 1. Facial bone vibration will correlate positively with the degree of perceptual resonance. 2.Resonant voice can increase the extent of facial bone vibration.	experience of voice training • medically healthy • normal hearing • no speech/voice disorders • no previous experience with accelometer • Recruited using snowball sampling method from the social circles of two authors	and the peri-laryngeal area during phonations • 72 nasal sounds produced were rated by two SLPs on the magnitude of auditory-perceptual resonance • Magnitude of bone vibration was compared across the three phonations • statistical analysis: ANOVA • Sessions were only 30 mins which is not typical RVT	vibration and the mean auditory-perceptual resonance ratings was low • No significant difference between nasal bridge and peri-laryngeal area vibrations • resonant voice has an increased magnitude of facial vibration than habitual, but no sig difference from strained voice • Nasal stimuli create more vibrations than non-nasal	• no sig difference between resonant and strained voice for vibrations • further studies on auditory and proprioceptive feedback are warranted • this study supports the use of piezoelectric accelometer for quantitative measures • resonance is variable across judges, so a more reliable way of measuring resonance should be used than just perceptual
Titze, I. R. (2001). Acoustic interpretation of resonant voice. *Journal of Voice, 15*(4), 519-528.	To describe the acoustic nature of resonant voice.				resonance is likely to be a reinforcement between VF vibration and supraglottal acoustic pressure
Subtelny, J., Whitehead, R. L., & Samar, V. J. (1992). Spectral Study of Deviant Resonance in the Speech of Women Who Are Deaf. *Journal of Speech and Hearing Research, 35*, 574-579. → Level III	<u>Questions:</u> 1.Is the second-formant frequency specifically lowered in deaf speakers when pharyngeal resonance is perceptually apparent during production of vowels /i/, /u/, and /a/? 2.Does the overall formant structures of /i/, /u/, and /a/ produced with pharyngeal resonance by women who are deaf differ from the formant structure of the analogous vowels produced by women with normal hearing? 3.Are they commonly described relationships between second-formant frequency and horizontal	• 4 deaf women • 20-22 years of age • severe bilateral sensorineural hearing loss • hearing aids • attended schools for HI people before mainstreaming for high school • semi-intelligible • moderate to severe pharyngeal resonance	• Speech sample: /i,u,a/ for 5-7 secs • Acoustic analysis: determined formant frequency of vowels • Same for hearing women	• F0s were similar for deaf and hearing • First formants were higher than normal for /i,/u and lower for /a/ for deaf women ○ But lower than normal tongue positions • Second Formant /u,a/ higher than normal and /i/ lower ○ restricted horizontal movement noted • F2 greater for hearing than deaf • F3 really limited. Consistently lower than hearing	• Limited lingual movements contribute to the great significance between the formant structure of deaf women • Lowering of F2 vowels may be vowel dependent • Deviant positions of the tongue, tongue root and epiglottis may be the cause • Suggestive differences in the genioglossus muscle in deaf women • Restricted mobility in the tongue is expressed in the pharynx

	tongue position and between first-formant frequency and vertical tongue position demonstrated in women who are deaf and who have pharyngeal resonance? Hypothesis: The retracted tongue will result in a lowering of the second-formant frequency	• 10 adult women with normal hearing & speech • 21-32 years old			
Higgins, M. B. & Carney, A. E., & Schulte, L. (1994) Physiological assessment of speech and voice production of adults with hearing loss. *Journal of Speech & Hearing Research, 37*(2), 510. → Level III	"To study the impact of hearing loss on phonatory, velopharyngeal, and articulatory functioning using a comprehensive physiological approach" Hypothesis: • "speakers with moderate-to-profound hearing loss attempt to compensate for reduced auditory feedback with an increased reliance on tactile feedback for speech motor control" • expect increased intraoral and subglottal pressure, greater vocal fold contact and longer durations of articulatory closure • and this would be more evident when deprived of amplification for short periods of time	• 7 women and 4 men with moderate-to-profound hearing loss and 7 women and 4 men with normal hearing • HL diagnosed 6 mos-7yrs • All but one regularly used amplification • 2= oral only; other 9 oral/sign • good to excellent communication abilities • intelligible • nonsmokers • no history of laryngeal, neurological, or craniofacial disorders	• (recorder both aided and unaided) say pi and pa and 6 different words and analyzed for phonatory and velopharyngeal/articulatory measures • intelligibility judged by people familiar with the speech/voice characteristics of people with HL • ANOVA to check for gender differences	• Gender differences for phonatory measures • no gender difference for velopharyngeal/ articulatory measures • good speech skills • had normal nasal cavity resistances • aided group had higher intraoral pressures, subglottal pressures, laryngeal resistances and F0s • intersubject variability was high*** ○ individual data provided • no significant differences between aided and unaided recordings	• have highly intelligible speech, but they had abnormal voices: strained, breathy, high pitch, cul-de-sac • VF hyperconstriction noted • louder (possibly so that they can hear themselves) • higher F0 may be due to high subglottal pressure • durational measures were not significantly longer • velophrayngeal control is not a significant problem • motoric complexity does not affect speech production • disagree with centralized tongue and claim that they use an appropriate range of tongue motion • hypothesis that subglottal pressure would increase in response to reduced auditory feedback was UNSUPPORTED

Nguyen, L.H.P, Allegro, J., Low, A., Papsin, B., & Campisi, P. (2008). Effect of cochlear implantation on nasality in children. *Ear, Nose & Throat Journal, 87*(3), 138-143.	Is there a difference in the effect of cochlear implantation on nasality in pre- and postlingually deafened children?	• 6 deaf children with CI • severe- profound bilateral sensorineural HL • Exclusion: structural anomalies of the palate, neuromuscular disorders, cognitive delay, age-related inability to perform the required vocal tasks • 4 boys; 2 girls ages 6.5-17.5 • 4 prelingual; 2 postlingual • unilateral Nucleus 24 implant • had AV therapy before and after TX	• nasalance measures obtained before surgery and 6 mos. after • MacKay-Kummer SNAP • Nasometer II • compared to normative data • t tests	• before implantation measures higher than norm • 6 mos after, measure within 1 SD or norm • ^ same for both syllable-repetition subtest and picture-cued subtest	• CI has a beneficial effect on the nasality of children
Ertmer, D. J. (2011). Assessing speech intelligibility in children with hearing loss: Toward revitalizing a valuable clinical tool. *Language, Speech, and Hearing Services in Schools, 42*(1), 52-58.	Tutorial: The purpose is to present a rationale for assessing children's connected speech intelligibility, review important uses for intelligibility scores, and describe time-efficient ways to estimate how well children's connected speech can be understood. Why are these scores important? 1. sensory aid functioning and speech perception 2. TX planning		• scaling: rate the speech samples • item-identification: open set ID from speech sample ○ The Beginner's Intelligibility Test ○ Monsen-Indiana University sentences ○ CID sentences • Guidelines:		• GFTA-2 not a good indicator of connected speech intelligibility • monitoring intelligibility is a good tool for assessing goal progress

	3. indicator of good oral communication		○ Use only the words produced to calculate intelligibility. don't give the a lower score for what they didn't recall ○ average all judges scores to get overall int score • overcoming barriers: ○ good recording tech ○ good judges (not familiar) ○ **get multiple scores not from the same person**		
Brannon, J. B. (1966). The speech production and spoken language of the deaf. *Language and Speech, 9*(2), 127-136. → Descriptive article	Hypotheses: • Deaf utilize a visual to motor conversion within the brain when speaking and monitor consciously by tactile-kinesthetic control • syntax: deafness creates telegraphic speech with reduced sentence length and omissions of essential words such as functors • Deaf speech contains mostly nouns and verbs	OLD ARTICLE, but good source for: • "Most congenitally deaf speakers have not achieved coordination of respiration, phonation, resonation, and articulation, and this destroys intelligibility and the smooth flow of speech." ○ section on breathing • "The deaf monitor their speech through tactile-kinesthetic sensations" • common artic errors: voicing, misarticulations, extend duration of vowels and voiced consonants, extend closure periods for plosives, distort vowel formants • voice quality • vocab • sentence length			

Uloza, V., Padervinskis, E., Uloziene, I., Saferis, V., & Verikas, A. (2015). Combined use of standard and throat microphones for measurement of acoustic voice parameters and voice categorization. *Journal of Voice, 29*(5), 552-559.	To evaluate the reliability of the measurement of acoustic voice parameters obtained simultaneously using oral and contact (throat) microphones and to investigate utility of combined use of these microphones for voice categorization.	157 subjects (105 healthy, 52 pathological voices)	• voice samples of sustained /a/ recorded in soundproof booth through two mics (oral AKG Perception and contact triumph PC mic placed on lamina of thyroid cartilage) • acoustic voice signal data measured for: **F0, jitter, shimmer, SNR, NHR, NNE** ○ using *Dr. Speech* software	• correlation of acoustic voice parameter in vocal performance were statistically significant for all measurements • combined mics identified CCRs at a higher rate	using both kinds of mics is better and reveals high CCRs when distinguishing between healthy and pathological voices validates the suitability of the throat mic
Barrichelo-Lindström, V., & Behlau, M. (2009). Resonant voice in acting students: perceptual and acoustic correlates of the trained Y-Buzz by Lessac. *Journal of Voice, 23*(5), 603-609.	Aims to investigate perceptually and acoustically Y-Buzz and to verify formant tuning and its association with RV	• 54 acting students (31 female, 23 male) • no voice problems • seven groups • 22-24 years old • exclusionary: HL, voice problems, more than 3 signs or vocal symptoms, younger 18, older 40	• four weekly sessions of training • pre and post training: hold /i/ • after training, analysis of RV by 5 voice specialists • measured: F0, first four formants, f1-f0, harmonic frequencies, f1-h2 (males)	• trained Y-Buzz more resonant than habitual /i/ samples, regardless of gender • lowering of four formants • f1 lower for both groups, stats sig for female • f1-f0 sig smaller for female YBuzz and f1-h2 smaller for male YBuzz → suggests formant tuning	• evidence for formant tuning • couldn't establish association between perceptual grades and measures f1-f0 or f1-h2
Chin, S. B., Bergeson, T. R., & Phan, J. (2012). Speech intelligibility and prosody production in children with cochlear implants. *Journal of communication disorders, 45*(5), 355-366.	The purpose of the current study was to examine the relation between speech intelligibility and prosody production in children with CI.	• 15 children with CI (10 males, 5 females) • 10 children norm (5 females, 5 males) • English-speaking • HL IDed at birth-6mos	• administered The Beginner's Int Test and Prosodic Utterance Production • judged by adults (44: 17 males, 27 females; normal hearing, native English speakers; little or no experience with deaf speech)	• % correct scores higher for int than for prosody • higher for norm hearing than CI • declarative sentences highest ratings • interrogative least IDed lowest ratings • correlations not sig	• int progresses ahead of prosody in both groups • children with norm hearing still do better than kids with CI in int and prosody • problems with interrogative intonation may be related to restrictions of rising intonation • int and sentence intonation may be dissociated at this age

		• amp fitting avg age 1.42 • CI avg age 1.82 • recruited: email list on IN Univ • no cog/dev delay	• BIT- int of words • PUP- grammatical/emotional moods (declarative, interrogative, happy or sad)		
Smith, C. G., Finnegan, E. M., & Karnell, M. P. (2005). Resonant voice: Spectral and nasendoscopic analysis. *Journal of Voice, 19*(4), 607-622.	Hypothesis: resonant voice is produced by narrowing the laryngeal vestibule and is characterized by first formant tuning and more ample harmonics.	• six subjects (3 men, 3 women) • 23-43 years • 2 trained vocalists, 1 trained actor and classical singer, 1 12 years of vocal training in commercial singing and 26 years of prof performance exp, others had 0 vocal training • no hx of resp, laryngeal or neuro DOs • no allergies to topical anesthetics	• 2- 30 minute sessions separated by 2 weeks • first= RV training and data collection for spectral comparison between non-RV and RV • second: videonasendoscopy looking at degree of narrowing of the laryngeal vestibule • data analysis: ○ perceptual ○ FFT ○ amp and f for F0 & harmonics ○ audio-perceptual ○ visual-perceptual	• spectral analysis showed that first formant tuning was exhibited during resonant voice productions and that the degree of harmonic enhancement in the range of 2.0-3.5kHz was related to voice quality • non-resonant voice had the least amount of energy in this range • resonant-relaxed had more energy • resonant-bright voice had the most • visual-percep: laryngeal vestibule constriction was not consistently associated with the resonant voice production	• greater first formant tuning happens with RV • amount of harmonic enhancement depends on the type of voice quality • laryngeal vestibule narrowing happens during both RV and non-RV, and so doesn't appear to be the physiologic basis behind resonant voice production
Titze, I. R. (2006). Voice training and therapy with a semi-occluded vocal tract: rationale and scientific underpinnings. *Journal of Speech, Language, and Hearing Research, 49*(2), 448-459.	to investigate the underlying physical principles behind the training and therapy approaches that use semi-occluded vocal tract shapes	• self-oscillating vocal fold model and a 44 section vocal tract	• computer simulations were used to create source-filter interactions for lip and epilarynx semi-occlusions	• a semi-occlusion in the front of the vocal tract (lips) heightens source-tract interaction by raising the mean supraglottal and intraglottal pressures • impedance matching by vocal fold adduction and epilarynx tube narrowing can	• narrow-wide vocal tract is preferred for maximal vocal output • rationale for therapy protocol

				then make the voice more efficient and more economic	
Verdolini-Marston, K., Burke, M. K., Lessac, A., Glaze, L., & Caldwell, E. (1995). Preliminary study of two methods of treatment for laryngeal nodules. *Journal of Voice, 9*(1), 74-85.	to conduct a preliminary investigation on the effectiveness of voice therapy for nodules	• 18 women with nodules from college sororities → only 13 data count • paid • 18-22 years • no HL	• 2 groups: confidential voice therapy vs. resonant voice therapy vs. no therapy over two weeks • pre and post: phonatory effort, auditory-perceptual voice, laryngeal appearance	• variable: improvement depends on carryover to home (therapy type- no sig, compliance- yes)	• Have a lot of work to do and need to account for compliance in order for specific therapies to work.
Roy, N., Weinrich, B., Gray, S. D., Tanner, K., Stemple, J. C., & Sapienza, C. M. (2003). Three Treatments for Teachers With Voice Disorders: A Randomized Clinical Trial. *Journal of Speech, Language, and Hearing Research, 46*(3), 670-688.	to assess the effects of 3 tx approaches	• 64 teachers with voice disorders (start with 87) • randomly assigned 3 groups: voice amp, RVT, respiratory muscle training • self IDed voice problems	• pre and post: VHI and severity self-rating scale • baseline comparability analysis • 6 week tx • follow-up 2, 4, 6 weeks	• VA group has greater improvement, clarity and ease of speaking/singing	• VA is more effective, but sample included all kinds of pathologies and severity, needs to be looked into to make sure there weren't other factors involved
Lopez, H. A. G., Mondain, M., de la Breteque, B. A., Serrafero, P., Trottier, C., & Barkat-Defradas, M. (2013). Acoustic, aerodynamic, and perceptual analyses of the voice of cochlear-implanted children. *Journal of Voice, 27*(4), 523-e1.	To compare voices of CI to HA (acoustic). To characterize voice of CI (aerodynamic). To classify voice of CI, HA, NH as normal or dysphonic (perceptual).	• 38 NH • 40 deaf with HA/CI implanted before 3 years • avg age: 9.9 • NH recruited from local elementary school (18 girls, 20 boys) • CI recruited from Monpellier CI Ctr (6 girls, 14 boys)	• acoustic measures from sustained /a/ • speech production and aerodynamic from syllables • perceptual= GRBAS	• some had sig diff some were similar, but they varied within each category (e7)	• CI may improve most acoustic measures → Ci voice is better quality that HA → jitter/shimmer/NHR sig diff & CoVarInt between CI and NH → F0 and MPT not sig • age and time with a CI plays a huge role • CI voices in this study don't represent traditional CI voice